Governance of Infrastructure for Resilience

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White Paper

V1

CDRI

THE RESILIENCE SHIFT

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Executive Summary

Infrastructure systems work to provide services such as energy, telecommunications and water and sanitation. Transport connects us through the movement of people, goods and information. Infrastructure also protects the things we value such as our built and natural environments. Their complex and interdependent nature, and fragmented governance has made infrastructure systems vulnerable to long-term climate change and natural hazards.

Significant investment is planned in infrastructure globally in the next two decades as we emerge from COVID-19 and work towards decarbonising our infrastructure systems. Poor governance is a key factor that has led to infrastructure projects failing to meet their resilience and societal objectives. Strengthening governance systems – the mechanisms that ensure that infrastructure is of high quality and is sustainable over the long-term – can lead to substantial increases in the efficiency and productivity of infrastructure.

Drawing on case studies and stakeholder engagement with infrastructure decision-makers and practitioners around the globe, this whitepaper explores the current key challenges and barriers to implementing governance of infrastructure for resilience, and the opportunities available for positive change.

Developing infrastructure that is resilient to climate change and natural hazards requires resilience thinking and resilience building decisions and actions by practitioners across the whole infrastructure lifecycle (Figure 1). At each stage there are opportunities to enhance the resilience value of an infrastructure project and to ensure that the resilience value that was built in the earlier stages.

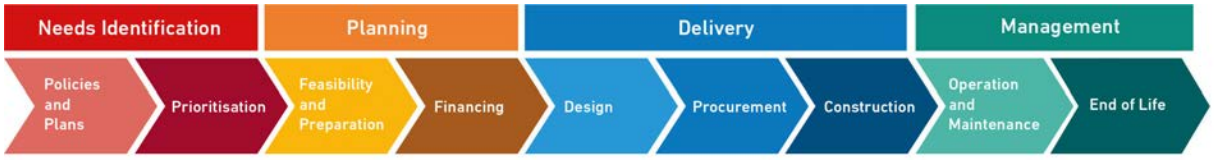

Figure 1 The infrastructure lifecycle (adapted from The Resilience Shift)

This white paper has highlighted the role that good governance can play in embedding resilience through seven key themes (Figure 2) which include: whole systems approaches; adaptive capacity; prioritising infrastructure needs; infrastructure financing; regulation, codes and standards; capacity and resourcing and; data, information and technology. Additionally, the governance challenges and opportunities related to integration of Nature-based Solutions into traditional decision-making have been highlighted and explored through the lens of the themes developed in this white paper.

A summary of each of the key themes and the associated challenges and actions for positive change is provided in Figure 2.

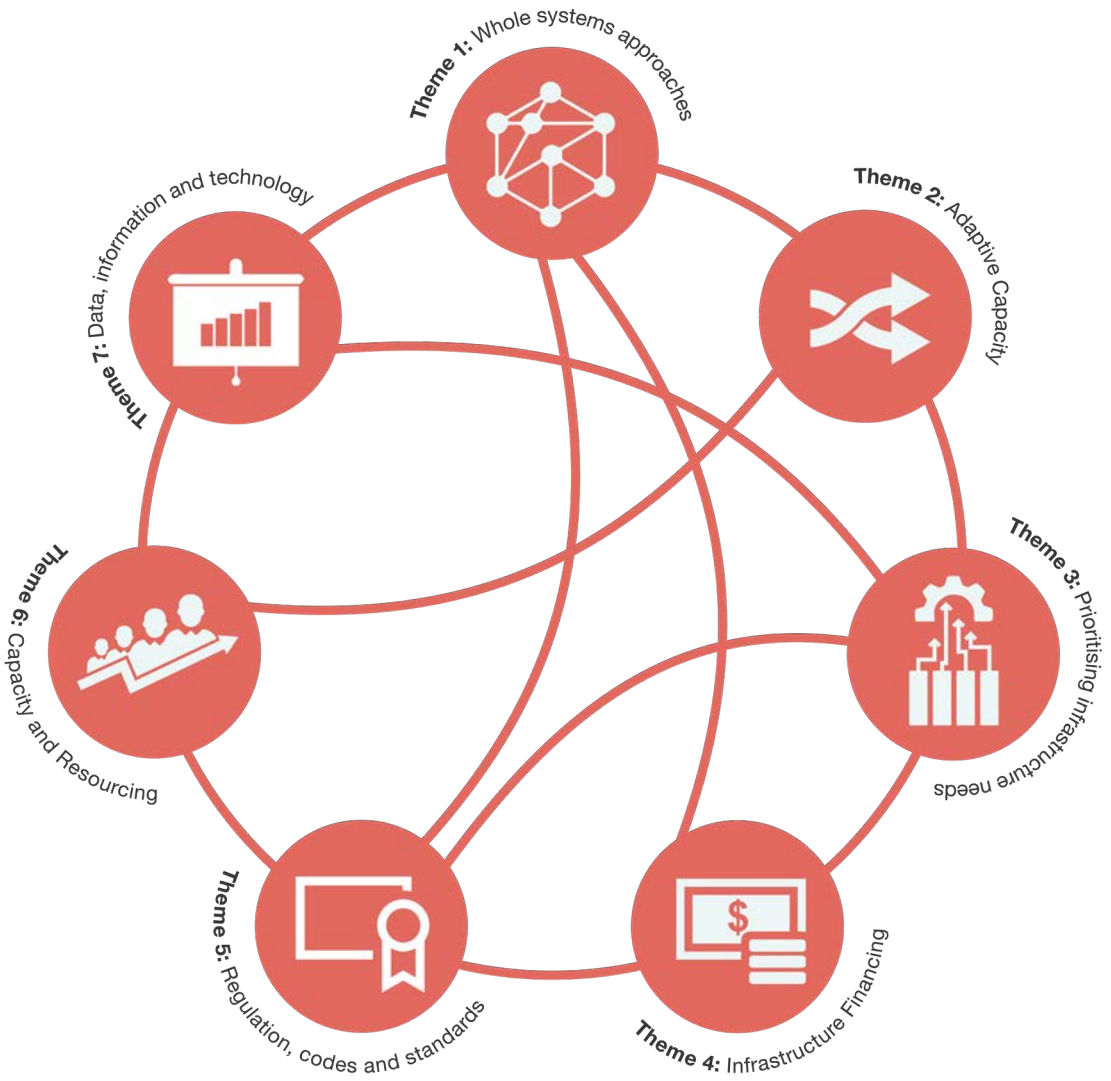

Figure 2 Summary of key themes

Whole systems perspective

Infrastructure systems are inherently complex entities that intricately interact with one another across a multitude of scales. The lack of strategic oversight and cooperation on the universal issue of climate change and natural hazards can limit the approach to resilience building across the whole system. Challenges identified in this theme included the fragmented and siloed nature of infrastructure governance, which typically leads to ineffective, misaligned and outdated policies. The following key actions have been identified as opportunities for positive change:

- Set up cross-sectoral bodies to reduce fragmentation.
- Create a shared vision for stakeholders to work towards, that supports coordinated solutions for infrastructure resilience.
- Periodically update infrastructure policies, frameworks and regulation to reflect a changing and uncertain world.

Adaptive Capacity

The unpredictability of climate change and natural hazard risks calls for a different approach that factors in risks earlier in the infrastructure lifecycle. This ultimately requires transformational adaptation and reflexive

governance tactics. The main challenge identified in this theme was how to integrate considerable uncertainty associated with natural hazards and climate change into infrastructure decision-making. The following key actions have been identified as opportunities for positive change:

- Undertake reflexive governance to ensure that infrastructure is resilient to complex, emerging and uncertain risks.
- Encourage and promote system-wide learning outcomes for infrastructure resilience through institutionalised programmes and platforms.

Prioritising infrastructure needs

Governments and administrations across the world must inevitably assess and select infrastructure priorities to decide how to allocate limited resources. However, governance flaws exist across the lifecycle, but are most noticeable and impactful during project prioritisation, evaluation and project selection. The challenges included the current inadequate frameworks available for infrastructure decision-making and the lack of coordination to incorporate resilience thinking into infrastructure prioritisation. The following key actions have been identified as opportunities for positive change:

- Adopt evidence-based approaches for infrastructure planning and asset management, justifying the need for resilience actions and how they contribute to whole system resilience.
- Develop and implement long-term infrastructure plans including methodical baseline evaluation to create committed objectives, goals and project pipelines.
- Develop viable and prioritised resilience programmes and project pipelines that stakeholders across the infrastructure lifecycle are accountable for.

Infrastructure financing

Despite infrastructure investment possibilities being plentiful, particularly in developing nations, investors are often unable to take full advantage of them. Investing in resilience is inherently risky and finance is difficult to access. The right assets to fund are hard to identify and nefficiencies waste much of the existing resources. The challenges identified in this theme was the overall lack of access to finance for resilience projects, ensuring that the right infrastructure is financed. Additionally, that finance is available to implement governance and pre-development activities, rather than simply a focus on the development of physical infrastructure. The latter will ensure the right infrastructure is being built and lead to 'shovel worthy' rather than 'shovel ready' projects. The following key actions have been identified as opportunities for positive change:

- Improve access to finance through providing support to governments and project sponsors.
- Provide capacity, funding and resources to support pre-development activities.
- Ensure investments are prioritised appropriately at an early stage of the lifecycle.
- Undertake continuous monitoring throughout the lifecycle to hold investors accountable for contractual commitments around resilience.
- Improve funding for governance initiatives that can have a significant impact on the efficient delivery of infrastructure projects.

Regulation, codes and standards

Regulatory frameworks must support the adoption of codes and standards that encourage or require the implementation of practices that maintain or improve the resilience of assets. Challenges identified included both a lack of consistent guidance and standards around infrastructure resilience alongside the lack or absence of regulation. The following key actions have been identified as opportunities for positive change:

- Design governance mechanisms that allow for continued monitoring of their effectiveness, in order to reliably improve upon them in future iterations.
- Understand the problem and its context through data and engagement before implementation.
- Promote adaptive regulation designed around resilience thinking.
- Actively encourage and incentivise the adoption of resilient approaches.

Capacity and resourcing

A lack of knowledge and capacity is a barrier to infrastructure resilience and can create additional vulnerabilities during a disaster The flight of human capital and inequalities in governance has the potential to have an intergenerational impact. Digital transformation has further disturbed traditional governance. Challenges identified include the loss of infrastructure skills and capacity, which was recognised by the majority of stakeholders engaged. Additionally, the inequalities and the impact of digital transformation within

traditional governance which can stifle some institutions. The following key actions have been identified as opportunities for positive change:

- Strengthen national and local actors capacities.
- Incentivise retention of talent in local markets.
- Provide funding for academic institutions and establishing courses around infrastructure resilience.
- Establish initiatives to empower youth and other marginalised and/or vulnerable groups and communicate the benefits of diverse teams to government staff.
- Harness existing digital skills to close the digital divide.

Data, information and technology

Data, information and technology underpins evidence-based infrastructure planning and is regarded as the foundation for effective Disaster Risk Management. Currently, there is a lack of availability, accessibility, trust and investment across the data ecosystem. Further restrictions on collection, access, use and redistribution of data and effective policy and processes prevents management of infrastructure systems at scale. Challenges included a lack of consistent data policy and standards which leads to the collection of data that might not provide the right information for infrastructure decision-making. Furthermore, the availability and accessibility of data can be limited, and asset management systems are needed. The following key actions have been identified as opportunities for positive change:

- Increase availability and accessibility to hazard and infrastructure data to infrastructure decision-makers.
- Develop appropriate policies and standards to ensure that data collected is consistent, reliable and trusted.
- Establish asset management systems to improve infrastructure decision-making and to inform evidence-based assessments.
- Provide support and learning programmes for establishing asset management systems and associated databases.
- Contextualise InfraTech applications for the country of operation which may have varying levels of investment, capacity and resources to install and manage this technology.

The themes and their related actions are significantly interdependent on each other, and need to be considered and implemented collectively to have maximum impact on improving the governance of infrastructure for resilience. The themes and actions identified should be prioritised to understand where the most significant benefits can be provided with limited resources and to identify critical actions that can have the biggest impact to the governance of infrastructure for resilience. The majority of actions are focused on stakeholders in the upstream sections of the infrastructure lifecycle (i.e. Government and Investors). The most significant and urgent opportunity is to ensure that good governance of infrastructure mechanisms are put in place to ensure wider socio economic outcomes are delivered enabling safe, sustainable and resilient infrastructure for all.

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1

The Urgency for Governance of Infrastructure for Resilience

More people than ever depend on the critical infrastructure systems that provide essential services and underpin society. Infrastructure systems work to provide services such as energy, transport, telecommunications and water, to protect things we value such as our built and natural environments, and to connect us through the movement of people, goods and information [1].

Infrastructure systems work to provide services such as energy, telecommunications and water, transport to connect us through the movement of people, goods and information and to protect things we value such as our built and natural environments. More recently, the impact of COVID-19 has highlighted the critical nature of many infrastructure systems and services and the potential vulnerabilities and inequalities in the systems across the globe [2]. These emerging risks are further exacerbated by the interdependent nature of infrastructure systems, and there has been a heightened sense of these in recent decades [3].

The fragility of our infrastructure systems has also been further compounded by fragmented governance and a lack of investment [4]. For example, in low- and middle-income countries, direct damages from natural hazards to power generation and transportation alone cost $18 billion per year [3]. However, a bigger impact is on the cost of disruption to businesses and households which for the same countries equates to $390 billion per year [3].

Right now, trillions of dollars of infrastructure are being planned, designed, constructed, managed, upgraded, or is conversely reaching the end of its life. The Global Infrastructure Hub has estimated that $94T of investment is needed across all the infrastructure sectors by 2040, which currently has a $15T current investment gap (see Figure 1) [5].

It has been argued that we are often not prepared for known challenges because of the constraints of static or out of date standards, regulation, and governance arrangements [6]. For example, Cape Town's Day Zero crisis made it clear that a fragmented, complex governance system, where mistrust and frustration between actors emerge over time, exacerbated the crisis [7]. An urgent shift is therefore needed in how we think about our infrastructure and what must be done now to make it more resilient. This is even more vital in the context of the current transition to net zero. Having capability to prevent and to prepare for infrastructural failures, and thus to manage infrastructural interdependencies, is seen as a major prerequisite for resilient societies. Moreover, the benefits of making new infrastructure resilient is clear, with the Global Commission on Adaptation (GCA) arguing that net benefits of $4T could be realised by 2030 [8]. These benefits will emerge through the triple dividend of avoided losses, economic benefits, and socio-environmental benefits.

It is argued that the operationalising of resilience-based approaches needs to extend beyond purely the development and deployment of resilient engineering approaches (i.e., physical

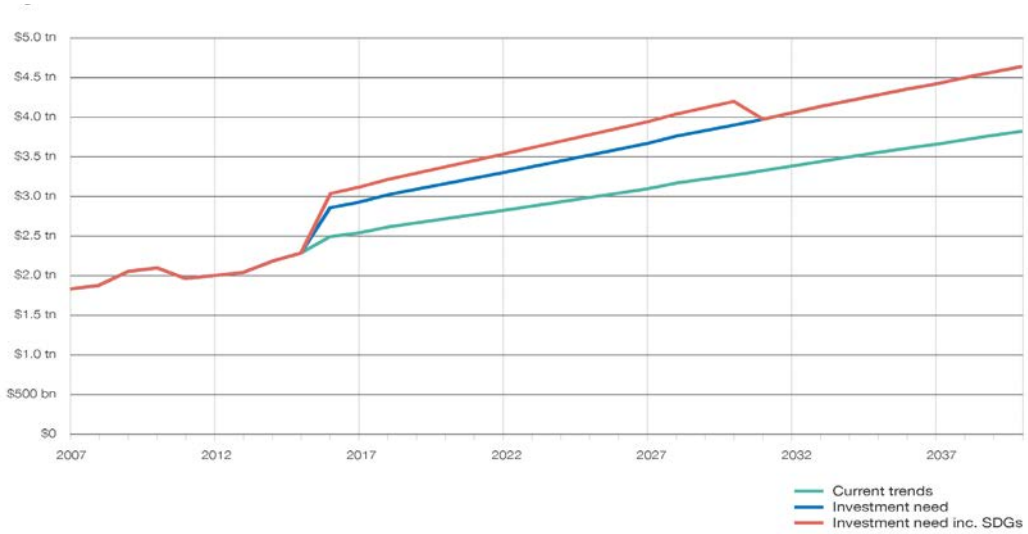

Figure 3 Infrastructure investment at current trends and need (Adapted from: Global Infrastructure Hub 2021)

infrastructure assets and systems) to include resilient management, policy, institutional arrangements and regulation. We need to take an adaptive approach in the planning, design, construction, operation and maintenance of critical infrastructure to meet the challenges of managing risk to known hazards as well as to deep uncertainty and emerging risks [1]. The OECD (Organisation for Economic Co-operation and Development) has highlighted that the significant investment planned is an opportunity, and an urgent one at that, to revaluate policies and governance to ensure that resilience is built in upfront while also ensuring the resilience of existing infrastructure [9].

The governance of infrastructure is not a new topic and has been discussed in multiple publications over the last several decades [10]. It is recognised that "**Poor governance is the major reason why infrastructure projects fail to meet their timeframe, budget and service delivery objectives**" [11]. Ensuring that good governance structures are in place for infrastructure decision-making is an essential enabler for resilience [12]. Many have highlighted the role of governance in embedding resilience, and conversely the negative consequences of fragmented governance.

Suitable governance approaches and arrangements can facilitate effective engagement and investment by governmental and non-governmental stakeholders to ensure infrastructure resilience to disasters. This is essential because even if we plan and deliver the appropriate infrastructure, we still won't be enabling systemic and long-term resilience.

1.1 Aim

The aim of this whitepaper is to set out what infrastructure governance mechanisms are required to support the development of safe, sustainable and resilient infrastructure systems to the benefit of all. Drawing on literature review, stakeholder engagement and case studies, it will explore current key themes and the associated challenges and opportunities for infrastructure governance from a global perspective.

This whitepaper will inform future work being planned by the Coalition for Disaster Resilient Infrastructure (CDRI). This includes the development of a Global Flagship report on Disaster and Climate Resilient Infrastructure in 2022 and the development of a framework for governance of infrastructure for resilience

1.2 Stakeholder engagement

The findings presented in this whitepaper are supported by interviews undertaken with stakeholders from several countries. Where possible, this paper has captured views covering a diverse range of geographies, levels of economic development and diversity with respect to the natural hazards and risks faced. This helps to ensure that the challenges and opportunities identified are representative of the current global issues surrounding infrastructure governance.

1.3 Scope and Structure

This whitepaper is aimed at infrastructure 'practitioners', i.e. all those involved in, responsible for or representing the lifecycle stages of an infrastructure system or assets. This includes but is not limited to government (national, sub-national and municipal including parastatal agencies), investors (private financiers, private developers, public finance institutions, development banks), contractors, owner-operators (public and private), designers and emergency responders. This paper will also recognise the 'recipients' of infrastructure where appropriate. This includes civil society, infrastructure users and impacted non-users. The latter including those who might be positively or negatively impacted by infrastructure assets or systems.

The following critical infrastructure sectors, which align with CDRI's current priority areas, are considered in the whitepaper: energy, transport, telecommunications and water & sanitation. The resilience of these systems will be considered in the context of the risks posed by natural hazards (e.g. earthquakes, cyclones etc.) and climate change, while also recognising the impact of transition risks (e.g. ambition for net zero).

Section 2 of this paper provides definitions of governance, infrastructure, resilience and risk that will be used in the context of this whitepaper. Section 3 will consider the infrastructure lifecycle and stakeholders. Section 4 outlines the benefits that good governance of infrastructure for resilience can provide and international commitments and agendas. Section 5 draws out key themes that have emerged from the literature review and stakeholder engagement, discussing the challenges and opportunities associated with these themes. Section 6 explores integration of NbS into traditional decision-making. Finally, Section 5 outlines the call to action for what is required to advance the debate on infrastructure governance for resilience.

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2

Definitions

This section sets out the key terms and definitions that are used throughout the paper. It is important to set these out upfront to fully understand the context in which they are being discussed.

INFRASTRUCTURE

DEFINITION	SOURCE
The systems, facilities and assets that deliver essential functions and services (i.e., provide, protect or connect) to our society and communities, the loss or compromise of which would result in major detrimental impact on the availability, delivery or integrity of essential services, leading to severe economic or social consequences, loss of life or an irreversible change in the nature of the physical environment, including climate, hydrology, and soils.	OECD (2019) Good Governance for Critical Infrastructure Resilience (adapted) [12]

GOVERNANCE OF INFRASTRUCTURE

DEFINITION	SOURCE
Governance of infrastructure is the processes, tools and norms of interaction, decision-making and monitoring used by governmental organisations and their counterparts with respect to making infrastructure services available to the public and the public sector. It thus relates to the interaction between government institutions internally, as well as their interaction with the private sector, users and citizens. It covers the entire lifecycle of the asset, but the most resource intensive activities will typically be the planning and decision-making phase for most assets.	OECD (2015), Towards a Framework for the Governance of Infrastructure [12a] and OECD (2020) Recommendation on the Governance of Infrastructure [12b].

RESILIENCE

DEFINITION	SOURCE
The ability of a system or community, exposed to hazards, to resist and absorb the hazard; recover from it or transform if conditions require it to, in a timely and efficient manner, including through the preservation and restoration of its essential basic services and functions.	2009 UNISDR terminology on disaster risk reduction

DISASTER RISK

DEFINITION	SOURCE
Disaster risk as one that reflects the concept of hazardous events and disasters as a function of hazard, exposure, vulnerability and capacity.	UNDRR (United Nations Office for Disaster Risk Reduction)

TRANSITION RISK

DEFINITION	SOURCE
Transition risks are risks that follow societal and economic shifts toward a low-carbon and more climate-friendly future. These risks can include policy and regulatory risks, technological risks, market risks, reputational risks, and legal risks	Adapted from GRESB [12e]

SUSTAINABLE INFRASTRUCTURE

DEFINITION	SOURCE
Sustainable infrastructure e is planned, designed, constructed, operated and maintained, and decommissioned in a manner to ensure equitable economic, social, and environmental benefits over the entire lifecycle.	International Coalition for Sustainable Infrastructure (ICSI) [12f]

Linking infrastructure resilience to key concepts

The following descriptions have been provided by the OECD to describe the links between infrastructure resilience and several key concepts relevant to this whitepaper. This information is drawn from their recent 'Building Resilience' report [99].

RESILIENCE AND ECONOMIC DEVELOPMENT

SDG Goal 9 is: to Build resilient infrastructure to promote sustainable industrialisation and foster innovation. Investment in transport, energy, communications, and water and sanitation infrastructure is essential to empower communities in developing and developed countries. Resilient infrastructure links with Goal 11: Making cities and human settlements inclusive, safe, resilient and sustainable. Climate-resilient infrastructure can also support efforts to achieve the Sendai Framework for Disaster Risk Reduction.

RESILIENCE, TRANSITION RISK AND MAINTENANCE

This applies to both 'normal' usage of the infrastructure facilities which need to be resilient to for example time, usage, obsolescence and environmental impacts (transition risk including slow onset impacts related to climate change). Inadequate maintenance can result in rapid deterioration of asset quality, require costly rehabilitation, and interruption of essential services. The repair and maintenance of existing assets is important in developing countries facing severe financing constraints for building new assets, coupled with capacity and technological challenges for carrying out maintenance.

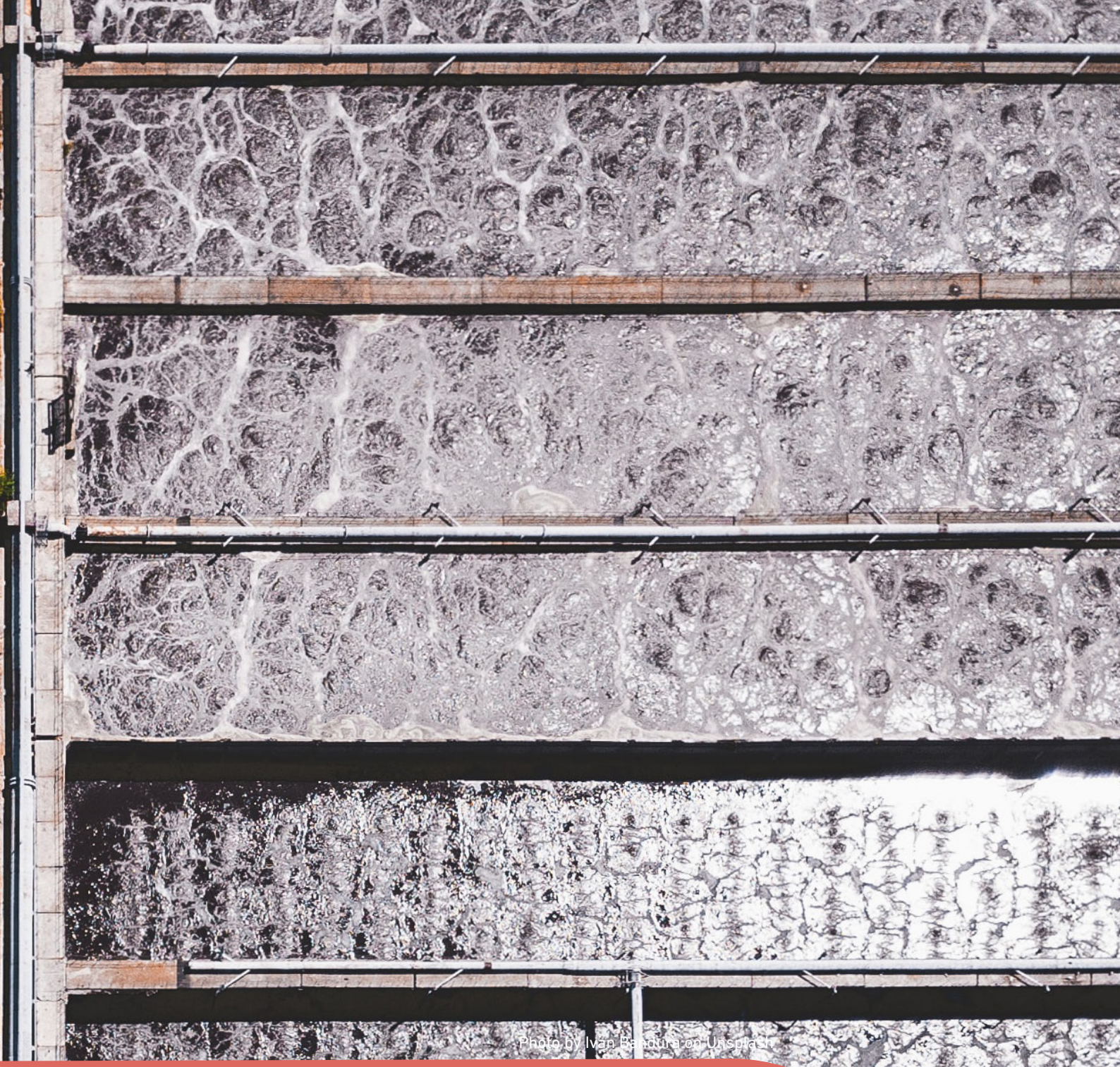
RESILIENCE AND PHYSICAL RISK – NATURAL HAZARDS OR HUMAN INDUCED THREATS

Resilience is usually connected to the occurrence of extreme events during the infrastructure lifecycle and related to the structural integrity of systems and physical infrastructure during their life cycle. The engineering concept of resiliency is based on specific criteria outlined by four pillars of resiliency: robustness, resourcefulness, rapidity, and redundancy.

Abnormal pressures could be stemming from natural hazards (e.g., earthquakes, tsunami, floods, storms etc., some of which may be exacerbated by climate change impacts) or large health crisis (e.g., epidemics or pandemics), as well as other human-induced threats including terrorism and industrial accidents. The system-wide impacts caused by COVID-19 and the key role played by infrastructure in sustaining economic and social activity have heightened the need to consider infrastructure resilience at a broader level.

SUSTAINABILITY AND RESILIENCE

Climate change has highlighted the close relationship between sustainability and resilience. From a policy standpoint, climate change mitigation efforts serve to reduce the risk of climate change – increasing sustainability – whereas climate change adaptation to improve resilience reduces the impacts of climate change for infrastructure.



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3

Infrastructure Lifecycle and Stakeholders

The infrastructure lifecycle (Figure 2) is an asset's estimated life before the next replacement happens. Developing climate and natural hazard resilient infrastructure requires resilience thinking and resilience-building decisions and actions by practitioners across the whole infrastructure lifecycle. At each stage (Figure 2), there are opportunities to enhance the resilience value of an infrastructure project and to ensure that the resilience value that was built into the project in earlier stages is retained. There is also a risk at each stage of eroding resilience value when resilience considerations are not communicated or actions across different phases are not coordinated.

Governance is not a linear process that follows a plan or is controlled by a specific actor or group of actors. Rather, governance is understood as the result of the interaction of numerous actors who have their own particular issues, who define goals and follow strategies to achieve them. Through the infrastructure lifecycle, it is important to understand which actors play what roles at every point.

Figure 2 also identifies where the infrastructure stakeholders have a role to play across the whole infrastructure lifecycle. Depending on the nature of the infrastructure system, stakeholders may have different or overlapping roles. For example, governments can be responsible for developing policies and plans, but also act as the investor and be the owner-operator of the

Figure 4 The infrastructure lifecycle and associated stakeholders (adapted from The Resilience Shift)

Photo © Arup

4

Governance of Infrastructure for Resilience

It is recognised that non-structural measures for example, policies, strategies, plans and governance to enhance the enabling environment are key to ensuring the development of resilient infrastructure [13]. However, improving the resilience of an infrastructure systems is often associated with the implementation of structural measures to improve resilience. For example, physical construction that reduces or avoids the possible impacts of hazards, reduces exposure or sensitivity (e.g. building a flood wall or levee). In its six key principles for quality infrastructure investment, the G20 stated 'Strengthening Infrastructure Governance' as a key priority [14].

This section outlines the need for governance to consider complimentary risk and resilience-based approaches (Section 4.1) and the benefits that good governance of infrastructure for resilience can provide (Section 4.2). Finally, international commitments and agendas around sustainable and resilient infrastructure that need to be integrated into opportunities for change around infrastructure governance are considered (see Section 3.3).

4.1 Governance for risk vs governance for resilience

Risk management and resilience approaches share important features and are typically complimentary [15]. There is an opportunity to build resilience into existing policies and risk frameworks. Traditionally, a Disaster Risk Reduction / Disaster Risk Management (DRR/DRM) approach seeks to reduce risk of particular assets and/or people, from specific, known hazards [16]. Resilience moves away from this traditional risk paradigm [17], and instead accepts that not all risks can be predicted and therefore mitigated and instead focuses on limiting the impact of a hazard event [18]. This is of particular importance when planning for emerging and uncertain risks. Ensuring that known risks are understood and mitigated against however, is still an important part of ensuring the resilience of our infrastructure systems.

Resilience also calls for a better understanding of the systemic interdependencies and linkages of our infrastructure systems, and the associated policies and processes. A multi-level governance framework provides an understanding of the complex web of interactions between different level of governments, non-state and non- governmental actors, all of whom contribute to infrastructure resilience (see Section 4.2).

Governing bodies and institutions can struggle to engage with resilience. This can result from a focus of efforts to address human suffering in the immediate aftermath of an extreme event (e.g. an earthquake, hurricane or flood

Box 1: Multi-level governance in coastal management around Australia

Coastal planning in Australia is primarily based on the concept of integrated coastal management, which is recognised and adopted globally. Despite a plethora of national- and state-level coastal inquiries and reports over 40 years since the mid-1970s, Australia still lacks a national coastal policy. Australia's federated system of governance fragments coastal management, which is planned and implemented by multiple levels of government across several jurisdictions. Variability in institutional approaches exists across these jurisdictions and scales. Despite the continuing gap between the projected impacts of climate change on Australian coasts and action at the state- and local-level, regional organisations provide a mechanism for cutting across jurisdictional boundaries and facilitating innovation. They are an important and effective governance mechanism for coastal management for regions experiencing global and climate change. The voluntary nature of collaborations is considered a strength, in contrast with the more rigid nature of the three-tiered federal system, but it potentially exposes the model to risk if resourcing is reduced. Collaborative regional alliances have developed in a range of coastal landscapes and demonstrate potential foundations for more resilient and integrated coastal planning and management [74]. For example, the Sydney Coastal Councils Group is a voluntary alliance represented by 15 local coastal councils, who work to develop improved coastal management and regional climate change and sand nourishment activities.

Source: https://press-files.anu.edu.au/downloads/press/n3935/pdf/book.pdf

event), which subsequently leads to a limit in the technical capacity for upfront resilience thinking and policy development. This can vary significantly across developed and developing countries. Often the scale of the disasters that are being responded to have been long in the making, due to a compendium of social, economic, and environmental challenges, and because strategies that were designed to address crisis and natural shocks were narrow. Despite stakeholder engagement and comprehension of resilience improvements, governing bodies are not recognising their potential to promote broader societal resilience to climate and natural hazards.

4.2 Scales of governance

Local governmental authority to act on improving the resilience of infrastructure systems is often 'nested' in legal and institutional frameworks at higher scales [19]. For example, while regional and local policies determine the specific details of land use, human settlement patterns and transportation planning, the space for action and potential for change is limited by national development paths, national policies, technical standards and financial restraints [20]. This suggests that the feasibility of local-scale action is limited nationally and vice versa, highlighting a two-way relationship between local and national action for resilient infrastructure.

Multi-level governance can help overcome obstacles to effective design and implementation of policies. Tools for multi-level governance – in the form of vertical and horizontal co-operation - may help to narrow the 'policy gap' among levels of government and promote implementation of stated policy goals and plans [21]. Multi-level governance frameworks encompass two different dimensions of action and influence. The first is the vertical dimension across scales or levels of governance and the second is the horizontal dimension of governance [22]. The vertical dimension is where policy development and governance is made in a centralised hierarchical manner, which is the more traditional form of governance. To take effective action and effectively implement national strategies to improve the resilience of infrastructure systems, local authorities and cities cannot operate in isolation from other parts of regional or national government. This is particularly important when responding to disaster risk. Horizontal governance provides an approach where policy is developed across levels of government, across boundaries between units of either a single or multiple departments or agencies [23]. This allows more coordination, cooperation and a shared responsibility for decisions and outcomes to improve infrastructure resilience.

In countries with low capacity to develop plans regionally, national policies tend to spill over to local policies. Improved co-ordination between levels of government and a 'relevant scale' for allocating public responsibilities and resources is therefore necessary. There is increasing evidence of multi-level patterns of governance and transnational networks, where actors work across organisational boundaries to influence outcomes. Within the multi-level regulatory framework, learning, information transmission and co-operation occurs horizontally with linkages increasingly being forged between cities, regions and national governments [24]. At the sub-national level, some of these horizontal relationships have been created through formalised information networks and coalitions acting both nationally and internationally, for example ICLEI's (Local Governments for Sustainability) Cities for Climate Protection, the Climate Alliance, the C40 Large Cities Climate Leadership Group, among others. These groups have given an institutional foundation to concerted effort and collaboration on climate change at city level [25].

Overlapping jurisdictions can address key issues of climate change, natural hazards and Disaster Risk Reduction separately and sometimes in parallel with other decisions. Therefore, an emphasis must be encouraged on involving business, research, environmental agencies, and NGOs in discussions around policy dialogue. Non-governmental actors have begun to participate in activities related to climate policy generation and advocacy from the generation of ideas and formulating policy to a 'watchdog' role to assess how well policies are performing with respect to their stated goals. As shown by the case study In Box 1, they are also instrumental in implementing activities/programmes towards achieving climate policy targets and supporting engagement across a wide range of stakeholder groups.

4.3 Benefits of good governance of infrastructure for resilience

Providing high quality infrastructure that is resilient to climate and natural hazards does not simply result from increasing the availability of finance for development. The benefits of infrastructure investment are often only realised when projects provide tangible benefits to society [26]. Countries need to ensure that limited resources are well spent, and that our infrastructure systems are equitable, sustainable and resilient.

On average, countries waste approximately a third of their infrastructure spending due to inefficiencies and in low-income countries this can exceed 50% [27]. In developing economies, where often basic infrastructure is not available, potential investors are in many cases deterred by weak governance structures [28]. Infrastructure companies or projects with poor governance practices pose significant risks to investors. Strengthening governance systems – the mechanisms that ensure that infrastructure is of high quality and is sustainable over the long-term – can lead to substantial increases in the efficiency and productivity of infrastructure [29]. The concept of good governance has been debated and has now become a well-established concept for most donor agencies. [30]. The G20 have outlined that infrastructure governance over a project's lifecycle is key to ensuring long-term cost effectiveness, accountability, transparency, and integrity of infrastructure investments.[14]

Photo by Jason Blackeye on Unsplash

4.4 International commitments

International commitments are key to employing shared objectives surrounding how to govern resilient infrastructure and reduce vulnerabilities and exposure of infrastructure systems to climate and natural hazards. It is therefore important to set out the context of international commitments in this paper (see Table 1).

Table 1: International commitments relating to sustainable and resilient infrastructure

INTERNATIONAL COMMITMENT	DESCRIPTION
United Nations Sustainable Development Goals	The 17 Sustainable Development Goals (SDGs) emerged from the development of the '2030 Agenda for Sustainable Development' [31] that was adopted by all of the United Nations Member States in 2015 [32]. The SDGs can provide a baseline for identifying the outcomes required from the development of resilient infrastructure [33]. Goal 9 of the UN SDGs is to 'Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation'. However, all the goals - to some extent - are underpinned by the development of infrastructure systems [34]. Resilient infrastructure also links with Goal 11: Making cities and human settlements inclusive, safe, resilient and sustainable, as well as being a key aspect which underpins all other SDGs. It has been shown that infrastructure either directly or indirectly influences all of the SDGs, including 72% of the targets [28].
Paris Climate Agreement	The Paris Climate Agreement targets climate risk and aims to limit global temperatures from rising to 2°C [35]. Approaches to limit warming will have critical impacts on infrastructure as by limiting the impacts of climate and natural hazards frequency and magnitude. However, transition risk may be heightened, which is getting increased attention from governing bodies [35]. Concurrently, adaptation of infrastructure systems to climate change is required as some of the impacts are already locked in.
Sendai Framework for Disaster Risk Reduction 2015-2030	The framework concentrates on reducing man made and natural losses to disaster risks. Governance is significant in challenging disaster risk The private sector and stakeholders have key roles to play [36]. Gaps have been identified through the framework in missing data on infrastructure damage. Therefore, to strive for disaster risk reduction, data collection is prioritised to make informed decisions to protect critical assets. The framework encompasses a wide scope, endeavours to raise awareness and educate governments, and prompts them to think and act on critical infrastructure resilience in multi-faceted ways [37].

Theme 1

Whole Systems Perspective

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Introduction

Systems are inherently complex entities that intricately interact with one another across a multitude of scales. Therefore, infrastructure governance mechanisms must be similarly complex and intricate to address the challenges that infrastructure systems present. However, at present, there are several barriers to understanding the complexities of infrastructure systems that stand in the way of effective and resilient governance.

Table 2 below outlines the key challenges and opportunities for improving infrastructure governance under the theme of 'whole systems perspective'.

Table 2 : Challenges and opportunities under the theme of 'whole systems perspective'

Current challenges	Opportunity for change	Required actions	Associated Lifecycle section	Key stakeholders involved
C1.1 Fragmented and Siloed Governance ***C1.2*** Ineffective, Misaligned, and Outdated Policies	***O1.1*** Collaborative and aligned approaches to infrastructure governance for resilience	Set up cross-sectoral bodies to reduce fragmentation. Create a shared vision for stakeholders to work towards, that supports coordinated solutions for infrastructure resilience. Periodically update Infrastructure policies, frameworks and regulation to reflect a changing and uncertain world.	Policies and Plans Procurement Feasibility / Preparation Operations and Maintenance	

C1.1 Challenge: Fragmented and siloed governance

Administrations and organisations often organise themselves into silos. While this is not necessarily an issue, the lack of effective coordination mechanisms between them is [38]. The failure to effectively coordinate within and across infrastructure sectors and systems on climate change, for example, can expose assets to shocks and stresses and exacerbate vulnerabilities inherent within systems. While there has been progress in DRM policies and processes resulting from improved understanding of the impacts of climate change and natural hazards, these remain siloed due to institutional arrangements and bureaucratic nuances within the governance structures of individual countries. Consequently, **the lack of strategic oversight and cooperation can stand in direct opposition to resilience building across infrastructure systems and results in fragmentation.**

Fragmentation can manifest in several ways, which can hinder implementation of resilient infrastructure [39]. For example, different government departments making different decisions or conflicting policies and regulatory approaches and oversight that can have inadvertent advertent harmful consequences in other sectors. **Making effective governance arrangements work is even more challenging when the impacts of a disaster crosses international borders,** as was the case during the 2003 blackout in Canada and the United States [40].

Countries in the Pacific Island States have reported progress in DRM, climate change laws and policies, however institutional arrangements and bureaucracies still lead to a siloed approach to the issue [41]. **Fragmentation and siloed governance can lead to blind spots or areas of inactivity,** which can be exacerbated in a disaster scenario as detailed in Box 2.

C 1.2 Challenge: Ineffective, misaligned, and outdated policies

The large-scale and long-term nature of infrastructure investment makes projects vulnerable to changes in shorter-term policy and regulation [33]. The right policies are therefore needed to ensure that the right infrastructure is developed for resilience. It is argued that the way government's approach

infrastructure policymaking is flawed which is often associated with: short-sightedness and a lack of a comprehensive plan; flaws in evidence foundation and modelling procedures, which can lead to poor project selection; failures to comply with guidelines for early shortlisting that can eliminate the optimal solution before it is properly considered and; business cases do not always give due prominence to different possible scenarios and the sensitivity of analytical assumptions to changing external conditions [42].

There is also often a disconnect between national, regional and local risk information availability and relevance. Disaster risk is frequently estimated at regional or national levels. Risk response and reduction, on the other hand, are fundamentally local processes, concentrating on community vulnerabilities and how disasters affect specific groups of people [43]. **Policy recommendations for entire regions or countries often have limited practical significance for communities at risk, especially when hazards' sources and effects are spatially intertwined at small scales.**

Many countries, particularly in developed countries, retain legacies of the last great national infrastructure vision and the challenges leaders sought to address, usually in the mid-20th century. However, we now live with the flaws of that vision [44]. Disproportionate spending on highways stretched distances between people and businesses, leading to divided neighbourhoods, burdensome transportation, and environmental harm. Constructing in flood plains and sensitive coastal areas has exposed communities to higher risks and costs from daily events or superstorms such as Hurricanes Katrina, Sandy, and Harvey in the USA. Limited direct investment in water utilities contributed to public health crises such as the one in Flint, Michigan [1].

Infrastructure schemes are often evaluated on cost and value for money, rather than wider positive outcomes and resilience benefits (e.g. social and environmental benefits). Governments are interested in projects that can create jobs and increase productivity and Gross Domestic Product (GDP) within the scope of short-term political cycles. Existing techniques for estimating 'dynamic effects' – those that change the structure of the economy – are costly to apply, difficult to undertake and relatively underdeveloped. Some industry models produce high numbers that lack credibility [24]. **Failing to fully capture these long-term welfare gains and losses will distort analysis with a bias towards those projects that are more carbon-intensive, less resilient or environmentally damaging.**

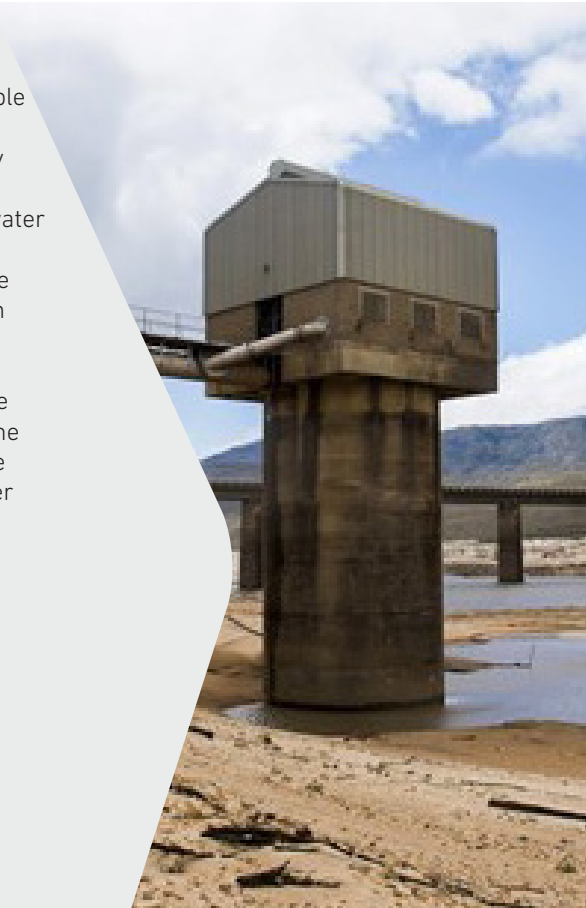
O1.1 Opportunity: Collaborative and aligned approaches to

Box 2: Cape Town Day Zero Water Crisis

The Cape Town Day Zero crisis highlighted the underlying governance challenges that compounded to the 2017-18 water crisis in South Africa.

Before the onset of the water crisis, the governance framework was highly fragmented. With mandates and responsibilities located at different levels of the system, allocated between the three spheres of government: national, provincial and local. This was also characterised by poor coordination and large degrees of mistrust. Central to the problem was the dysfunctionality of the national Department of Water and Sanitation, which had suffered skills losses and depletion of capacity over several years.

The department is legally responsible for the provision of bulk water, but during the crisis the Cape Town City Government lost confidence in the system's ability to reliably supply water to it. As a result, it asserted certain responsibilities and duties not in the strict conduct of City business, such as augmenting supply. In the wake of the water crisis, improvement of water governance and reform of the governance framework have become unavoidable, with a more direct role for cities in future in their own water planning and management.



Source: https://www.drought-response-learning-initiative.org/

infrastructure governance for resilience

At the national level, overarching and accountable leadership is a fundamental driver of policy implementation. It connects policy agendas, and aligns competing priorities across ministries and between national and local government [45]. National coordination platforms that promote the integration across ministries and levels of government and cooperation between governmental and non-governmental entities, as well as efforts to establish and strengthen capacities that promote resilience throughout are tools that ensure that the required leadership is suitably stable and interconnected [46]. Ultimately, collaboration is needed to develop a shared understanding, agree on purpose, and establish mutual trust for infrastructure decision-making.

Considering the diversity and range of the elements that play a part in building resilient infrastructure, effective treatment of the problem calls for the **use of methods that create integrated knowledge that transcend the boundaries between disciplines, between sub-divisions of governing bodies and between science and society (e.g. Figure 6). Practical and conceptual steps in this direction have been taken, including major improvements in stakeholder engagement processes** [47], and establishing cross-sectoral bodies to bridge the communication gap. However, there are varied differences in how well these are implemented.

All government actors at the national and sub-national levels can engage to coordinate a range of stakeholders in inclusive policy-making processes that would support citizen engagement and invite communities, businesses, individuals, and households to take greater responsibility for their own safety. It is essential to **develop a shared vision of critical risks and the division of responsibilities for shouldering the management burden and foster a whole-of-society approach to infrastructure resilience** and to make the public aware of those risks [45].

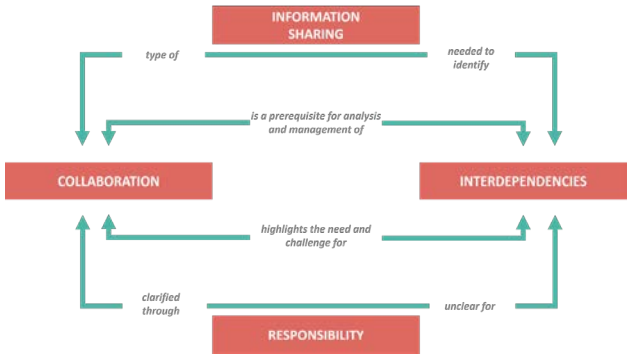


Figure 5 Governance and interdependencies of critical infrastructures: Exploring mechanisms for cross-sector resilience (Adapted from Sonesson et al (2021))

Governments of all scales should establish partnerships with the private sector to achieve responsiveness and shared responsibilities aligned with national strategies by identifying common goals and shared interests across the public and private sectors in the governance and management of critical risks. For example, administrations can develop models for public-private partnerships (PPPs) that incorporate trusted information sharing networks. To manage risks relating to transboundary lifeline infrastructure, governments should consider establishing inter-regional and transboundary coordination and collaboration mechanisms.

Replacing and maintaining our outmoded infrastructure systems with the same traditional policies, technologies, and designs is no longer enough. Policies must be updated to reflect a changing world, as demonstrated in Box 4. There is a **role for cooperation and collaboration to reduce siloes and fragmentation which will lead to the development of aligned policies.** Strategic policy statements are an effective way for the government to communicate long-term strategic goals to those investing in infrastructure and to regulators. To tackle the issue of short-term thinking and the influence of election cycles on the advancement of infrastructure projects, **some countries are seeking or are already developing the legislation of infrastructure policy**.

However, legislating bodies should be aware of the potential for inhibiting innovative approaches in the long-term and seek to adapt where required [49]. Legislation is not a singular mechanism, or a 'silver bullet', for resolving the

challenges associated with enabling resilience for infrastructure and communities [1].

There is a **potential role for multi-sector regulators**, which is a regulatory agency that is able to coordinate across more than infrastructure sector. For example, since 2005: Bundesnetzagentur has been responsible for the regulation of telecommunications, postal services, electricity, gas, and rail in Germany. Having a **multi-sector regulator offers potential advantages, including greater inter-sectoral consistency of regulation, reduced administrative costs through sharing of functions, lower risk of regulatory capture, inter-sectoral learning and sharing of best practice.** However, some disadvantages may include neglect and deprioritisation of certain sectors due to capacity challenges, neglect of differences between sectors, lower expertise at higher levels, lack of competition impacting on innovation and best practice approaches [50].

Box 3: Policy changes after 2007 Peru Earthquake

The 2007 Earthquake in south Peru revealed vulnerabilities related to the interconnectedness of lifeline sectors (water and health, electric power and health). Following the observed complications associated with significant infrastructure damage in the wake of the earthquake, the government enacted a new law (Law No 29078) to create an autonomous Fund for the Reconstruction of the South (FORSUR) and authorized a supplementary credit of USD 31.6 million to enable the reconstruction of public infrastructure in the areas affected by the earthquake.

Scaling this up to the national level, the government passed a law (Law No 29951) providing for the specific allocation of resources to finance risk identification activities for the environment, health, housing, and water and sanitation sectors. The law also validates resources earmarked for financing risk reduction in the agriculture, health, housing, education and transportation sectors. Building on the experience of the 2007 earthquake, the government also restructured the country's emergency management and disaster risk reduction responsibilities to ensure adequate focus and funding for both risk identification and reduction and preparation and response processes (Law No 29664; IDB, 2015).

Source: https://publications.iadb.org/publications/english/document/Policy-Evaluation-Framework-on-the-Governance-of-Critical-Infrastructure-Resilience-in-Latin-America.pdf

Image from https://alchetron.com/2007-Peru-earthquake

Photo by Simon Berger on Unsplash

Theme 2

Adaptive Capacity

Introduction

Adaptive capacity is the ability of an asset or system to adjust to a hazard, take advantage of new opportunities and/or cope with change [51]. Some risks can be factored in as they are site-specific and predictable. However, unforeseen consequences due to transition risks (e.g. decarbonisation) or the unpredictability of climate change and natural hazard risks, require a different approach that factors in risks earlier in the infrastructure lifecycle. This ultimately requires transformational adaptation and reflexive governance tactics.

Table 3 below outlines the key challenges and opportunities for improving infrastructure governance under the theme of 'adaptive capacity'.

Table 3 : Challenges and opportunities under the theme of 'adaptive capacity'.

Current challenges	Opportunity for change	Required actions	Associated Lifecycle Section	Key stakeholders involved
C2.1 Integrating Uncertainty into Decision-Making	***O2.1*** Reflexive Governance and Policy Approaches	Undertake reflexive governance to ensure that infrastructure is resilient to complex, emerging and uncertain risks.		
	O2.2 Institutionalise learning for infrastructure resilience	Encourage and promote system-wide learning outcomes for infrastructure resilience through institutionalised programmes and platforms.		

C2.1 Challenge: Integrating uncertainty into decision-making

The difficulty of making infrastructure decisions is exacerbated by uncertainties about the size, kind, timing, and location of climate and natural hazard impacts. For example, while climate change is predicted to have an impact on the frequency and magnitude of precipitation and temperature events, in some locations the magnitude of change is unknown or highly uncertain. It is therefore difficult for policymakers to determine whether they should take a 'wait and see' approach, as they wait for more accurate scientific assessments, wait for the effects of climate change to appear, or to wait and follow the example of other countries. Also whether long-term structural changes should be implemented whose benefits may not be obvious for another 20, 50, or 100 years. A focus on short-term, more pressing challenges, might risk locking in maladaptive investments for decades. However, **uncertainty should not be used as an argument to postpone action and long-term changes should support resilience to more short-term shock events** (e.g. natural hazards and extreme weather).

The time horizon considered becomes of increased relevance where analysis concerns long-term impacts [52] for example considering emissions mitigation and climate resilience and adaptation projects. These may have high initial capital investment, but generate long-term benefits for society. The **time horizon often practically limits the forecasting of demand of the relevant infrastructure system, which is necessary to analyse the long-term cost and benefit flows**, such as those related to emissions of greenhouse gases. The **impact on communities over time also needs to be considered, otherwise increasing the resilience of a system can lead to negative social consequences**, for example the development of sea walls in Japan (see Box 5).

O2.1 Opportunity: Reflexive governance and policy approaches

Governance systems are needed that can positively adapt to the constantly changing needs, expectations, rights, capabilities of all actors and institutions that are responsible for infrastructure decision-making. This will help to ensure improved resilience of our infrastructure systems to a range of shocks and stresses.

Box 4: Japan's Sea Wall's

Following the Great East Japan earthquake, tsunami and nuclear disaster of 11 March 2011, the Japanese government began constructing a series of 440 seawalls along the Northeastern coast of Honshu. Cumulatively measuring 394.2km, they are designed to defend coastal communities against tsunami that frequently strike the region.

The defences nearing completion in Taro, Japan are stronger than previous. In the event of a Level 1 tsunami, they are intended to prevent considerable damage and save lives. Taro's new layout is also safer and some transformational adaptation to living space is being implemented, but this is not in response to climate change.

However, it is not unimaginable for sea levels to rise so that some Level 1 tsunami events could become Level 2, and for Level 2 events to become large enough potentially to overwhelm defences, just as the 'unimaginable' tsunami of 11 March 2011 overwhelmed what were then the strongest defences ever built in Taro and Kamaishi. Despite mitigating the vulnerability of significant natural hazards, the development of the sea wall has had a tertiary socio-economic impact of disconnecting coastal fishing communities from the sea which is resulting in longer-term societal issues.

Source: Matanle, Peter & Littler, Joel & Slay, Oliver. (2019). Imagining Disasters in the Era of Climate Change: Is Japan's Seawall a New Maginot Line? The Asia-Pacific Journal: Japan Focus. 17. 1-29.

Photo by Keisuke Kuribara on Unsplash

Reflexive (or adaptive) governance is a mode of governance that is able to adapt to emerging and uncertain shocks and stresses through the ongoing pursuit and integration of knowledge of socio-ecological and socio-technical system dynamics influencing the targets for transformative change [16] (see Box 6). **Infrastructure decision-makers should assess and explore current and future trends to not only understand threats to the physical infrastructure systems but also to understand the impacts to people, policies and processes that might require organisational changes** [53].

Resilience investment and policy decisions in infrastructure management have significant and often long-term consequences, this is particularly the case in the water and flood risk management sector. Long-term resilience objectives also typically require near-term decisions. There is a **clear role for government in providing information and research, extension and capacity building to improve human capital, infrastructure that allows other decision-makers to take adaptive actions, and ensuring that market signals incentivizing adaptive measures are not distorted by policy frameworks that lock stakeholders into maladaptive systems.** To use resources effectively, and to avoid the lock in of risks, adaptive pathways approaches need to be taken. **Adaptive approaches or 'pathways' enable the development of resilience options to be carried out in a way that is agile to the latest science around climate and natural hazards, growth projections and other changes to the local environment.** They have become recognised as sequences of policy and investment actions, which can be implemented progressively to achieve a set of pre-specified objectives under uncertain changing conditions [54]. The recent development of a British Standard provides recommendations and guidance to support organizations implementing adaptation pathways [55].

Taking an adaptive approach to governance will require deliberative dialogue and engagement with a multiplicity of actors (e.g. government, policy makers, regulators, business, civil society and communities) and political coalitions at all levels. Bringing together the different knowledge and perspectives on problems, reflexive governance champions continuous learning to engage with uncertainties and unintended consequences. It embraces "the full, messy, intermingled natural reality" [56] as opposed to the modernist practice of problem-solving through specialist perspectives on narrow problem definitions. It builds on the principle that system dynamics can never be fully appraised because different actors tend to vary in their understandings of system boundaries and how best to prioritize, achieve, and assess different sustainability goals (e.g. related to climate, biodiversity, public health, green growth, and social justice) [57]. Consequently, pathways to achieving sustainability and resilience outcomes are opened up to continuous negotiation and reinterpretation [58]. It is in this very process of iterative reinterpretation that an understanding is built of the complex realities of socio-ecological and socio-technical systems [59].

Self-governance necessitates innovative capacities and private resources, both of which are not evenly distributed throughout society. So, in addition to the fact that impacts vary by region, city, neighbourhood, and even household, the capacity to recognise and sense new threats and respond to them differs as well. Coordinated adaptation through reflexive governance is also more likely to include problems of fairness in the process, as well as to promote the interests and voices of vulnerable people, resulting in more equitable outcomes as in the case study in Box 6 below. Moreover, **adaptive and reflexive governance needs to be institutionalised within organisations**. If not, there is a risk that although on a cognitive level reflexive governance will be considered as an effective way of working, the frame change will be superficial and underlying ideas regarding governance will remain unchanged [60]. This **change in governance approach also needs to be done quickly,** as while countries that are considered more vulnerable to climate change and natural hazards will be striving for sustainable development, resilient infrastructure and improving their adaptive capacity, climate impacts will continue to intensify [61].

O2.2 Opportunity: Institutionalise learning for infrastructure resilience

Learning from past experiences of shocks and stressors on infrastructure systems can build adaptive capacity and resilience [62].

However, scaling up learning experiences from projects to whole organisations is lacking [63]. Infrastructure resilience, as discussed in Theme 1, cuts across various governmental departments and portfolios. It is recognised that a strategic level response is needed to natural hazards, both within and across infrastructure sectors [64].

Collective learning can be defined as *"a set of actions that allow new information or knowledge to be acquired, processed, shared, and transferred across individuals within a group"* [63]. A roundtable of local stakeholders and decision-makers who were responsible for Christchurch's recovery following the 2011 earthquake felt that that **more effort is needed to develop and maintain forums in non-emergency circumstances**, so that they become part of ordinary working habits and help to embed resilience approaches [65].

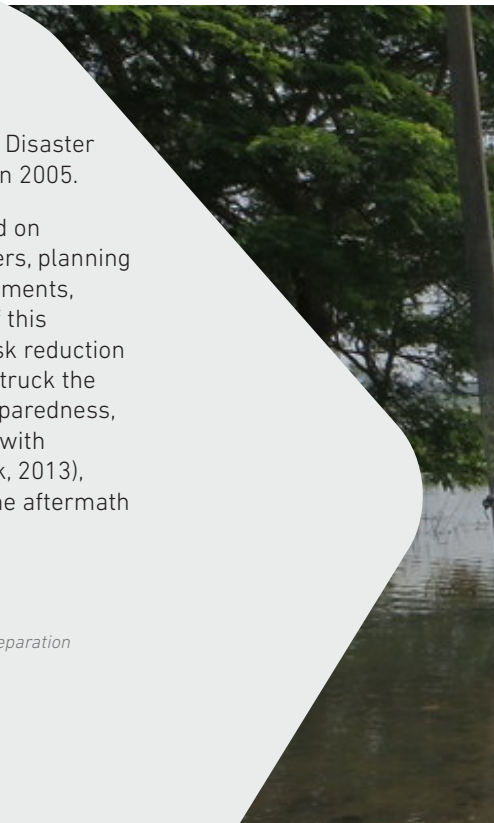
Both during stress events (e.g. long-term droughts) and in post-disaster contexts, **learning is essential for the operators and owners of infrastructure systems to innovate and adapt their current practices to changing requirements of society**. Learning gained from projects should be shared and used to influence the approach of whole organisations [63]. For example, how uncertainty has been accounted for within infrastructure decisions.

There is a need for learning to become institutionalised through appropriate learning programmes and platforms. In Bolivia for

Box 5: Adaptive Governance in the State of Odisha, India

In 1999, a super cyclone (Cyclone 05B) struck Odisha, India, resulting in the deaths of more than 9,000 people. It directly affected 15 million people and more than 2 million households. The shock of this event that coincided with new political leadership, led to a strong political commitment to improve disaster resilience and risk reduction. New institutions were created and more collaboration between the segments of the society was promoted. Mainly, the Odisha State Disaster Management Authority (OSDMA) was established in 1999, and helped to institutionalise DRR in Odisha (Walch, 2019). At the time, the OSDMA was the first disaster management authority in India. The Disaster Management Act was then passed in 2005.

Since this time, support has focused on disaster preparation, building shelters, planning evacuations, strengthening embankments, and conducting drills. The impact of this commitment to improve disaster risk reduction was evident when Cyclone Phailin struck the state in 2013. Due to the state's preparedness, impacts were significantly reduced with the deaths of 38 people (World Bank, 2013), compared to more than 10,000 in the aftermath of the 1999 cyclone.



Source: https://www.tandfonline.com/doi/full/10.1080/17565529.2018.1442794
World Bank, 2013 https://www.worldbank.org/en/news/feature/2013/10/17/india-cyclone-phailin-destruction-preparation

Box 7: Infrastructure for Resilient Island States (IRIS)

Small Island Developing States (SIDS) face several economic, social, and environmental challenges owing to their geophysical and structural constraints. Most of these countries are prone to disastrous effects of climate change while already facing unique development challenges such as remoteness to global markets, poor connectivity, lack of economies of scale, and inadequate labour-mobility. These challenges are compounded by capacity constraints and weak institutional frameworks for infrastructure development and management. Resilient, sustainable, and inclusive infrastructure plays a key role in mitigating these challenges and meeting development needs of SIDS.

Against this background, Infrastructure for Resilient Island States (IRIS) is co-curated by CDRI partners and SIDS to achieve sustainable development through a systematic approach to promote resilient, sustainable, and inclusive infrastructure in SIDS. IRIS is envisaged to provide technical support on multifaceted issues posed by infrastructure systems and promote disaster and climate resilience of infrastructure assets in SIDS.

Source: CDRI

Photo by Alec Douglas on Unsplash

example, lessons learnt from recent water crises have largely been assimilated and exchanged informally, and stakeholders have called for learning to be formalised [66]. This should be used to **share and upscale positive experiences and mechanisms linked with integrated planning and community-based adaptation**. Moreover, efforts should be put into raising awareness in neighbouring areas so that stakeholders can see the benefits of adaptation and resilience measures and adopt them [66]. The recent establishment of Infrastructure

Theme 3

Prioritising Infrastructure Needs

Photo by fortytwwo on Unsplash

Introduction

Governments and administrations across the world must inevitably assess and select infrastructure priorities to decide how to allocate limited resources. The issue of limited resources is especially acute for infrastructure development, where massive funding shortfalls are expected in the next several decades. As a result, governments must prioritise and select proposed infrastructure projects in a systematic manner, in addition to increasing their budget space through alternate sources of money.'
An objective, holistic analysis of infrastructure needs, and a long-term strategic plan to address them, can help secure better-quality infrastructure for all, better value for money for the taxpayer, and certainty and security for investors. It is then critical to communicate this vision across vertical and horizontal governance structures (see Section 2.1.1) so that a clear picture of future infrastructure is set.

Table 4 below outlines the key challenges and opportunities for improving infrastructure governance under the theme of 'prioritising

> *"Well-planned and prioritised infrastructure investment improves productivity, engenders competitiveness and contributes to long-term sustainable economic growth."*
>
> *GI Hub (2019) Leading Practices in Governmental Processes Facilitating Infrastructure Project Preparation*

Table 4 : Challenges and opportunities under the theme of 'prioritising infrastructure needs'.

Current challenges	Opportunity for change	Required actions	Associated Lifecycle Section	Key stakeholders involved
C3.1 Inadequate frameworks for infrastructure decision-making	***O3.1*** Evidence-based infrastructure resilience development	Adopt evidence-based approaches for infrastructure planning and asset management, justifying the need for resilience actions and how they contribute to whole system resilience.	Policies and Plans Prioritisation	
C3.2 Lack of resilience coordination	***O3.2*** Shared vision, accountability and transparent decision-making	Develop and implement long-term infrastructure plan including methodical baseline evaluation to create committed objectives, goals, and project pipelines. Develop viable and prioritised resilience programmes and project pipelines that stakeholders across the infrastructure lifecycle are accountable for.	Policies and Plans Prioritisation Financing Feasibility / Preparation	

C3.1 Challenge: Inadequate frameworks for infrastructure decision-making

There are **recognised infrastructure governance flaws across the public investment cycle, which are most prominent at the allocation and implementation stages,** particularly during project evaluation and project selection. Project development is hampered by a lack of institutional capacity including organisational, technical, commercial skills, coordination, and expertise. Furthermore, political demands can lead to sudden changes in priority of infrastructure systems. All of this can lead to **project prioritisation studies being undertaken with increasing degrees of accuracy and can result in costly scope modifications, a failed bidding process, a project that is unable to secure private funding and importantly resilience not being embedded.** Project prioritisation typically considering the demand for infrastructure services, the cost of the asset, environmental impact assessments, and cost/benefit analyses [68].

Appraisal and prioritisation processes outside of OECD countries are largely undocumented, but evidence suggests that **prioritisation is often based on politics, loose qualitative assessments, or professional judgment, but without clear principles underpinning selection** [69]. The task therefore becomes identifying alternative instruments for usage in various circumstances that are most likely to assist policymakers and governments in making

investment decisions. However, such decision frameworks must pass effectiveness, efficiency, and public legitimacy requirements in project prioritisation, as well as assure long-term asset sustainability and, when appropriate, bankability for private investment.

Governments, particularly those at smaller scales such as municipalities, have generally lacked the tools to determine multiple benefits of infrastructure [70]. An infrastructure asset's value also depends in part on its effects beyond the asset's monetary cost and on a government's ability to model and measure these additional values. For example, defining or **measuring the extent of the benefits offered by nature-based solutions has remained a significant challenge** (see Section 6). While several administrators have begun to explore the wider benefits of infrastructure assets within their own infrastructure programs, no general method for estimating or documenting such benefits has yet emerged to streamline this process.

O3.1 Opportunity: Evidence-based infrastructure resilience development

Evidence-based infrastructure decision-making can help to maximise the accessibility and quality of infrastructure services, improve productivity, engender competitiveness and contribute to long-term sustainable economic growth and overall resilience of our infrastructure systems [71] [72]. The pool of accessible finance accessible for the development of resilient infrastructure is limited (see Theme 4). This is despite global estimates of infrastructure investments required to support economic growth and human development by 2040 being in the order of USD 94 trillion [73]. **Governments need to therefore decide how to spend their limited resources on infrastructure development**, especially as funding disparities are expected to widen in the next several decades.

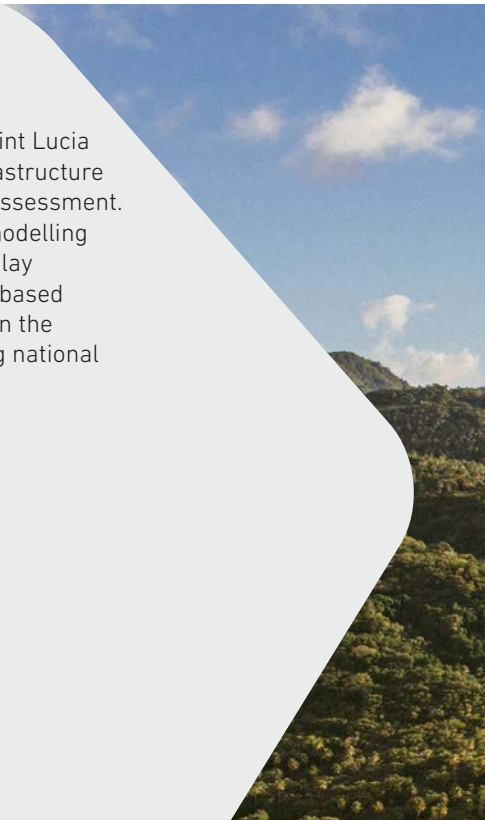
Governments need to better justify and legitimise infrastructure investment decisions through systematic, evidence-based analysis [74]. This necessitates the establishment of structures and methods for transforming long-term priorities and goals into a credible, prioritised, and potentially successful programme and project pipeline [75]. Identifying and defining new assets developed to increase capacity and resilience (for example, additional lanes or widening a road) is challenging however and depends on the availability and access to data (see Theme 7), alongside the challenge of few countries having the capability of having a holistic view of all the systems.

Ensuring that mechanisms are in place to develop a national infrastructure strategy can enable governments to make decisions on a consistent basis and prioritise competing options and projects [42]. National Infrastructure Assessments (see Box 8) will also need a firm grasp on the inter-relationships between and across sectors as well as within them [76]. However, to do this, every aspect of

Box 6: St. Lucia National Infrastructure Assessment

Saint Lucia's government has worked with the United Nations Office for Project Services (UNOPS) and the University of Oxford's Infrastructure Transitions Research Consortium (ITRC) to integrate informed, cross-sectoral decision-making into its national infrastructure policy.

The National Integrated Planning and Programme unit (NIPP), based in the Department of Finance, was established in 2018 with the goal of creating the overarching vision, strategy, and roadmap for the development of Saint Lucia's national infrastructure agenda. A complete spatial infrastructure asset database for Saint Lucia and a cross-sectoral, long-term infrastructure planning model are included in the assessment. The transfer of these open-source modelling tools to in-country stakeholders will lay the groundwork for future evidence-based infrastructure development, based on the most up-to-date data and developing national objectives and sustainability targets.



Source: https://content.unops.org/publications/Saint-Lucia-National-Infrastructure-Assessment.pdf

the infrastructure systems in a country need to be studied, assessed, and understood but very few countries have the capacity, technology, finance, access or data to do it well. Tools such as the World Bank's Infrastructure Prioritisation Framework is a multi-criteria prioritisation approach that helps governments seeking to prioritise and select projects under conditions of limited information and capacity [71]. These long-term infrastructure plans should include **a methodical baseline evaluation to create a committed articulation of objectives, goals, and project pipelines** that then cascade infrastructure planning down to the level of national and sub-national governments. Evidence-based analysis to prioritise projects, such as the World Bank's Infrastructure Prioritisation Framework [74] can help with this.

Operationalising resilience is often challenging due to the presence of complex interdependencies across multiple systems, the requirement for cross boundary collaboration, difficulty with balancing bureaucratic values (such as efficiency with adaptability, redundancy and innovation) and challenges in articulating an explicit value of resilience. Within the sphere of asset management, resilience requires infrastructure to be planned, designed, delivered and operated to serve communities under both ordinary and extraordinary circumstances. Asset management is an existing framework that requires evidence-based, data-driven decision-making. However, it does not routinely include resilience aspects. There is therefore an **opportunity to build resilience into existing policies and structures including asset management**. For example, a performance measure linked to level of service provided during severe weather event would be a tangible entry point to enact policy requirements around climate change adaptation using an established and common framework such as asset management. Another point is that asset management can ensure there is line of sight with common goals and strategies set by policy makers.

C3.2 Challenge: Lack of resilience coordination

Resilience is not embedded in governance processes in a systematic way therefore, the **prioritisation of infrastructure needs around resilience can be siloed as infrastructure development is dealt with by different government departments** (see also Theme 1). Given this context, it is likely that initiatives emerging from different departments will end up addressing the same end-user service need. For example, government departments in charge of national highways and railways may be seeking to address travel demand on the same corridor through a new greenfield expressway and a high-speed rail project respectively, when one of these projects might suffice. The IMF estimates that inefficiency in the sector amounted to 53% and 34% [77] of total expenditure on infrastructure in low-income countries and emerging market economies. On the other hand, situations also arise where critical development priorities are missed between two departments with

overlapping mandates.

High-level infrastructure decision-makers such as ministers and senior public servants are sometimes unable to recognise different risk scales and risk interconnectedness. As a result, the uncertainties and dangers associated with infrastructure investment and operation can be misunderstood by decision-makers. For example, ministers who are risk averse may not see the ambiguity of expected benefits, civil officials may prepare budgets based on shaky projections and ultimately the failure to convey risks can misinform the public and oversight committees. Even when there are significant uncertainties, there has been minimal planning for what happens if things go wrong in some circumstances [22]. As a result, when feasible possibilities, taken as accurate predictions, turn out to be erroneous, the government is left with few viable options.

Government budgets are limited and there is often a need to prioritise one need or one sector over another [71]. While the national and regional scales are critical, it is also important to think about the impact of projects at a local level for example, balancing top-down with bottom-up approaches to resilience. **Many stakeholders are involved in infrastructure decision-making, which can exacerbate the coordination issue,** and can be problematic in ensuring that any solution developed meets all needs and is equitable. In most contexts, political will and administration changes following a political election could see sudden and significant changes, with some high-profile projects facing cancellation or substantial change alongside the addition of new projects proposed in a party's manifesto [78]. These often ambitious proposals risk overloading an already full plate.

O3.2 Opportunity: Shared vision and transparent decision-making

Developing medium and long-term infrastructure plans is critical. This entails a systematic assessment of critical infrastructure gaps, the identification of critical priorities to drive socio-economic transformation, the setting of actionable goals around these priorities, and the identification of projects to achieve the goals [79]. A key aspect to setting overarching priorities is to **develop a shared vision for societal or a community's risk tolerance and resilience expectations with respect to identified hazards and areas of infrastructure vulnerability.** Understanding risk tolerance helps to identify a balance of performance and economy at an early stage.

Transparent decision-making at the prioritisation stage helps to prevent corruption and mismanagement and create an effective and robust infrastructure sector [75]. A prioritisation process that focuses on transparency and accountability provides better value for all decision-makers (see Box 9). For governments, it can demonstrate how public money is spent, building trust between citizens and the government. For the private sector, it can provide better

Photo by Nate Watson on Unsplash

Box 7: CoST – The Infrastructure Transparency Initiative

CoST – the Infrastructure Transparency Initiative (CoST) is one of the leading global initiatives improving transparency and accountability in public infrastructure. Working with government, private sector and civil society it promotes the disclosure, validation and interpretation of data from infrastructure projects. This informs and empower citizens and enables them to hold decision-makers to account. Informed citizens and responsive public institutions help drive reforms that reduce mismanagement, inefficiency, corruption and the risks posed to the public from poor quality infrastructure.

The initiative works globally in addition to working with CoST members at national and sub-national levels, to share and promote experience and knowledge on transparency, participation and accountability.

https://infrastructuretransparency.org/about-us/

value as it ensures a level playing field and reduces the costs and risks of doing business. **Prioritisation can also help to identify possibilities for private-sector investment and a strategic vision for infrastructure can help governments to optimise investor investment in infrastructure** [80]. For donors, it allows a line of sight and coordination to achieve the maximum impact with their scarce resources. Ultimately, it promotes better value from public infrastructure, delivering quality infrastructure at lower cost, with increased predictability of outcomes.

A list of priority projects is not a complete strategy. The strategy should, in theory, address all of the components that must be harmonised in order to meet national needs and realise the long-term vision for the resilience of infrastructure [33]. Once long-term plans have been established, it needs to be transformed into a viable and prioritised programme and project pipeline. If accountability is anchored for infrastructure planning within capable and empowered public institutions this will be the difference between successful and mis-directed outcomes downstream. **Linkages between the plan and downstream resilience actions needs to be created to operationalise the plans**.

Accountability also needs to be set to continuously update infrastructure plans on a regular basis to reflect lessons gained and increase planning credibility. Downstream actors, such as designers, contractors and owner operators, need to be encouraged to develop master plans, which can be used as a

Box 8: Australia's strong governance for project development

The project preparation environment in Australia reflects the country's devolved constitutional structure, with state governments establishing their own autonomous enabling frameworks to help project development. These organisations help with all elements of project preparation, including formulating policies and giving guidelines, drafting and monitoring long-term strategic plans and providing approvals, quality assurance, and capacity building support to state contracting authorities

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The governance framework is set out as follows: Infrastructure Australia (IA) assists in the delivery of nationally significant projects, the Department of Infrastructure and Regional Development provides policy advice and delivery support, the Department of Treasury conducts independent reviews and appraisals of nationally significant projects, and the Department of Treasury conducts independent reviews and appraisals of nationally significant projects.

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Source: https://cdn.gihub.org/umbraco/media/2357/case-studies-pages-90-247.pdf

Theme 4

Infrastructure Financing

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Introduction

The OECD estimates that overall worldwide infrastructure investment requirements for transportation, electricity generation, transmission and distribution, water, and telecommunications is USD 71 trillion by 2030 [79]. To address social requirements and enable faster economic growth, infrastructure investment in most developing and emerging economies must be significantly increased. In recovering from the COVID-19 pandemic, much of the financial stimulus expected is in the form of long-lived infrastructure assets [80].

Despite infrastructure investment possibilities being plentiful, particularly in developing nations, investors are often unable to take full advantage of them. It is worth noting that private savings with institutional investors are at an all-time high [81] with USD 80 trillion in assets under management [82]. Inadequacies in the enabling environment for investments often lead to funding gaps. However, underinvestment in resilient infrastructure will not be cost effective over the long-term. The Global Centre for Adaptation argues that although making infrastructure more climate resilient will add approximately 3% upfront costs, it will provide $4 of benefit for every $1 spent [3].

Table 5 below outlines the key challenges and opportunities for improving infrastructure governance under the theme of 'infrastructure financing'.

Table 5 : Challenges and opportunities under the theme of 'infratructure financing'.

Current challenges	Opportunity for change	Required actions	Associated Lifecycle Section	Key stakeholders involved
C 4.1 Lack of access to infrastructure finance	***O 4.1*** Innovative financing mechanisms	Improve access to finance through providing support to governments and project sponsors.	Prioritisation Feasibility / Preparation Financing	
C 4.2 Ensuring the right infrastructure is financed	***O 4.2*** Develop robust monitoring of public and private investment	Ensure investments are prioritised appropriately at an early stage of the lifecycle. Undertake continuous monitoring throughout the lifecycle to hold investors accountable for contractual commitments around resilience.	Policies and Plans Prioritisation Feasibility / Preparation Financing	
C 4.3 Lack of resources for governance and pre-development activities	***O 4.3*** Increase access to pre-development funding	Improve funding for governance initiatives that can have a significant impact on the efficient delivery of infrastructure projects. Provide capacity, funding and resources to support pre-development activities. This will ensure that the right infrastructure is being built. For example, ensuring 'shovel-worthy', rather than 'shovel ready' projects.	Prioritisation Feasibility / Preparation Financing	

C4.1: Challenge: Lack of access to infrastructure finance

Public financing alone will not be enough to meet the challenges posed by climate change, natural hazards and other threats. Governments struggle to ensure that public interventions, including public finance, mobilises private capital. Despite sustained efforts by governments, the amount of private funding mobilised by each dollar of public finance invested has remained flat at levels insufficient to keep the goal of limiting warming to 1.5°C within reach [83]. In developing countries, the World Bank has shown that private participation in infrastructure financing has seen minimal growth since 2007 and is falling.

Resilience usually comes at a higher cost up front, as it predominantly provides long-term economic rewards, which might be regarded as risky by decision-makers and investors. **Business cases also do not place high value on mitigating what could be perceived to be a risk of lower probability in the short term** [84]. Making such decisions is tough given political processes that are focused on short-term gains and is only exacerbated, particularly in many developing nations, by the difficulty in obtaining private financing. If foreign aid is expected to be disbursed in the case of a disaster, it may deter investment in resilience [85]. Similarly, mismatched political incentives can skew investment in resilience, since governments may be rewarded politically for responding to disasters rather than preventing them [86]. Moreover, the immediate benefits realised when spending following a disaster is immediately clear, and governments are eager to be seen helping communities recover quickly [87].

Climate adaptation and resilience options tend to be more difficult to implement than mitigation strategies. Adaptation and resilience solutions necessitate a high-level of local knowledge and input since climate change impacts emerge in different ways depending on location. Because of this, **local governments capacity to prepare projects to the standards required by investors can be limited** [88]. Funding is therefore difficult to access and, unlike mitigation, adaptation still relies heavily on grant funding, as revenue-generating business concepts for adaptation programmes are either underdeveloped or unsuited for low-income settings [83].

A compartmentalised strategy at the international level also leads to fragmentation at the national and sub-national levels. Outputs from UNDRR workshops with Small Island Developing States (SIDS) countries in the Pacific note that many climate change departments in the region are now under the jurisdiction of the Ministry of Finance, due to funding streams (especially the attractiveness of climate finance) causing competition among ministries [41]. A strong and established connection between implementing agencies and the finance ministry is required to ensure that financing is translated into action on the ground. Although it is unclear how this will function in practice.

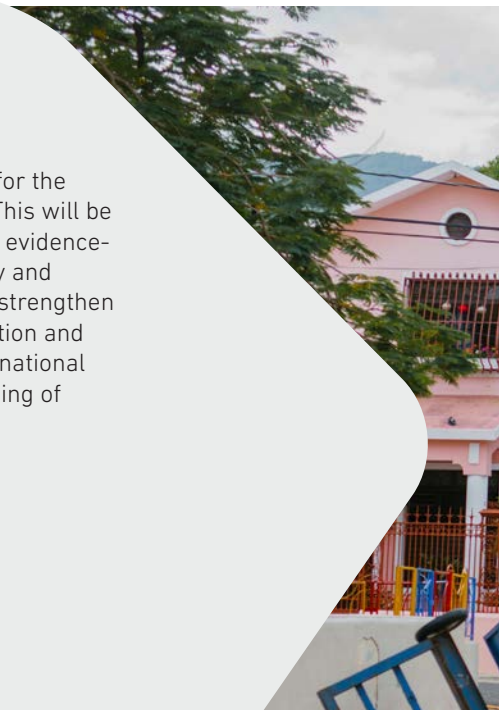
O4.1 Opportunity: Improve access to finance

Overall, there will be reliance on traditional finance mechanisms for infrastructure development however, **innovative mechanisms are needed to capture private capital** [81]. This is particularly relevant in developing countries, where infrastructure has not generally

Box 9: Caribbean Regional Resilience Building Facility

The Caribbean is exposed to a range of natural hazards including, earthquakes, volcanoes, storms, extreme temperatures, droughts, floods and landslides. Increasing climate variability is likely to exacerbate many of these hazards. The Caribbean Regional Resilience Building Facility is a partnership between the European Union, the Global Facility for Disaster Reduction and Recovery and the World Bank. The facility's objective is to enhance the long-term disaster resilience and adaptation capacity for the most vulnerable in the Caribbean. This will be achieved through a comprehensive evidence-based effort, using various advisory and financial services and analytics, to strengthen the capacity for disaster risk reduction and financial resilience at regional and national levels, as well as through co-financing of resilience investments.

Source: https://www.gfdrr.org/en/caribbean-rrb



been developed as a viable asset class for financial institutions and investors. Moreover, in the developing world context there is a reduced ability of users to be able to pay for infrastructure asset services, further leading to the deficit gap [85].

There are some recent examples of where **countries who are at significant risk from natural hazards and climate change have benefitted from innovative risk-financing instruments.** For example, the recent deadly earthquake in Haiti in August 2021 which led to the loss of 2,200 lives lost and 130,000 homes being damaged or destroyed. However, within 14 days the government had received a pay-out of approximately $40 million from the Caribbean Catastrophe Risk Insurance Facility Segregated Portfolio Company (CCRIF SPC) to support its recovery. The CCRIF SPC had been established in 2007 as the first multi-country risk pool, with technical support from Japan [89]. See more on the Caribbean Regional Resilience Building Facility, and how it is supporting countries to access risk finance, in Box 11.

Public Private Partnerships (PPPs) are becoming more popular as a means of building and managing infrastructure assets [13]. For instance, in an OECD survey, 9 of the 20 countries surveyed, PPPs constitute between 0% and 5% of public sector investment in infrastructure. Furthermore, in 9 countries PPPs constitute between 5% and 15% of total public sector infrastructure expenditure [90]. PPPs can support infrastructure delivery by leveraging the fiscal resources of the public purse and supporting the delivery of more efficient services. They also encourage the sharing and transfer of risk from the public to private sector, which in turn helps to drive greater innovation as private organisation develop their own approaches to meet the required outcomes of the infrastructure service [91].

Typically, PPPs encourage investors to hold the asset as a concessionaire for a 20-30 year period. This long timeframe encourages investors, developers and operators to incorporate resilience into the design of infrastructure [92]. Conversely, PPPs associated with relatively short concessionaires (i.e. <7 years) are less likely to invest in resilience. **Moving forward, long-term concessionary periods should be encouraged to promote more resilient infrastructure systems.** Panama has recently legalised the use of PPPs, however the World Bank recommends that the PPP framework needs to be operationalised and a number of pilot projects under the framework should be undertaken [29].

Governments, donors and institutions have **sought to help narrow the finance gap by providing funding for Project Preparation Facilities (PPFs).** In recent years there has been an increasing number of PPFs established [93]. These platforms support activities early in a project's lifecycle and provide upstream support to create opportunities for project development and investment [94]. A PPF may provide both technical and/or financial supports to project owners and concessionaires. Support covers a range of activities including undertaking project feasibility studies, value for money analysis, developing procurement documents and project concessional agreements, undertaking socio-environmental studies and creating awareness among stakeholders. The Inter-American Development Bank (IDB) has also identified a number of 'mobilizers' who work with governments to develop bankable projects [95].

C4.2 Challenge: Ensuring the right infrastructure is financed

Inefficiencies lead to more than a third of the resources spent on building and maintaining public infrastructure on average being wasted [75]. These inefficiencies can be caused by ineffective inter-agency coordination mechanisms, political factors, corruption, and bad budget management [96]. The lack of comprehensive data collection on performance jeopardises evidence-based decision-making and the dissemination of information. Countries should carefully consider whether their chosen delivery method (public works, PPP, etc.) will provide the most value for money. Due to a lack of systematic data, good practice necessitates the deployment of comprehensive cost-benefit methodologies and a strong assurance process. Currently, **only a few countries gather and use financial and non-financial data from diverse types of infrastructure investments in a systematic manner** [5]. However, one of the most important levers of government action in terms of directing infrastructure stakeholders on how to extend the life of infrastructure and reduce costs, as well as assess risk exposure and develop resilience, is regulation (see Theme 5 for further information on regulation).

Coming out of the COVID-19 pandemic, getting infrastructure right is even more important. The recent pandemic has heightened awareness of the demand for infrastructure services. Combined with current ambitions for decarbonisation, and increasing urbanisation [95], this has made a more compelling case for ensuring that our infrastructure systems are safe, resilient and sustainable. Governments, under great pressure to deliver results quickly, have turned to infrastructure as a means of stimulating the economy. However, hazards in infrastructure development, such as corruption, public waste ("white elephant") projects, and debt sustainability, could have significant budgetary consequences for governments and undermine investor confidence [97]. **Many administrations find it challenging to adjust to climate and natural hazard related risks and opportunities using traditional tools**, such as risk management and financial modelling. Existing tools are often siloed within departments, and there exists multitudes of broader frameworks and a lack of clarity of which ones to apply tends to be a barrier to effective adoption. This calls for the development of an overall framework with common methodologies and tools to meet the accounting standard.

Public attention has been on the temporary or permanent stranding of assets following a climate change event (e.g. flooding), or the rapid and disruptive low-carbon energy transition (e.g. renewables) [98]. Investing in infrastructure today needs to consider a wide variety of factors and scenarios, both in the short and long-term, and ultimately how to plan for and avoid impacts of these future scenarios. Some countries identified issues around donor funding that due to **a lack of effective prioritisation that would take a systemic view and conduct effective and appropriate stakeholder engagements and inclusive consultations**, has resulted in largely unusable infrastructure. Such developments are also less likely to be resilient to future scenarios.

Investing in assets that may be quickly superseded or do not contribute to resilience and achieving net zero in the future is not an efficient use of resources. Avoiding stranded investments and ensuring intergenerational fairness would benefit from better integrated, whole system forecasting and policy action, as well as analysis of factors that may make certain technologies more prone to stranding at the time of investing. Governments, businesses, and financial institutions are all increasingly dedicated to creating a replicable model and are already devoting resources and efforts to do so. However, because reaching agreement on the approach and technique has been difficult, governments and organisations should create their own thresholds and benchmarks that are appropriate for their purposes [85]. As a result, work is needed to harmonise approaches in order to make decisions that are both consensual and transparent while still allowing for some flexibility. Governments, thought leaders, and international stakeholders must continue to promote greater debate and exchange of experiences in order to achieve a common understanding.

Governments in developing countries also have political incentives to build new infrastructure, which is widely publicised and can benefit particular constituencies. The same is not true for maintenance. The repair and maintenance of existing assets are important in developing countries that face severe financing constraints for building new assets [99].

The 2021 G20 Italian presidency has recognised the importance of Infrastructure Maintenance and it has set out a policy agenda, as it recognises that **spending on maintenance has been limited and the gap is widening**. This is due to it generally being easier to raise

resources to finance new investment or major rehabilitation than to cover continuous operation and maintenance costs [100]. The G20 has highlighted three policy interventions, that are [101]:

- Better planning and institutional coordination across sectors and/or administrative levels
- Measures to secure funding and financing
- Approaches for effective delivery of maintenance

However, **maintenance of existing infrastructure – generally built by previous governments – simply does not attract the attention of the media, nor does it win votes** [102]. In addition, access to investment for maintenance spending is challenging given the comparatively small scale of investment and maintenance is also less visible compared to new investments. Moreover, maintenance can usually be delayed, which makes it an easy target for budget cuts [100]. The same incentives exist for politicians in developed countries. However, due to independent bureaucracies, strict procurement rules, and the less salient nature of patron-client relations, these incentives are less pronounced. Governments in developed countries are also not recipients of aid.

04.2 Opportunity: Develop robust monitoring of public and private investment

Monitoring and evaluation plays an important role in promoting learning, accountability and improved impact of infrastructure projects [103]. Publicly funded infrastructure projects tend to have incentives for monitoring and evaluation, particularly if a resilience agenda is built in from the beginning, throughout its lifetime as the government has a mandate to maintain the asset. However, for projects that are funded by donors, for example, their monitoring of the project ends when the project has been built, or soon after [104]. Downstream, the ownership is then passed onto the government which may focus its monitoring efforts on other projects, or not necessarily on the resilience indicators that would have initially been defined as there is no incentive to monitor the asset through its lifetime.

Efforts to institutionalise the use of the information generated for example, by designing programmes with clear objectives, planning ahead for monitoring and evaluation and analysing the context, are essential. Through the infrastructure lifecycle, goals and risks are likely to evolve as settings change and lessons are learnt and so continuous learning will be required. **A monitoring and evaluation framework should be integrated into the institutional framework for policy monitoring and evaluation** [105], which allocates roles, resources, and objectives to various institutional actors (ministries, departments, etc.). Government can also provide thematic considerations for the selection of policies to be monitored and assessed based on criteria such as government priorities or budgetary constraints and create action plans for commissioning monitoring and evaluation exercises.

There is no agreement on what constitutes successful adaptation to a changing landscape of threats. This is also likely to change depending on the context. As a result, **more and better monitoring and evaluation, as well as a focus on learning, are required to assess and enhance the effectiveness of investments and initiatives.** For example, the Task Force for Climate-related Financial Disclosures (TCFD) is asking organisations to assess and report on their climate risks (see Box 12). Regulatory authorities in charge of infrastructure networks should be empowered to **collect data on asset condition and maintenance requirements and set performance indicators** accordingly to ensure that service levels do not deteriorate over time and that adequate funding is allocated to maintenance and replacement activities. Improving maintenance and operations is a no-regret option to increase infrastructure asset resilience while lowering total costs [99]. Good maintenance generates substantial savings for example, it can reduce the total lifecycle cost of transport and, water and sanitation infrastructure by more than 50% [106].

Complementary monitoring and evaluation efforts are necessitated by the complex nature of many adaptation initiatives. Administrations that have a reflective approach that is dynamic and iterative can continuously improve their monitoring and evaluation designs and performance [107]. One solution is to **include an explicit learning phase in the planning cycles to solve the common problem of activities moving directly to further activities without taking the time to properly learn from the previous ones** [108]. This can improve the monitoring and assessment situation inside the planning cycle. Another way to include learning into monitoring and evaluation is to **involve stakeholder participation and allowing for modifications and learning from the evaluation process.** The use of key performance indicators (KPI) to oversee infrastructure service delivery is fast evolving and proving to be a powerful tool for monitoring and benchmarking infrastructure

performance during the delivery phase [109]. However, the experience of developing KPIs in the water sector, for example, demonstrates the difficulty of agreeing on a common methodology, as well as the capacity required by regulators and utilities to provide meaningful, high-quality data that informs key processes [106].

C4.3 Challenge: Lack of resources for governance and pre-development activities

In its simplest form, pre-development activities are defined as *"the tasks that need to be completed before construction can occur"* [110]. Despite pre-development costs typically not exceeding 10% of the total project cost and the significant benefits associated with undertaking pre-development activities, funding can often be limited. It is argued that if the pre-development process is flawed, then the infrastructure itself will be similarly flawed [111].

Factors including fiscal constraints, the extent of overall needs, and risk aversion mean that governments at a range of scales tend to focus their scarce resources on constructing and developing conventional projects to address their most critical infrastructure needs [112] . This results in an **underinvestment in pre-development.** Ultimately, there is currently a significant gap between identifying projects for climate and natural hazard action and an ability to bring them to fruition [113].

Costs associated with the recovery of key infrastructure from natural hazards is often the responsibility of national governments, regardless of institutional frameworks. In the aftermath of a disaster, infrastructure costs account for the majority of government spending, especially in the absence of risk transfer mechanisms such as insurance. This can detract them from spending on pre-development. However, **uncertainties, new technologies, a growing body of policy-relevant research, and a diversity of citizen perspectives, demand new skills for effective and timely policy advice.** Anecdotally, OECD research has raised issues of low engagement of employees within government, insufficient competency frameworks, and underdeveloped targeted management/leadership training [114].

For fundamental change to be achieved across the development of infrastructure strategies and practices as well as in the effective communication and implementation of novel governance approaches, sustained funding is required. This is most often a limiting factor in countries and areas where access to consistent and reliable funds is not guaranteed and can therefore hamper the ability to implement change activities effectively. Underfunding can therefore lead to poorer implementation that inadequately address vulnerabilities across the infrastructure lifecycle, leading to continued vulnerabilities [53].

Photo by Marcus Kauffman on Unsplash

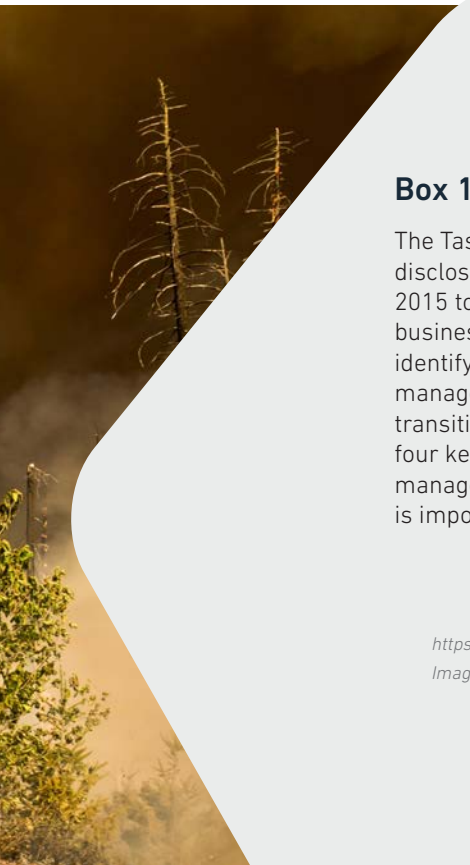
04.3 Opportunity: Increase access to pre-development funding

In some contexts, particularly regions dependant on donor funding, the prospect of new funds can be a significant motivator for shifting risk and resilience attitudes. Donors might emphasise the necessity of incorporating resilience into existing programmes and/or outline potential new financing sources, such as concessional loans and catastrophic risk insurance underwriting.

Rather than a flurry of new projects and money, prioritisation should be undertaken to build resilience more cohesively (see Theme 3). **Governments should remove disincentives that undermine and instead create an incentive structure that encourages ex ante investments.** Greater attention should therefore be paid to the pre-development phase of infrastructure development. This is particularly essential for PPPs, both to assess whether PPP funding can save money for taxpayers over the project lifecycle and because the quality of preparation can have a considerable effect on a PPP's terms and long-run profitability [115].

To maximise the potential for success, **projects that obtain pre-development funding should be linked to other government resources and sources of funding to ensure their successful implementation.** Pre-development funding should also be expanded to cover associated costs from activities such as community engagement, which is essential for equitable infrastructure systems that meet the needs of local communities. There is also a need to understand the role that the private sector can play in supporting pre-development activities. All of this will help to prioritise and ensure that projects are 'shovel worthy' and not just 'shovel ready'.

Developing institutional capacity within national governments improves these institutions' ability to spend sufficient time to project preparation efforts, which can help to accelerate the development of investible project pipelines. It is critical to create an enabling environment to scale infrastructure investments successfully. However, funding tends to be directed toward the development of physical infrastructure, rather than the 'softer' governance processes that can support and enhance the delivery of resilient infrastructure. Local government is frequently the missing link in capacity-building efforts, despite the fact that it is not always included. It is the institution most likely to maintain stability in a community after an infrastructure project has been completed, and it usually has the legal responsibility to provide fundamental community services [116].



Box 10: Task Force for Climate-related Financial Disclosures

The Taskforce for Climate-related financial disclosures (TCFD) has been working since 2015 to provide a framework for both business and financial organisations to identify, assess, disclose and eventually manage their climate-related physical and transition risk. Organisations report under the four key themes of governance, strategy, risk management and metrics and targets. TCFD is important because it has wide support, both by governments and by the business and financial community. It is fast becoming the de facto standard for organisations to disclose their climate risks and in countries such as the UK, New Zealand and Hong Kong, reporting to TCFD recommendations will soon become mandatory for listed companies and large financial institutions..

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https://www.fsb-tcfd.org/

Image source: https://unsplash.com/photos/-iretlQZEU4

Theme 5

Regulation, codes and standards

Photo by Russ Ward on Unsplash

Introduction

Infrastructure governance failure concerns policy misalignment among the many stakeholders involved in infrastructure resilience across the whole lifecycle (Figure 2). Regulatory choices and policy frameworks, such as those governing procurement, might unwittingly skew incentives and inhibit the implementation of innovative solutions like ecosystem and nature-based solutions. To circumvent this, these regulatory frameworks must support the adoption of codes and standards that encourage or require the implementation of practices that maintain or improve the resilience of assets, systems or governance mechanisms. Making use of new prospects for infrastructure resilience, such as Infratech and nature-based solutions (see Section 6), comes with a plethora of governance issues. While falling primarily under the purview of digital or environment ministries, scaling-out and mainstreaming such solutions across infrastructure sectors necessitates strong governance systems and cross-government coordination.

Table 6 below outlines the key challenges and opportunities for improving infrastructure governance under the theme of 'regulations,

Table 6 : Challenges and opportunities under the theme of 'regulations, codes and standads'.

Current challenges	Opportunity for change	Required actions	Associated Lifecycle Section	Key stakeholders involved
C 5.1 Lack of Consistent Guidance and Standards	***O 5.2*** Contextualisation, Harmonisation and Improvement of Codes and Standards	Governance mechanisms must be designed in such a way, as to allow for the continued monitoring of their effectiveness, in order to reliably improve upon them in future iterations. Understanding of the problem and implementation in its context through data and engagement is required before implementation.		
C 5.2 Lack or Absence of Regulation	***O 5.3*** Adaptive Regulation	Adaptive regulation designed around resilience thinking and actively encourage the adoption of resilient approaches.		

C5.1 Challenge: Lack of consistent guidance and standards

A lack of consistent guidance and standards, developed in partnership with the private sector, is commonly associated as a barrier to the implementation of robust resilience measures. Several resources already exist and new ones are constantly published, but the landscape is crowded, confused and fragmented [117]. The absence or inaccessibility of reliable data can hamper efforts to continuously improve and update regulations, codes and standards linked to the lifecycle of infrastructure systems [118]. The **inability to regularly inform and develop regulations, due to the absence of data results in a positive feedback loop which sees developers, owners, and operators unable to improve their practices, given the absence of well-informed standards.** This cycle is evident at the final stage of the infrastructure lifecycle, where a lack of foresight across several sectors, has meant that there are few regulations, codes, and standards in place today that address the decommissioning, deconstruction, demolition or redevelopment of ageing and obsolete infrastructure, in particularly in particular in relation to resilient approaches [119].

The **lack of consistent guidance and standards can be borne out of inefficiencies within governing and regulating structures.** These inefficiencies could come in the form of resource scarcities, meaning that governing bodies simply lack the necessary capacity to effectively collect and analyse information pertaining to the evaluation of regulation, codes and standards. In other instances, a lack of inter-agency and

cross-departmental collaboration could result in the breakdown of communication on relevant topics, resulting in a lack of clarity around ownership of responsibility and accountability [120] (see Theme 1)**. These inefficiencies, when exacerbated across the entire lifecycle, have the potential to cause spiralling costs related to difficulties in the monitoring of performance and consequently the enforcement of standards, resulting in a loss of resilience value** [3]. Furthermore, given that codes and standards developed at the international level are tailored towards countries with well-established and robust regulatory mechanisms of their own, they are often ill-suited for implementation within countries and regions that lack the necessary governance apparatuses to adapt them to their specific circumstances.

O5.1 Opportunity: Contextualisation, harmonisation and improvement of codes and standards

Contextualisation of codes and standard is important, but often governments of various scales may be ill-equipped to implement codes and standards in the precise way they are required to. This could be due to several factors, including lack of access to necessary equipment or expertise, insufficient regulatory institutions, or the lack of financial resources. In these instances, it is imperative that codes and standards are suitably flexible to remain useful and implementable under a diverse set of circumstances. Globally, codes and standards related to the resilient governance, construction, and management of infrastructure are at an early stage in development [121]. This presents an opportunity for these to be developed from the outset in such a way, that they are more adaptable and inclusive, and more in suited to a range of circumstances.

There are significant benefits to having codes and standards that are fit for the future, for example Japan's strict building codes has seen it significantly increase its resilience to seismic hazards [122]. Moreover, developed countries with strict regulatory systems have experienced 47% of disasters globally, but only 7% of disaster fatalities. Benefits are particularly apparent in the case of long-lived infrastructure, which when adopted at the early stage of the infrastructure lifecycle can help to build in resilience and avoid costly 'retrofit' solutions later [123]. However, once implemented or adhered to early in the infrastructure lifecycle, it **cannot be assumed that regulations, codes, and standards will continue to be suitable, robust, or fit for purpose throughout the useful life of infrastructure.** Infrastructure governance mechanisms must therefore be designed in such a way, as to allow for the continued monitoring of their effectiveness, in order to periodically and reliably improve upon them in future iterations.

Similarly, **mechanisms must be in place that help to identify codes and standards that require updating to include resilience-related criteria and how they should be harmonised.** There should be engagement with programmes that are tasked to modify them (e.g. the Eurocode committee in the European Union). For example, many codes and standards have yet to incorporate the consideration of climate change and many still use historical weather information. For example, the recent construction of levees in New Orleans, costing $14billion, will in a matter of less than a decade be at risk from flood events [124]. It is recognised that there is a need to update climate thresholds in design standards, codes and guidelines for infrastructure development to account for climate variability [125]. Due to the long timescales of implementing codes and standards, **developing good practice guides, which can be led by respective professional sector bodies should also be encouraged.** The recent publication of ISO 14090:2019 – Adaptation to climate change [126] should be integrated into project planning and investment proposals (e.g. PPPs) to increase climate resilience.

Continuous monitoring can be mandated or encouraged by decision-makers using disclosure requirements embedded in regulations. Not only can this result in risk alleviation through the early identification of potential issues, but the feedback can be used to inform future regulations, codes and standards [127]. In addition, it is critical to establish good communication and processes that will lead to effective controls by allowing controlling entities and contracting authorities to communicate in real-time using existing digital technology to the extent practicable [128]. By requiring continuous monitoring of assets, networks and governance mechanisms, decision-makers can more easily hold themselves and others accountable for failures or inefficiencies, thus improving both the governance mechanisms and maintenance of assets and networks while also continuously improving upon the resilience of regulations [12]. For example, in the Australian state of Victoria, there is a requirement under the Victoria Emergency Management Act to conduct a simulated emergency exercise. As a component of the 12-month cycle, exercises are undertaken in a controlled environment where infrastructure operators/owners

can evaluate their plans, explore problems, encourage awareness and identify any gaps and contributes to the continuous improvement of the infrastructure. Here, the level of competency and ultimately the resilience of the infrastructure can be assessed for the cases of emergency and relevant policies and standards updated [49].

Controls should also be ex-ante rather than ex-post, and constructive (i.e., seek solutions to the problems detected) rather than punitive (i.e., confined to penalising the identified faults). For example, Ex-ante third-party controls on the legality of tender papers promote and maintain the probity and transparency of the award procedures utilised in certain procurement procedures. Given the specific checks on the validity of each procedural stage in the tender, this system may serve as a deterrence for future cases of corruption. It also aids in the restoration of confidence among relevant market participants in the transparency and probity of award procedures and subsequent tender management.

C5.2 Challenge: Lack or absence of regulation

A fundamental problem, particularly in the developing world, is the lack of regulation governing infrastructure development, operation and maintenance. The universe of regulation is divided, between the design of regulatory incentives (utility pricing, subsidies, entry costs, market extensity etc) and the design of the governance apparatus (institutions, administrative processes, review mechanisms, and dispute procedures) that administers these incentives [129]. The complexity in addressing this issue therefore lies in the fact that **the root cause of the lack of regulation is the absence of the necessary institutional capacity, or government apparatus, to develop and implement these.** A compounding factor is that there are significant costs involved in the development of every aspect of the process (i.e. establishing the required institutional capacity, developing the regulations themselves, and enforcing them)**.**

Particularly in resource-scarce countries, those where the institutions and regulations are lacking, policymakers may be disincentivised from contemplating the development of the required mechanisms due to the perceived imbalance between the apparent costs and benefits associated with introducing and enforcing regulations3. Given the difficulty in establishing and quantifying the avoided costs and accrued benefit that would result from the implementation of the relevant regulations, policy and decision-makers influenced by shorter-term political cycles in these countries may choose to allocate the limited resources available to developments whose costs are more straightforward to quantify and whose benefits are more readily visible by voting constituents. There is a perception that introducing regulations that support resilience may negatively impact a ruling body's ability to remain in power and this is then seen as a negative development [130].

While institutional failures exist in all sorts of regulatory agencies, from legally established independent groups that operate with a high degree of autonomy to those inside the mainstream public sector, the difficulty of reaching full efficacy in the latter may be more acute. This is because **overemphasis on political responsibility and outmoded rules on financial matters and staff procedures may make it difficult to improve performance.** Such organisations are usually influenced by cultural tendencies inherited from the public sector that are incompatible with a high achieving organisational environment [131].

O5.3 Opportunity: Adaptive regulation

For resilience to be appropriately considered across the whole infrastructure lifecycle, it is necessary for regulations that govern them to be designed around resilience thinking and actively encourage the adoption of resilient approaches. **It is important to ensure that legislation is not a barrier to innovative actions.** Successful mechanisms of risk reduction and hazard adaptation in developed countries have relied in large part on effective and efficient building of regulatory systems, which have been incrementally improved over time.

Adaptive models, such as adaptive regulation, are used in regulatory and governance systems to deal with the deep uncertainties of complex systems. Defined as a regulatory framework designed to facilitate a more dynamic approach to regulatory policy making, **adaptive regulation enables regulations to be changed and adapted to achieve an agreed-upon end goal as new evidence and data becomes available.** However, there is no set way for achieving or implementing adaptive regulation. Therefore, adaptive regulation relies on a conscious data collection and review linked to pre-determined performance indicators. Box 13 outlines a case in the Netherlands, where an adaptive regulatory approach has been successfully implemented in the context of flood protection.

It is worth noting that in certain contexts, the stability of a pre-existing regulatory system may outweigh the benefits of introducing an adaptive approach.

In a similar vein to the whole system view outlined in Theme 1, a whole-of-regulations view would be helpful to weed out the incompatibilities and highlights the crossovers between different sets of regulations in different sectors. Another approach to adaptive regulation is one that sees codes and standards tailored to the specific local context in which they are being applied (see opportunity O5.1).

Continuous monitoring and adaptive regulation should ensure that there is adequate capacity to sustain infrastructure over its operational phase as well as learning for future iterations.

Box 11: The Delta Programme, Netherlands

Delta Works, created in 1953, resulted in the creation of an expansive series of flood defences over several decades, following severe flooding in the spring of that year, that resulted in the loss of lives, livestock, and livelihoods. The system has developed over time into The Delta Programme, whose purpose is on preventative and adaptive management approaches that address future challenges like climate change. The shift from reactive flood defences to adaptive management was introduced to better tackle the challenges of uncertainty across multi-decadal timeframes.

The Adaptive Delta Management Approach, adopted in 2007 paved the way for the introduction of institutional mechanisms enshrined in Dutch Law through the 2012 Delta Act, which requires periodic reviews, secures continuous funding and introduced a commissioner to facilitate cross-governmental collaboration and stakeholder engagement.

In 2017 fundamental changes were made to the Netherlands' flood defence standards, shifting the focus to outcome-oriented thinking, which brought with it a shift in focus from hazard to vulnerability, providing a stronger rationale for adaptive methods. The programme now includes use of probabilistic tools to include uncertainties in the design assessments and extensive relevant data, indirect and direct dyke failure modes (i.e., a breach or maintenance issues) and an option of a multi-layered flood strategy depending on risk-levels.

Adaptive regulation, in the context of this case study, brought about several benefits, including: consensus building to ensure commitment to the end goal; systems thinking, opening up regulatory options to achieve the desired outcome, and; adaptive leadership, which enabled adaptive regulatory responses through the systematic tracking of relevant indicators.

Richard Judge & Arthur Petersen, Planned Adaptive Regulation – Learnings from the Delta Programme [then bluirb about RAEng providing case study] Case study provided by The Safer Complex Systems mission delivered by Engineering X, an international collaboration founded by the Royal Academy of Engineering and Lloyd's Register Foundation.

Photo by Adrien Olichon on Unsplash

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Theme 6

Capacity and Resourcing

Introduction

Human resources with the necessary skills to plan, deliver, and manage sustainable, resilient infrastructure at the scale required to satisfy demand is lacking. This is particularly so in developing nations, which account for the majority of the world's infrastructure gaps [34].

A lack of government funding, brain drain, and poor governance are examples of what limits the capacity of governments to predict, plan, mitigate and respond to disasters. Capacity necessitates financial resources, but it also necessitates technical competence and personnel to handle projects, finances, and procurement. In many of the countries that are aiming to fill their infrastructure gap, there are not enough engineers, town planners and technical specialists who have the skills to satisfy basic infrastructure needs of the country [34]. In such contexts, the lack of knowledge and capacity become a barrier for infrastructure resilience and further create vulnerabilities during a disaster.

Table 7 below outlines the key challenges and opportunities for improving infrastructure governance under the theme of 'capacity and resourcing'.

Table 7 : Challenges and opportunities under the theme of 'capacity and resourcing'.

Current challenges	Opportunity for change	Required actions	Associated Lifecycle Section	Key stakeholders involved
C 6.1 Loss of Skills and Capacity	***O 6.1*** Nurture and Establish Skills around Infrastructure Resilience	Strengthen national and local actors' capacities. Incentivise retention of talent in local markets. Provide funding for academic institutions and establishing courses around infrastructure resilience.		
C 6.2 Inequalities and Digital Transformation Within Traditional Governance	***O 6.3*** Building Inclusion within Governance	Establish initiatives to empower youth and other marginalised and/or vulnerable groups and communicate the benefits of diverse teams to government staff. Harness existing digital skills to close the digital divide.		

C6.1 Challenge: Loss of skills and capacity

The capacity and human resource available to governments and institutions is typically constrained, particularly in the developing world context. This can often be exacerbated due to large numbers of highly skilled nationals leaving their home country to pursue work elsewhere and attracted by the promise of higher compensation, known as 'brain drain'. This issue has the potential to harm the economies of the countries of origin by impeding the growth and development of industries and service sectors such as infrastructure, that require highly qualified workers. Moreover, it is argued that infrastructure investments are less successful when they are undertaken during periods of higher-than-average public investment, as a result of reduced capacity.

In Africa, it is estimated that approximately 70,000 skilled professionals emigrate every year. Africa's demographics reflect is the world's youngest continent, with an estimated 10 to 12 million young Africans joining the labour force each year [132]. Yet the continent is able to create only about 3 million jobs annually. With limited economic opportunities, many young Africans are migrating to Europe and America for economic opportunities [133].

Much of the skills and capacity development needs to take place within government departments as approximately 85% of infrastructure globally is funded through public money [34]. For example, the loss of skills in Government was a major contributor in the Cape Town Day Zero Crisis, where over a course of decades, the loss of staff had led to a reduction in the functionality of a cooperative government

Box 12: Asset Management Programmes within Engineering, University of the West Indies at St. Augustine, Trinidad and Tobago

Caribbean countries are in the phase of their development where the majority of the industrial and economic activities comprise of procuring, installing and effectively operating and maintaining plant and assets, and using these to produce value-added products and services locally and internationally. Effective asset procurement, operation, maintenance, reliability and disposal are the core competency requirements for the region. However, this is currently a skill gap.

Engineering Asset Management is a programme designed for engineering majors in the University of the West Indies which is an emerging inter-disciplinary field that combines and optimizes the technical issues of asset reliability, maintenance, safety and asset performance with the requisite financial and managerial skills. The emphasis of Engineering Asset Management is to achieve sustainable business outcomes and competitive advantage by applying holistic, systematic and risk-based processes to critical thinking and root cause analysis decisions concerning an organisation's physical assets, including its fixed plant, mobile equipment, and it's civil, electrical and mechanical infrastructure. For these short courses students are invited to bring along their managers and technicians, in reliability and maintenance, so that these stakeholders can all share in some of the taught MSc material and thus together develop the critical thinking and root cause analysis capabilities necessary to optimally manage the industry's assets.

https://infrastructuretransparency.org/about-us/

approach to water management [134]. Moreover, in Latin America and the Caribbean, only half of the dedicated PPP agencies have full-time staff, with Governments having to borrow staff from other departments to fulfil requirements.

The flight of human capital, particularly in regional and local government, has the potential to have an intergenerational impact on innovation and the higher-value-added sectors of the economy like infrastructure. Communities will also bear the brunt of most climate change impacts, where adaptation and disaster risk reduction measures must be undertaken, and where the success of these measures, as well as community buy-in, will be critical to their long-term viability. SIDS are the most vulnerable in the broader context of vulnerability due to their unique human resource situation, which is characterised by persistent professional out migration. In this setting, the involvement of civil society and non-governmental organisations (NGOs) is critical in establishing synergies between donor and national capacity development projects [41].

O6.1 Opportunity: Nurture and establish skills around infrastructure resilience

Strengthening national and local actors' capacities is a critical step toward better resilience to shocks and stresses [135]. A key impediment to strengthening adaptation efforts is a lack of resources and expertise to provide hands-on experience. As resources to improve capacity are often limited, it is crucial to consider how to develop existing capacity rather than starting afresh. Hence governments must look to harness existing skills, frameworks, and processes within government, but also to utilise human resources outside of government, within the private sector and the wider population. Capacity efforts must be value-driven and intend to uplift the most vulnerable.

Further education around resilience is required across the sector. While it is important to continuously train key decision makers about threats and challenges to building infrastructure resilience, a potential way to incorporate resilience thinking is to integrate disaster preparedness in the coursework of students with majors such as construction, planning or management [136]. Formal education, as well as technical and vocational education and training, lays a foundation and necessitates the creation of relevant curricula and modules for training professionals (see Box 14). Moreover, professional institutions have a role to play in controlling and informing education standards and embedding resilience in their qualification specifications (e.g. chartership). Given the need to 'build better' going forward and develop better responses to the challenges of tackling various dangers and the uncertainties associated with climate change, learning by doing is critical (see Box 15). However, learning from others is also essential to avoid reinventing the wheel and to expedite learning and apprenticeships can help with this.

Education will help to raise awareness of

the importance of disaster management and preparedness for these disasters so that students can assist their family members and friends in facing the challenges head-on. Additionally, students majoring in fields such as construction, planning, management and policy will develop an understanding of threats, which will benefit them later as policymakers, engineers and leaders in the field.

The implementation of a disaster preparedness course necessitates the participation of all local stakeholders. Infrastructure design and delivery in a changing and uncertain climate will necessitate new talents and competencies in a variety of disciplines. This is a particularly difficult problem in Asia and the Pacific, where considerable financial resources and cutting-edge knowledge are still scarce [137].

Participating in nation-building without physically relocating is known as virtual involvement. Virtual involvement views the brain drain not as a loss but as a possible gain. Highly skilled expatriates are considered as a pool of potentially helpful human resources for the country of origin. The key is to activate these brains. But there may be some challenges of working on a continent where government–Diaspora relations are tumultuous, information technology is scarce, and development demands are complicated and need long-term commitment [138]**. Incentivizing retention of talent and skills in local markets through enabling legislation is required.**

Virtual engagement offers enormous potential for channelling untapped intellectual and material resources. It also revealed a growing understanding among the migrant diaspora of their moral, intellectual, and social obligations to support the home country's development efforts. However, virtual platforms won't replace 'boots on the ground' and that requires investing in local skills upgrade and employment.

As public sector organizations increasingly rely on technology and a smaller work force to deliver quality services, the value of work force intelligence cannot be overstated. Organizations with dynamic technical capabilities excel at balancing the problem of seeking new solutions while maintaining high levels of present service, thereby building resilience into their systems. All levels of leaders in governance should be at the forefront of addressing this looming loss of accumulated knowledge.

C6.2 Challenge: Inequalities and digital transformation within traditional governance

Young people are politically disenfranchised in several ways, one of which is due to age-based restrictions on political involvement. 1.65% of parliamentarians around the world are in their 20s and 11.87 % are in their 30s [139]. Cultural biases and a lack of social and financial capital can make things even more difficult. Youth councils and parliaments, which can teach young people about the governance process and provide training in the skills they need to be effective, are a traditional channel for youth governance engagement [140].

Similarly, while many governments recognise gender equality considerations as a fundamental aspect of successful infrastructure policy, often there are challenges applying and implementing such policies. Disproportionately, women and other marginalised groups bear the burden of underdeveloped and non-inclusive

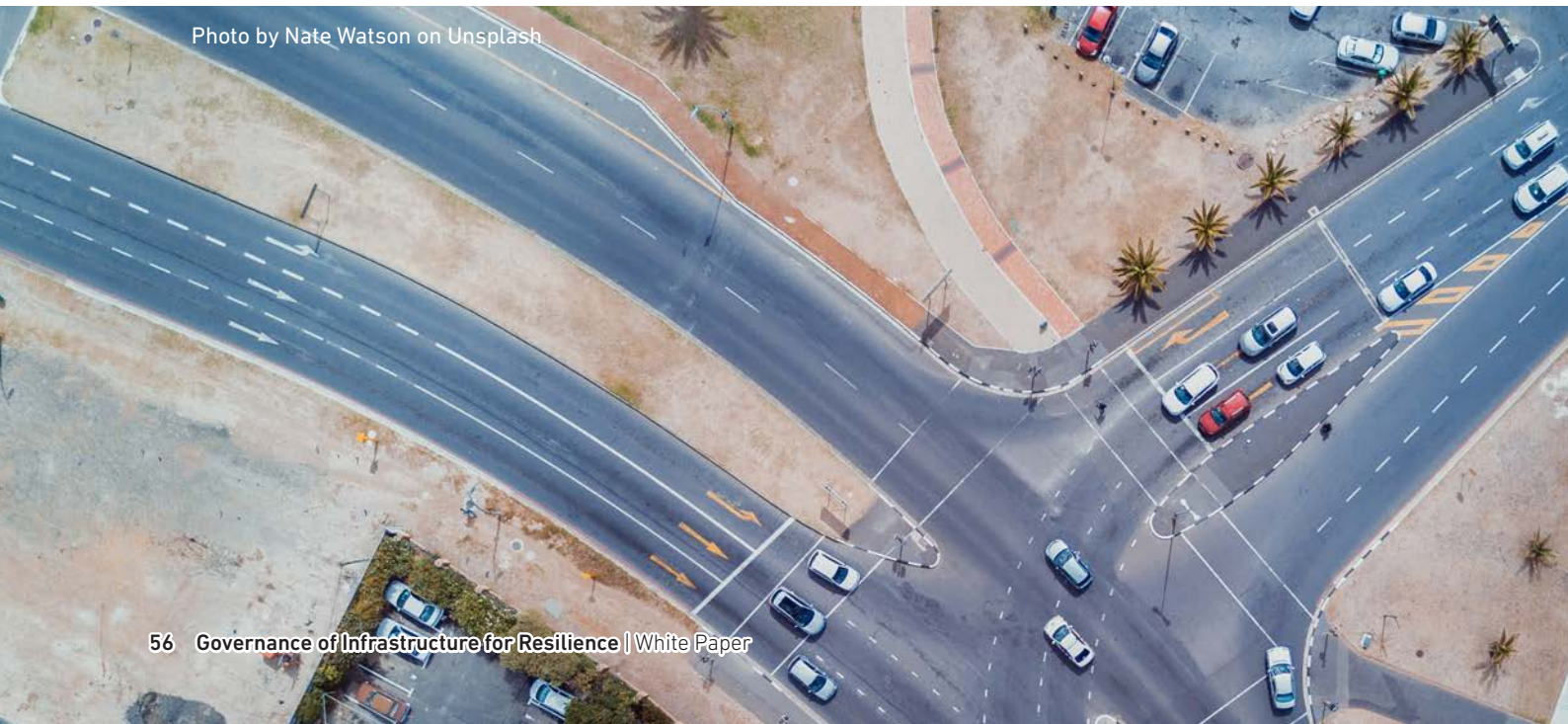

Photo by Nate Watson on Unsplash

infrastructure. This burden is intrinsically linked to the underrepresentation of women within the decision-making process at all levels of government. This failure is exacerbated by the gender-data gap, resulting from the absence of sex-disaggregated data collection activities and the consequential inability to monitor and evaluated the effect that governance shortcomings have on women and girls. These flaws are repeated across the socio-economic spectrum, where underserved and marginalised groups, whether due to age, gender, or religious or cultural alignment are not appropriately involved in the governance of infrastructure [141]. If not adequately managed, these groups might devolve into spaces for passive consultation rather than active participation in decision-making.

On the other hand, 'retirement brain drain' creates generational workforce shifts when the wisdom and experience that a career professional gains over their lifetime is lost [142]. A larger-than-usual quantity of retirement removes more of this accumulated knowledge, forcing companies to replace this talent with persons who are less qualified and untested. A 'talent vacuum' or loss of institutional knowledge might result from retirement brain drain [142].

Many issues might arise with implementing inclusive policies, including unclear or complex regulatory frameworks, a lack of financial resources, strict human resource management systems, and cultural barriers. However, the major impediment to attaining inclusion is a lack of genuine or concrete proof of the benefits it may bring to the performance of governance [143]. As a result, **implementing diversity programmes necessitates a lengthy process of trust-building to get support from public officials, employees, and people.**

Technological transformation profoundly alters how infrastructure governance operates and how services are delivered. However, there are significant variances in the speed and direction with which technology impacts distinct businesses and services. Some organisations master the development of dynamic technology capacities and experience rapid and revolutionary changes, whereas others do not and suffer gradual changes. This disparity is due to both internal and environmental factors [144]. Theme 7 speaks about this in further detail.

O6.3 Opportunity: Building inclusion within governance

Capacity building has largely been reported in Sendai to mitigate disaster risks [36] and has been identified as a means to substantially reduce global disaster losses [145]. Community empowerment for Disaster Risk Management requires their engagement in risk assessment, mitigation planning, capacity building, implementation, and the creation of monitoring systems, assuring their stake in the outcome.

Inclusion requires integration of not only a diversity of backgrounds and skills, but also an appreciation of people's skills, experience, and viewpoints to increase government efficiency and effectiveness, as well as to meet the professional expectations of administrators. Diversity of age and gender within administrations may help to improve the quality of public services by better understanding community needs and boosting

Box 13: African Union Development Agency – AUDA-NEPAD

The African Union Development Agency (AUDA-NEPAD) has partnered with Australian Aid in an Infrastructure Skills for Development (IS4D) Initiative to build human capacity for the effective implementation of regional infrastructure projects.

IS4D targets professionals in public sector agencies, from all over Africa, involved in delivering priority African infrastructure projects. The "on-the-job" training allows participants to achieve project management competencies necessary to fast-track the development and delivery of large-scale infrastructure projects they are working on.

IS4D is an essential component for the implementation of the Programme for Infrastructure Development for Africa (PIDA) which promotes the development of high priority, regional infrastructure across the four sectors – Energy, Transport, Trans-boundary Water and ICT. The Community of Practice provides IS4D participants and alumni a workspace for e-learning, mentoring and cross-border collaboration.

Source: https://cdn.gihub.org/umbraco/media/2357/case-studies-pages-90-247.pdf

social interaction and communication with the general public (see Box 16). This may aid in the advancement of the reform agenda and the promotion of good governance practises by improving government-citizen relations and increasing trust in government.

It is not sufficient to improve the capacity of the central government alone to reduce disaster-related damage. Local governments, provinces, districts, and towns will also be more effective in responding to disasters in a timely and effective manner if their disaster management capacities are strengthened. This approach will result in improved coordination of national and international actors and the central government during disasters, as well as in the more efficient use of resources. As technical knowledge within the general population improves, governments should look to effectively integrate such knowledge within relevant governmental ministries. Hence as local technical capacity improves, governments should take the opportunity to learn from, consult or employ local technical experts to better predict and manage disasters.

For governance of infrastructure systems to be inclusive and accessible to all, emphasis must be put on holistic stakeholder engagement from an early stage of development. No system, network, asset, or community is truly resilient, unless those that designed, developed and maintain it have done this in a way that brings the largest possible number of benefits to the widest range of stakeholders. This includes those communities and groups that may otherwise be marginalised or underrepresented at the governance level. In addition, communities typically silenced by others or who would put themselves at risk by speaking out, must be afforded the opportunity to provide input in a safe space.

For the system to be considered equitable, it must also be acknowledged that a development could bring disproportionately negative impacts to some groups or communities. These must be included in early discussions, so avoidable negative consequences can be designed out. This requires that those designing the engagement opportunities understand the cultural, religious, economic, and societal nuances of all of the stakeholder groups. Consideration must be given to the timing of events, in order to ensure that those individuals constrained by time, or the lack thereof, can have their voices heard.

If there are unavoidable negative consequences, stakeholders must be suitably compensated and viable alternatives found, taking the needs of the whole community and its members into account. Inclusive and equitable stakeholder engagement practices allows those in power to access local knowledge and inform solutions that would otherwise have not been considered [146]. In this way, outcomes will be more robust, equitable and inclusive. Guidance exists on the most appropriate approaches to stakeholder engagement at various scales [147] [148].

Box 14: Brain Builders International, Nigeria

Nigeria has over 30 million youth population and 29.7% of these are unemployed. There is a need for collaboration among the government and other stakeholders to tackle this enormous problem and related ones. BBI is one of many organizations in the country that seek to do this.

Brain Builders International (BBI), is a youth-based non-profit making and non-governmental organization supported by the United Nation's sustainable development goal partnership platform that promotes civic engagement and peaceful political participation, youth entrepreneurship and empowerment project, youth participation in community development, education development programme, human rights and good governance. BBI has since its establishment, reached out to over three hundred thousand youths across Nigeria on areas such as leadership, entrepreneurship, capacity development, and community development. necessary to optimally manage the industry's assets.

Source: https://sustainabledevelopment.un.org/partnership/?p=11924

Photo by Koukichi Takahashi on Unsplash

Theme 7

Data, information and technology

Introduction

Information and data underpins evidence-based infrastructure planning (see Theme 3) and is regarded as the foundation for effective Disaster Risk Management [149]. Infrastructure decision-makers therefore need access to high quality, timely and consistent data and information [150], which has been described as the 'golden thread' that should run through projects [151]. In newer models of infrastructure delivery, this thread becomes a 'golden loop' as information generated by a project can be integrated back into operating systems to inform requirements for future upgrades. However, the right data, risk models and decision-making methods need to be available to ensure more resilient infrastructure systems [100].

Table 8 below outlines the key challenges and opportunities for improving infrastructure governance under the theme of 'data, information and technology'.

Table 8 : Challenges and opportunities under the theme of 'data, information and technology'.

Current challenges	Opportunity for change	Required actions	Associated Lifecycle Section	Key stakeholders involved
C 7.1 Lack of Consistent Data Policies and Standards	***O 7.1*** Enable and Accelerate Accessibility to Infrastructure and Risk Data	There is a need to ensure that hazard and infrastructure data is available and accessible to those making infrastructure decisions at all stages of the project lifecycle. Appropriate policies and standards are also required to ensure that data collected is consistent, reliable and trusted.		
C7.2 Lack of Data Availability and Accessibility	***O 7.2*** Support the Development of asset management systems and intelligent monitoring	Having an asset management system in place is essential for ensuring improved infrastructure decision-making and can be used to inform evidence-based assessments. Support and learning programmes for establishing asset management systems and associated databases should be established.		
	O 7.3 Embrace InfraTech	Technological systems can provide near real-time information on infrastructure assets, supporting asset management activities and informing infrastructure decision-making. However, the application of InfraTech should be contextualised for the country of operation which may have varying levels of investment,		

C7.1 Challenge: Lack of consistent policy and standards

When deciding whether to pursue a certain investment or which delivery method to use, most governments employ some form of numerical value analysis (See Box 15). Cost-benefit analysis, business case methodology, and public sector comparators all require assumptions as well as more confirmed evidence, which includes both quantitative and qualitative factors and data, also see opportunity O3.1. **Data is the most important factor in ensuring the validity of any type of value for money analysis.**

The availability of infrastructure and risk data can vary significantly across the globe. Additionally, consistent data on the cost and performance of infrastructure assets is lacking in most regions. Even in developed countries, such as the United States, data for certain infrastructure sectors can be sparce or if available, unreliable [152]. The need for better national datasets has been known for some time, which can be used to inform risk assessments [153].

Restrictions on access, use and redistribution of natural hazard datasets and risks assessments is regarded as an often-overlooked challenge [149]. **The main policy challenges around data governance [154, 129] include the need to reinforce trust across the data ecosystem, stimulate investments in data access and sharing, and foster effective re-use of trustworthy data.** Currently, a number of barriers limit data sharing, which include:

- Privacy and legal impediments to the sharing and use of personal data, as well as a lack of clarity on whether it is permissible
- Contractual limitations for non-personal data sharing may limit the scope for data sharing
- Security barriers and concerns that sharing data may lead to security breaches, data losses, and, in extreme cases, critical cyber-attacks
- Risk allocation and data ownership
- Data trust concerns owing to a lack of awareness and attention on the potential benefits of data and new technology [155]
- Competitive hurdles where data sharing and collaborative approaches are not the norm
- Incompatible formats and the inability to share create technical impediments.

Governments require a solid governance framework, as well as the appropriate institutional and legal structures to develop a digital government environment.39 However, the capability and appetite to implement such frameworks vary across governments. New technologies are usually imposed on rigid and traditional organizational structures in the infrastructure sector. Due to their financial structure and regulatory mechanisms, the infrastructure sector operates with low profit margins, hence utilities have relatively low internal incentives to adopt new technologies, particularly when the long-term benefits accrue to other stakeholders. Most people and organisations now use digital tools, but they are frequently underutilised and not inclusive (see Box 16). Despite practically all organisations being connected to the Internet, just 33% of large and 11% of small organisations utilize big data analysis [154].

From a technical standpoint, platforms must be built on standards-based, open, and widely available hardware and software components. This platform should be scalable and capable of performing many of the basic activities necessary for API use, as well as security, authentication, auditing, and access rights management [156].

Federated systems enable ease of access through a single point of entry, or ease of data management in general, with common standards and the complexity of underlying structures largely hidden [157]. While the popularity of federated systems is increasing, there are numerous regulatory and governance concerns. Gaining agreement and commitment from federation members on goals, operating principles, performance measures, and allocation of benefits and commercial value is one of the most critical hurdles.

C7.2 Challenge: Lack of data availability and accessibility

There is an increasing need, especially with limited financial resources and competing interests, to provide evidence-based decision-making for infrastructure projects (see Theme 3). However, this needs to be mindful of the capacity (see Theme 6) of the Government making those decisions [29].

In 2018, the G20 Finance Ministers' meetings and announcement emphasised on the **need for more and better data collection on the long-term performance of infrastructure assets and projects.** This means not just the financial performance, but also measure of environment and social sustainability, governance, and operational performance. Creating and making

this type of data available to investors will be the key to helping unlock private capital flows, not only into G20 country infrastructure projects, but also into those in emerging markets [158] (see also Theme 4).

Data regimes are often shaped in a vacuum. Emerging technologies, socio-economic shocks and stresses, geo-political changes and global crises have the ability to significantly alter the facts on the ground. Good benchmarking practices require consistent data and a data collection process. However, in contexts where many players don't yet have fully developed digital strategies and how they respond to the new risks and possibilities, **the availability of data plays a role in how independent stakeholders are able to coordinate towards common goals such as adaptation and resilience.** Some countries that were engaged with as part of the development of this paper spoke of national governments accessing national data sources (e.g. weather forecasts) while regional governments looked to regional sources for the same data.

While many governments collect data, much of the information needed to assess the overall costs of projects funded through various alternative sources **is not collected, processed, or provided in a systematic way [159] and data is also often stored across multiple datasets.** For example, in cities passengers obtain journey information from apps that link real-time data from multiple data sources. Therefore, it would be valuable to **link these different datasets to obtain valuable information about the performance of an infrastructure system [160]. Often, the lack of appropriate data can be a barrier to private investment within a country** [161]. To exacerbate this issue, data collection is resource intensive.

Broadly, data could be classified into 'official' and 'unofficial' data. For official data, there can be a hesitancy or unwillingness to share, which is often due to concerns around corporate privacy, regulatory constraints, protection of intellectual property and that online data may be mismanaged, resulting in a loss of data value [162]. In the context of Disaster Risk Management, there is a need for early warning systems which require near real-time data to be of use. However, such data is often not made available as 'official' data. Therefore, agencies may then turn to unofficial data (e.g., crowdsourcing and social media) [155]. Understandably, there can often be a reluctance to use 'unofficial' data to make infrastructure decisions unless there are standardisation protocols in place.

The lack of coordinated data gathering, and systematic publishing of data also obstructs effective asset performance monitoring. Governments often also don't understand current asset condition, and therefore whether there is a need to update certain pieces of infrastructure.

O7.1 Opportunity: Enable and accelerate accessibility to infrastructure and risk data

Data should be treated as a critical resource [163], which has shown to be more vital emerging from the Covid-19 pandemic. Having better data on infrastructure development and hazards will help governments around the world to make better investment decisions going forward [164] (for example, See Box 18). Stakeholders, including members of the public, need to be active agents in the digital economy and have confidence and trust in how data – including citizen data – is used [165]. This will be especially important as governments transform use of data to drive efficiency and improve infrastructure services – with a clear understanding that utilising data delivers better outcomes. A **successful data system will need to be flexible and react quickly to changes.** Templates should be developed to capture data from peer organisations in the benchmarking network. **Where possible, industry-standard data frameworks should be used across geographies for data collection** from different organisations to avoid any discrepancies [109].

Data should be used to inform infrastructure policy. A key gap identified by many stakeholders was that there has been no overarching set of principles that provided advice and clarity on problems like data ownership, what constitutes data, what defines personal and non-personal information, assuring security by design, etc. While such a framework may never be regarded definitive, **a standard set of principles applicable across the whole sector can be used as a starting point for data sharing in the future** [166] drawing on the work of industry groups to provide overall guidance. This would benefit from leadership by a public body with an invested interest in each infrastructure sector, which would be complementary to the work carried out by industry-led groups. Stakeholders such as industry and academia should also be involved, facilitated by public bodies such as regulators. See Box 17 for an example of how this has been implemented in Australia. The World Bank has developed an 'Open Government Data Toolkit' that *"helps governments, Bank staff and users understand the basic precepts of*

Open Data, then get 'up to speed' in planning and implementing an open government data program, while avoiding common pitfalls" [167].

The Royal Academy of Engineering argues that the following things are required to ensure better access [160] to data: ensuring that the costs and benefits of collecting, storing and distribution of data is fairly distributed; policy, guidance and standards are available on how data should be used; the necessary skills to support people in managing data is provided; data quality assurance; ensuring data privacy; and the secure storage and transmission of data.

The **difficulty of data gathering also makes systematic ex-post learning difficult,** however certain independent audit bodies such as Supreme Audit Institutions (SAIs) and regional and local audit institutions are working to close the gap [168]. Bodies like the SAI would ex-post audit and review individual projects, as well as the infrastructure programme as a whole in terms of performance, money, and compliance. However, this necessitates the use of specific resources and tools that not all regions or scales of governance would have equal access to.

O7.2 Opportunity: Enhance asset management systems for resilience

In low- and middle-income countries, asset management approaches are weaker than other parts of a project's lifecycle [169]. Infrastructure decision-making is often hampered by poor asset management frameworks and systems, tools and data [99]. Recognising the particular lack of accurate data in some contexts, establishing methods to demonstrate compliance may be difficult. One way to deliver this is through starting with **an asset management framework that puts sustainable service delivery as central, rather than condition or resilience of a particular piece of infrastructure.** Asset management offers a real opportunity to accelerate uptake of resilience practices by enhancing existing policies, frameworks and systems rather than inventing something wholly new.

Asset management is vital to build controls, plans, and processes that manage, monitor, and mitigate risk while consistently delivering performance to enable preparedness for unforeseen events. Understanding fully the pre-, during-, and post-event performance requirements and expectations, as well as the asset capabilities, risks, and vulnerabilities, and having plans in place to deliver them, in the


Photo by Mika Baumeisteron Unsplash

Box 15: Data Integration Partnership for Australia

The Data Integration Partnership for Australia (DIPA) is a co-ordinated, Australian Public Service-wide investment to maximise the use and value of the government's vast data, allowing cost-effective and timely insights into data that is already available, while ensuring the safe use of data in secure and controlled environments. A core component of the DIPA is to establish a central analytics 'hub' and issue-specific data analytics units that integrate and link data assets to solve complex policy issues over multiple portfolios.

The Office of the National Data Commissioner (NDC) provides oversight and regulation of the new data-sharing and release framework, including monitoring and reporting on the operation of the framework and enforcing accompanying legislation. The NDC is also responsible for the criteria and process for accreditation. This includes the accreditation of 'trusted users' (end-users of data shared or released by data custodians) and 'Accredited Data Authorities (ADAs)' (entities that have strong experience in data curation, collation, linkage, de-identification, sharing and release).

The National Data Advisory Council (NDAC) advices the NDC on ethical data use, community expectations, technical best practice, and industry and international developments. NDAC will help find the right balance between streamlining the sharing and release of data and ensuring the protection of privacy and confidentiality.

Source:
https://www.oecd-ilibrary.org/sites/15c62f9c-en/index.html?itemId=/content/component/15c62f9c-en

context of asset management, will help with determining quickly what is required to return to service.

Drawing on and combining their experience, insights and contacts across the infrastructure and technology, administrators can bring together key stakeholders. Future impacts of technology on infrastructure include shaping procurement approaches and contracting models to support greater integration and deliver required outcomes.

Good governance provides a wider role to play in navigating the challenges and accelerating the enablers to InfraTech, for example (see opportunity O7.3), by facilitating introductions, collaboration, and skills and knowledge sharing across different sectors and organisations, or by providing strategic advice in developing new delivery and business models that ultimately result in more resilient infrastructure [170].

O7.3 Opportunity: Embrace InfraTech

Infrastructure technology (InfraTech) offers higher margins via technology-driven business transformation. Delivering, operating and maintaining connected infrastructure adds a new layer of value over constructing physical infrastructure [170]. Today's communities and economy are being transformed by the fast integration of digital technologies. New technologies have the potential to solve problems while negating the need for stronger government intervention. They can also assist in reducing infrastructure maintenance costs while increasing operational efficiency, and provide alternatives to traditional infrastructure design, building, and maintenance methods. Technological breakthroughs can increase efficiency in governing bodies, empower consumers, and level the playing field.

In the critical infrastructure sector, policies and programmes are looking to democratise the use of technology [171]. For example, this may include government decentralisation programmes, the devolution of infrastructure governance responsibilities to local levels, aid projects or grassroots community development projects, policy-focused research, the opening up of government data to public scrutiny to improve transparency, the provision of information to citizens about government policies or procedures, citizen monitoring of government spending, and the mobilisation of mass citizen protests.

Intelligent monitoring and modelling technology, as well as new processes and analytics, have made it possible to better plan investments and extend asset life [99]. The goal of predictive maintenance (also known as knowledge-based maintenance) is to optimise maintenance by making predictions. Intelligent infrastructure can produce self-diagnostic systems that alert in case of worsening state, expected failures, and intervention needs by accessing monitoring data utilising sensors, digital technologies, and artificial intelligence approaches [39].

The Covid-19 pandemic has hastened digital transformation in the public sector, particularly in government. During the lockdowns imposed since early 2020 in response to the first wave of the pandemic, governing bodies had to devise new measures to assure the continued operation of important institutions and the

Box 16: ProAdapta Brazil– Support for adaptation to climate change

Out of a partnership between the Ministry of Infrastructure and the Ministry of Science, Technology and Innovations in Brazil, they have recently developed the platform AdaptaBrasil. This allows users to access climate change information and assess the impacts of climate change, both observed and projected, at a national scale. It also provides subsidies to the competent authorities for decision-making.

AdaptaBrasil currently offers information to the energy, food and water sectors. The project has established a strategy to enhance capacities and efficiently execute the National Adaptation Plan in collaboration with the Brazilian Ministry of Environment. Climate change adaptation has also been incorporated into the Brazilian Ministry of Infrastructure's internal sustainability guidelines.

Source Supporting Brazil in the implementation of its National Agenda for Climate Change Adaptation (accessed 2021) GIZ https://www.giz.de/en/worldwide/66671.html

delivery of public services. Technological advancements have been critical in the aftermath of the COVID-19 crisis, allowing infrastructure to become more resilient to future disasters [2]. To meet this challenge, **governing bodies must adapt how they work and organise themselves, as well as ensure that they have the necessary skill sets to use new digital technologies, collaborate, and communicate with citizens and businesses.**

A strategic approach to digital transformation necessitates, first and foremost, a digital governance plan that lays out the practical and strategic stages for disseminating and deploying digital technologies for more collaborative, innovative, and open governance. Such a strategy should be accompanied by the proper data architecture, an adequate governance infrastructure to guide and integrate the use of digital technologies, and a legitimate measurement methodology to monitor the agency's progress toward full digitalization. Specifically in the public sector, strong political support will be required to accomplish digital transformation at scale [172].

Infrastructure businesses are working with tech firms in two ways. One approach is the **embedding of technological capabilities within their businesses through acquisitions or by creating in-house technology units.** The other, more common, form is via contractual mechanisms such as sub-contracting and PPPs [170]. Models for funding and techniques to procuring ICT will need to be reconsidered. Agile business case methodology, creative approaches to the commissioning of ICT goods and services, and agile project delivery models are all required for system-based rather than silo-driven decisions [39].

6

Mainstreaming Nature-based Solutions into infrastructure decision making

Nature-based solutions (NbS), including Green Infrastructure (GI), are **approaches that weave natural features or processes into the built environment to promote adaptation and resilience** [173]. They are gaining traction as a comprehensive strategy for reducing trade-offs and promoting synergies among the SDGs. Examples of NbS include the Sand Motor in the Netherlands [174] or mangrove protection in the British Virgin Islands [175].

Governance challenges and opportunities related to integration of NbS into traditional decision-making have been highlighted and explored applying – where relevant - the thematic challenges and opportunities framework developed by this paper.

Photo by Kameron Kincade on Unsplash

6.1 Current challenges

NbS typically span large landscapes and seascapes and cross jurisdictional lines. Effective storm-water drainage management across watersheds utilising nature-based approaches, for example, necessitates collaboration between local, regional, and even national governments, as well as several ministries (agriculture, forestry, and environment, finance, development, transport). As a result, **for NbS governance to be successful, active cooperation and coordinated action across stakeholders whose goals, interests, or values may not coincide, or even conflict, is required** [176]. When one agency views 'adaptation' as the responsibility of another, a lack of policy consistency can lead to inaction [177]. It can also cause trade-offs, which can lead to conflicts.

Incentives and laws that are unsupportive or even contradictory might further prevent NbS adoption [178] [179]. Existing legal frameworks, such as land use rights, environmental and building permit schemes, plans, or codes, or sectoral policies, can conflict with environmental management demands and act as a barrier to implementation of NbS [39].

A large part of the problem is that **many of the benefits associated with NbS cannot be capitalized by any one party or organization**. They create externalities that impact on many different groups, resulting in a problem of ownership. Financing for NbS requires the provision of appropriate risk-sharing arrangements for decision-making [118].

Despite broad recognition of the severe threats to the global economy posed by climate change, **less than 5% of climate finance goes towards dealing with climate impacts, and less than 1% goes to coastal protection, infrastructure and Disaster Risk Management, including NbS** [180]. The short-term nature of public and private sector decision-making hinders the longer-term planning and maintenance required for the emergence and sustained provisioning of NbS benefits [177].

The ability of NbS to deliver the desired advantages has not been thoroughly evaluated [178]. If climate mitigation policies support NbS with low biodiversity value, such as afforestation with non-native monocultures, trade-offs may develop. This can lead to maladaptation, which is particularly dangerous in a fast-changing world where biodiversity-based resilience and multi-functional landscapes are essential.

Lack of capacity development and knowledge building is also a challenge to a more widespread adoption of NbS. Decision-makers use solutions that are familiar to them which can be a strong obstacle [42]. Factors such as lack of understanding of the ecosystem services offered by NbS, a lack

of perceived responsibility for action, or the discounting of climate threats [181], as well as other challenges that limit innovation [182], compound such biases.

Whereas new approaches and studies have developed ways to quantify and assess risk reduction benefits in NbS, **finding the data to assess such services in data poor environments, both for regional and local scales, remains challenging**. Ecosystem services and the implications of their degradation on flood protection are not adequately included into risk planning, limiting the use of NbS as a disaster risk reduction approach. Significant data needs on climate dangers, bathymetry and elevation, ecosystems, land uses, and assets sometimes make such modelling difficult [183].

6.2 Opportunities for positive change

It is vital to approach NbS in a holistic manner. Collective action can be achieved by including the government, investors, owner/operators, designers, academia, local residents, and the private sector, and acknowledging the skills and resources that each provides, see ReNature case study in Box 19 [184]. **Local communities and indigenous peoples must be consulted and involved as active contributors at all stages since they can provide insightful methods for implementation on the ground** [62]. Aligning

Box 17: ReNature, Malta

The project ReNature aims to establish and implement a NbS research strategy for Malta with a vision to promote research and innovation and develop sustainable solutions whilst improving human well-being and tackling environmental challenges. The strategy is complemented by a newly developed research and practitioners' cluster to act on it, with a vision to stimulate both scientific excellence and innovation capacity to promote action towards the SDGs.

ReNature has established collaborative research and capacity-building initiatives between the Malta College of Arts, Science and Technology (MCAST), as a tertiary and research organisation based in Malta, and the Trinity College Dublin (Ireland), University of Trento (Italy), University of East Anglia and University of Cambridge (United Kingdom), and Pensoft Publishers (Bulgaria). The activities carried out have included training and networking events aimed at building up the research capacity and at promoting research excellence in the field of nature-based solutions. The ReNature team has organised four training courses, attended by academics and relevant stakeholders, focussed on topics relating to: biodiversity and land monitoring, mainstreaming NbS in planning and policymaking, both for urban environment and rural landscapes. The main objective of these capacity building activities is to create a space for open and inspiring discussion among project partners, academics, practitioners and stakeholders.

Source: https://riojournal.com/article/58970/

Photo by Adrien Olichon on Unsplash

Box 18: Glasgow, Scotland: Overcoming procedural barriers to NbS procurement

The Glasgow City Council intended to procure suppliers for various NbS, including rainwater management solutions. Given the difficulty in the quantification of costs and benefits of NbS, the council faced challenges related to their adoption.

Firstly, given the councils internal procurement mechanisms, difficulties in demonstration a robust business case for NbS hampered this process. This was further complicated by the lack of expertise within the relevant teams, exacerbated by budget cuts.

Further, the city's established calls-for-tender process proved suboptimal in identifying suitable NbS suppliers. This combined with the lack of relevant expertise resulted in the procurement of unsuitable contractors and therefore the failure to deliver successful NbS projects.

Following this, Glasgow City Council have begun to adapt their current practices and adopt new approaches in order to overcome these challenges. This has seen the council collaborate with charities and other public bodies with less restrictive procurement mechanisms to overcome internal barriers to the procurement of suitable suppliers. To address the lack of expertise, a temporary business manager was appointed to promote cooperation and knowledge sharing.

Finally, changes to the calls-to-tender process has seen the council emphasise the quality of submission over the cost. Combined, these solutions have improved the resilience of the council's procurement process by improving the robustness, efficiency and quality of their approach.

Source: Public procurement of nature-based solutions Addressing barriers to the procurement of urban NBS : case studies and recommendations (2020) European Union https://op.europa.eu/en/publication-detail/-/publication/d75b2354-11bc-11eb-9a54-01aa75ed71a1

policy priorities on social inclusion and NbS will help to ensure that existing inequalities are understood, and a meaningful attempt is made to address them.

Authorising and enabling NbS and allowing for regulatory flexibility can help create an enabling environment to integrate NbS into Disaster Risk Management and other development strategies. Governments can include use of NbS into environmental requirements of building codes, water safety regulations, and environmental impact mitigation plans [185]. There are many policy documents where NbS could be integrated, such as documents defining spatial development, strategic development, environmental protection, noise levels, low carbon economy plans, public transport development, and long-term financial forecast of a city [186]. This involves employing NbS to meet climate mitigation and adaptation goals, as well as air quality and public health goals. Similarly, **regulation can also be used to allow NbS to be treated as a capital asset on the balance sheet in exchange for the services it delivers.**

To overcome obstacles of capacity and knowledge, robust institutions are required, as well as established planning structures, procedures, and instruments that ensure benefits across landscapes and seascapes. Because the investments relate to human, social and natural capital, not just material and financial capital, there is also a need to greatly **improve the measurement of these forms of capital.** The failure to recognise expenditures on human, social and natural capital as assets, depreciated accordingly, partly explains the lack of investment in NbS projects [118].

The scope of the value offer from integration of NbS needs to include an emphasis on environmental, social, and economic benefits, as well as the identification of additional stakeholders and alternative value capture methods. Combined with greater support from Project Preparation Facilities (PPF's), new sources of funding may be discovered [187]. The **creation of multilateral consortia of close partnerships between companies, communities, local governments, national governments, non-governmental organisations, local financial institutions, and national and international financial institutions is emerging as critical to the provision of large-scale, long-term investments in ecosystems.** The readiness of the consortia to give various forms of finance and procurement mechanisms (see Box 20 below) demonstrates their understanding, influence, and trust in the project [188].

7

Implementing Good Governance of Infrastructure for Resilience

Infrastructure systems are essential for protecting, connecting and providing for our societies. Their complex and interdependent nature, long design lives, a lack of investment and fragmented governance has made infrastructure systems, and the decisions made about them, vulnerable to long-term climate change and natural hazards. **They are also now operating in an increasingly uncertain future and resilience needs to built in upfron**t to ensure that these systems are able to resist and absorb hazards, recover from it or transform if conditions require it to, in a timely and efficient manner, including through the preservation and restoration of its essential basic services and functions.

Significant investment is planned in infrastructure globally in the next two decades as we emerge from COVID-19 and work towards decarbonising our infrastructure systems. **Poor governance is a key factor that has led to infrastructure projects failing to meet their resilience and societal objectives.**

Good governance for infrastructure decision-making will ensure that resilience is embedded across all stages of the infrastructure lifecycle. This white paper has highlighted the role that good governance can play in embedding resilience through seven key themes. Opportunities and actions for positive change have been identified across each of these themes, as outlined in Table 9 below. **The themes and actions (Table 9) are significantly interdependent on each other, and need to be considered and implemented collectively to have maximum impact on improving infrastructure governance for resilience.** For example, having capacity and resources (Theme 6), and data and information (Theme 7) is essential for better understanding the whole infrastructure system (Theme 1) and for prioritising where resilience strengthening is needed (Theme 3). The **themes and actions identified should be prioritised** to understand where the most significant benefits can be provided with limited resources and to identify critical actions that can have the biggest impact to the governance of infrastructure for resilience.

The **majority of actions are focused on stakeholders in the upstream sections of the infrastructure lifecycle** (i.e. Government and Investors). Government is predominantly responsible for setting the policies and programmes, and to prioritise infrastructure projects Investors should ensure that they are financing infrastructure that is contributing to resilience of the whole system and owner operators should ensure that the programmes and policies are embedded in the development of infrastructure systems, through design, construction, operation and maintenance and end of life activities. But overall, it is the responsibility of all infrastructure stakeholders to ensure that resilience is embedded across the whole lifecycle.

Ultimately, the most significant and urgent opportunity is to ensure that good governance of infrastructure mechanisms is put in place to ensure **wider socio economic outcomes are delivered enabling safe, sustainable and resilient infrastructure for all.**

Table 9: Summary of themes, actions and key stakeholders

	Theme	Actions	Key Stakeholders
	**Whole Systems Perspective** Infrastructure systems are inherently complex entities that intricately interact with one another across a multitude of scales. The lack of strategic oversight and cooperation on the universal issue of climate change and natural hazards can limit the approach to resilience building across the whole system.	Set up cross-sectoral bodies to reduce fragmentation. Create a shared vision for stakeholders to work towards, that supports coordinated solutions for infrastructure resilience. Periodically update Infrastructure policies, frameworks and regulation to reflect a changing and uncertain world.	
	**Adaptive Capacity** The unpredictability of climate change and natural hazard risks require a different approach that factors in risks earlier in the infrastructure lifecycle. This ultimately requires transformational adaptation and reflexive governance tactics	Undertake reflexive governance to ensure that infrastructure is resilient to complex, emerging and uncertain risks. Encourage and promote system-wide learning outcomes for infrastructure resilience through institutionalised programmes and platforms.	

	Theme	Actions	Key Stakeholders
	**Prioritising Infrastructure Needs** Governments and administrations across the world must inevitably assess and select infrastructure priorities to decide how to allocate limited resources. However, governance flaws exist across the lifecycle, but are most noticeable and impactful during project prioritisation, evaluation and project selection.	Adopt evidence-based approaches for infrastructure planning and asset management, justifying the need for resilience actions and how they contribute to whole system resilience. Develop and implement long-term infrastructure plan including methodical baseline evaluation to create committed objectives, goals, and project pipelines. Develop viable and prioritised resilience programmes and project pipelines that stakeholders across the infrastructure lifecycle are accountable for.	
	Infrastructure Financing **Despite infrastructure investment possibilities being plentiful, particularly in developing nations, investors are often unable to take full advantage of them. Investing in resilience is inherently risky and finance is difficult to access. The right assets to fund are hard to identify and Inefficiencies waste much of the existing resources.**	**Improve access to finance through providing support to governments and project sponsors.** **Provide capacity, funding and resources to support pre-development activities. This will ensure that the right infrastructure is being built. For example, ensuring 'shovel-worthy', rather than 'shovel ready' projects.** **Ensure investments are prioritised appropriately at an early stage of the lifecycle.** **Undertake continuous monitoring throughout the lifecycle to hold investors accountable for contractual commitments around resilience.** **Improve funding for governance initiatives that can have a significant impact on the efficient delivery of infrastructure projects.**	
	**Regulation, Codes and Standards** Regulatory frameworks must support the adoption of codes and standards that encourage or require the implementation of practices	Design governance mechanisms that allow for continued monitoring of their effectiveness, in order to reliably improve upon them in future iterations. Understand the problem and	

	Theme	Actions	Key Stakeholders
	that maintain or improve the resilience of assets. However, there is a lack of regulation alongside consistent guidance and standards for resilience across the whole infrastructure lifecycle.	its context through data and engagement before implementation. Promote adaptive regulation designed around resilience thinking. Actively encourage and incentivise the adoption of resilient approaches.	
	Capacity and Resourcing **A lack of knowledge and capacity is a barrier to infrastructure resilience and can create additional vulnerabilities during a disaster The flight of human capital and inequalities in governance has the potential to have an intergenerational impact. Digital transformation has further disturbed traditional governance.**	**Strengthen national and local actors' capacities.** **Incentivise retention of talent in local markets.** **Provide funding for academic institutions and establishing courses around infrastructure resilience.** **Establish initiatives to empower youth and other marginalised and/or vulnerable groups and communicate the benefits of diverse teams to government staff.** **Harness existing digital skills to close the digital divide.**	 
	**Data, Information and Technology** Data, information and technology underpins evidence-based infrastructure planning and is regarded as the foundation for effective Disaster Risk Management. Currently, there is a lack of availability, accessibility, trust and investment across the data ecosystem. Further restrictions on collection, access, use and redistribution of data and effective policy and processes prevents management of infrastructure systems at scale.	Increase availability and accessibility to hazard and infrastructure data to infrastructure decision makers. Develop appropriate policies and standards to ensure that data collected is consistent, reliable and trusted. Establish asset management systems to improve infrastructure decision-making and to inform evidence-based assessments. Provide support and learning programmes for establishing asset management systems and associated databases. Contextualise InfraTech applications for the country of operation which may have varying levels of investment, capacity and resources to install and manage this technology.	   

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