INTRODUCING INFRASTRUCTURE RESILIENCE

Use this resource if you want a quick introduction - or a quick refresh - on some key aspects of thinking about resilience in infrastructure.

DOI: http://dx.doi.org/10.12774/eod_tg.july2016.gallegolopezessex1

First published July 2016

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1. INTRODUCING AND DEFINING RESILIENCE

1.1 SCOPE OF THIS DOCUMENT: RESILIENCE OF INFRASTRUCTURE TO CLIMATE, ENVIRONMENTAL AND DISASTER RISKS – EXCLUDING POST-DISASTER OR CONFLICT ISSUES

This document forms part of the **Evidence on Demand** **Resilience Resource** and focuses primarily on the way that resilience - to climate, environmental and disaster risks - is considered for proactive investment in new and existing infrastructure. It aims to provide a quick overview of the topic, while related resources look in more detail at two particular aspects of strengthening resilience in infrastructure – Designing for Infrastructure Resilience and Understanding Risk and Resilient Infrastructure Investment. A consolidated list of references used in these three pieces can be found here.

Other outputs in the Resilience Resource complement this suite of information focussing on infrastructure with a wider introduction and guide to key concepts, issues and reads on What is Resilience, Measuring Resilience and Risk Management and Financing.

Best practice, tools and approaches, and case studies for post disaster reconstruction are considered separately in the DFID Topic Guide on Reconstruction (Lloyd-Jones, Davis and Steele, 2016, forthcoming). Another aspect of infrastructure resilience that is not considered in this report is the risk of damage during conflict. This includes the design of infrastructure to ensure resilience and continued operation during conflicts, though it is noted that little infrastructure can withstand targeted attacks. Guidance on this area is highlighted by Merriam, Long and Crum (2008) and Jones and Haworth (2012).

Resilience has strong gender and poverty dimensions. Women and girls constitute the largest percentage of the world's poorest people, and are most affected by climate, environment and disaster risks, but further research and action is required to properly integrate gender into decision making (Brody et al, 2008). Women and girls are also more likely to be absent from consultation and decision making. Measures to improve resilience should therefore be gender sensitive: informed by an understanding of the differential needs of women, girls, men and boys – as well as youth and the aged – and designed to improve the participation and outcomes of women and girls in particular. This includes both disaster resilience and climate resilience[1]. This document brings out a few examples to highlight the importance of a consistent gender focus and understanding of other potentially disadvantaged groups.

[1] Paris Agreement (https://sustainabledevelopment.un.org/frameworks/parisagreement) Article 7.5: Parties acknowledge that adaptation action should follow a country-driven, gender-responsive, participatory and fully transparent approach … with a view to integrating adaptation into relevant socioeconomic and environmental policies and actions.

1.2 DEFINING RESILIENCE

The concept of resilience brings together disaster and climate risks (ARUP, 2014). UNDP (2011) describes how climate resilience relates to both existing disaster risks and growing climate impacts. Existing disaster risks are increased (in scale, frequency and variability) by climate change – as well as climate change causing slow-onset impacts such as temperature increase and sea-level rise.

The Global Facility for Disaster Risk Reduction (GFDRR, 2015a) highlights that, considering just climate risk alone over the last 20 years, extreme weather events have impacted on more than four billion people, claiming over 600,000 lives and resulting in nearly $US 1.9 trillion in economic losses (Bringing resilience to scale, GFDRR, 2015a).

The widely accepted UN definition for resilience is:

> *"The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions". (UNISDR, 2009)*

1.3 DEFINING THE RESILIENCE OF INFRASTRUCTURE

There is an increasing international discussion on improving the resilience of infrastructure. For example, the first Africa Climate Resilient Infrastructure Summit took place last year in Addis Ababa, Ethiopia[2].

The UN Sustainable Development Goals (SDG) set a target to provide resilient infrastructure[3]. Resilient infrastructure also links with Goal 11: Making cities and human settlements inclusive, safe, resilient and sustainable (see Box 1).

BOX 1 RESILIENT INFRASTRUCTURE AS PART OF SDG 9

United Nations (2015) established targets related to resilient infrastructure (part of Goal 9)

- Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all;
- By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities;
- Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing states.

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2 See http://www.au.int/en/newsevents/13003/africa-climate-resilient-infrastructure-summit-acris-addis-ababa-ethiopia.

3 This considers infrastructure development as essential to achieve sustainable development and it is the main focus of SDG Goal 9: to "Build resilient infrastructure to promote sustainable industrialization and foster innovation". Investment in transport, irrigation, energy, communications, and water and sanitation infrastructure is essential to empower communities in developing and developed countries (Goal 9: Build resilient infrastructure, promote sustainable industrialization and foster innovation, UN, 2015).

For engineers the concept of resilience has generally been related to the structural integrity of systems and physical infrastructure, essential to ensure continued operational performance during extreme loading. Engineers therefore have tended to view resilience as part of their professional duty of care, which is reflected in the engineering concept for resilience:

"Resilience covers both 'physical and societal systems' through four 'R' principles:

- **Robustness:** the inherent strength or resistance in a system to withstand external demands without degradation or loss of functionality;
- **Redundancy**: system properties that allow for alternate options, choices, and substitutions under stress;
- **Resourcefulness**: the capacity to mobilize needed resources and services in emergencies; and
- **Rapidity**: the speed with which disruption can be overcome."

(Bruneau et al, 2003)

This is reflected in the infrastructure resilience wheel below:

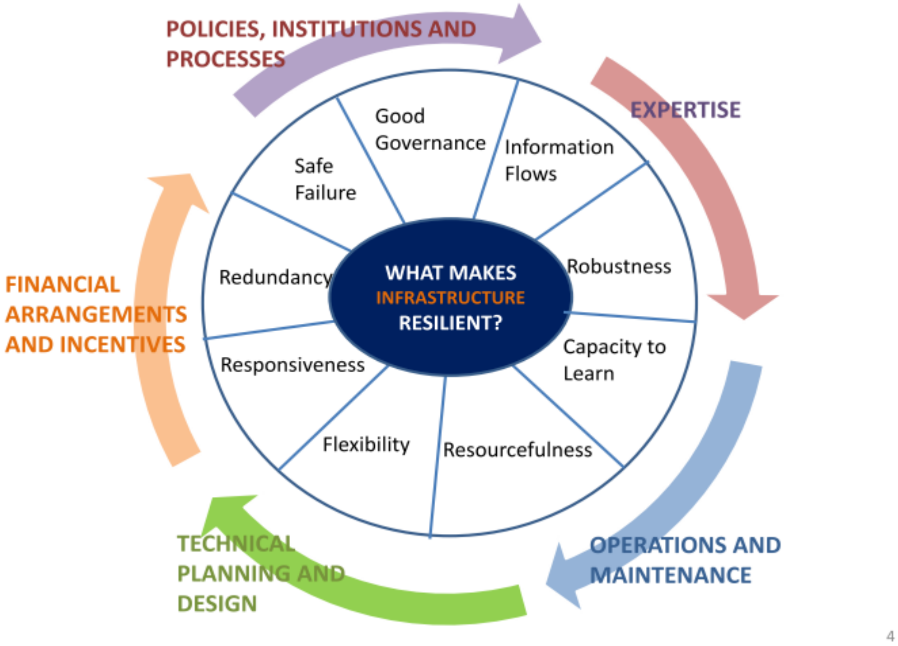

FIGURE 1 INFRASTRUCTURE RESILIENCE PROPERTIES. Source: Adapted from Moor et al, 2015.

Resilience in infrastructure should include both direct and indirect impacts. Direct impacts include resilience to sudden shocks (e.g. disaster resilience) and to slow-onset impacts (e.g. climate change). Indirect impacts include the effects of depleting or degrading the natural environment, such as through deforestation or pollution. This is considered as a reduction of 'ecosystem services' that enable the natural environment to increase our resilience (MEA, 2005).

1.4 DEFINING CRITICAL INFRASTRUCTURE AND INFRASTRUCTURE SYSTEMS

Critical infrastructure is defined by the UNISDR (2009) as follows:

> *"Critical facilities are the primary physical structures, technical facilities and systems which are socially, economically or operationally essential to the functioning of a society or community, both in routine circumstances and in the extreme circumstances of an emergency".*

Critical infrastructure can include transport systems such as air and sea ports, electricity, water and communications systems, hospitals and health clinics, and centres for fire, police and public administration services. The concept of critical infrastructure varies from country to country and between communities as per availability and needs:

- In many developing countries, such as Bangladesh, educational facilities are considered as key assets both for schooling as well as acting as evacuation shelters during emergencies.
- In contrast the UK's National Infrastructure Commission's remit excludes social infrastructure in its plans.

Infrastructure systems are important when considering infrastructure resilience. This means that resilience is not just related to individual infrastructure elements but how these work together as energy, transport, water and sanitation, ITC networks – and affect each other (see Savage et al, 2016).

2. HOW DO RESILIENCE AND INFRASTRUCTURE RESILIENCE RELATE TO EACH OTHER?

2.1 CONTRASTING RESILIENCE OF COMMUNITIES AND INFRASTRUCTURE RESILIENCE

In the context of the resilience of development interventions, the resilience of infrastructure could be considered as both in terms of:

The resilience of infrastructure itself, and

- **How infrastructure affects resilience**: both of other infrastructure systems, and of individuals, households and communities.

To date discussion of resilience and infrastructure has focused on the former, addressing primarily the resilience of critical (important, often national) infrastructure, but potentially to the neglect or detriment of local community resilience. Improving infrastructure resilience can have a direct negative impact on communities and livelihoods if done in isolation.

Examples:

- Increased capital spending on infrastructure has been justified as more resilient because it is bigger, that is "more robust”. But increased spending to strengthen and extend road embankments and bridge infrastructure running east-west across Bangladesh (as opposed to relying on ferries) has led to road networks restricting the flow of water north-south, which has increased the impact of monsoon seasonal flooding.
- Maintenance such as improving the drainage of a road and enhancing surface run off, discharging into surrounding land may increase the resilience of the road but may impact adversely on local community health, with increased run-off carrying more pollutants on to agricultural land and into groundwater sources [4] .

Where sub-national budgets are allocated towards improving resilience of infrastructure that plays a wider economic role (e.g. roads, ports, airports, etc.) this can reduce available budgets for infrastructure that is critical at the community level, such as housing, emergency shelters and productive land.

A key lesson is that there is a need to establish community views, possibly consulting men and women separately (as their views are likely to be different)[5], which will include sharing information too.

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4 While ‘resilience’ may be used to secure increased maintenance funding, which is needed irrespective of disaster or climate risk, unless this significantly enhances such resilience this could be considered as misappropriation of funding. Similarly there is a risk that rural road maintenance specialists rebrand themselves as climate resilient road specialists, without changing how road systems are designed in any fundamental way.

5 For example, in developing these resources, anecdotal findings from work on the Maputaland Corridor Road, Northern Kwa Zulu Natal in 1999 were women tend to be particularly concerned about child-road safety while men have other concerns such as livestock safety, how to get their herds between pasture on either side of a road embankment.

2.2 IMPROVING THE RESILIENCE OF INFRASTRUCTURE MUST ALSO ADDRESS (NOT CONTINUE TO INCREASE) CLIMATE (AND DISASTER) RISKS

Resilience is a consideration for both developed and developing countries, as disaster and climate impacts are not proportional to GDP.

> *"Wealthier cities/countries are not necessarily more resilient ... conversely; relatively poor cities/countries can make choices to build resilience" (Arup, 2014).*

Risks apply to both existing and new infrastructure.

McKinsey Global Institute (2013) estimate that US$ 57trillion in infrastructure investment is needed for infrastructure supply to keep pace with infrastructure demand, set by the expected global GDP growth up to 2030. An additional investment of US$ 1–1.5trillion/year is required until 2020 in low and middle income countries in services such as transport, water and energy (see Climate finance for cities, ODI, 2015).

McKinsey goes on to propose climate finance as a potential source for finance for this infrastructure – by combining the supply of infrastructure with enhanced resilience. However, it is crucial to recognise that to mitigate climate change we can't afford to continue to expand infrastructure that increases global demand for fossil fuel use.

2.3 RESILIENCE OF INFRASTRUCTURE *SYSTEMS*

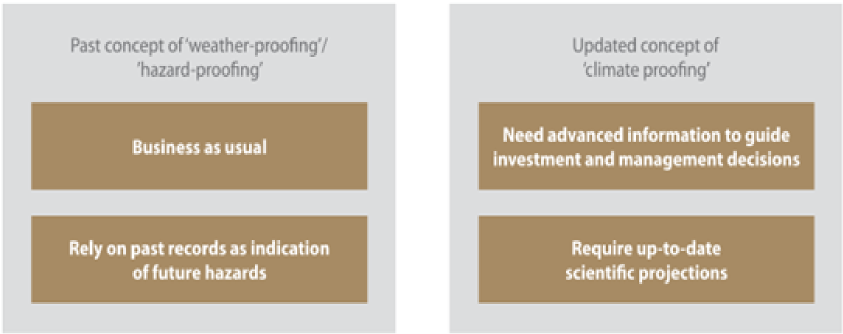
Refocus partners et al (2015) state that resilience is best understood at the 'system' level as well as at the level of individual infrastructure assets, or projects. Integration, coordination, and sequencing are needed to ensure that when one structure fails it doesn't take down a whole system. In practice that means that good infrastructure systems are likely to be made up of smaller, interconnected pieces and parts rather than a few large projects. This means designing whole systems and networks to be resilient and requires a different approach.

When it comes to resilient systems, success is often something that isn't recognised, reported or celebrated. For example, success is when a city does *not* flood or there is *no* loss of power after an extreme weather event. A resilient infrastructure system will be sufficiently robust, have sufficient redundancy, and allow for sufficient resourcefulness to resolve issues with sufficient rapidity to continue operating at normal or near normal performance levels. Capturing those benefits and savings over time requires thoughtful design and advance planning, and new approaches to funding and financing for resilient infrastructure (Reinvest - A Roadmap for Resilience: investing in resilience, reinvesting in communities, Refocus partners, 2015: p14). This requires better coordination between donors and stakeholders at a regional, national and local level; it requires the interdependencies between projects, networks and systems to be recognised and optimised to improve resilience across infrastructure systems.

2.4 RESILIENCE REQUIRES LONGER-TERM INFRASTRUCTURE INVESTMENT

Typically infrastructure investment is based on a return on investment and lifespan that is short. For example, the World Bank's normal internal rate of return for road investment projects is 12%[6], with a twenty year design life. However, most infrastructure will be required to last much longer than this (and infrastructure systems even more so). As a result the economic case for infrastructure investment, as well as the technical design, often does not take into account the true scale of future (including climate) risks.

It needs to be recognised that infrastructure investment made today will not only need to respond to future climate impacts on the infrastructure itself, but will determine how future users live. Assuring climate resilience of infrastructure thus requires a broad spectrum of analysis to be taken into account in investment decisions and design choices (UNDP, 2011).



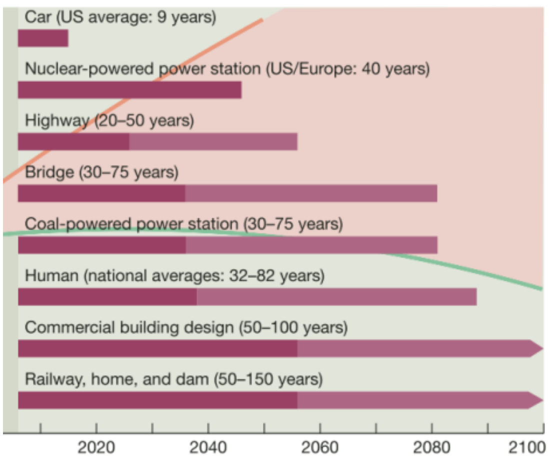
Source: UNDP, 2011

FIGURE 2 FROM WEATHER-PROOFING AND HAZARD-PROOFING TO CLIMATE

Delivering resilient infrastructure thus requires a fundamentally different approach, and not a revised business-as-usual approach.

As indicated in Figure 2, a business-as-usual approach would lead to infrastructure that is only able to cope with historic events, but has no design basis for surviving events exacerbated by climate change (UNDP, 2011). Rather, UNDP calls for 'climate proofing' with investments made based on scientific projections for a changing climate.

2.5 LONG TERM DECISION MAKING LINKS RESILIENCE AND SUSTAINABILITY



Adapted from: WWF Living Planet Report, 2006: p26

FIGURE 3 LIFESPANS OF PEOPLE, ASSETS AND INFRASTRUCTURE.

Infrastructure choices can lock in ways of living for the lifetime of a given infrastructure investment, as illustrated in Figure 3 (WWF, 2008). This links infrastructure investment to livelihoods, both now and for a significant time into the future. It is vital that decision making around infrastructure choices and investment in developing (as well as developed) nations addresses resilience and low carbon development together. Climate resilient infrastructure must enable communities and society to both mitigate *and* adapt to climate change impacts.

6 This means infrastructure funded by the World Bank needs to demonstrate it pays for itself in less than six years.

3. CONCLUSIONS

Key considerations relating to infrastructure and resilience include:

- A need to focus both on improving the resilience of infrastructure itself and on how infrastructure impacts community resilience and livelihoods;
- Critical infrastructure may include social infrastructure;
- The need for resilient infrastructure is global, but the greatest need tends to be in low-income countries;
- There is a need to engage both men and women, separately if needed, noting that women's voice in decision making is often lost / not respected unless measures are introduced to ensure that this does not happen;
- A critical aspect of resilience is how individual structures interact at an infrastructure system scale as well; and
- Infrastructure often lasts a long time, so climate and disaster risks should be considered over the full lifespan, which means infrastructure must be planned as part of wider climate resilient, low carbon development strategy.

REFERENCES

Please refer to the consolidated reference list for Infrastructure Resilience resources at http://dx.doi.org/10.12774/eod_tg.july2016.gallegolopezessex4