disaster resilient
infrastructure
vulnerability
disaster preparedness
resilience pathways
resourcefulness
sustainable
development
systemic change
organizational learning
ecosystem services
multi-hazard
risk
contingent liabilities
cost benefit analysis
local knowledge
direct and indirect loss and damage
flexibility
redundancy
fiscal shocks
reliability
nature based
solutions
retrofitting

/ˈlɛksəˌkan/ - lex-i-con

DRI Lexicon

Shared Understanding of Terms that Matter for Disaster Resilient Infrastructure

resilience
assessment
stress testing
robustness
disruption and loss
of services
decision support system
spatial planning
unintended consequences
sustainable

CDRI
Coalition for Disaster Resilient Infrastructure

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Cover design: Anandita Bishnoi.

DRI Lexicon

Shared Understanding of Terms that Matter for Disaster Resilient Infrastructure

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Contents

Introduction

The Coalition for Disaster Resilient Infrastructure (CDRI) is a platform set up with the aim of galvanizing action by national governments, international development and financing institutions, private sector, academia and civil society to strengthen the resilience of new and existing infrastructure. This endeavour surfaced a number of questions on the lexicology of key concepts that shape and focus the conversations around disaster resilient infrastructure (DRI). What comprises infrastructure? Does a single standpost in rural flood-prone hinterland qualify as infrastructure? Does the provision of boats for telecom operators so that they can supply fuel to run generator sets that power telecom towers during city-wide floods have anything to do with resilience? What about the designed failure of smaller power installations in the path of a cyclone to secure the integrity of the larger network? What is the difference between the established domain of "disaster risk (reduction) finance" and the emerging domain of "disaster resilience finance"? What is meant by "system of systems" with reference to infrastructure and what is the relevance of this approach for promoting resilience?

There are existing glossaries developed by experts within the international community that support the disaster risk and climate change domains, but there are gaps in explaining how the central concepts in these domains apply specifically to infrastructure. This gap led to the practical imperative of building upon the foundational work in those glossaries, to develop a globally accepted "Lexicon for Disaster Resilient Infrastructure".

It is now well recognized that "disaster risk" is mostly systemic in nature and that development must be risk-informed to be sustainable. This has significant implications on the ongoing effort to achieve the 17 United Nations Sustainable Development Goals (SDGs), many of which have a direct relationship with infrastructure development. For instance, SDG 7 (Access to affordable and clean energy), SDG 9 (Building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation) and SDG 11 (Making cities and human settlements inclusive, safe, resilient and sustainable) can be best realized if countries take a resilience approach to infrastructure development. Other SDGs that can be achieved through disaster resilient infrastructure investments are SDG 3 (Good Health and Well-being), SDG 12 (Responsible Consumption and Production) and SDG 13 (Action to Climate Change and its Impacts). Many of these SDGs also have strong positive correlations with each other (Fonesca et al., 2020 and Krellenberg & Koch, 2021).

In 2015, the Sendai Framework for Disaster Risk Reduction (SFDRR) was endorsed by the UN General Assembly. The SFDRR recognizes that to meet the SDGs there is a need to minimize disaster damage to critical infrastructure and disruption of services, by developing their resilience. SFDRR has seven strategic global targets that directly or indirectly depend on access to resilient infrastructure.

Targets (a) and (b) are aimed at achieving substantial reductions in global disaster mortality and the number of people affected globally in the decade 2020-2030 compared to 2005-2015. Target (c) is aimed at reducing disaster economic loss in relation to gross domestic product (GDP) by 2030. Meeting these targets is contingent on infrastructure development being resilient and providing uninterrupted critical services. Finally, Target (d) has a direct interest in promoting DRI as it explicitly seeks to reduce substantial damage to critical infrastructure and disruption of basic services, by developing resilience.

The Paris Agreement is a legally binding international treaty on climate change. Its goal is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels

(UNFCCC, 2015). Resilient infrastructure systems must respond to the climate mitigation agenda while simultaneously increasing social equity, public health, and human well-being (IPCC, 2022). The whole idea of "resilience" of infrastructure hinges on the adaptation of infrastructure development to future climate scenarios.

Our vision for the DRI Lexicon Project is to provide a common and consistent set of reference definitions that apply the core concepts of resilience, sustainability, risk and disaster risk management (among others) to infrastructure; and in so doing, to help countries and their stakeholders to use the opportunity of DRI to achieve the SDGs, deliver on the expectations of SFDRR, and fulfill the mandates of the Paris Agreement.

A glimpse into the complex world of DRI

Access to infrastructure is foundational to the human pursuit of greater well-being. It provides better, faster and more equitable access to economic and social development. By its very nature, infrastructure works like a network: it has both nodes and connections. It can be lineal, when dealing with services such as energy, transport, communications, potable water and sewage; or point located when dealing with education, health, and government services. It can be provided by government, the private sector, or civil society and/or a community for itself.

Infrastructure operates at different spatial scales, i.e., it can serve local, regional, national, or international markets or demands. No matter the scale of planned provision, most infrastructure is linked in some way to systems that serve other scales (for example, local road networks and local health frameworks link to regional and national scale service provision; while national road, energy, or telecommunication networks link at the international level).

Thus, most infrastructure is constituted as systems; particular systems link to other service systems in many ways. For example, some lineal service systems follow similar land routes and even use similar underground access. Energy, water and sewerage systems link to the needs of different point-located service providers. Some service-generating infrastructure can have multiple users and demands such as hydroelectric energy providers where dams and associated infrastructure also serve to control water supplies for irrigation and flood control downstream. Whichever way we look at it, infrastructure, together with the services it provides, is a complex, systemic endeavor, requiring advanced planning and execution.

Infrastructure, along with its services, is tightly connected to development and economic growth. On the one hand, infrastructure provides a means for growth and development (human, economic, environmental, etc.). On the other hand, the level and quality of development and economic growth have significant impact not only on the scale and quality of infrastructure, but also on the levels of differential access to the services it provides. Economic growth, as well as human and social development, can only be promoted and permanently expanded and improved if infrastructure systems and the services provided are safe and secure, and if they include provisions for redundancy. The measure of success of an infrastructure system is its ability to provide quality services to a broad and egalitarian-based market. Such an infrastructure system should not only be well-maintained and cared for, but also be permanently in expansion and improvement, and safe against possible interruptions and damage due to foreseen or unforeseen disaster triggers such as earthquakes, floods, civil unrest, war, or even financial crises.

This is why any discussion of infrastructure systems and the services they provide must connect with the broader well-established vocabularies of human, social and economic development, and their modalities, and challenges. Themes of sustainability, resilience, resistance, crisis and disaster, quality, equality and inclusion, are among the most prevalent. These are all themes that the overall concept of DRI must encapsulate as well. Sustainability underpins the notion of resilience conceptually and practically, and the idea of resilience is firmly related to themes such as disaster risk management, adaptation to climate change, innovation, and transformation.

While development provides the backdrop, crises and disasters are increasing in impact and saliency, as we encounter more complex hazard contexts and try to deal with the growing exposure and vulnerability of people, businesses, and territories. However, we remain more reactive than proactive in our response. Post-impact crisis or disaster interventions and planning take up increasing amounts of finance and human energy in disaster response and reconstruction. While the call for "build back better" is common, in practice we do not follow this practice often enough, and our financial outlays remain largely reactive, increasing rapidly over time, and failing to promote sustainable recovery and transformation. Such processes increase social inequality, and vulnerable groups often remain the most susceptible to disaster risk and its consequences.

This renews the call for the more proactive approaches of risk-safe development, risk prevention and risk mitigation, rather than simply focusing on response and reconstruction. An emphasis on sustainability and resilience is at the center of such efforts, and infrastructure and service provision are key to their attainment.

Methodology of developing the Lexicon

In a multidisciplinary field such as DRI, a lexicon can serve as a boundary object – that is, function as a bridge between different specialist communities to provide shared meanings and common ground so that they can collaborate effectively. In this sense, the DRI Lexicon can be a valuable instrument for promoting consistency and common understanding for use by the public, by governments, by specialists in different domains, and by practitioners from different disciplines. CDRI's goal with the Lexicon is to facilitate the creation and use of a common vocabulary on key terms and concepts of the DRI field. Its objectives include:

- to consolidate a more systematic, comprehensive, and consistent understanding of the domain;
- to promote effective communication and coordination across multiple stakeholder groups; and
- to support research, learning, and the creation and sharing of new knowledge in a rapidly developing field of practice.

This resonates with CDRI's aim to work collaboratively with partners and stakeholders to co-create a common and internationally recognized knowledge resource, accommodating broadly agreed definitions and facilitating a common understanding of the DRI terminologies while respecting their multidisciplinary origins.

The process of creating this kind of Lexicon posed a number of challenges:

- This is a wide, multidisciplinary field – how should we set boundaries and define its scope, and set criteria for inclusion or exclusion?
- There are multiple potential beneficiaries who would find such a resource useful – which beneficiary groups would benefit most, how might they use the Lexicon, and what features should it have to benefit them?
- What kind of balance should we strike between promoting standard, generalized terms and

definitions, while also respecting the specificity of the many diverse contexts in which DRI concepts are applied (disciplinary, geographic, socioeconomic)?
- How do we balance the need for breadth and comprehensiveness, with the pragmatic goal of getting a core Lexicon out within a defined timeframe, while also ensuring that it has a structure that can be scaled?

These were addressed in the Lexicon through a co-creation approach. Over a period of 10 months (from April 2022 – January 2023), the panel of subject matter experts identified from the government, the private and non-profit sectors, and academia representing different geographies and varied disciplines including engineering and architecture, spatial planning, finance, social sciences and knowledge management engaged with the CDRI Secretariat to develop the definitions of priority terms relevant for DRI. The group began by identifying key notions and concepts now in use for DRI. As an initial entry point, the group referred to the CDRI's stated objectives, and listed 270 terms that were potentially relevant, relatable to these objectives, and to CDRI's priority programmes and action areas. Some other terms such as sustainable development that are relevant but did not require further interpretation/explanation for DRI have not been included in the DRI Lexicon for ease of reference by users.

While the panel focused on just the DRI aspect of this complex picture, they defined and annotated the concepts included here against that larger picture of sustainable and resilient infrastructure. More generic concepts are explained or annotated in relation to how they manifest in an infrastructure context. Terms relating to specific aspects of infrastructure are connected to the broader themes of disaster resilience, sustainability, and systems. The hope of the CDRI panel is that users of the Lexicon will be able to appreciate how DRI connects to a much broader landscape, and why it is so important that our colleagues working in infrastructure do plan and implement with those connections in mind.

As a method for focusing on the most relevant terms, the working group characterized use cases for different potential users of the Lexicon. A range of specific use cases was mapped out, relating to different stakeholders within the infrastructure, disaster resilience, and climate resilience domains. The panel developed different scenarios of activities performed by the stakeholders, with example task descriptions to illustrate how the stakeholders might want to use the DRI Lexicon, and what features would be valuable to them. This mapping exercise helped the working group to consider how the DRI Lexicon can respond to users' requirements, and it generated insights into additional features providing added value. For example, it became clear that for several user groups, it would be valuable to map associations between terms, so that users might be directed from one term and definition to another term and definition, and thereby use the Lexicon to build up an understanding of the DRI landscape. The use cases also helped the working group to determine which terms would be most useful to different types of users.

The working group then discussed and ranked what would make good indicators of the quality and usefulness of the terms and definitions, and decided they should be comprehensive, complete, unambiguous, simple, and – where relevant – indicating to users where there are important context-specific variations in understanding or interpretation. The working group used a poll to select five initial types of users for the first phase of the Lexicon. The chosen user types were: (i) Academia and research think tanks; (ii) Multilateral development banks and infrastructure banks; (iii) professional practitioners; (iv) government institutions; and (v) NGOs undertaking DRI and reconstruction work.

With these user groups in mind, the working group was asked to rank terms from the original master list as follows:

- "low priority" (terms that already have widely understood standard definitions, so it is not clear how the Lexicon would add value);
- "medium priority" (terms that have definitions in the literature but their definitions need enhancement to contextualize them to DRI, or terms that are necessary in order to make the Lexicon comprehensive); and
- "high priority" (terms which do not currently have standard widely-accepted definitions but which represent important concepts in the DRI domain for these user groups).

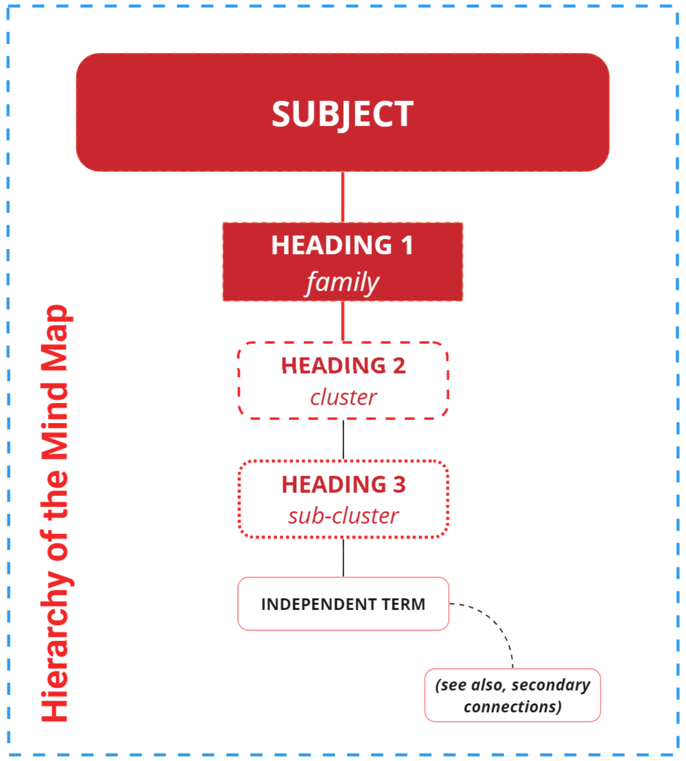
To provide assurance of completeness and comprehensiveness, the idea of "buckets" was used to classify the medium and high priority terms into subject areas. Besides ensuring coverage of the whole domain and identifying gaps, this was a helpful method for thinking about how related terms could be grouped together, making connections between them, associating new terms and definitions with established ones, and linking them with other terms which were placed in other "buckets". In a sense, these "buckets" provided a form of mental scaffolding designed to ensure the Lexicon is comprehensive, has no obvious gaps, and can be scaled in multiple directions that guides its development and will not be obvious to the Lexicon's users.

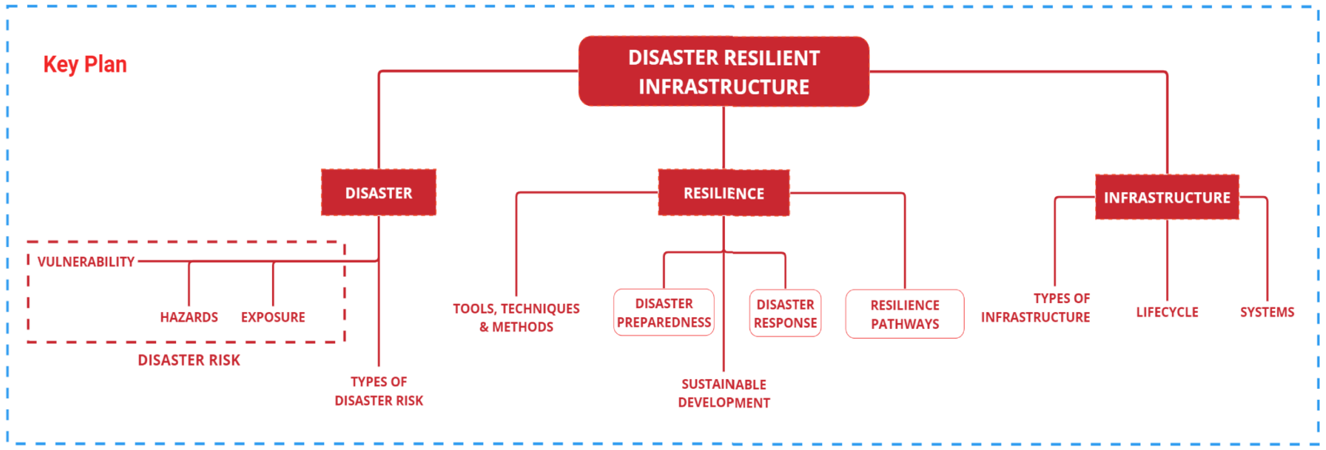
The "buckets" guiding the Lexicon are concepts relating to:

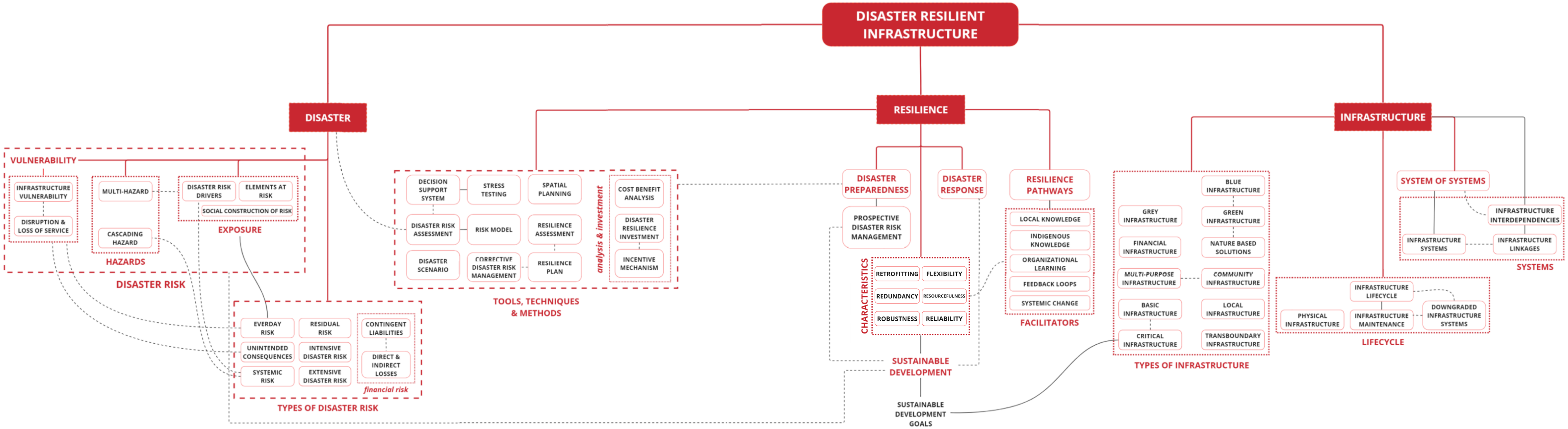
- Analyzing or evaluating risk and its components
- Decision-making criteria and methods for disaster risk management (DRM) and resilience
- Disaster impacts and effects (realized risk)
- Learning, capacity, and capacity building
- Resilience policy, planning and strategy
- Resilient infrastructure components and goals
- Risk factors and components with respect to infrastructure
- Risk: characteristics, attributes and process
- Social actors and people-centred approaches
- Types of actions and instruments for DRM, climate change action, and resilience

Following the classification of terms into the buckets according to their priority, the list was narrowed down or in some buckets supplemented to 116 terms. The CDRI staff and working group identified, drafted or fine-tuned definitions for each term, examining various existing definitions and suggesting whether to merge them, to select one definition over others based on its relevance to DRI, or to adapt or re-write them. Towards this end, it was a conscious endeavour to not duplicate terms and their definitions that were already widely accepted and did not require redefinition from a DRI perspective. Documents such as the UNDRR Sendai Framework Terminology on Disaster Risk Reduction, Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) Glossary served as easy references for this purpose. Where applicable, adequate references have been provided; at all other places definitions have been drafted by the Working Group as part of CDRI's Lexicon Project.

The final coverage of terms in this Lexicon evolved to grouping around "Disaster", "Resilience" and "Infrastructure".


Hierarchy of the Mind Map
SUBJECT
HEADING 1
family
HEADING 2
cluster
HEADING 3
sub-cluster
INDEPENDENT TERM
(see also, secondary connections)


Key Plan
DISASTER RESILIENT INFRASTRUCTURE
DISASTER
RESILIENCE
INFRASTRUCTURE
VULNERABILITY
HAZARDS
EXPOSURE
DISASTER RISK
TYPES OF DISASTER RISK
TOOLS, TECHNIQUES & METHODS
DISASTER PREPAREDNESS
DISASTER RESPONSE
RESILIENCE PATHWAYS
SUSTAINABLE DEVELOPMENT
TYPES OF INFRASTRUCTURE
LIFECYCLE
SYSTEMS


DISASTER RESILIENT INFRASTRUCTURE
DISASTER
RESILIENCE
INFRASTRUCTURE
VULNERABILITY
INFRASTRUCTURE VULNERABILITY
DISRUPTION & LOSS OF SERVICE
MULTI-HAZARD
CASCADING HAZARD
HAZARDS
DISASTER RISK DRIVERS
ELEMENTS AT RISK
SOCIAL CONSTRUCTION OF RISK
EXPOSURE
DISASTER RISK
EVERDAY RISK
RESIDUAL RISK
UNINTENDED CONSEQUENCES
INTENSIVE DISASTER RISK
SYSTEMIC RISK
EXTENSIVE DISASTER RISK
CONTINGENT LIABILITIES
DIRECT & INDIRECT LOSSES
financial risk
TYPES OF DISASTER RISK
DECISION SUPPORT SYSTEM
STRESS TESTING
SPATIAL PLANNING
DISASTER RISK ASSESSMENT
RISK MODEL
RESILIENCE ASSESSMENT
DISASTER SCENARIO
CORRECTIVE DISASTER RISK MANAGEMENT
RESILIENCE PLAN
analysis & investment
COST BENEFIT ANALYSIS
DISASTER RESILIENCE INVESTMENT
INCENTIVE MECHANISM
TOOLS, TECHNIQUES & METHODS
DISASTER PREPAREDNESS
PROSPECTIVE DISASTER RISK MANAGEMENT
DISASTER RESPONSE
CHARACTERISTICS
RETROFITTING
FLEXIBILITY
REDUNDANCY
RESOURCEFULNESS
ROBUSTNESS
RELIABILITY
SUSTAINABLE DEVELOPMENT
SUSTAINABLE DEVELOPMENT GOALS
RESILIENCE PATHWAYS
LOCAL KNOWLEDGE
INDIGENOUS KNOWLEDGE
ORGANIZATIONAL LEARNING
FEEDBACK LOOPS
SYSTEMIC CHANGE
FACILITATORS
BLUE INFRASTRUCTURE
GREY INFRASTRUCTURE
GREEN INFRASTRUCTURE
FINANCIAL INFRASTRUCTURE
NATURE BASED SOLUTIONS
MULTI-PURPOSE INFRASTRUCTURE
COMMUNITY INFRASTRUCTURE
BASIC INFRASTRUCTURE
LOCAL INFRASTRUCTURE
CRITICAL INFRASTRUCTURE
TRANSBOUNDARY INFRASTRUCTURE
TYPES OF INFRASTRUCTURE
SYSTEM OF SYSTEMS
INFRASTRUCTURE INTERDEPENDENCIES
INFRASTRUCTURE SYSTEMS
INFRASTRUCTURE LINKAGES
SYSTEMS
INFRASTRUCTURE LIFECYCLE
PHYSICAL INFRASTRUCTURE
INFRASTRUCTURE MAINTENANCE
DOWNGRADED INFRASTRUCTURE SYSTEMS
LIFECYCLE

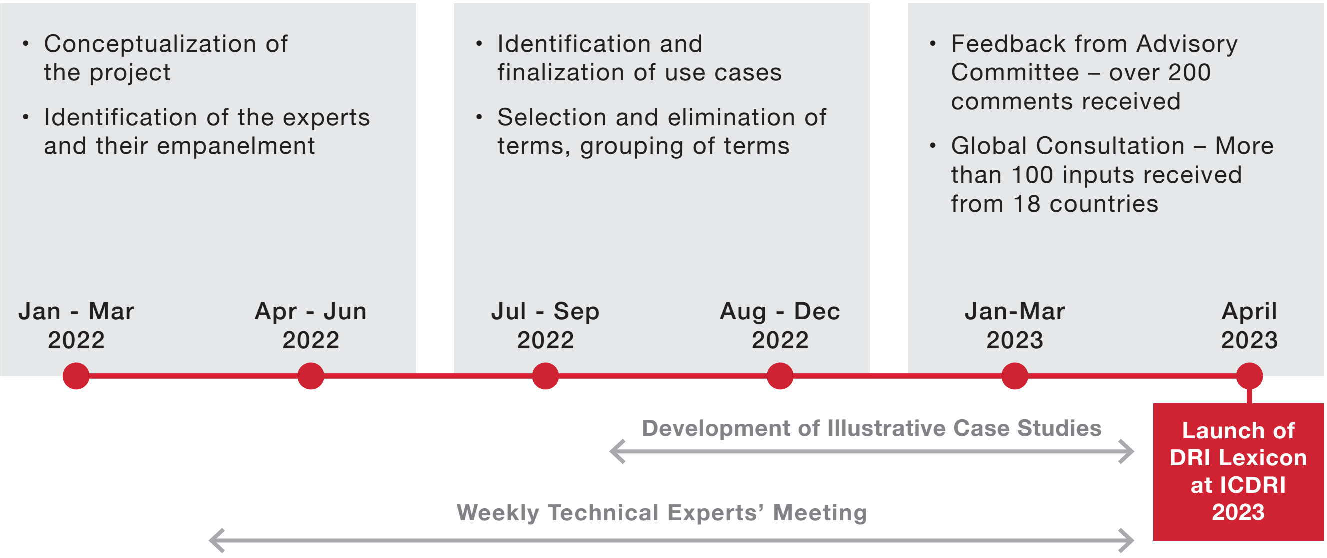
In the process of developing the Lexicon, it became obvious that these terms are not merely neutral or technical, but also represent values, priorities, approaches, and political stances. Terms may acquire different meanings, depending on whether they are considered from a macroeconomic perspective, explored as part of an inequality debate, or examined from a social or community-based approach. By integrating such differentiations into the term definitions, the working group highlights the (often competing) interests and priorities of the multiple social actors and stakeholders involved, and this underscores the fact that the meanings of terms in usage are socially constructed as well as changing and evolving over time.

This fluidity highlights the important role of the definitions and their accompanying notes in providing contextual guidance and linking concepts together, so that users of the Lexicon can build up a nuanced and useful understanding of the domain and its various actors. While the principle was and is to begin with widely accepted and authoritative definitions that have already been through some form of consensus building or peer review process, if it is to deliver value to its users, the Lexicon must also add contextually relevant remarks, and help users to understand the broader landscape of DRI.

For example, we use infrastructure as a broad category to include green/grey/blue infrastructures(s) as well in relation to nature-based solutions. Upon defining the terms and phrases in their broad categories, we have added notes to show linkages between concepts, as well as examples and applicable concepts to strengthen each term. We recommend that each term be read considering the accompanying notes and cross-references to maximize its applicability. Like terms and definitions, the notes are also searchable in the online version of the Lexicon.

The Lexicon has benefitted from the strategic guidance and inputs by an Advisory Committee, consisting of representatives from member organizations of the Coalition including the Asian Development Bank (ADB), The World Bank, United Nations Office for Disaster Risk Reduction (UNDRR) and members of the Appraisal and Steering Committee (ACS) for CDRI Knowledge Initiatives. Over 185 strategic inputs were received which were discussed and incorporated by the Experts Panel. Following which, the final draft compilation of terms and their working definitions were put out for Global Consultation to receive feedback from professionals and practitioners with all levels of understanding about disaster resilience and infrastructure, across the world. Over 100 comments were received from 18 countries during the Global Consultation.

MILESTONES



The DRI Lexicon and its relevance

The Lexicon is intended to strengthen a common conceptual understanding of infrastructure-related terms and phrases. It provides a set of globally applicable references to concepts and phrases that can provide a better understanding of the domain, act as a guide to research and understanding, and aid in infrastructure-related decision making of governments, academia and financial institutions, among others.

The DRI Lexicon:

- May be used as a starting point for incorporating preparedness, response, or recovery-related concepts and actions within infrastructure projects, and that are often not currently included in action plans. For example, to create initial awareness of the value of disaster resilience finance within projects.
- Should help standardize concepts between agencies, governments, institutions, etc. Its adoption will be key in encouraging clear, concise, and comprehensible communications and understanding between organizations at local, national, and international levels.
- Will be capable of being applied by search engines, analytical software, and other information technology, in addition to being used as a dictionary resource.
- Can be a powerful tool that not only simplifies and clarifies concepts but communicates their inter-relationships and their intended use. Rather than being viewed as simply a list of terms and their textbook definitions, it must be emphasized that the notes, annotations, and examples and references included here are intended to enhance the reader's ability to understand and apply the topics in a practical and integrated way.

We hope to see the Lexicon adopted and used as it was intended, to bring people together to work and build knowledge effectively around one of the most pressing challenges of our time.

B

1. Basic infrastructure

Infrastructure that provides services considered fundamental for human development, growth, safety, and security.

Notes:

1. Infrastructure that is seen as fundamental for human development and growth may change over time and geography.
2. See also “Critical infrastructure”.
3. Basic infrastructure provides public and private services that meet basic human needs including drinking water, sanitation, hygiene, energy, mobility, waste collection, health care, education, information and communication.

Early provision of basic infrastructure in low-risk areas in Peru

Targeted infrastructure development can be used to prevent unplanned development in developing countries. Many households choose to reside in informal settlements because the formal housing market is beyond their financial capacity. Once such informal settlements reach critical mass, local governments find it very difficult and expensive to relocate or retrofit households to adapt to the risk of natural hazards.

As a planning strategy for greenfield development of the Comás squatter community in Lima, Peru, one of the first actions undertaken to facilitate the project was to provide the most basic infrastructure and services. Ensuring the provision of basic infrastructure in low-risk areas prior to human settlement can guide the population towards areas that are relatively safe from natural hazards. Right-of-way for roads, water supply systems and sewage systems were developed as priorities, in such a manner that designated blocks could be delineated for residential structures to be constructed. Similar approaches have been used with success in sites and services (S&S) projects in India and Tanzania.

Source:
Rozenberg, Julie et al. (2019). From A Rocky Road to Smooth Sailing: Building Transport. Resilience to Natural Disasters. Sector note for LIFELINES: The Resilient Infrastructure Opportunity, World Bank, Washington, DC.

B

2. Blue infrastructure

Bodies of water, watercourses, ponds, lakes and storm drainage that provide ecological and hydrological functions including evaporation, transpiration, drainage, infiltration and temporary storage of runoff and discharge.

Reference: *IPCC, (2022). Annex II: Glossary [Möller, V., R. van Diemen, J.B.R. Matthews, C. Méndez, S. Semenov, J.S. Fuglestvedt, A. Reisinger (eds.)]. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2897–2930, doi:10.1017/9781009325844.029.*
URL: *https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_Annex-II.pdf*

Notes:
1. See also “Green infrastructure”, “Nature-based solutions” and “Infrastructure”.
2. Blue infrastructure may be considered together with “Green infrastructure” in the term “Blue-Green infrastructure”.

Eastern Kolkata Wetlands (EKW), India

The historic city of Kolkata, located on the banks of the Hooghly River in eastern India, is a bustling center of culture, commerce, and politics. It is also home to the East Kolkata Wetlands (EKW), an ecological treasure covering 12,500 hectares on the city’s eastern fringes. This unique system, which includes integrated aquaculture, horticulture, and agriculture, is a model for resource recovery and protection, and is recognized as a “Wetland of International Importance” by the Ramsar Convention. EKW acts as a natural barrier, protecting Kolkata from floods while treating its wastewater. It provides livelihoods for over 50,000 people through pisciculture and agriculture and is a significant carbon sink, mitigating 118 Gg of atmospheric CO_2 each year (Mitsch et al. 2013). The wetlands also serve as a major food source for the city with its daily production of 150 tonnes of fresh vegetables and 10,500 tonnes of fish. However, increased urban development and improper solid waste management have disturbed the functioning of these wetlands by increasing pollution and siltation. The wetlands, nonetheless, remain a testament to the harmonious balance between environmental protection and development that is possible through community effort and initiative.

Sources:

- *Nag, S. K., Nandy, S. K., Roy, K., Sarkar, U. K., & Das, B. K. (2019). Carbon balance of a sewage-fed aquaculture wetland. Wetlands Ecology and Management, 27(2), 311-322.*
- *Ramsar Sites Information Service. (2002, August 19). East Calcutta Wetlands. Ramsar. Retrieved January 13, 2023, from https://rsis.ramsar.org/ris/1208*

C

3. Cascading hazards

Hazards that are related in a systemic causal relationship and expressed in a sequence of secondary events in natural and human systems that lead to physical, environmental, social, or economic disruption, and where the resulting impact is significantly larger than under a single hazard event.

Reference: *Modified from IPCC (2019). Annex I: Glossary [Weyer, N.M. (ed.)]. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)].*
URL: *https://apps.ipcc.ch/glossary/*

Notes:

1. Cascading hazards have a relationship to cascading impacts, which refer to the social, economic and political consequences related to the hazards themselves. Cascading impacts are sometimes referred to as a "Domino effect".
2. Cascading hazards may also be referred as "Concatenated hazards", which are factored into multi-hazard risk assessment. See also "Disaster risk assessment", and "Multi-hazard".
3. The impacts of cascading hazards are conditioned by the variable vulnerabilities of systems and their components. They are complex and multi-dimensional and are associated more with the magnitude of vulnerability than with that of the hazard (cf. Pescaroli & Alexander, 2015).
4. See also "Direct and indirect loss", "Infrastructure interdependencies", "Systemic risk", and "Organizational learning".

Reference for Note 3: *Pescaroli, G., & Alexander, D. (2015). A definition of cascading disasters and cascading effects: Going beyond the "toppling dominos" metaphor. Planet@ risk, 3(1), 58-67.*

Liquefaction of soil and incapacitation of ports following Haiti earthquake

Two major secondary hazards following the 2010 Haiti Earthquake were liquefaction and landslides, which resulted in increased damage and loss after the earthquake. When loosely packed and water-logged sediment at or near the ground surface is shaken because of earthquake forces, it loses its strength. This is called liquefaction. Most of the flatlands near Port-au-Prince are composed of loose sedimentary material and such soil composition favours liquefaction. Much of the liquefaction occurred around the international port and docks of Port-au-Prince, Haiti's capital and most populous city. As a result of extensive liquefaction, lateral spreading occurred along the wharf. This resulted in the collapse of jetties, ramps and cranes, which were then submerged in the bay. Satellite imagery revealed that the south pier lost several sections and the north wharf completely collapsed, leaving important facilities in the water. With the seaports incapacitated, the transport of aid supplies and personnel for relief and recovery operations was greatly hampered. It took three months for the ports to resume partial operations.

Sources:

- *Basile, V. M. (2021, May 14). The causes and effects of the 2010 Haiti earthquake. ArcGIS StoryMaps. Retrieved December 16, 2022, from https://storymaps.arcgis.com/stories/156382f2727c40a28db502817f7d18f3*
- *Petley, D. (2010, October 21). Earthquake-triggered liquefaction damage to the docks at Port-au-Prince in Haiti. The Landslide Blog. Retrieved December 16, 2022, from https://blogs.agu.org/landslideblog/2010/01/16/earthquake-triggered-liquefaction-damage-to-the-docks-at-port-au-prince-in-haiti/*
- *Booth, E., Saito, K., & Madabhushi, G. (2011). The Haiti earthquake of 12 January 2010 (a field report by EEFIT). The Institution of Structural Engineers. Retrieved December 16, 2022, from https://www.istructe.org/*

C

4. Community infrastructure

Primarily refers to small-scale basic structures, and systems developed at the community level, that are critical for sustenance of lives and livelihoods of the population and are conceived as critical lifelines for survival of the community. These are generally low-cost and small-scale infrastructures, that may develop over time in response to the needs and aspirations of the population, and they may use both community and external resources (e.g. from NGOs, local government).

Notes:

1. Community infrastructure is a fundamental first step in achieving community resilience as it relates directly to the immediate needs of population in achieving an everyday, sustainable existence.
2. Community infrastructure is often built through a co-production process involving one or more local stakeholders including communities, NGOs and government.
3. Community infrastructure is often seen to be initiated informally by people's own efforts to address a pressing local need. As such, it may function in isolation, or be connected to the formal system in an informal manner.
4. See also "Local infrastructure".
5. ISO/TC 292 /WG5 "Community Resilience" is working on standards regarding infrastructure resilience, urban resilience, and organizational resilience. ISO/TC 268/WG6 "Smart Community Infrastructure" is working on disaster risk reduction. Findings from these groups will be incorporated in future editions of this Lexicon.

Reference for Note 3: *a. Global Facility for Disaster Reduction and Recovery, the World Bank, the United Nations Development Programme - Headquarters and European Union (2017). Community Infrastructure, PDNA Guidelines Volume B, 213, p.3.*

METI handmade school –Bangladesh

Dipshikha, a local NGO in rural Bangladesh, has been working to empower the community by providing education and training that promotes self-confidence and independence among children. Their initiative includes the Modern Education and Training Institute (METI), which offers classes and workshops for trade-oriented professions for children and young people up to age 14. The NGO's strategy is to develop knowledge and skills within the local population to maximize the use of available resources. In particular, the region's low cost of labor and the availability of resources such as earth and bamboo provide great potential for developing buildings. Dipshikha has been working with local tradesmen to improve historic building techniques and pass on their skills, transforming the image of these techniques.

Sources:

- *Saieh, N. (2010, March 4). Handmade School / Anna Heringer + eike roswag. ArchDaily. Retrieved March 17, 2023, from https://www.archdaily.com/51664/handmade-school-anna-heringer-eike-roswag*
- *Anna Heringer. Headergrafik | Anna Heringer. (n.d.). Retrieved March 17, 2023, from https://www.anna-heringer.com/projects/meti-school-bangladesh/*

C

5. Contingent liabilities

Potential liability that may occur in the future depending on the disaster-related outcome of a hazard impact. In disaster risk evaluations, contingent liability refers to future projected damage and loss that must be paid for by the government, individuals, private sector, or others.

Notes:

1. Liability can arise from the need for response, reconstruction and recovery funding, insurance contracts, social assistance needs, and international agreements for compensation.
2. The presence and adequate accounting of contingent liabilities can often be an incentive and justification for others to reduce, avoid or transfer the risk.
3. Estimation of contingent liabilities is critical to understanding the resources the government may require from public finances or other sources in the event of a disaster.

Contingent liabilities from disasters in Sri Lanka

The Democratic Socialist Republic of Sri Lanka faces a range of natural hazards, including droughts, floods, landslides, cyclones, and coastal erosion. From 2012 to 2016, the Sri Lankan government's expenditure on contingent liabilities following disasters increased by 49 percent, while total government spending remained stable. The government uses a portion of its expenditure to fund relief, recovery, and rehabilitation activities after a disaster. In 2017, the estimated post-disaster liability was approximately 1 percent of total government expenditure, about US$149 million. Contingent liabilities can be a legal obligation or a social expectation wherein the government acts as insurer of last resort. In 2017, following drought and flood events, 25 percent of Sri Lanka's post-disaster expenditure was addressed as contingent liabilities. The Government of Sri Lanka (GoSL's) post-disaster liabilities can be categorized into seven areas, including relief payments, resettlement, response efforts, economic recovery support, rehabilitation, disaster-linked insurance schemes, and transfers to Ceylon Electricity Board.

Source:

World Bank Group - Disaster Risk Financing and Insurance Program. (2020). Contingent Liabilities from Natural Disasters: Sri Lanka (Rep.). GFDRR. Retrieved December 20, 2022 from https://www.alnap.org/system/files/content/resource/files/main/Contingent-Liabilities-from-Natural-Disasters-Sri-Lanka.pdf

C

6. Corrective disaster risk management

Corrective disaster risk management activities address and seek to remove or reduce disaster risks, that are already present, and which need to be managed and reduced now. Examples are the retrofitting of critical infrastructure or the relocation of exposed populations or assets.

Reference: *UNDRR Sendai Framework Terminology on Disaster Risk Reduction (2023)*
URL: *https://www.undrr.org/terminology/disaster-risk-management*

Notes:

1. This is achieved through intervening in hazard exposure and vulnerability contexts seeking to eliminate, mitigate or reduce existing risk factors, thus promoting the safety and security of affected populations, businesses, infrastructure, livelihoods and others.
2. See also “Disaster risk”, “Prospective disaster risk management” and “Retrofitting”.

DPWH-led Philippines Seismic Risk Reduction and Resilience Project, Philippines

The metropolitan city of Manila, Philippines, is highly exposed to earthquake hazards, which combined with the vulnerability of buildings and infrastructure leads to a very high risk of loss of life, direct damage and economic losses. For example, in a scenario of a 7.2 magnitude earthquake along the West Valley Fault could result in about 48,000 fatalities and US$48 billion in economic losses.

The World Bank-funded Department of Public Works and Highways (DPWH) project, is aimed at enhancing the safety and seismic resilience of selected public buildings in Manila as well as the agency’s capacity to prepare for and respond to emergencies.

This project will improve public facilities’ resilience for multi-hazards, by retrofitting about 425 priority buildings, including schools and health centers in accordance with the most up-to-date seismic and wind loading provisions of the National Structural Code of the Philippines (NSCP), 2015. Along with reducing building damage and potential casualties, additional benefit of the scaled-up retrofitting activities is the provision of higher-skilled, labour-intensive jobs in the short to medium term, thereby broadening the capacity for retrofitting in the national construction industry.

Source:
Philippine Daily Inquirer (2020). Retrofitting to make PH buildings resilient to earthquakes. Retrieved from https://business.inquirer.net/312035/retrofitting-to-make-ph-buildings-resilient-to-earthquakes#ixzz7x95sGP6f as on 27 March 2023.

C

7. Cost benefit analysis

Quantitative (monetary) assessment of all negative and positive impacts associated with a given action. Cost benefit analysis enables comparison of different interventions, investments or strategies and reveals how a given investment or policy effort pays off for a particular stakeholder.

Reference: *Modified from IPCC (2018)*
URL: *https://www.ipcc.ch/sr15/chapter/glossary/*

Notes:

1. Cost benefit analysis requires quantifying and aggregating together all benefits (and costs). However, some benefits may be difficult to quantify or measure in uniform units that enable them to be aggregated such as social impacts, damage to cultural assets, damage to the environment and externalities. It is also typically dependent on several key assumptions – such as the time horizon that is being evaluated, and the discount rate used to aggregate costs and benefits over time.
2. Possible alternate assessment methods to cost benefit analysis could include multi-criteria analysis, expert elicitation methods like Delphi, and methods that analyze the effects of not taking action.
3. “Benefit cost analysis” is an equivalent to “Cost benefit analysis” and offers an evidence-based evaluation of options that can help in data-driven decision making.

Cost benefit analysis findings – GDh Thinadhoo

The Republic of Maldives is an archipelagic state of 26 atolls in the South Asian region of the Indian Ocean. Thinadhoo Island is located approximately 410km from the capital city Malé. Heavy rainfall often results in flooding. However, flooding has only become prominent after land reclamation began in the 1990s.

Thinadhoo’s geographic location also means it is exposed to swell waves, storm surges and tsunamis in addition to flooding due to increased intensity of rains. Assessments suggested that a severe tsunami would result in great loss of life. Multiple protection scenarios were drawn up – “Safe Island Protection”, “Selected Safe Island Protection” and “Limited Protection”, in descending order of cost. Variable costs were assessed for ongoing maintenance, and benefits were estimated as a percentage reduction in losses. Cost benefit analysis findings indicated that the optimum benefits would be delivered in the limited protection scenario, and a full suite of measures may not be the most cost-effective approach.

Source:
Venton, Cabot. (2009, September). Cost Benefit Study of Disaster Risk Mitigation Measures in Three Islands in the Maldives. UNDP.

C

8. Critical infrastructure

The physical structures, facilities, networks, and other assets, which provide services that are indispensable to the social and economic functioning of society, and which are necessary for managing disaster risk.

Reference: *Modified from UNDRR Sendai Framework Terminology on Disaster Risk Reduction (2023)*
URL: *https://www.undrr.org/terminology/critical-infrastructure*

Notes:

1. Well-designed critical infrastructure normally prevents the creation of secondary risks that may result from environmental degradation as an outcome of service provision such as infrastructure for safe sanitation.
2. "Criticality" is dependent on scale and context. For example, a wind turbine may be considered critical in a community that relies on it as a sole source of electricity, but it might be a choice where multiple sources of electricity generation are available.
3. Services provided by critical infrastructure may be referred to as "Critical services".
4. Critical infrastructure includes what is essential (indispensable) for the functioning of a system during an emergency or disaster situation or other crisis situation.
5. See also "Basic infrastructure".

Reference for Note 4: *https://www.cisa.gov/topics/critical-infrastructure-security-and-resilience*

Failure of electrical grid due to heatwaves in Argentina (2022)

In mid-January 2022, the Southern Cone faced a severe heatwave which made the region the hottest place on earth while it lasted, from 10 January 2022 to 26 January 2022. It affected the countries of Argentina, Brazil, Paraguay and Uruguay. On 11 January 2022, temperatures in Argentina's capital city, Buenos Aires, reached 41.1°C, the second highest maximum in its recorded history. During the heatwave, electricity consumption was above 28,000MW, a new national record. Edenor and Edesur, electricity distributors in Buenos Aires and the Greater Buenos Aires area reported power outages as energy demand soared, to cool homes and businesses. The blackouts affected over 700,000 users.

To avoid further blackouts, the government requested the industrial sector to reduce demand and decreed teleworking for public employees for the remaining days of the heatwave. The outage also affected drinking water supplier AySA, which asked the population to optimize water use due to lack of adequate electricity required for water purification.

Source:
Raszewski, E. (2022, January 11). Argentina capital hit by major power outage amid heat wave. Reuters. Retrieved February 20, 2023, from https://www.reuters.com/world/americas/argentina-capital-hit-by-major-power-outage-amid-heat-wave-2022-01-11/

D

9. Decision support system

An information system that aids an organization in decision-making activities that require judgment, determination, and a sequence of actions.

Reference: *Modified from Corporate Finance Institute (CFI) (2022)*
URL: *https://corporatefinanceinstitute.com/resources/knowledge/other/decision-support-system-dss/*

Notes:

1. The information system assists managers and leaders by analyzing data and accumulating information that can help solve problems and make decisions.
2. A decision support system is either human-supervised, automated, or a combination of both.
3. In the context of disaster resilient infrastructure, a decision support system can accelerate decisions and actions in time-sensitive situations.

Namibia Sensor Web Pilot Project

The Namibia Sensor Web Pilot Project has been implemented as a crucial testbed for decision support systems (DSS) aimed at monitoring floods and enabling flood risk assessment. The project provides flood extent maps generated from satellite images, which are readily available on demand, and delivered within just 12 hours of image acquisition. SRI has developed the Grid infrastructure that supports these services. By utilizing satellite data, the Namibian government has been able to significantly reduce the time required for delivering flood protection, prevention, and information services to the end users of infrastructure. This has allowed them to select reliable services that are crucial for safeguarding the population and reducing the negative impacts of flood-related disasters.

Source:
Kussul, N., Skakun, S., Shelestov, A. Y., Kussul, O., & Yailymov, B. (2014). Resilience aspects in the sensor Web infrastructure for natural disaster monitoring and risk assessment based on Earth observation data. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 7(9), 3826-3832.

D

10. Direct and indirect loss

Direct loss refers to the loss directly associated with original hazard impacts. Indirect loss is a consequence of such direct loss.

Notes:

1. For instance, direct loss of roads and bridges due to a landslide may lead to indirect losses such as interruption of commercial flows between places.
2. Loss of factories due to an earthquake may lead to unemployment and unpayable debt; a need for reconstruction finance may lead to diversion of planned development funds from other activities.
3. Partial loss that can be repaired/ remedied is referred to as damage.
4. Direct and indirect loss could be interpreted as an element of cascading impact. See also "Cascading hazards".
5. See also "Disruption and loss of services".

Indirect loses in education due to disaster events

IIn countries and communities where access to educational resources is strained, disaster events can have devastating impacts. For instance, in 2010 the Pakistan floods destroyed 11,000 schools. Thousands of additional schools had to be repurposed as emergency shelters, interrupting children's schooling. Research indicates that children who experience climate shocks experience lower academic performance, higher absenteeism rates, and reduced educational attainment, leading to long-term implications for their future earnings. Repairs to schools and infrastructure in the aftermath of such events are often delayed, further exacerbating the situation. Disaster events disproportionately affect vulnerable students, particularly adolescent girls. In addition to missing school due to damage to infrastructure, children may also miss school due to sickness, injury, or displacement. The interruption of education caused by climate events can have lasting effects on individuals, communities, and societies.

Source:
Chuang, E., Pinchoff, J., & Psaki, S. (2018, January 23). How natural disasters undermine schooling. Brookings. Retrieved March 16, 2023, from https://www.brookings.edu/blog/education-plus-development/2018/01/23/how-natural-disasters-undermine-schooling/

D

11. Disaster preparedness

A condition where different levels and types of social, political and economic organization (and individuals) are able to anticipate and are ready to undertake actions that limit immediate hazard impacts, provide for early recovery, and promote sustainable post disaster recovery, including improved resilience.

Reference: *Modified from UNDRR Sendai Framework Terminology on Disaster Risk Reduction (2023).*
URL: *https://www.undrr.org/terminology/preparedness*

Notes:

1. Preparedness resources include the knowledge, capacities, human resources, assets, instruments and hardware developed or provided by governments, the private sector, response and recovery organizations, communities and individuals that facilitate response, including the existence of early warning systems at different spatial scales.
2. Preparedness is based on an analysis of disaster risks and good linkages with early warning systems, and includes activities such as contingency planning, the stockpiling of equipment and supplies, arrangements for coordination, evacuation, and public information, and associated training and field exercises. These must be supported by formal institutional, legal, and budgetary capacities.
3. Preparedness is a continuous cycle of planning, organizing, training, equipping, exercising, evaluating, and taking corrective action. A preparedness plan establishes arrangements in advance to enable timely, effective, and appropriate responses to specific potential hazardous events or emerging disaster situations. Preparedness activities increase a community's ability to respond when a disaster occurs. Training is a cornerstone of preparedness and focuses on readiness to respond to all-hazard incidents and emergencies.
4. In relation to infrastructure, preparedness should be informed by the analysis of the physical condition of infrastructure, its robustness and resilience, and existing levels of system redundancy, should any infrastructure system fail or be destroyed. This should be accompanied by the determination of alternatives for service provision following impact in the medium and long terms.
5. See also "Disaster response".

RESIST, DELAY, STORE, DISCHARGE - disaster preparedness for Hoboken, New Jersey

In the aftermath of Superstorm Sandy in 2012, Hoboken, New Jersey, found itself submerged in floodwater, leaving its 53,000 residents in the dark and surrounded by contaminated waters. Hoboken Mayor Dawn Zimmer vowed to make her city resilient to future storms, securing US$230 million from the Rebuild by Design programme to protect the city. The plan, which was developed by the Office for Metropolitan Architecture (OMA) and engineering consultancy Royal HaskoningDHV, called for a comprehensive strategy to resist, delay, store, and discharge floodwaters. OMA's proposal included both hard and soft infrastructure to protect the city's coastlines and slow down rainwater runoff, including a retention system and a pump station. The proposal also added amenities such as parks, benches, murals, and green walls to make the protective infrastructure a benefit to the city's residents. The Metropolitan Waterfront Alliance recognizes the project as a national model for preparedness, as it offers replicable solutions that can guide other communities towards a sustainable and safer future.

Sources:

- *Hill, A. C., & Martinez-Diaz, L. (2020). Building a resilient tomorrow: How to prepare for the coming climate disruption. Oxford University Press, USA.*
- *Rosenfield, K. (2013, November 19). Rebuild strategy for Hoboken / OMA. ArchDaily. Retrieved March 16, 2023, from https://www.archdaily.com/450236/resist-delay-store-discharge-oma-s-comprehensive-strategy-for-hoboken*
- *Resist, delay, store, discharge: A comprehensive urban water strategy. OMA. (2013). Retrieved March 16, 2023, from https://www.oma.com/projects/resist-delay-store-discharge-comprehensive-urban-water-strategy*

D

12. Disaster resilience

The ability of a system, community or society exposed to one or more hazards to resist, absorb, accommodate, adapt to, transform, and recover from disasters in a manner that is timely, efficient, and reduces risk, including through the preservation and restoration of essential basic structures and functions.

Reference: *Modified from UNDRR Sendai Framework Terminology on Disaster Risk Reduction (2023) term "Resilience".*
URL: https://www.undrr.org/terminology/resilience

Notes:

1. Infrastructure resilience depends on the resilience of societal systems, governance systems, ecological systems, etc. See also "Disaster resilient infrastructure".
2. An associated phrase is "adaptive capacity" which is the ability of systems, institutions, humans, and other organisms to adjust to potential damage, or to take advantage of opportunities.
3. "Transformative capacity" is the ability of individuals and organizations to transform themselves and their society in a deliberate, conscious way. In the context of resilient infrastructure, transformation may manifest in the form of progressive governance arrangements, updating of codes and standards, and formulation of policies that enable resilience approaches in infrastructure development. See also "Organizational learning" and "Feedback loops".
4. See also "Flexibility".

Reference for Note 2: *ISO (2020). ISO 14050:2020(en) Environmental management - Vocabulary: 3.8.7.*
URL: https://www.iso.org/obp/ui/#iso:std:iso:14050:ed-4:v1:en

Reference for Note 3: *Modified from Ziervogel G, Cowen A, Ziniades J. (2016). Moving from adaptive to transformative capacity: Building foundations for inclusive, thriving, and regenerative urban settlements. Sustainability, 8:1–26.*
URL: https://www.mdpi.com/2071-1050/8/9/955

Disaster resilience for the Dutch delta-city of Rotterdam

The Netherlands, a country mostly below sea-level, has a history of building dikes and other control structures to protect against flooding. In the face of increased intensity and unpredictability of rainfall, the city of Rotterdam has taken up a climate adaptation strategy focusing on water storage. City squares are set lower than streets and pavements and can fill up with water, acting as water plazas. Underground parking garages are built with basins for storing water. Increased green areas, including green roofs and green facades are designed to absorb water. The Dutch have also embraced the idea of floating neighborhoods – homes, schools, offices, parks, and even factories.

At the mouth of the Rotterdam port sits the Maeslantkering, a storm surge barrier. The width of each of the two doors of the Maeslant storm surge barrier is 210m, the largest in the world.

Sources:

- *Braw, E. (2013, November 18). Rotterdam: Designing a flood-proof city to withstand climate change. The Guardian. Retrieved February 7, 2023, from https://www.theguardian.com/sustainable-business/rotterdam-flood-proof-climate-change*
- *Ministry of Infrastructure and Water Management. (2022, August 23). Maeslant Barrier. Rijkswaterstaat. Retrieved February 7, 2023, from https://www.rijkswaterstaat.nl/en/about-us/gems-of-rijkswaterstaat/maeslant-barrier*

D

13. Disaster resilience investment

Investment tools, resources, and processes that aim to avoid, reduce, and transfer risk, mitigate the impact of disaster, and fund resilience measures in infrastructure development, recovery, and reconstruction.

Notes:

1. Disaster resilience investment includes investments made in corrective, prospective, reactive, and compensatory DRM actions. This covers expenditures towards disaster and disaster risk prevention (avoidance), mitigation, preparedness, response, recovery, reconstruction, and overall resilience building.
2. Disaster resilience investment depends on disaster resilience finance, a notion equivalent to Disaster Risk Finance (DRF).
3. Investment comprises expenditures in hard infrastructure as well as in nature-based solutions, and can include the promotion of behavioral change, including the development, enactment and control over laws, norms, and technical standards, as well as learning and capacity building.
4. Disaster resilience investment is to date dominated by immediate pre-impact and post-impact response, reconstruction, and recovery activities. Numerous mechanisms exist for this including emergency funds, insurance and reinsurance, contingent credits, loans, and national budgeting reallocations. Pre-impact corrective and prospective disaster risk reduction and avoidance investments are a very small part of total investment. A permanent but not yet heeded call exists for a significant increase in disaster risk mitigation and prevention spending.
5. Adaptation financing would be an equivalent seen from the angle of climate change investments.

FONDEN: A tool used by the Mexican Government to enhance fiscal resilience

FONDEN, Mexico's fund for natural disasters, was established to support the rehabilitation of federal and state infrastructure affected by disasters. It comprises of two budget accounts: the FONDEN Program for Reconstruction and the FOPREDEN Program for Prevention. The former serves as the primary budget account to channel resources to reconstruction programs for rebuilding infrastructure, low-income housing, and natural environments. The latter funds activities related to risk assessment, risk reduction, and capacity building in disaster prevention. FONDEN is funded through the Federal Expenditure Budget, with the annual appropriation of no less than 0.4 percent of the budget. The FONDEN Trust holds these resources and makes payments for reconstruction services to implementing entities. The process for accessing and executing reconstruction funding from FONDEN balances the need for time-efficient disbursement with accountability and transparency concerns. It aims to prevent the recurrence of vulnerabilities by rebuilding infrastructure at higher standards and relocating public buildings or communities to safer zones. FONDEN's resources are leveraged with market-based risk transfer instruments.

Source:
World Bank. (2012, May). FONDEN: Mexico's Natural Disaster Fund - A Review. Open Knowledge Repository. Retrieved February 14, 2023, from https://openknowledge.worldbank.org/handle/10986/26881

D

14. Disaster resilient infrastructure

Infrastructure systems and networks, the components, and assets thereof, and the services they provide, that are able to resist and absorb disaster impacts, maintain adequate levels of service continuity during crises, and swiftly recover in such a manner that future risks are reduced or prevented.

Notes:

1. Disaster resilience measures are relevant to the planning, design, financing, operation and maintenance of infrastructure systems and networks.
2. See also "Disaster resilience".

BIG U – Rebuild by design

Rebuild by Design was created in New York, USA, after Hurricane Sandy, with the aim of promoting resilience in the affected region through an innovative community- and policy-based solution. The initiative, called the "Big U," encircles Manhattan, protecting ten continuous miles of low-lying geography that make up a densely populated and vulnerable urban area. The eponymous project is designed by the Bjarke Ingels Group (BIG), a Copenhagen and New York-based group of architects, designers, and builders. The project aims to provide flood protection while also offering social and environmental benefits to the community and fostering improved public spaces. The Big U is divided into three sections, each with a physically discrete flood-protection zone that can be isolated from flooding in adjacent areas, while presenting opportunities for integrated social and community planning. Proposed solutions for each component were designed in consultation with local stakeholders and have a benefit-cost ratio greater than one. The project serves as a blueprint for how socially resilient infrastructure can safeguard vulnerable regions of a city while also making them more environmentally and economically resilient.

Sources:

- *Project Pages: The BIG U. Rebuild by Design. (2014). Retrieved March 16, 2023, from https://www.rebuildbydesign.org/work/funded-projects/the-big-u/*
- *Quirk, V. (2014, April 4). The big U: Big's New York City Vision for "Rebuild by design". ArchDaily. Retrieved March 16, 2023, from https://www.archdaily.com/493406/the-big-u-big-s-new-york-city-vision-for-rebuild-by-design*

15. Disaster response

Actions taken once a disaster is imminent or actualized in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected. These normally include a strategic perspective on cascading impacts of the event, new/emerging risk conditions as well as needs for rehabilitation, reconstruction, recovery, and resilience building after the disaster event.

Reference: *Modified from UNDRR Sendai Framework Terminology on Disaster Risk Reduction (2023)*
URL: *https://www.undrr.org/terminology/response*

Notes:

1. Effective and efficient response is dependent on availability of resilient infrastructure for search and rescue, evacuation, provisioning of basic services and distribution of food and water. The institutional elements of response include the provision of emergency services and public assistance by public and private and community sectors, as well as community and volunteer participation. "Emergency services" are a critical set of specialized agencies that have specific responsibilities in serving and protecting people and property in emergency and disaster situations. They include civil protection authorities and police and fire services, among many others.
2. Disaster response is predominantly focused on immediate and short-term needs but must also consider long-term sustainability goals. It can be organized, or emergent and spontaneous on the part of those affected. It should consider local priorities and existing capacities and it should be informed by cultural values and include the conservation of assets such as cultural heritage.
3. The effectiveness of response in relation to infrastructure is seen in immediate post-impact analysis of the security of damaged infrastructure, controls over use of such infrastructure and immediate activation of alternative service provision.
4. Effective, efficient, and timely response relies on disaster preparedness measures, including the development of the capacities of individuals, communities, organizations, countries, and the international community. See also "Disaster preparedness".
5. The division between the response stage and the subsequent recovery stage is not clear-cut. The adequacy and efficiency of response will influence more permanent recovery and reconstruction processes. Some response actions, such as the emergency provision of housing, electricity, and water, may extend well into the recovery stage. Although only designed for temporary use, these provisions may become permanent for various reasons.

Gujarat Earthquake Reconstruction Programme, 2001

One of the worst disasters to strike Gujarat, India was the Kutch earthquake of 26 January 2001. Its magnitude, intensity and geographic spread posed massive challenges in rescue, relief, and rehabilitation. The Gujarat Earthquake Reconstruction Programme was designed to comprehensively address the needs of the affected population. It involved the community and encompassed several sectors such as housing, physical infrastructure, social infrastructure, urban reconstruction, livelihood restoration, social rehabilitation, and long-term disaster risk reduction. It adopted the "building back better" approach.

The short-term focus of the reconstruction programme was on immediate needs. This included construction of temporary shelters, debris removal, repair of houses and public buildings and emergency repair of irrigation structures. The medium-term focus of the programme included repair and reconstruction of houses, public infrastructure, and social infrastructure, and initiating efforts towards disaster mitigation and reduction. The long-term focus of the programme was on further strengthening the capacity of government institutions and the community towards disaster risk reduction and implementation of risk transfer mechanisms.

Source:
UNDP. (2012, March). Disaster Management in India: United Nations Development Programme. UNDP India. Retrieved December 12, 2022, from https://www.undp.org/india/publications/disaster-management-india-0

D

16. Disaster risk

The potential loss of life, injury, and/or destroyed and damaged assets, which could occur in a system, society or community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.

Reference: *UNDRR Sendai Framework Terminology on Disaster Risk Reduction (2023)*
URL: *https://www.undrr.org/terminology/disaster-risk*

Notes:

1. The definition of disaster risk reflects the concept of hazardous events and disasters as the outcome of already present or projected vulnerability and exposure conditions. Disaster risk comprises different types of potential losses that are often difficult to quantify. Nevertheless, with knowledge of the prevailing hazards and the patterns of population and socio-economic development, disaster risks can be assessed and mapped, at least in broad terms.
2. With regard to infrastructure, disaster risk is associated with infrastructure systems that serve communities or businesses located in hazard-prone zones, or where infrastructure serving different (not necessarily hazard-prone) areas passes through hazard-prone zones.
3. See also “Corrective disaster risk management” and “Disaster risk drivers”.

Fastest sinking city in the World – Jakarta

Jakarta, the capital city of Indonesia, is particularly vulnerable to flood risk due to its geography and rapid urbanization. Located on a deltaic floodplain at the mouth of the Ciliwung River on Jakarta Bay, the city is surrounded by several dormant volcanoes whose slopes form the upstream catchment areas of the 13 rivers that flow through Jakarta. However, these catchment areas have been developed for residential and agricultural use, exacerbating the effects of flooding. Moreover, sedimentation, illegal settlements, and poor waste management have decreased the capacity of Jakarta's rivers. The situation is worsened by land subsidence caused by the draining of aquifers (Taylor, 2020). The northern region of Jakarta is sinking at a rate of approximately 150-250mm every year, with 40 percent of the city now believed to be below sea level (World Bank, 2019). By 2050, 95 percent of North Jakarta could be entirely submerged, putting millions of people at risk (BBC, 2018).

Sources:

- *Taylor, M. (2020, January 7). To avert future flood chaos, Jakarta urged to defend nature. news.trust.org. Retrieved March 15, 2023, from https://news.trust.org/item/20200107131405-e3g6q/*
- *World Bank. (2019, September 17). Urban flood resilience in Indonesia: New approaches through an urban design lens. World Bank Blogs. Retrieved March 15, 2023, from https://blogs.worldbank.org/eastasiapacific/urban-flood-resilience-indonesia-new-approaches-through-urban-design-lens*
- *BBC. (2018, August 12). Jakarta, the fastest-sinking city in the world. BBC News. Retrieved March 15, 2023, from https://www.bbc.com/news/world-asia-44636934*

D

17. Disaster risk assessment

Qualitative and quantitative approaches to determine the nature and extent of disaster risk by analyzing existing or potential hazards and evaluating existing or potential conditions of exposure and vulnerability that together could lead to harm to people's lives and livelihoods and to the property, services, livelihoods, and the environment on which they depend.

Reference: *UNDRR Sendai Framework Terminology on Disaster Risk Reduction (2023)*
URL: *https://www.undrr.org/terminology/disaster-risk-assessment*

Notes:

1. Disaster risk assessments include the identification and review of the technical characteristics of hazards such as their intensity, frequency and probability (hazard assessment or analysis); the analysis of the levels of exposure of population, assets, infrastructure, cultural heritage, amongst other aspects, to specific hazards (exposure assessment or analysis); and the vulnerability of these items, including the physical, social, health, environmental and economic dimensions of such vulnerability (vulnerability assessment and analysis). These assessment processes should be linked sequentially, iteratively, and temporally.
2. Based on qualitative decision-making criteria in relation to acceptable or tolerable levels of risk for likely scenarios, risk assessments serve as a basis for prospective and corrective actions for delivery of critical services through infrastructure.
3. See also "Elements at risk".

RiskScape: A tool for Multi-Hazard risk analysis

RiskScape is an open-source software that enables users to customize risk analysis to their domain and input data. It calculates consequences to people, buildings, infrastructure, environment, and other exposed elements. RiskScape provides a flexible data processing framework for building and executing geospatial risk models, taking various input layers, and geospatially stitching them together. Developed in a collaboration between the National Institute of Water and Atmospheric Research (NIWA), Toka Tū Ake EQC, and Geological and Nuclear Sciences in New Zealand, RiskScape can analyze the impact of various natural hazards.

Source:
National Institute of Water and Atmospheric Research Ltd, & Geological and Nuclear Sciences Ltd. (2022). Highly customisable spatial data processing for multi-hazard risk analysis. RiskScape. Retrieved February 15, 2023, from https://riskscape.org.nz/

D

18. Disaster risk drivers

Processes or conditions, related to the workings of a particular development model or practice, that influence the level of disaster risk by creating or increasing hazard, exposure and vulnerability, or reducing capacity.

Notes:

1. Disaster risk drivers, also referred to as underlying disaster risk factors, include poverty, inequality and other conditions of inherent vulnerability; climate change and variability; unplanned and rapid urbanization; the lack of disaster risk considerations in land use; environmental and natural resource management; as well as compounding factors such as demographic change, non-disaster risk-informed policies; the inadequacies of regulations and incentives for private disaster risk reduction investment; complex supply chains; the limited availability of technology; unsustainable uses of natural resources; pandemics and epidemics.
2. Disaster risk may result from one or more of the drivers mentioned above. See also "Disaster risk" and "Disaster scenario". These may be classified as chronic stresses that either predispose a location to acute events (disasters) or hinder the recovery from them.
3. See also "Social construction of risk".

Climate change as an everyday risk driver in Sudan

Sudan, the largest country in Africa, is among the most vulnerable countries in the world in respect of climate variability and change. By 2030, Sudan will have over 18 million poor people who are vulnerable to drought, flood and temperature hazards. IPCC's Fifth Assessment Report acknowledges that changes in climate system and socio-economic processes, including adaptation and mitigation actions, are drivers of hazards, exposure, and vulnerability.

Sudan has high exposure to several geophysical and climate related hazards. The World Bank's Global Facility for Disaster Reduction and Recovery's online tool "ThinkHazard!" classified as "high" the following hazards in Sudan: volcano hazard, river flooding hazard, extreme heat, wildfire, coastal flooding hazard and water scarcity hazard. Sudan is included in the list of 11 countries most at risk of disaster-induced poverty and inadequate capacity to minimize the impacts of disasters (ODI, 2013).

Sources:

- *World Bank Group. Sudan. Vulnerability | Climate Change Knowledge Portal. (n.d.). Retrieved December 16, 2022, from https://climateknowledgeportal.worldbank.org/country/sudan/vulnerability*
- *GFDRR. (n.d.). ThinkHazard Report: Sudan. Think hazard - Sudan. Retrieved December 16, 2022, from https://thinkhazard.org/en/report/6-sudan*
- *Shepherd, A., Mitchell, T., Lewis, K., Lenhardt, A., Jones, L., Scott, L., & Muir-Wood, R. (2013). The geography of poverty, disasters and climate extremes in 2030*

D

19. Disaster scenario

Scenarios are descriptions of plausible events that may occur in the future, leading to a particular set of outcomes. In relation to resilient infrastructure, disaster scenarios are based on assumptions about key driving forces, infrastructure interdependencies for a deeper understanding of causality of disruption and failure in the event(s) of a disaster. They include the hazard, vulnerability, and exposure characteristics that predict or project a future disaster of determined magnitude, impact, and effect.

Reference: *Modified from Strong, K., Carpenter, O., Ralph, D. (2020). Scenario Best Practices: Developing Scenarios for Disaster Risk Reduction. Cambridge Centre for Risk Studies at the University of Cambridge Judge Business School and Lighthill Risk Network, Cambridge, United Kingdom.*
URL: *https://www.jbs.cam.ac.uk/wp-content/uploads/2021/11/crs-developing-scenarios-for-disaster-risk-reduction.pdf*

Note:

1. Disaster scenarios can help articulate measures required to build the resilience of an infrastructure system based on characteristics of risk that may result from one or more of the drivers mentioned above. See also "Disaster risk drivers".

Use of disaster risk scenario to build back better in New Orleans, USA

Located below sea level and surrounded by large bodies of water, the city of New Orleans in the United States of America (USA) is prone to hurricanes and flooding. The devastating impact of Hurricane Katrina in 2005 led the city to develop a disaster risk scenario to assess its infrastructure's potential vulnerability to future hurricanes. The scenario analyzed different levels of storm surge and wind speed and their consequences for buildings, roads, and critical infrastructure. Based on the analysis, the city implemented several measures to enhance its infrastructure's disaster resilience. These included reinforcing buildings and critical infrastructure, improving evacuation routes, and investing in better early warning systems. Additionally, the city elevated homes in flood-prone areas and rebuilt them using stronger building codes. The disaster risk scenario was critical in the city's efforts to reduce the risk of future hurricanes and to build a more resilient infrastructure capable of withstanding the hazards' impacts.

Source:
Link, L. E., Foster, J. L., Patev, R. C., Jones, H. W., Baecher, G. B., McCann, M. W., & McAllister, T. (2009). A general description of vulnerability to flooding and risk for New Orleans and vicinity: past, present and future. US Army Corps of Engineers.

D

20. Disruption and loss of services

A situation whereby access to infrastructure services is interrupted temporarily or lost, following damage or destruction of individual assets or networks or breakdown in the system as a whole.

Notes:

1. Disruption of services is reversed by restoration of services, which is the process by which access to services is re-established post impact. Priorities in restoration or services should distinguish between short-term emergency provision and long-term sustainable solutions.
2. See also “Direct and indirect loss”.

Disruption of power supply post Hurricane Maria in Puerto Rico, 2017

Hurricane Maria, a Category 4 storm, made landfall on Puerto Rico on 20 September 2017. A few weeks earlier, Hurricane Irma, a Category 5 storm, had struck Puerto Rico and had already damaged a significant amount of the electrical grid infrastructure. Maria further destroyed much of what was still functioning, leaving the island of 3.4 million inhabitants completely without power. In some areas, power could not be restored for up to a year. This loss of power is also thought to have been an important factor in the loss of 3,000 lives because of the storm. A major wholesale medical supply company in San Juan, Puerto Rico’s capital, was unable to maintain production. This resulted in critical shortages across hospitals in the United States, many of which sourced their supplies from this company in San Juan. The cost of intravenous bags went up by 600 percent in the United States.

Sources:

- *UNDRR. (n.d.). Disaster Losses & Statistics. Disaster losses and statistics. Retrieved December 13, 2022, from https://www.preventionweb.net/understanding-disaster-risk/disaster-losses-and-statistics*
- *Scott, M. (2018, August 1). Hurricane Maria’s devastation of Puerto Rico. NOAA Climate.gov. Retrieved December 13, 2022, from https://www.climate.gov/news-features/understanding-climate/hurricane-marias-devastation-puerto-rico*
- *Meyers, T. (2022, May 10). 10 disasters that changed the world. Direct Relief. Retrieved December 13, 2022, from https://www.directrelief.org/2019/12/10-disasters-that-changed-the-world/*

D

21. Downgraded infrastructure systems

Infrastructure that is incapable of efficiently and securely performing to the intended standards for which it was designed. This can be due to poor implementation or construction, wear and tear, age, usage, and/or lack of maintenance that may affect performance especially in the face of shocks and stresses.

Notes:

1. Poor performance of infrastructure is typically categorized as downgraded through a process of evaluation according to established norms and standards.
2. The pace of downgrading can be accelerated by (i) social factors, (ii) governance mechanisms, (iii) natural decay and deterioration, (iv) poor detailing and design, (v) lack of maintenance. See also "Infrastructure maintenance".
3. In some contexts, infrastructure can be downgraded for reasons other than poor performance, e.g., reclassification of a highway from one type to another.
4. Upgraded infrastructure is the infrastructure that meets a higher performance standard, often through improvements, expansions, or renewals to parts of an infrastructure system.

Submerged handpumps in flooded areas

Handpumps are prevalent in rural regions around the world as a reliable source of potable water. In the event of a flood, sources of water such as ponds, wells or handpumps are affected. Submerged handpumps can become ineffective or even completely ruined if the water column is contaminated due to flooding. A practical solution to this problem is to elevate the pumps above the High Flood Level (HFL). Raised handpumps mounted on a platform to mitigate the impact of flooding are increasingly becoming a common practice across the Indo-Gangetic floodplains in India as well as across the border in Nepal.

Sources:

- *Jaiswal, P. (2016, August 30). Elevated hand pumps: Boon for up Flood Zones. Hindustan Times. Retrieved March 17, 2023, from https://www.hindustantimes.com/lucknow/elevated-hand-pumps-boon-for-up-flood-zones/story-Zci6358gL5g6SpyxjQTxqK.html*
- *Khakda, R. (2021, August 11). Elevated hand pumps supply clean water during floods. Flood Resilience Portal. Retrieved March 17, 2023, from https://floodresilience.net/blogs/elevated-hand-pumps-supply-clean-water-during-floods/*

22. Elements at risk

All objects, persons, animals, plants, activities, and processes that may be adversely affected by hazardous phenomena, in a particular area, either directly or indirectly. This includes buildings, infrastructure, production facilities, population, livestock, economic activities, cyber networks, public services, environment, and cultural heritage among others.

Reference: *Caribbean Handbook on Risk Information Management, ACP-EU Natural Disaster Risk Reduction Programme.*
URL: *http://www.charim.net/methodology/52*

Note:
1. See also "Disaster risk assessment".

Understanding elements at risk from multi-hazard risk assessment

The Asian Disaster Preparedness Center (ADPC) classifies elements at risk into physical, economic, societal, and environmental categories that can be linked to vulnerability. While existing data sources such as cadastral and census data can provide some information, additional data is often required to fully understand elements at risk for vulnerability assessment. This additional data can be collected by mapping different aspects, including building types and construction materials, population characteristics, basic infrastructure, and environmental problems like waste disposal and polluted areas. Participatory mapping can also be conducted by members of the local community. By collecting and analyzing this information, researchers and policymakers can better understand the risks faced by different communities and develop effective strategies for disaster preparedness and risk reduction.

Sources:
- *Westen, CJ. (n.d.). Characterization of assets - Elements at Risk, Carribean Handbook on Risk Information Management. Retrieved from http://www.charim.net/methodology/52*
- *Westen, C. V., Kingma, N., & Montoya, L. (n.d.). Session 4: Elements at Risk. In Introduction to Risk Assessment. CENN.*

E

23. Everyday risk

Day-to-day conditions that severely impede the achievement of a healthy and productive life by different sections of a society or a community. These include conditions such as lack of access to basic services, infrastructure, and livelihood opportunities as well as overall well-being.

Notes:

1. Also known as “Quotidian risk” or “Chronic stresses”.
2. Such risk is seen as a precursor to extensive and intensive disaster risk and disaster. See also “Social construction of risk”, “Extensive disaster risk” and “Intensive disaster risk”.
3. The term “everyday” may be taken by some to mean “normalcy,” which could lead to the conclusion that these conditions are unavoidable. However, the concept of “everyday risk” is an important one, and widely used in social science research, because it highlights the fact that disaster risk is often constructed on the basis of the chronic, quotidian, ongoing unsafe and insecure living conditions of individuals, families and communities, which comprise their “normalcy”. It forms an important part of the spectrum of risk, from everyday, to extensive, to intensive. Only by recognising this can everyday risk become addressable; i.e. by integrating disaster risk reduction into sustainable development objectives and planning processes related to such goals as the reduction of poverty, inequality and exclusion, or improving access to health and employment.

Reference for Note 2: *Maskrey, A., Jain, G., Lavell, A. (2021). “The Social Construction of Systemic Risk: Towards an Actionable Framework for Risk Governance”. United Nations Development Programme, Discussion Paper.*
URL: *https://www.undp.org/sites/g/files/zskgke326/files/2021-08/UNDP-Social-Construction-of-Systemic-Risk-Towards-an-Actionable-Framework-for-Risk-Governance.pdf*

Everyday risk in Somalia

The country of Somalia has been in a state of perpetual crisis since 1991, fueled by political instability and civil strife. Over the decades, recurrent droughts, floods and desertification are wreaking havoc on Somalia’s agriculture and livestock sectors, plunging the country into an unsustainable cycle. These sectors, which have sustained the Somalis for centuries, are being undone by the effects of the climate emergency. The impact of drought on the people is compounded by an interrelated set of factors that include environment, government, conflict, displacement, and poverty.

Source:
Santur, H. G. (2019, November 19). Weather and war: How climate shocks are compounding Somalia’s problems. The New Humanitarian. Retrieved December 15, 2022, from https://www.thenewhumanitarian.org/feature/2019/11/19/Climate-shocks-Somalia-problems

E

24. Extensive disaster risk

The risk of low-severity, high-frequency hazardous events and disasters, mainly but not exclusively associated with highly localized hazards.

Reference: *UNDRR Sendai Framework Terminology on Disaster Risk Reduction (2023)*
URL: *https://www.undrr.org/terminology/extensive-disaster-risk*

Notes:

1. Extensive disaster risk is usually high in cases where communities are exposed to, and vulnerable to, recurring localized floods, landslides, storms or drought. Extensive disaster risk is often exacerbated by poverty, rapid urbanization and environmental degradation.
2. When dealing with infrastructure loss and damage, extensive disaster risk relates to small-scale, local infrastructure systems, rather than large-scale infrastructure.
3. See also "Intensive disaster risk" and "Everyday risk".

Reference for Note 1: *UNDRR Sendai Framework Terminology on Disaster Risk Reduction(2023)*
URL: *https://www.undrr.org/terminology/extensive-disaster-risk*

Lightning risk in Canada

Lightning is a common hazard in Canada, damaging property and disrupting economic and social activities. Lightning not only impacts human health, it also affects infrastructure systems including electricity generation, transmission and distribution, and also telecommunications. According to some studies, lightning-related damage and disruption costs in Canada range from CA$600 million to CA$1 billion per annum. Forestry and electricity infrastructure damages account for over 85 percent of the total. A deeper effort is needed to evaluate the risk and to develop damage prevention measures, such as the expanded use of the Canadian Lightning Detection Network data by both public and private sector clients.

Source:
https://www.researchgate.net/publication/225365288_Assessment_of_lightning-related_damage_and_disruption_in_Canada

F

25. Feedback loops

A feedback loop arises from causal relations within a system and either enhances or limits a change in the system. Feedback loops may be positive or negative in nature. A negative feedback loop reduces the effect of change and helps maintain equilibrium. A positive feedback loop increases the effect of the change and produces instability.

Reference: *Modified from National Oceanic and Atmospheric Administration: Global Monitoring Laboratory.*
URL: *https://gml.noaa.gov/education/info_activities/pdfs/PSA_analyzing_a_feedback_mechanism.pdf*

Notes:

1. In climate change, a feedback loop is something that speeds up or slows down a warming trend.
2. Design and management of infrastructure for resilience should consider feedback loops.
3. Feedback loops are important in learning and decision-making processes, which may be single-loop, double-loop or triple-loop, depending on the type and extent of change.
4. Feedback loops are significant for building the intelligence of a system to respond to future shocks and stresses based on past, current and projected performance for a dynamic risk context.
5. See also “Disaster resilience” and “Organizational learning”.

Positive climate feedback loop – Increased carbon emissions to offset higher temperatures contributing to global temperature rise

There has been an unparalleled rise in temperatures globally, much of which is due to a sharp increase in carbon emissions. While some countries have been able to adjust to this rising temperature, some infrastructures have not been able to effectively combat these heatwaves. Warm temperatures cause people to run electrical appliances, like fans, air conditioners, freezers. These electrical appliances are notorious for emitting hydrofluorocarbons, which contribute to global greenhouse gas (GHG) emissions. Additionally, to satisfy this increase in electricity demand, governments are forced to increase the use of fossil fuel-powered power plants. This emits more GHGs, thereby contributing to increasing global temperatures. This feedback loop creates a vicious circle of increased air conditioning use leading to increased electricity consumption and refrigerant production, causing increased emissions of GHG, accelerating global temperature rises, and provoking further increased use of air conditioning, and so on.

Source:
Climate Reality. (2020, January 7). How feedback loops are making the climate crisis worse. Climate Reality Project. Retrieved February 14, 2023, from https://www.climaterealityproject.org/blog/how-feedback-loops-are-making-climate-crisis-worse

F

26. Financial infrastructure

Hard infrastructure (including physical assets such as telecommunication assets, buildings, and equipment), and soft infrastructure (such as rules, standards, policies and processes) that enable financial transactions and other functions of the financial system to take place.

Sustainable financial landscape in Brazil

Brazil's financial institutions and its central bank have been integrating sustainability issues in the financial system. This began with the Forest Code (2008) followed by the responsibility principles for environmental risks for financial institutions (2014). To develop assessment and monitoring instruments proportional to the complexity of their operations, financial institutions active in the country need to integrate environmental risks into their risk management processes. Working in this direction, on 1 July 2022, the Central Bank of Brazil launched its Sustainability Dimension 13. It is a comprehensive agenda for the alignment of financial regulation with international best practices covering climate risk assessment and management, financial incentives for green finance through collateral and liquidity management, and disclosures and reporting.

Source:
CEPR, Schoenmaker, & Volz. (2022, October). Scaling up sustainable finance and investment in the Global South. CEPR. Retrieved December 22, 2022, from https://cepr.org/publications/books-and-reports/scaling-sustainable-finance-and-investment-global-south

F

27. Flexibility

The ability of an infrastructure system including its governance, material assets and human resources, to serve business-as-usual as well as adjust to shocks/stresses.

Reference: *Adapted from Woods, D. D. (2006). Essential characteristics of resilience. Resilience Engineering: Concepts and Precepts, Aldershot: Ashgate,21-34 and Jackson, S. (2010). The Principles of Infrastructure Resilience. CIP-R, 17 February 2010.*

Notes:

1. In planning for service continuity for infrastructure systems, flexibility includes rearrangement of management structures and decision-making to mitigate or manage crises.
2. The flexibility of a system is intended to secure core functions, sometimes at the expense of ancillary/non-core functions/components of the system.
3. See also “Organizational learning”, “Disaster resilience”, and “Prospective disaster risk management”.

Case of German solar power grid during the 2015 solar eclipse

The International Energy Agency’s (IEA) definition of power system flexibility highlights its capacity to adapt to changes in electricity production or consumption. Renewable energy technologies such as biogas, hydroelectric, and geothermal can provide a fully dispatchable and flexible power supply, which can balance residual load variations. Similarly, demand response refers to the flexibility on the demand side, where factories can be retrofitted, or control systems redesigned to accommodate residual load flexibility.

A notable instance of such flexibility occurred during the solar eclipse in Germany in March 2015, which witnessed a drop in solar power production from 21.7 GW to 6.2 GW. This event acted as a stress test for Germany’s solar power grid, the largest in Europe by capacity, and demonstrated the need for alternative power sources to manage such variability in supply. During this event, four aluminium factories in Germany reduced their power consumption during the eclipse, allowing the solar-powered grid to manage the event without incident. This highlights the growing importance of flexible power supply systems in managing a renewable energy-driven world.

Sources:

- *Renewables, I. H. V. (2011). A Guide to the Balancing Challenge. Paris Cedex, France: International Energy Agency (IEA).*
- *Eckert, V. (2015, March 20). European power grids keep lights on through solar eclipse. Reuters. Retrieved December 8, 2022, from https://www.reuters.com/article/us-solar-eclipse-germany-idUKKBN0MG0S620150320*

G

28. Green infrastructure

The interconnected set of natural and constructed ecological systems, green spaces and other landscape features that can provide functions and services including air and water purification, temperature management, floodwater management and coastal defense, often with co-benefits for human and ecological well-being. Green infrastructure includes planted and remnant native vegetation, soils, wetlands, parks, and green open spaces, as well as building and street-level design interventions that incorporate vegetation.

Reference: *Modified from Culwick and Bobbins (2016) and IPCC (2022).*
URL: *https://cdn.gcro.ac.za/media/documents/GCRO_Green_Assets_REPORT_digital_ISBN.pdf*
https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_Annex-II.pdf
.

Notes:
1. This definition is based on the IPCC (2022) definition but amplifies it with more DRI-specific examples.
2. “Blue infrastructure” may be considered together with “Green infrastructure” in the term “Blue-Green infrastructure”. See also “Blue infrastructure”, “Nature-based solutions”, and “Infrastructure”.

The role of green infrastructure in post disaster recovery

Green infrastructure is emerging as a promising alternative to traditional approaches for managing stormwater. Systems such as rain gardens, stormwater planters, and permeable surfaces use vegetation and organic materials to retain and filter water near its source, providing adaptation benefits for smaller and larger weather events at a watershed scale. The New York City Department of Parks & Recreation’s implementation of green streets has successfully increased resilience during disasters, such as Hurricane Sandy in 2012. Furthermore, preservation of green infrastructure along the USA’s coastline, including reefs, dunes, marshes, and coastal vegetation, can protect 67 percent of the high-hazard areas where 1.3 million people reside, and maintain US$300 billion in residential property value. Nature-based approaches, such as preserving and restoring natural habitats, have proven to be an effective way to increase resilience against natural disasters. Green infrastructure offers a promising solution for communities to combat the impact of extreme weather events and to safeguard people and assets.

Source:
Rouse, D. (2014). Green Infrastructure and Post-disaster Recovery. American Planning Association. Retrieved December 22, 2022, from planning.org

G

29. Grey infrastructure

Engineered physical structures that underpin energy, transport, communications (including wireless and digital), built form, water and sanitation, and solid-waste management systems and that protect human lives and livelihood.

__Reference:__ IPCC, (2022). Annex II: Glossary [Möller, V., R. van Diemen, J.B.R. Matthews, C. Méndez, S. Semenov, J.S. Fuglestvedt, A. Reisinger (eds.)]. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2897–2930, doi:10.1017/9781009325844.029.
URL: *https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_Annex-II.pdf*

Notes:
1. Grey infrastructure may be interpreted more narrowly to refer to subsets of the above definition.
2. See also “Infrastructure”.

Tokyo Bay Aqua-Line, Japan

Tokyo Bay Aqua-Line, also called Trans-Tokyo Bay Expressway, is a bridge-tunnel system connecting the cities of Kawasaki and Kisarazu in Japan. The construction of this system shortened the drive between the two industrial areas from 90 minutes to 15 minutes. It has an overall length of 23.7km, including a 4.4km bridge and a 9.6km tunnel underneath the bay – the fourth longest underwater tunnel in the world. The system also features an artificial island, acting as a rest stop and a ventilation tower, erected above the middle of the tunnel. The structure was designed to withstand earthquakes and typhoons, common disasters in the region. It features reinforced concrete pillars and a system for absorbing seismic vibrations, ensuring the safety and continuity of transport services, even in the event of a disaster.

Sources:

- *Hotta, K. (2002). Tokyo Bay Reformation. Engineered Coasts, 85-102.*
- *Norio, Y., & Toshiyuki, O. (1998). Tokyo Bay Aqualine. Earthquake-proof and wind resistant measures for bridge. Foundation Engineering & Equipment, Monthly, 26(1), 89–92.*

30. Incentive mechanisms for disaster resilient infrastructure

Methods and instruments that promote and/or facilitate the upgrading of existing infrastructure and the building of new resilient infrastructure.

Notes:

1. Incentive mechanisms may be promoted by the public and private sectors and in joint public-private ventures. This includes incentives provided by finance, insurance, real estate and government stakeholders.
2. Incentives can be built into mortgages, insurance policies, tax incentives, grants, and other mechanisms.
3. Incentives are necessary to promote an increased investment in corrective and prospective disaster risk reduction, which are intended to reduce overall societal costs of disasters in the short, medium and long terms.

Reference for Note 1 and 2: *Multi-Hazard Mitigation Council (2020). A Roadmap to Resilience Incentivization. Porter, K.A. and Yuan, J.Q., eds., National Institute of Building Sciences, Washington, DC, 33 p.*
URL: *https://www.nibs.org/files/pdfs/NIBS_MMC_RoadmapResilience_082020.pdf*

Incentive mechanisms to strengthen building control and planning in Kathmandu

Nepal, one of the most seismically active regions in the world, has a long history of destructive earthquakes, such as the 2015 Gorkha earthquake that killed 8,964 people and injured 21,952 others. Kathmandu Valley is the centre of Nepal's political, commercial, educational, administrative, and cultural activities, with nearly half of the country's urban population concentrated in this region. Municipal and city governments that comply with minimum building performance measures focusing on disaster risk reduction are awarded access to intergovernmental awards and cash awards as financial incentives to increase resilience in the valley. Existing bylaws in Kathmandu Valley provide incentives for developers to avoid hazard-prone areas and build disaster-resilient buildings by reducing registration fees and providing access to training in earthquake-resistant construction. This also includes income-generating opportunities for masons and carpenters. Extra floor construction incentives are also offered to developers who facilitate well-managed new housing and commercial buildings in residential zones, town extension zones, or urbanizing village development committees.

Source:
McDonald, K. (2016). Incentives for reducing disaster risk in urban areas. Asian Development Bank.

I

31. Indigenous knowledge

Indigenous knowledge is rooted in culture and tradition, and refers to place-based understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings.

Reference: *Adapted from Local and Indigenous Knowledge Systems (LINKS). UNESCO. (2022, January 6). Retrieved March 3, 2023 and Sillitoe, P. (2006). Indigenous knowledge in development. Anthropology in Action, 13(3), 1-12.*
URL: *https://en.unesco.org/links https://www.berghahnjournals.com/view/journals/aia/13/3/aia130302.xml*

Notes:

1. Indigenous knowledge comes from a range of sources and is a dynamic mix of past tradition and present invention with a view to the future. The view to the future is highly relevant in the context of climate change and its influence on the environment, and in the context of migration of indigenous populations to more urbanized areas.
2. Indigenous is also referred to as autochthonous, tribal, traditional, aboriginal or by other nomenclatures according to place and academic discipline.
3. This knowledge is integral to cultural complexes, which also encompass language, systems of classification, resource use practices, social interactions, values, ritual, and spirituality.
4. Indigenous knowledge is not just locally based and can be expressed and applied at regional, or even national and transnational scales.
5. See also "Local knowledge".

Reference for Note 1: *Sillitoe, P. (2006). Indigenous knowledge in development. Anthropology in Action, 13(3), 1-12.*
URL: *https://www.berghahnjournals.com/view/journals/aia/13/3/aia130302.xml*
Reference for Note 3: *Local and Indigenous Knowledge Systems (LINKS). UNESCO. (2022, January 6). Retrieved March 3, 2023.*
URL: *https://en.unesco.org/links*

Meghalaya's living root bridges

Situated in the north-east region of India, Meghalaya is famous for its high rainfall, sub-tropical broadleaf forests and biodiversity. In the West Jaintia Hills district and East Khasi Hills district, the local Khasi and Jaintia tribal communities have trained the rubber (Ficus elastica) trees to form bridges, helping more than 70 remote villages stay connected. The roots of rubber trees are manipulated to grow horizontally across the numerous rivers that traverse the hills. These bridges, locally called jing kieng jri, have strong and deep roots that provide a stable foothold, but take around 10-15 years to develop. Their load-bearing capacity progressively increases with time, making it increasingly resilient and robust. The longest known living root bridge is the 50m long Rangthylliang bridge which hangs 30m above ground. There are 72 living root bridge cultural landscapes (LRBCL) villages in the state.

These bridges have withstood extreme disasters for centuries and represent a profound human-environment symbiotic relationship. They play an essential socio-economic role and contribute to the ecology through forest and riparian restoration. They have a remedial impact on surrounding soil, water, and air. The local community is also involved in the growth process across multiple generations. These bridges are now on UNESCO's tentative list of World Heritage Sites.

Sources:
- *Chaudhuri, P., Bhattacharyya, S., & Samal, A. C. (2016). Living Root Bridge: A potential no cost eco-technology for mitigating rural communication problems. Int. J. Exp. Res. Rev, 5, 33-35.*
- *Shankar, S. (2015, September). Living Root Bridges: State of knowledge, fundamental research and future application. In Proc. of 2015 IABSE Conf.—Structural Engineering: Providing Solutions to Global Challenges (Vol. 105, pp. 1-8).*
- *Azad, S. (2022, September 23). Centuries-old living root bridges of Meghalaya hit by water scarcity: Dehradun News - Times of India. The Times of India. Retrieved December 23, 2022, from https://timesofindia.indiatimes.com/city/dehradun/centuries-old-living-root-bridges-of-meghalaya-hit-by-water-scarcity/articleshow/94387099.cms*
- *Lifestyle Desk. (2022, March 29). Meghalaya's Living Root Bridges in UNESCO's Tentative List of World Heritage Sites; know more about them. The Indian Express. Retrieved December 23, 2022, from https://indianexpress.com/article/lifestyle/destination-of-the-week/meghalayas-living-root-bridges-unescos-tentative-list-of-world-heritage-sites-know-more-7841998/*

I

32. Infrastructure

Individual assets, networks and systems that provide specific services to support the functioning of a community or society.

Notes:

1. Infrastructure is commonly classified into hard, soft, and nature-based infrastructure. This distinguishes between tangible, intangible, and biotic systems. It may also be classified into social or economic infrastructure, referring to systems that are a blend of tangible and intangible elements.
2. Hard infrastructure consists of physical, engineered, or artisan-built infrastructure, networks, buildings, and other assets. See also "Infrastructure systems" and "Grey infrastructure".
3. Soft infrastructure includes governance structures, regulatory frameworks, management, systems and technologies, interdependencies within and between infrastructure sectors, and human factors, such as skills and knowledge. See also "Infrastructure systems".
4. Nature-based infrastructure refers to the natural environment's resources and features that provide people, organizations and businesses with critical services or products directly, or through hard infrastructure. See also "Blue infrastructure" and "Green infrastructure".
5. Social infrastructure refers to the hard, soft, and nature-based infrastructure that provides for human welfare such as social, cultural, educational, and health-related services.
6. Economic infrastructure refers to the hard, soft, and nature-based infrastructure that provides economic benefits through the production of goods and services. It includes provision of power, telecommunications, transportation, and financial services.
7. In common usage the term "infrastructure" usually refers to hard infrastructure. However, the concept of resilience implies a more nuanced appreciation of the different forms of infrastructure.

High Line in New York City

The High Line is a public park built on a former elevated railway line on the west side of Manhattan. It runs for 2.3km from Gansevoort Street in the Meatpacking District to 34th Street near the Javits Center. The park offers unique views of the city and is a popular destination for both tourists and locals. The High Line is an example of how infrastructure can be repurposed and transformed into a public space serving multiple functions, including providing green space in an urban environment, supporting local businesses and communities, and promoting sustainable transportation. It is also an example of innovative design, with its unique combination of landscapes, art installations, and seating areas that blend into the surrounding cityscape.

Sources:

- *Diller Scofidio + Renfro. (2019). The High Line. DS+R. Retrieved February 17, 2023, from https://dsrny.com/project/the-high-line*
- *James Corner Field Operations. (n.d.). High Line. Project details. Retrieved February 17, 2023, from https://www.fieldoperations.net/project-details/project/the-high-line.html*

I

33. Infrastructure interdependencies

Functional linkage(s) within and across different infrastructure sectors or systems (e.g., energy, transportation, telecommunications, water/ wastewater, solid waste, and food).

Notes:

1. Interdependencies are often seen to increase the risk of failure or disruption in multiple infrastructure sectors, which may lead to cascading impacts, or escalation of impact. See also "Cascading hazard".
2. Identifying infrastructure interdependencies is a necessary step for building resilient infrastructure systems. See also "Infrastructure linkages".

Interdependencies of urban infrastructures

Various infrastructure systems that underpin our cities - water, energy, transportation, and communications - may seem distinct, but they are in fact interdependent. Consider, for instance, the fact that a full 3 percent of energy consumption in the United States of America is attributable to the treatment and supply of water. When the energy used to heat water in homes is factored in, that figure doubles. The implication is clear: by conserving water, we can also save energy - a clear example of the kind of synergy that is possible within the city. The interdependencies between these systems are becoming more apparent.

Source:
Mitchell, C., & Campbell, S. (2004). Synergy in the City: making the sum of the parts more than the whole. 2nd IWA leading-edge on sustainability in water-limited environments, 125-135.

I

34. Infrastructure lifecycle

The series of stages during the lifetime of an infrastructure asset, starting from planning, prioritization and funding to the design, procurement, construction, operation, maintenance and decommissioning.

Partial collapse of Morandi Bridge in Italy, 2018

Bridges are essential components of road transportation and play a crucial role in connecting communities and enabling commerce. Across Europe and the United States of America, many highway bridges are close to the end of their design lives, making their structural integrity increasingly important. Tragically, this criticality was illustrated in 2018 when the Morandi Bridge in Genoa, Italy, collapsed, killing 43 people. The disaster was traced back to corrosion of steel strands in one of the pylons, likely caused by a highly saline environment and nearby industrial pollution. The collapse also directed attention to the state of other bridges in Europe, with several studies finding that many more structures require immediate repair or replacement due to corrosion and structural deterioration. The importance of maintaining the safety and stability of bridges cannot be overstated, as their collapse not only endangers lives, but also has severe economic implications.

Sources:

- *La Storia del Ponte Morandi: Un tempo avveniristico, ma non mancavano criticità. GenovaToday. (2018, August 14). Retrieved February 23, 2023, from https://www.genovatoday.it/cronaca/storia-ponte-morandi-a10.html*
- *Willsher, K., Tondo, L., Henley, J. (16 August 2018). "Bridges across Europe are in a dangerous state, warn experts". The Guardian. Retrieved 16 August 2018.*
- *BBC. (2018, August 14). Italy Bridge: Dozens feared dead in Genoa as motorway collapses. BBC News. Retrieved February 23, 2023, from https://www.bbc.com/news/world-europe-45183624*
- *Expert reaction to Genoa Motorway Bridge collapse. Science Media Centre. (2018, August 14). Retrieved February 13, 2023, from https://www.sciencemediacentre.org/expert-reaction-to-genoa-motorway-bridge-collapse/*
- *Fumagalli, M. (2021, November 30). The corrosion of the Morandi bridge: The story of a predictable collapse? IPCM. Retrieved December 26, 2022, from https://www.ipcm.it/en/article/corrosion-morandi-bridge-the-story-of-a-predictable-collapse.aspx*

35. Infrastructure linkages

The notion that infrastructure systems may be highly interconnected and mutually dependent in complex ways. Interlinkages are a significant source of systemic risks, which are increasingly transboundary and transnational.

Note:

1. See also “Infrastructure interdependencies”, “Infrastructure systems”, “System of systems”, “Systemic risk” and “Transboundary infrastructure”.

Linkages in Energy Infrastructure

The energy infrastructure linkages encompass a complex network that provides electricity to homes and businesses, including power plants, substations, transformers, and power lines. To ensure a reliable and resilient system, these components and their linkages need to be designed to withstand various stressors, including extreme weather and cyber-attacks. Some electric utilities generate their own electricity, while others purchase it from other utilities or a regional transmission reliability organization. The final stage of delivering electricity to consumers is through electric power distribution, which has become increasingly integrated with renewable energy sources such as solar and wind. To maintain a stable power system, it is critical to ensure the resilience and reliability of energy infrastructure linkages.

Sources:

- *U.S. Energy Information Administration (EIA). (2022, August 11). U.S. Energy Information Administration - EIA - independent statistics and analysis. Delivery to consumers. Retrieved February 13, 2023, from https://www.eia.gov/energyexplained/electricity/delivery-to-consumers.php*
- *Fathabad, A. M., Cheng, J., Pan, K., & Qiu, F. (2020). Data-driven planning for renewable distributed generation integration. IEEE Transactions on Power Systems, 35(6), 4357-4368.*

I

36. Infrastructure maintenance

Maintenance is a cycle of activities designed and undertaken to preserve the optimal functioning of infrastructure, including in adverse conditions. It is a necessary precondition for the preservation of its operational capability, and to guarantee service continuity.

Reference: *Modified from ISO 9001 7.1.3 Infrastructure*
URL: *https://www.iso.org/obp/ui/#iso:std:iso:9001:ed-5:v1:en*

Notes:

1. See also "Robustness".
2. Maintenance includes regular inspection (planned and unplanned), which is vital to an understanding of the condition and performance of the infrastructure, and to determine the need for downgrading. See also "Downgraded infrastructure".
3. Maintenance of infrastructure accounts for over 70% of total costs including building costs, and the lack of this is a major cause of non-resilient infrastructure. This requires budgetary allocations commensurate with the need for maintenance, which is not included in in many cases.

Morbi Bridge Collapse in Gujarat, India (2022)

The Jhulto Pul, a 230m pedestrian suspension bridge spanning the Machchhu River in the Morbi district of Gujarat, India, suffered a catastrophic collapse on 30 October, 2022, killing over 135 individuals and injuring over 180 more. Built in the 1880s, the bridge was owned by the Morbi Municipality and had undergone repairs for six months prior to its reopening on 26 October 2022. Investigations revealed that the bridge was reopened prematurely without the required fitness certification from local authorities. Forensic reports indicate that the cause of collapse was due to a combination of factors, including the bridge's rusted cables, broken anchors, and loose bolts connecting cables to the anchors, together with the weight of the new heavy flooring. At the time of the collapse, the bridge was loaded well over its rated capacity, with an estimated 500 individuals present.

Sources:

- *Langa, Mahesh (31 October 2022). "Morbi bridge collapse tragedy: 141 deaths reported so far". The Hindu. Retrieved 24 November 2022.*
- *Khanna, Sumit (30 October 2022). "At least 40 killed in India bridge collapse, state minister says". Reuters. Retrieved 30 October 2022.*
- *Sharma, Shweta (1 November 2022). "How India's bridge collapse tragedy that killed 135 unfolded". The Independent. Retrieved 1 November 2022.*

I

37. Infrastructure systems

Arrangements of infrastructure components and linkages that provide a service or services.

Note:

1. See also “Infrastructure”, “Infrastructure linkages”, and “Physical infrastructure”.

Increasing resilience of telecommunication infrastructure in Puerto Rico (Hurricane Maria, 2017)

Hurricane Maria made landfall on Puerto Rico on 20 September 2017 as a high-end Category 4 storm. Emergency response, recovery and coordination efforts were hampered due to the collapse of telecommunications in Puerto Rico. Lack of maintenance was identified as the main cause of this lack of resilience. Use of extensive above-ground telecommunication infrastructure, as opposed to underground ducts, also contributed to the extent of network outage and infrastructure damage. The recovery plan highlights activities in public and private sector capacity building as pre-requisites to create the right enabling environment for investments in telecommunications and other infrastructure. Key activities include building up GIS capabilities, infrastructure deployment planning, improving emergency response, upgrading Land Mobile Radio Systems (LMRS), implementing standardized power backup, developing communications networks in rural areas, use of submarine cables to reduce redundancy, performing periodic audits, etc.

Source:
Sandhu, H. S., & Raja, S. (2019, June 1). No Broken Link: The Vulnerability of Telecommunication Infrastructure to Natural Hazards. Open Knowledge Repository. Retrieved December 12, 2022, from https://openknowledge.worldbank.org/handle/10986/31912

I

38. Infrastructure vulnerability

The sensitivity or susceptibility of a system to harm, and its lack of capacity to cope and/or adapt to stresses and shocks.

Reference: *Modified from UNDRR Sendai Framework Terminology on Disaster Risk Reduction (2023)*
URL: *https://www.undrr.org/terminology/vulnerability*

Notes:

1. This definition is an adaptation of the UNDRR definition of "Vulnerability" contextualized to disaster resilient infrastructure.
2. Vulnerability relates to characteristics that could render infrastructure inadequate to perform its designated function in the face of a hazard. These characteristics could be an outcome of processes by which infrastructure was planned and built, to external conditions associated with its use, operation and maintenance, and/or to changes in the external environment that may threaten its functioning.
3. See also "Residual risk".

Reference for Note 2: *IPCC (2014)*
URL: *https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf*

Climate vulnerability of road infrastructure in Netherlands

Large parts of the Netherlands are below sea-level, making it one of the most vulnerable countries in Europe. The Dutch have built extensive safety measures in the last century to protect against flooding. However, increased frequency and intensity of rainfall affects the frequency and intensity of floods, which may lead to disruption of transportation services. Sea level rise and the subsequent increase in coastal flooding can damage rail and road transport infrastructure in low-lying coastal areas in the Netherlands, which has a particularly high concentration of such infrastructure. Increase in rainfall intensity will also increase erosion of embankments and frequency of landslides. Higher temperatures resulting from climate change are anticipated to lead to an increase in maintenance costs as road surfaces become more susceptible to melting. Hence, infrastructure which might not have been vulnerable earlier, can be vulnerable now and in future, due to change in hazard parameters.

Sources:

- *Transport, infrastructure and building in Netherlands. Climate change post. (2022, November 30). Retrieved January 13, 2023, from https://www.climatechangepost.com/netherlands/transport-infrastructure-and-building/*
- *Lundberg, T. (2016, May 1). The Netherlands is Europe's most dangerous place to live. IamExpat. Retrieved January 13, 2023, from https://www.iamexpat.nl/expat-info/dutch-expat-news/netherlands-europes-most-dangerous-place-live*

39. Intensive disaster risk

The risk of high-severity, mid- to low-frequency disasters, mainly associated with major hazards.

Notes:

1. Intensive disaster risk relates to large-scale infrastructure systems (complex infrastructure) which affect densely populated urban and rural areas and regions of systemic economic importance, as distinct from small-scale local infrastructure systems.
2. Intensive disaster risk is a characteristic of large cities or densely populated areas that are not only exposed to intense hazards such as strong earthquakes, active volcanoes, heavy floods, tsunamis or major storms but also have high levels of vulnerability to these hazards.
3. See also "Extensive disaster risk" and "Everyday risk".

Reference for Note 2: *UNDRR Sendai Framework Terminology on Disaster Risk Reduction (2023).*
URL: *https://www.undrr.org/terminology/intensive-disaster-risk*

Haiti Earthquake in 2010

The most powerful earthquake to hit Haiti in the past 200 years occurred on 12 January 2010. It had a magnitude of 7.3 on the Richter scale. Transport and Communications sub-sectors suffered losses leading to a reduction of 24.8 percent in growth. Services of information and communications technology companies were interrupted which hampered relief and recovery efforts. Streets were filled with rubble and many vehicles and buildings were destroyed or damaged. Utilities sub-sectors, such as electricity, gas and water, were also badly affected, with a subsequent 12.6 percent reduction in growth. Water supply to the metropolitan areas was interrupted owing to damages faced by the water production and distribution companies. There was a 19.8 percent reduction in growth of social sector services, such as health and education services. The destruction of health infrastructure caused a reduction in employment and revenue. Most of Haiti witnessed loss of income for teachers, school staff and small businesses that provided services to educational institutions. Many commercial buildings in the capital city center were destroyed along with equipment and material stock within them. Retail, which contributed to 25 percent of the GDP, was badly affected. The tourism sector not only suffered damage to hotels and restaurants, but also faced the threat of aftershocks. Rum, a popular export product of Haiti saw a sharp decline as its main producer in the country was badly affected, and 50 to 60 percent of the rum distilleries were affected.

Source:
Government of Republic of Haiti. (2010). Annex to the Action Plan for National Recovery and Development of Haiti. UNEP. Retrieved December 13, 2022, from https://wedocs.unep.org/bitstream/handle/20.500.11822/8868/Haiti_earthquake_PDNA.pdf?sequence=3&%3BisAllowed=

L

40. Local infrastructure

Facilities at the local level, including water, drainage and sanitation networks, road, river and rail networks, bridges, health, and education facilities, as well as other local facilities services to individuals, households, communities, and businesses in their current locations.

Reference: *Modified from Maskrey, A., Jain, G., Lavell, A. (2021). "The Social Construction of Systemic Risk: Towards an Actionable Framework for Risk Governance". United Nations Development Programme, Discussion Paper.*
URL: *https://www.undp.org/sites/g/files/zskgke326/files/2021-08/UNDP-Social-Construction-of-Systemic-Risk-Towards-an-Actionable-Framework-for-Risk-Governance.pdf*

Notes:

1. Refers to infrastructure service delivery at local and/or sub-national scale.
2. See also "Community infrastructure".

Cloudburst management system, Copenhagen

Denmark's capital city Copenhagen is vulnerable to flooding, sea level rise and extreme rainfall events. Recent modelling by some researchers projects a sea level rise of 1m in the next 100 years. As such, the city has a high risk of stormwater flooding and damage to infrastructure services.

During July 2011, the city witnessed 50mm precipitation within 30 minutes. This is well beyond the definition of extreme rainfall event given by the Danish Meteorological Institute (DMI), which is 15mm precipitation within 30 minutes. This led to the development of a cloudburst management plan for implementing mitigation and adaptation to build resilience for future extreme events.

A climate adaptation plan, designed for 20 years, was developed to map a holistic approach. The city, divided into 26 local water catchment areas of 10 sq. km each, was assessed based on risk, implementation potential and coherence with the urban development plan. This helped identify prioritizing measures. Blue-green infrastructure measures were adopted to address the insufficient conventional piped system. These adaptable and interactive solutions help store stormwater and drain excess water into waterbodies, effectively addressing flood risks.

Source:
NIUA. (2022, December 6). Catalogue of Best Practices for Building Flood Resilience. NIUA - Climate Center for Cities. Retrieved December 13, 2022, from https://reliefweb.int/report/india/catalogue-best-practices-building-flood-resilience

L

41. Local knowledge

The knowledge which people in each sub-national setting or community have developed over time and continue to develop with regard to their environment, culture and society.

Notes:

1. Local is defined in academic and public sector terms in different ways, covering different territorial scales, from community through to larger sub-national jurisdictions such as states and departments. Given the focus of this lexicon on DRI, a preference exists for smaller spatial expressions represented by terms such as community, district, and municipality.
2. It offers a firm basis for designing resilient strategies for infrastructure adopted at the local level.
3. Local knowledge is held by persons and groups with potentially different understandings of the environment and of causal relations that will influence their ways of behaving and acting. These may be contradictory and conflicting.
4. See also “Indigenous knowledge”.

Water harvesting in Alwar, India

The district of Alwar in Rajasthan, India, is prone to various hazards, including severe droughts, due to the state’s arid climate and low rainfall. A piped water supply is the primary source of water for the community. Local methods of water harvesting, such as Johads have deteriorated due to lack of maintenance. Johads are earthen percolation ponds that collect rainwater to address water scarcity. To combat this issue, local non-governmental organizations (NGOs) and the government of Alwar have collaborated to revive these local methods and build new ones to augment the city’s piped water supply. Check dams were built along contours or in low-lying areas, and mud and rubble masonry was used to construct embankments on three sides to hold water. Existing johads were rejuvenated through a participatory planning, design and implementation process, and the community was sensitized to rainwater harvesting measures. These efforts have been replicated in other districts of the state, highlighting the potential for local knowledge to address contemporary problems.

Sources:

- *Government of Rajasthan, Disaster Management & Relief Department. (2014). State Disaster Management Plan (SDMP) - 2014. DM Relief. Retrieved January 9, 2023, from http://dmrelief.rajasthan.gov.in/*
- *NIUA. (2022, December 6). Catalogue of Best Practices for Building Flood Resilience. NIUA - Climate Center for Cities. Retrieved December 13, 2022, from https://reliefweb.int/report/india/catalogue-best-practices-building-flood-resilience*

M

42. Multi-hazard

Specific contexts where hazardous events may occur singly, simultaneously, cascadingly, or cumulatively over time, taking into account the potential interrelated effects.

Note:

1. See also “Cascading hazard”.

Great East Japan Earthquake, 2011

The Great East Japan Earthquake (GEJE) struck the northern coast of Japan on 11 March 2011 with a magnitude of 9.0 on the Richter scale. It overwhelmed Japan’s resilience measures because of its sheer scale and it had unprecedented impacts. GEJE’s ripple effects included a tsunami which hit the Tohoku coastline, leading to the loss of 20,000 lives and widespread destruction of infrastructure, agriculture, housing and industry. Cascading impacts resulted in a nuclear meltdown and hydrogen explosion at the Fukushima Daiichi Nuclear Power Plant.

Key services – critical infrastructure and facilities – the “lifelines” of society such as transportation, communication, sanitation, medical care – were disrupted. The disruption of water supply and complete submergence of the water treatment plant directly impacted 500,000 people in Sendai city. As a ripple effect, lack of clean water and sanitation facilities further impacted public health and emergency services, hampering response and recovery efforts.

Source:
World Bank. (2018). Resilient Water Supply and Sanitation Services: The Case of Japan. World Bank. Retrieved February 21, 2023, from https://thedocs.worldbank.org/en/doc/448651518134789157-0090022018/original/resilientwssjapancasestudywebdrmhubtokyo.pdf

43. Multi-purpose infrastructure

Infrastructure assets and systems that serve more than one primary objective or purpose. The multi-purpose nature of such systems offers better value for money and a promise of sustainability due to the sheer variety of users that would have an interest in the maintenance and upkeep of the system for diverse reasons.

Notes:

1. The term has traditionally been used in the context of Multi-Purpose Water Infrastructure (MPWI) comprising all constructed water systems, including dams, dykes, reservoirs and associated irrigation canals and water supply networks, which may be used concomitantly for economic, social and environmental activities.
2. It has been observed that often single-purpose infrastructure evolves into multi-purpose use over time. As a result, to derive best value for money and for the sustainability of projects, infrastructure assets are now often conceptualised for multiple use by design.

Reference for Note 1: *OECD (2017). Multi-Purpose Water Infrastructure: Recommendations to maximise economic benefits, OECD Environment Directorate.*
URL: *https://www.oecd.org/env/outreach/MPWI_Perspectives_Final_WEB.pdf*

Shardara Multi-purpose Water Infrastructure (MPWI), Kazakhstan

As a result of the National Policy Dialogue on water, facilitated by the OECD and UNECE, the Kazakhstan government recognizes the potential of Multi-Purpose Water Infrastructure (MPWI) for contributing to overall economic growth. The Shardara reservoir, located in the Low Syr Darya region of Kazakhstan, encompasses the entire Aral Lower Syr Darya basin, which receives a significant portion of its water flow from beyond the borders of Kazakhstan.

Originally designed for irrigation, the Shardara reservoir has proven to be a valuable asset, protecting downstream communities from devastating floods. Over time, the reservoir has evolved into a multi-purpose facility that provides a range of services, including irrigation, livestock support, hydropower generation, potable water supply, flood control, and commercial fisheries. Additionally, recreational activities are being planned for the future, further expanding the positive impact of the Shardara MPWI on the region.

Source:
OECD. (2017). Multi-purpose water infrastructure - Recommendations to maximise economic benefits. Organisation for Economic Co-operation and Development. Retrieved February 10, 2023, from https://www.oecd.org/env/outreach/MPWI_Perspectives_Final_WEB.pdf

N

44. Nature-based solutions (NbS)

Actions based on the protection, conservation, restoration, sustainable use and management of natural or modified terrestrial, freshwater, coastal and marine ecosystems. These actions address social, economic, governance and environmental challenges effectively and adaptively, while simultaneously, ecosystem services, disaster risk reduction, resilience and biodiversity benefits and supporting human well-being.

Reference: *Modified from UNEP, 2022*
URL: *https://wedocs.unep.org/bitstream/handle/20.500.11822/39864/NATURE-BASED%20SOLUTIONS%20FOR%20SUPPORTING%20SUSTAINABLE%20DEVELOPMENT.%20English.pdf?sequence=1&isAllowed=y*

Notes:
1. Nature-based solutions (NbS) use Green and Blue infrastructure.
2. See also “Green infrastructure” and “Blue infrastructure”.
3. Sometimes also referred to as “Environment-based solutions”.

Green corridors of Colombia

The country of Colombia in South America has the second highest level of biodiversity in the world. Medellín, the second largest city in Colombia after its capital city Bogotá, is located in the central region of the Andes mountains. In 2018, its population was 2.5 million. Medellin faces the threat of rising urban temperatures, driven by climate change and accelerated by the urban heat island effect. To protect its citizens and workers, the city has turned to sustainable cooling solutions. The city authorities have spent the past few years transforming the verges of 18 roads and 12 waterways into an award-winning green metropolis of shade. Planting vegetation along busy streets and former waterways creates a better environment for the city residents by purifying the air and reducing temperatures of built-up areas, in addition to shading bike lanes and pathways. The 1.5 million m^2 of public space is enjoyed by all members of society.

By 2019, the city had planted 8,000 trees and 350,000 shrubs, focusing on areas that did not have green spaces. The carefully selected trees, palms, and various smaller plants have allowed the native wildlife to return. The area beneath raised metro lines is used to collect surface runoff from the bridge to water the green belts. The web-like network connects the city’s parks and waterways with lush green cycling lanes and walkways. Temperatures in these intervention areas and surroundings have dropped by over 3°C, from 31.6°C to 27.1°C. Surface temperatures dropped from 40.5°C to

30.2°C. The city's average summer temperature has also dropped. The particulate pollutant PM 2.5 levels fell from 21.81 μg/m^3 to 20.26 μg/m^3; PM 10 levels fell from 46.04 μg/m^3 to 40.4 μg/m^3 and ozone levels dropped from 30.1 μg/m^3 to 26.32 μg/m^3. The construction of dedicated bike paths resulted in a 34.6 percent increase in cycling activity cycling, and walking rose by 4 percent. Overall, these had significant health benefits for the city's residents. This was quantified in the dropping of the city's morbidity rate from acute respiratory infections from 159.8 per thousand inhabitants to 95.3 per thousand inhabitants. The project also created employment and training opportunities for disadvantaged communities by creating thousands of positions for gardeners and workers.

Sources:

- *CicloVivo. (2019, July 23). Medellín Crea 30 corredores verdes para mitigar el calentamiento Urbano. ArchDaily en Español. Retrieved December 23, 2022, from https://www.archdaily.cl/cl/921605/medellin-crea-30-corredores-verdes-para-mitigar-el-calentamiento-urbano*
- *Sustainable Energy for All Initiative Kigali Cooling Efficiency Program. (2021, May 12). Colombia: Green corridors help reduce heat risk in Medellín. PreventionWeb. Retrieved December 23, 2022, from https://www.preventionweb.net/news/colombia-green-corridors-help-reduce-heat-risk-medellin*
- *Dewan, A. (2022, August 4). These cities are better at enduring extreme heat. here's what they're doing different. CNN. Retrieved December 23, 2022, from https://edition.cnn.com/2022/08/04/world/cool-cities-heat-wave-climate-cmd-intl/index.html*

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45. Organizational learning

Organizational learning means the process of systematically improving actions through better collective knowledge and understanding.

Reference: *Modified from Fiol, C. M., & Lyles, M. A. (1985). Organizational learning. Academy of management review, 10(4), 803-813.*
URL: *https://doi.org/10.2307/258048*

Notes:

1. In the context of disaster resilient infrastructure, the term "organizational learning" can be applied very broadly to any organized entity (even a community), that has established learning processes, such as observation, analysis, knowledge sharing, reflection, sensemaking, experimentation, and change design. Through these processes, the entity seeks to learn from experience, especially from adverse events, to change the way it works, and improve the outcomes from its actions. See also "Systemic change".
2. In the context of disaster resilient infrastructure, "better knowledge and understanding" often refers to improved understanding of the causal relations and feedback loops within infrastructure systems, and especially the behaviours of complex systems. See also "Feedback loops", "System of systems", "Systemic change", "Systemic risk" and "Cascading hazards".
3. Organizational learning offers a particular approach to single-, double- and triple-loop learning. See also "Feedback loops".
4. See also "Flexibility".

Reference for Note 3: *Romme, A. G. L., & Van Witteloostuijn, A. (1999). Circular organizing and triple loop learning. Journal of Organizational Change Management.*
URL: *https://doi.org/10.1108/09534819910289110*

Learning post Fukushima Daiichi Nuclear Power Station accident, Japan

In the aftermath of the Fukushima Daiichi nuclear accident, Japan has taken significant strides to enhance its safety protocols and reinforce the resilience of its nuclear infrastructure. By implementing new safety requirements beginning in July 2013, Japan has set a higher standard for disaster preparedness, including low-frequency accidents and external events like fires, volcanic eruptions, and landslides. These new regulations emphasize a "defence in depth" approach, meaning the implementation of multiple layers of measures to mitigate potential human and mechanical failures. Some of these measures include raising the assumption level of disasters and reinforcing measures for events which could result in loss of safety functions. Additional measures include improving reliability through frequent communication between the local population and authorities.

Source:
ERIA (2020), 'Policy Recommendations', in Murakami, T. and V. Anbumozhi (eds.), Securing the Resilience of Nuclear Infrastructure against Natural Disasters. ERIA Research Project Report FY2020 No. 06, Jakarta: ERIA, pp.52-55.

46. Physical infrastructure

Infrastructure components that are (a) essential to the production, delivery and distribution of products, activities and services, (b) which have economic value, and (c) which are managed as tangible assets. Such assets include traditional infrastructure facilities, like roads, water and sanitation facilities, as well as the land and any buildings required.

Reference: *Modified from UN, 2021*
URL: *https://www.un.org/development/desa/financing/sites/www.un.org.development.desa.financing/files/2021-08/IAMH_ENG_Jun2021.pdf*

Note:
1. See also “Infrastructure systems”.

Highway as infrastructure asset and its management –Derbyshire County Council, UK

The Derbyshire County Council (DCC) is responsible for the largest and most prominent asset in the region, the highway infrastructure. This massive network spans over 5,000km and includes not only roads, but also cycle routes, bus stations, and parking facilities, among others. This infrastructure plays a significant role in fulfilling the Council’s plan, which includes objectives such as promoting social inclusion, health, and environmental protection. The DCC has identified a resilient network of roads that receive priority during adverse weather conditions and events, accounting for about 10 percent of the roads managed by the council. To ensure the best value for money, a strategy has been devised with short-term, medium-term, and long-term outcomes. The highway infrastructure serves as a vital tool in addressing the transport vision and challenges outlined in the Local Transport Plan (LTP).

Source:
Highways Infrastructure Asset Management. Derbyshire County Council. (n.d.). Retrieved December 26, 2022, from https://www.derbyshire.gov.uk/transport-roads/highways-infrastructure-asset-management/highways-infrastructure-asset-management.aspx

P

47. Prospective disaster risk management

Activities that address and seek to avoid the development of new or increased disaster risks. They focus on addressing disaster risks that may develop in the future if disaster risk reduction policies are not put in place.

Reference: *Modified from UNDRR Sendai Framework Terminology on Disaster Risk Reduction (2023)*
URL: *https://www.undrr.org/terminology/disaster-risk-management*

Notes:

1. Examples include well-designed and built resilient infrastructure, ensuring robustness of assets, and planning for flexibility, safe failure, and redundancy in service provision. In the context of resilient infrastructure, they can focus on reducing risk through better build back, post impact policies and actions. Feedback loops are critical for this purpose. See also “Feedback Loops”.
2. See also “Residual risk”, “Robustness”, “Flexibility”, “Redundancy” and “Corrective disaster risk management”.

Solar Microgrids in Fiji

The Republic of Fiji, an island country in the South Pacific Ocean, has over 300 islands. Two of these are much larger and more heavily populated. Island countries are particularly vulnerable to climate change, sea-level rise and hydrometeorological disasters. Compared to centralized systems, distributed renewable energy is less vulnerable to storm damage of electrical transmission lines. To reduce the impact of disaster risks, three solar microgrids, with a combined capacity of 555kW have been installed, to meet 40 percent of the daily electricity demands of three Fijian islands. This includes a 249kW solar plant in Kadavu island, and two 153kW solar plants in Lakeba and Rotuma islands. The Solar microgrid Fiji project was financed under the UAE-Pacific Partnership Fund, to support development of renewable energy projects. This US$5 million project, launched in March 2013, has been able to address the power outages faced by Fiji during cyclones. The microgrids will provide energy for residences as well as for developing small-scale industries and enterprises on the remote islands, and they will help avoid emitting 772 tons of CO_2/annually.

Source:

- *Reve. (2015, February 18). Micro grid solar energy plants in Fiji. REVE News of the wind sector in Spain and in the world. Retrieved February 3, 2023, from https://www.evwind.es/2015/02/18/micro-grid-solar-energy-plants-in-fiji/50572*
- *Weir, T., & Kumar, M. (2020). Renewable energy can enhance resilience of small islands. Natural Hazards, 104(3), 2719–2725. https://doi.org/10.1007/s11069-020-04266-4*

R

48. Redundancy

Alternative or back-up means created within an infrastructure system to accommodate disruption, extreme pressures, or surges in demand. It includes diversity, i.e., the presence of multiple ways to achieve a given need or fulfil a particular function.

Reference: *Adapted from Asian Development Bank (2016). Enhancing Urban Climate Change Resilience: Seven Entry Points for Action.*
URL: *https://www.adb.org/sites/default/files/publication/213291/sdwp-047.pdf*

Notes:

1. Redundancy increases reliability. See also "Reliability".
2. See also "Resourcefulness", and "Prospective disaster risk management".

Use of redundancy in full suppression of three Wildland Urban Interface (WUI) wildfires in south-western United States in the summer of 2010

Researchers analyzed the response strategies to three large-scale wildfires that resulted in the evacuation of residents and threatened key infrastructure assets. The researchers identified four redundancy strategies: backup, cross functionality, duplication, and cross check.

- The **Backup** strategy involved bringing in personnel and equipment from outside to the affected area to scale up and meet the changing needs. In anticipation of technological limitations and failures, backup plans were put in place to restore or prevent loss of functionality.
- **Cross Functionality** involved allocating human and technology resources to serve multiple roles or functions within the system. This allowed for effective resource management and the ability to do more with less.
- **Duplication** involved the use of multiple communication technologies, such as face-to-face, radio, and cell phones, which were essential for effective incident management. This also involved multiple individuals holding key positions on the incident command team, allowing for cooperating agencies to easily locate the person they needed.
- **Cross Check** strategies were implemented to detect and correct errors, including procedural, information, and tactical verification. Fire operation planners worked with archaeological or biological resource advisors to protect cultural sites and sensitive habitats from damage. Safety officers were employed at various levels to ensure the safety of firefighters and community members.

It is crucial to note that each redundancy type has its own strengths and risks when it comes to enhancing system resilience.

Source:
Nowell, B., Bodkin, C. P., & Bayoumi, D. (2017). Redundancy as a strategy in disaster response systems: A pathway to resilience or a recipe for disaster? Journal of Contingencies and Crisis Management, 25(3), 123–135. doi:10.1111/1468-5973.12178

49. Reliability

Ability of an infrastructure asset or system to perform the desired function based on specified requirements over time without interruption or degradation.

Reference: *Modified from ISO 19904-1:2019(en), 3.40, Accessed from https://www.iso.org/obp/ui/#iso:std:iso:19900:ed-2:v1:en.*

Note:
1. See also "Redundancy".

Reliability of Taipei 101's tuned mass damper

Taipei 101, also known as the Taipei Financial Center, is a landmark skyscraper located in Taipei, Taiwan. The building was completed in 2004 and at 508m, it is one of the tallest buildings in the world. Inside the skyscraper is the world's largest and heaviest tuned mass damper. The 660 metric tonne steel sphere is suspended by eight cables in the upper floors. It is an engineering marvel meant to limit the vibrations of the building by essentially acting as a huge pendulum. Since its completion, Taipei 101 has faced several earthquakes, including the 7.1 magnitude earthquake that struck Taiwan in 2006, and many others of varying magnitudes. The building has performed well during these earthquakes, and its structure has remained intact and operational, demonstrating its reliability.

Sources:

- *CTBUH. (2019). TAIPEI 101. The Skyscraper Center. Retrieved February 13, 2023, from https://www.skyscrapercenter.com/building/wd/117*
- *Trevor. (2010, April 12). Tuned mass damper of Taipei 101. Atlas Obscura. Retrieved February 13, 2023, from https://www.atlasobscura.com/places/tuned-mass-damper-of-taipei-101*

R

50. Residual risk

Disaster risk that remains, despite disaster risk reduction measures that may be in place, and for which emergency response and recovery capacities must be maintained.

Reference: *Modified from UNDRR Sendai Framework Terminology on Disaster Risk Reduction (2023).*
URL: *https://www.undrr.org/terminology/residual-risk*

Note:
1. See also "Infrastructure vulnerability" and "Prospective disaster risk management".

Residual flood risk in Jargeau, France

Levees designed for flood protection carry an inherent residual risk, i.e., risk of flooding greater than the design standard in case of levee breach (levee overtopping). Jargeau city, on the banks of the Loire River Valley, is protected by the Orléans Valley Levee system. The 51km long levee system promises protection greater than 250-year flood for 160 sq. km of valley bottom: 30km long and 5km wide, occupied by 70,000 inhabitants. During the 1856 flood, the levee protecting the east part of the city failed, flooding farmlands. This part of the levee was converted into a spillway and another levee was built to protect the south-east part of the city. The responsibility of recognizing residual risk associated with protection structures such as levees rests with local governments. The local government should also control development in areas of residual risk. For example, Frances has a top-down approach in this regard. It designates areas behind levees as part of the regulatory flood prone areas. There are mandatory land-use restrictions, building codes, and emergency measures with appropriate risk communication.

Source:
Serra-Llobet, A., Tourment, R., Montané, A., & Buffin-Belanger, T. (2022). Managing residual flood risk behind levees: Comparing USA, France, and Quebec (Canada). Journal of Flood Risk Management, 15(2), e12785.

51. Resilience assessment

A qualitative and quantitative approach to determine the extent of resilience by analysing the potential risk and the existing capacity to resist, absorb, accommodate, adapt to, transform, and recover from the negative effects associated with a disaster in a timely and efficient manner.

Reference: *Modified from UNDRR Sendai Framework Terminology on Disaster Risk Reduction (2023) on "Disaster risk assessment" and "Resilience".*
URL: *https://www.undrr.org/terminology/disaster-risk-assessment and https://www.undrr.org/terminology/resilience*

Note:

1. Resilience assessment requires a listing of metrics that would vary based on infrastructure sector, scale, and geographic location.

Resilience assessment of interdependent energy systems during hurricanes

The increasing interdependence of different infrastructure systems implies that traditional standalone system analysis is no longer sufficient. This is particularly evident in the case of power supply systems, which play a crucial role in maintaining regular operations in other Critical Infrastructures (CIs). However, power supply systems are highly vulnerable to extreme weather events (EWEs), such as hurricanes. In addition, the internal complexity between CIs and rising environmental risks from EWEs could amplify disruptive effects and pose a threat to reliable and continuous energy supply. To effectively measure the resilience of transmission power systems under hurricanes, a multi-attribute construct of indices is required to quantify the system performance from operation and infrastructure perspectives. These assessment indices can be used proactively to guide the preparation of power systems or integrated energy systems in the event of an approaching hurricane. Resilience assessment methods can also be used in co-planning of integrated power systems or to serve as a decision-making tool for selecting resilience enhancement strategies in the future.

Source:
Zhang, H. (2019). Resilience assessment of integrated energy systems under hurricanes. Doctoral thesis, Nanyang Technological University, Singapore.

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52. Resilience pathways

Strategies and actions for reducing, managing, and recovering from impacts of disasters. With reference to infrastructure development, resilience pathways refer to perspectives, strategies and actions that help infrastructure systems to withstand and recover from disasters in a timely and efficient manner with minimal impact on essential basic structures and functions.

Note:

1. Climate resilient development pathways (CRDPs) are trajectories that strengthen sustainable development and efforts to eradicate poverty and reduce inequalities while promoting fair and cross-scalar adaptation and resilience to a changing climate. They raise the ethics, equity and feasibility aspects of the deep societal transformation needed to drastically reduce emissions to limit global warming (e.g., to well below 2°C) and to achieve desirable and livable futures and well-being for all.

__Reference for Note 1:__ IPCC, (2022). Annex II: Glossary [Möller, V., R. van Diemen, J.B.R. Matthews, C. Méndez, S. Semenov, J.S. Fuglestvedt, A. Reisinger (eds.)]. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2897–2930, doi:10.1017/9781009325844.029.
URL: *https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_Annex-II.pdf*

Resilience of Water Distribution Systems (WDS)

Ensuring a consistent and reliable supply of water is a crucial challenge facing modern societies. The design and implementation of a Water Distribution System (WDS) plays a critical role in this regard, particularly with regard to resilience. One of the aspects of resilience in a WDS argues for the presence of alternative paths for water supply to customers, such as parallel pipes or dense grid network configurations.

Additionally, redundant network connectivity, such as emergency pipe connections between district metering areas (DMAs), can provide access to water stored in neighbouring tanks during emergencies. The physical strength of tanks and pipelines can also play a critical role in preserving water resources during seismic events. Furthermore, the availability of sufficient emergency response staff and teams can enable rapid response to any pipe or pump failures, ensuring continued availability of water even in adverse conditions.

Source:
Jung, D., Lee, S., & Kim, J. H. (2019). Robustness and Water Distribution System: State-of-the-Art Review. Water, 11(5), 974.

53. Resilience plan

A resilience plan involves developing goals and coordinating or integrating policies, programmes and actions taken across infrastructure sectors and diverse stakeholder groups, to reduce risks, and to enable communities to adapt and thrive when faced with challenges related to natural and human-caused hazards.

Notes:

1. Infrastructure sectors include transportation, energy, housing and built environment, telecommunications, water and waste, etc. Stakeholder groups include political and economic entities and interests.
2. Planning for resilience empowers diverse stakeholders to evaluate plans, set strategic policies and implement projects. This may need to include capacity development provisions.

New Orleans' Comprehensive Resilience Plan post 2005

After the devastation caused by Hurricane Katrina in 2005, the city of New Orleans implemented a comprehensive resilience plan to make its infrastructure more resilient to future natural disasters. The plan included measures such as:

1. improving the city's levee system to better protect against future floods;
2. elevating or relocating buildings in flood-prone areas to reduce the risk of damage from future storms;
3. developing a comprehensive evacuation plan to ensure the safe and efficient evacuation of residents in the event of a hurricane or other disaster;
4. improving communication systems to ensure that emergency responders and residents can stay in contact during a disaster; and
5. implementing green infrastructure projects, such as parks and green roofs, to help absorb excess rainfall and reduce the risk of flooding.

These measures have helped make the city of New Orleans more resilient to natural disasters and better equipped to recover quickly in the event of a future disaster

Sources:

- *City of New Orleans. (2015, August 25). Resilient New Orleans -Strategic actions to shape our future city. Resilient NOLA. Retrieved February 7, 2023, from http://resilientnola.org/wp-content/uploads/2015/08/Resilient_New_Orleans_Strategy.pdf*
- *City of New Orleans, Resilient NOLA, & NOLA Ready. (2016, August 16). New Orleans Main Street Resilience Plan. City of New Orleans. Retrieved February 7, 2023, from https://www.nola.gov/nola/media/One-Stop-Shop/CPC/Main-St-Resilience-Plan-FINAL-8-16-16.pdf*

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54. Resourcefulness

The ability of stakeholders in an infrastructure system to mobilize the required human, material and financial resources necessary to prepare for, mitigate against, respond to and recover from shocks and stresses, particularly under resource constraints.

Notes:

1. Resourcefulness includes measures taken before a crisis to prepare the infrastructure system and its managers, including agreements for mobilization of surge capacities.
2. Resourcefulness helps the system to swiftly move from the response to the recovery phase.
3. See also “Redundancy”.

__Reference for Note 2:__ Petit, F. D., Eaton, L. K., Fisher, R. E., McAraw, S. F., & III, M. J. C. (2012). Developing an index to assess the resilience of critical infrastructure. International Journal of Risk Assessment and Management, 16(1), 28-47.

Sports stadiums converted into temporary COVID-19 quarantine facilities

During the COVID-19 pandemic, many countries repurposed sports stadiums into quarantine facilities to cope with the overwhelming demand. In India, the Sports Authority of India (SAI) and the Board of Control for Cricket in India (BCCI) worked together to convert the country’s stadiums into isolation centres, with the Indira Gandhi Athletic Stadium in Assam transformed into a makeshift hospital with a capacity of 1,000. Similarly, the Dumurjala indoor stadium was quickly converted into a 150-bed quarantine centre, while the iconic Eden Garden stadium in Kolkata was repurposed to accommodate Kolkata Police personnel. The stadiums’ pre-existing infrastructure, including lighting, water, and sewage systems, was effectively utilized to provide essential care for those in need.

Sources:

- *Olympic Channel Writer. (2021, February 24). Sport stadiums in India to be made temporary quarantine sites. Olympics.com. Retrieved January 17, 2023, from https://olympics.com/en/news/sports-authority-india-stadiums-quarantine-sites-coronavirus*
- *AFP. (2020, July 11). Famed India Cricket Stadium to be used for coronavirus quarantine. WION. Retrieved January 17, 2023, from https://www.wionews.com/sports/famed-india-cricket-stadium-to-be-used-for-coronavirus-quarantine-312546*
- *Sports stadiums are being converted to quarantine centres, blood donation camps and more to handle the surge of covid-19 patients. Business Insider. (2020, April 9). Retrieved January 17, 2023, from https://www.businessinsider.in/slideshows/sports-stadiums-are-being-converted-to-quarantine-centres-blood-donation-camps-and-more-to-handle-the-surge-of-covid-19-patients/slidelist/75064118.cms*

55. Retrofitting

Reinforcement or upgrading of existing physical structures to become more resistant and resilient to the damaging effects of hazards.

Reference: *Modified from UNDRR Sendai Framework Terminology on Disaster Risk Reduction (2022).*
URL: *https://www.undrr.org/terminology/retrofitting*

Notes:

1. Retrofitting requires consideration of the design and function of the structure, the stresses that the structure may be subject to from hazards or hazard scenarios, and the practicality and costs of different retrofitting options.
2. Examples of retrofitting include adding bracing to stiffen walls, reinforcing pillars, adding steel ties between walls and roofs, installing shutters on windows, and improving the protection of important facilities and equipment. See also "Corrective disaster risk management".
3. Retrofitting may sometimes be referred to as "Hardening".

Eco-Roof retrofit in Portland to reduce urban flooding risk

Urban runoff is a major contributor to water pollution and flooding in urban communities across the globe, with roof surfaces accounting for a significant portion of impermeable areas in urban regions. Retrofitting roofs presents an excellent opportunity to reduce urban runoff, and the Amy Joslin Memorial Building in Portland, Oregon, serves as an excellent example. Situated on the confluence of the Columbia and Willamette rivers, Portland is particularly vulnerable to flooding, and the 16,000 square foot roof retrofit provided a prime opportunity to address this issue. The extensive green roof garden captures stormwater, reduces energy demands, and provides a habitat for insects and birds. Over an 18-month period, the green roof reduced peak flow by 86 percent, run-off by 25 percent, and reduced air conditioning loads by 5-10 percent. By demonstrating the viability of retrofitting, Portland's project highlights the potential for such measures to enhance community resilience, reduce pollution, and foster sustainable urban growth.

Sources:

- *Lamond, J. E., Wilkinson, S. J., Rose, C. B., & Proverbs, D. G. (2014). Sustainable Urban Drainage – Retrofitting for Improved Flood Mitigation in City Centres. Royal Institution of Chartered Surveyors. Retrieved December 27, 2022, from https://www.rics.org/globalassets/rics-website/media/knowledge/research/research-reports/sustainable-urban-drainage/*
- *Lamond, J. E., Rose, C. B., & Booth, C. A. (2015). Evidence for improved urban flood resilience by sustainable drainage retrofit. Proceedings of the Institution of Civil Engineers-Urban Design and Planning, 168(2), 101-111.*
- *Stovin, V. (2010). The potential of green roofs to manage Urban Stormwater. Water and Environment Journal 24(3): 192-199.*

R

56. Risk model

A mathematical representation of a system, whose aim is to quantify the probability, location, and intensity of a future adverse event and its consequences due to exposure and vulnerability conditions. These models typically use historical data, expert knowledge, and theoretical insights in their construction. More recently in the context of climate change, risk models also take into account future climate scenarios.

Use of Coastal Storm Modelling System (CoSMoS) to model hydrodynamic impacts of shoreline protection

The U.S. Geological Survey's Coastal Storm Modelling System (CoSMoS) was used to model hydrodynamic impacts of shoreline protection for three counties in the San Francisco Bay Area and it was used to simulate potential traffic impacts on the basis of current roadway infrastructure and commuter data. This has proved valuable in the coastal areas' protection against rising sea levels in one area, to avoid flooding in another area along the coast, by subsequently flooding major roadways and disrupting traffic flows beyond the original inundation zone. This is important because linkages between multiple and interconnected infrastructure systems can give rise to cascading disruptions.

CoSMoS was designed to provide emergency responders and planners with critical storm hazard information that can be used to manage complex coastal settings while improving public safety and mitigating physical damage.

Results from CoSMoS can be incorporated with Geographic Information System (GIS) platforms to include social and resource data.

Sources:

- *Eos - AGU. (2020, October 19). Modeling the cascading infrastructure impacts of Climate Change. PreventionWeb. Retrieved December 19, 2022, from https://www.preventionweb.net/news/modeling-cascading-infrastructure-impacts-climate-change*
- *Coastal and Marine Hazards and Resources Program. (2019, June 17). The Coastal Storm Modeling System. U.S. Geological Survey. Retrieved December 19, 2022, from https://www.usgs.gov/programs/coastal-and-marine-hazards-and-resources-program/science/coastal-storm-modeling-system?qt-science_center_objects=0#qt-science_center_objects*

57. Robustness

The inherent strength of an infrastructure asset or a system to withstand shocks and stresses that may be intrinsic or extrinsic in nature, without degradation or loss of functionality.

Reference: *Adapted from UK (2016). Introducing Infrastructure Resilience, DFID.*
URL: *https://assets.publishing.service.gov.uk/media/57d6bc17e5274a34de000040/Introducing_Infrastructure_Resilience_25May16_rev_external.pdf*

Note:

1. See also "Infrastructure maintenance" and "Prospective disaster risk management".

Earthquake countermeasures for buildings in Japan

Japan is highly vulnerable to earthquakes, experiencing over 5,000 minor earthquakes annually. In 2011, the Great Tohoku earthquake destroyed more than 100,000 buildings and triggered a nuclear disaster. The Japanese government is promoting earthquake-resistant housing, with the Building Standards Act including new earthquake resistance standards for buildings constructed after 1982. Multi-storey buildings commonly use seismic isolation and damping systems. During the Great Hanshin-Awaji Earthquake of 1995, only 10 percent of buildings constructed after 1982 with new earthquake resistance standards suffered damages, compared to 30 percent of buildings with old standards. As of 2018, 87 percent of buildings in Japan are earthquake resistant.

Source:
Ltd., P. H. (2022, July 29). Earthquake countermeasures for buildings in Japan. PLAZA HOMES. Retrieved December 27, 2022, from https://www.realestate-tokyo.com/news/earthquake-countermeasures-in-japan

S

58. Social construction of risk

The process by which disaster risk exists as a result of human decisions, perceptions and actions, policies and practice, whether enacted individually or collectively, publicly or privately.

Notes:

1. Recognition of the underlying social drivers of risk to infrastructure and services is an important reminder that disasters are not "natural" and are amenable to risk reduction and mitigation actions if those drivers are understood.
2. "Underlying risk drivers such as poverty and inequality, badly planned and managed urban and infrastructure development, environmental degradation, climate change, conflict and displacement and weak territorial governance configure hazard, vulnerability and exposure. These in turn generate patterns of everyday, extensive, intensive, and systemic risk. […] [R]isk tends to become concentrated in the same social groups and territories, independently of the type of hazard involved."
3. See also "Everyday risk" and "Disaster risk drivers".

Reference for Note 2: *Maskrey, A., Jain, G., Lavell, A. (2021). "The Social Construction of Systemic Risk: Towards an Actionable Framework for Risk Governance". United Nations Development Programme, Discussion Paper.*
URL: *https://www.undp.org/sites/g/files/zskgke326/files/2021-08/UNDP-Social-Construction-of-Systemic-Risk-Towards-an-Actionable-Framework-for-Risk-Governance.pdf*

Social construction of risk in Small Island Developing States (SIDS) – Case of Dominica

Dominica is a Caribbean Island nation having a population of 73,000 spread over an area of 750 sq.km. It has an undiversified economy and a GDP under US$1 billion. 90 percent of its population and most of its infrastructure is concentrated along the seaboard. The Kalinago people, also known as the island Caribs, are exposed to extreme climatic events and oceanographic events such as hurricanes, storm wave actions and sea-level rise. The extent of systemic risk on the island was revealed as Dominica faced Tropical Storm Erika in 2015 followed by Hurricane Maria in 2017. Disaster impacts become systemic as they are linked to high levels of debt and dependence on external finance, economic instability, insularity, remoteness, physical vulnerability, lack of redundancy, and environmental fragility.

Source:
Maskrey, A., Jain, G., Lavell, A. (2021). "The Social Construction of Systemic Risk: Towards an Actionable Framework for Risk Governance". United Nations Development Programme, Discussion Paper. Retrieved December 15, 2022, from https://www.undp.org/sites/g/files/zskgke326/files/2021-08/UNDP-Social-Construction-of-Systemic-Risk-Towards-an-Actionable-Framework-for-Risk-Governance.pdf

S

59. Spatial planning

A territory-based process aimed at the establishment of land uses to allow for sustainable development, environmental protection, public health, infrastructure connectivity, economic development, heritage protection and other measures, in a context of diverse and sometimes conflicting priorities and interests of different stakeholders.

Note:

1. Also referred to as "Regional planning", "Urban - regional planning", "Territorial planning", "Physical planning", "City - regional planning", "Town - regional planning".

Integration of flood risk assessment and spatial planning for disaster management in Egypt

Flooding is a serious and significant hazard in Egypt, as the country is often exposed to floods, particularly flash and fluvial floods occurring in urban areas. Rapid urbanization and climate change has increased the flood risk in Egypt. Urbanization, resulting in changes in land use or land cover has led to reduced soil permeability, increased surface run off and overloaded drainage systems. This has resulted in increased flood risk. In Egypt, researchers have observed a discontinuity between current spatial planning practices and flood risk management on the policy, academic and professional levels. Spatial planning could help to protect exposed assets from hazards, reducing surface water runoff and consequently reducing vulnerability. Integrating flood risk assessment in spatial planning, improving stakeholder awareness and collaboration, strengthening risk communication, and improving both quality and access to data can help to overcome the identified difficulties and enhance the integration between spatial planning and flood risk assessment, effectively increasing their flood resilience.

Source:
Esmaiel, A., Abdrabo, K. I., Saber, M., Sliuzas, R. V., Atun, F., Kantoush, S. A., & Sumi, T. (2022). Integration of flood risk assessment and spatial planning for disaster management in Egypt. Progress in Disaster Science, 15, 100245.

S

60. Stress testing

Type of performance efficiency testing conducted to evaluate an asset or system's performance under conditions beyond specified requirements.

Reference: *Modified from ISO (2022): ISO/IEC/IEEE 29119-1 (en): Software and systems engineering — Software testing — Part 1: General concepts: 3.79.*
URL: *https://www.iso.org/obp/ui/#iso:std:iso-iec-ieee:29119:-1:ed-2:v1:en*

Notes:

1. In laboratory conditions stress testing may be used to study the behaviour and performance of a material, structure or system under conditions of a pre-defined risk to evaluate its vulnerability and resilience.
2. In disaster risk reduction, stress testing is an analysis of potential response and/or reaction of the system to adverse or demanding circumstances.

EU-funded INFRARISK project, entitled "Novel Indicators for Identifying Critical Infrastructure at Risk from Natural Hazards": Stress Testing

INFRARISK (INFRAstructure at RISK from Natural Hazards) is a European Commission-funded project that aims to support the decision-making process for protection of critical infrastructure by providing infrastructure owners and managers with the support tools and methods to analyze potential impacts of extreme natural hazards. To this end, INFRARISK developed reliable stress tests for critical European road and rail infrastructure. It proposed a framework that can be used to perform stress tests for distributed road and rail networks. This can be employed to evaluate potential losses associated with the occurrence of intensive disaster risk scenarios for road and rail infrastructure. Extreme, low probability hazard scenarios, including earthquakes and floods, and cascading hazard scenarios can be analyzed using novel methods proposed in this methodology.

As a part of the project, a case study was conducted in the province of Bologna, a seismically active region in Italy. Stress tests were performed for the 3,410km of road networks in terms of seismic hazard and the associated cascading hazard of earthquake-triggered landslides, using the framework developed by INFRARISK. The impacts were analyzed according to direct consequences and additional consequences to society. To support this stress test framework by assessing potential cascading risks from natural hazards to critical infrastructure, an online INFRARISK Decision Support Tool (IDST) was also developed.

Sources:

- *Final Report Summary - INFRARISK (Novel Indicators for identifying critical INFRAstructure at RISK from natural hazards). CORDIS - European Commission. (2017, May). Retrieved December 19, 2022, from https://cordis.europa.eu/project/id/603960/reporting*
- *Novel indicators for identifying critical INFRAstructure at RISK from Natural Hazards. INFRARISK. (n.d.). Retrieved December 19, 2022, from http://www.infrarisk-fp7.eu/*

61. System of systems

Integrated functioning of several independent subsystems connected by layers of interdependence.

Notes:

1. In a system of systems approach, subsystems are independently useful and can be operated as stand-alone components, independent of the larger system of systems, and regardless of the physical proximity or the specific sectoral service they deliver.
2. Resilience of individual infrastructure assets and subsystems should be viewed in the context of the larger system of systems they comprise. Resilience of the system of systems is dependent on the resilience of the subsystems as well as the critical nodes of interdependence between subsystems. See also “Infrastructure linkages”.
3. See also “Organizational learning”.

Cyberattacks on data centres - Impacts on cities

Cities are intricate webs of people and services, comprised of a complex and interdependent system of systems. These systems include energy, water, sewage, food, transport, health, biodiversity, as well as economic, social, and cultural systems. The resilience of critical nexus infrastructures such as data centres is vital to ensure the effective functioning of these interconnected systems.

The rising threat of cyber-attacks on such infrastructure is a significant risk to the entire city. In the past, cyber-attacks targeted specific organizations or service providers, but the growing importance of data and connectivity across all city systems means that an attack on a city’s data centre or telecommunications network can now bring the entire city to a halt. This lack of connectivity and data access can disrupt automated businesses, prevent people from accessing food and medicines, and even leave city officials without the information needed to manage the city’s infrastructure, transport, and environment.

Source:
Beeton, D., Thrower, G., Nair, S., Tewdwr-Jones, M., Kempton, L., & Giorgini, P. (2020). (tech.). Cities at risk - Building a resilient future for the world’s urban centres. Lloyd’s. Retrieved February 15, 2023, from https://assets.lloyds.com/assets/cities-at-risk-building-a-resilient-future-for-the-worlds-urban-centres/1/cities-at-risk-building-a-resilient-future-for-the-worlds-urban-centres.pdf

S

62. Systemic change

Transformation in the structure, dynamics and relationships of a system and/or system of systems.

Notes:

1. In the context of the disaster resilience of infrastructure, systemic change implies tackling underlying causes of problems to deliver tangible and enduring benefits that can have significant impacts on material conditions.
2. Systemic change differs from systematic change in several aspects:
   - Systemic changes describe what relates to or affects an entire system.
   - Systematic changes involve a method or plan, arranged within or comprising an ordered system.

   Systematic changes are necessary to drive systemic change.
3. See also "Organizational learning".

Reference for Note 1: *Adapted from IDS (2014). Business and International Development: Is Systemic Change Part of the Business Approach?, Institute of Development Studies, Brighton, United Kingdom.*
URL: *https://opendocs.ids.ac.uk/opendocs/bitstream/handle/20.500.12413/4307/ER92%20Business%20and%20International%20Development%20Is%20Systemic%20Change%20Part%20of%20the%20Business*

Amendment of building code for seismic resilience, New Zealand

The New Zealand Building Code has been frequently amended to reduce the impact of natural hazards. For example, after the 2011 Christchurch earthquake and the 2016 Kaikoura earthquake, the code was amended to improve the overall resilience of the built environment. Amendment and implementation of building codes can be a pathway to achieve resilience of building stock in a country. This new building code requires all new buildings to be constructed with increased seismic resistance and requires retrofitting of existing buildings to meet higher standards, which helps to reduce the impact of future earthquakes. The implementation of the code involves not only changes to building design and construction practices, but also to the regulatory framework, stakeholder engagement, and community education. This systemic change addresses the root causes of vulnerability to earthquakes.

Sources:

- *Nwadike, A., & Wilkinson, S. (2020, January). Building code amendment process: a case study of New Zealand. In 9th International Conference on Building Resilience-ICBR, Bali, Indonesia.*
- *Authority, B. I. (1992). The New Zealand Building Code Handbook. Standards New Zealand. (NZBC).*

63. Systemic resilience

A property of an infrastructure system that manifests when the larger system is organized in such a way that it can provide agreed critical services (power, heat, communications, mobility, water, and waste management) despite the impacts on its constituent systems, networks and assets due to a variety of hazard(s).

Reference: *Modified from UNDRR (2022). Principles for Resilient Infrastructure.*
URL: *https://www.undrr.org/publication/principles-resilient-infrastructure*

Note:

1. "Larger system" may refer to transboundary, national or sub-national infrastructure depending on the jurisdiction. See also "Transboundary infrastructure".

Mississippi River and Gulf Outlet (Mr Go) shipping canal

An 11m deep and 200m wide shipping canal was built in 1965 to link the New Orleans industrial canal with the open sea to the east to allow shipping to approach the city. Within 3 months of completion Hurricane Betsy made history as the first US disaster to cost more than $1 billion with the unfortunate assistance of the Mr Go canal. Hurricane Betsy was a Category 3 storm of easterly winds from the Gulf of Mexico which the defenses along Lake Pontchartrain would otherwise have resisted. However, Hurricane Betsy funneled a 3.6-meter-high volume of water along the Mr Go canal toward the industrial canal, up and over the newly exposed low embankments of the industrial canal. This caused flooding in the eastern side of the city, which led to 13,000 houses being immersed in 2.7 meters deep flood waters, 60,000 people becoming homeless and 58 fatalities.

Construction of the Mr Go canal is an example of a failure to prioritize the systemic resilience of a city system (New Orleans) to a known resilience challenge (hurricanes). The asset itself, i.e., the Mr Go canal, was resilient, but it reduced the systemic resilience of the city system to which it was added. By contrast its closure after Hurricane Katrina (which reinforced the poor systemic outcomes of Mr Go) improved the systemic resilience of New Orleans.

Sources:

- *Shaffer, G. P., Day Jr, J. W., Mack, S., Kemp, G. P., van Heerden, I., Poirrier, M. A., ... & Penland, P. S. (2009). The MRGO navigation project: a massive human-induced environmental, economic, and storm disaster. Journal of Coastal Research, (10054), 206-224.*
- *Kiefer, P. K. (2021, August 11). The end of mr. go. Sierra Club. Retrieved February 15, 2023, from https://www.sierraclub.org/sierra/end-mrgo-new-orleans-katrina-climate-restoration*

S

64. Systemic risk

In the context of infrastructure, systemic risk is a cumulative risk to a system as an outcome of physical, biological, social, environmental, or technological shocks and stresses. These may be internal or external to the system. Impact on individual components of the system (assets, networks, and subsystems) becomes systemic due to interdependence and interactions between them.

Reference: *Adapted from Sillmann, J., Christensen, I., Hochrainer-Stigler, S., Huang-Lachmann, J., Juhola, S.,Kornhuber, K., Mahecha, M., Mechler, R., Reichstein, M., Ruane, A.C., Schweizer, P.-J. and Williams, S. 2022. ISC-UNDRR-RISK KAN Briefing note on systemic risk, Paris, France, International Science Council, DOI: 10.24948/2022.01*
URL: *https://www.undrr.org/publication/briefing-note-systemic-risk*

Notes:
1. Systemic risk can be seen as a feature of systems at all possible scales – global, national, regional, and local – with varying system boundaries depending on the context.
2. Interactions within a system can either aggravate or contain the overall effect of the constituent parts, creating the potential for cascading impacts on system elements far from the first impact. See also "Feedback loops".
3. A key attribute of systemic risk is that it can transgress spatial and sectoral boundaries in relation to other systems, sectors, and geographical regions, thus leading to cascading effects. See also "Cascading hazards".
4. Systemic risk management requires a holistic understanding of the interconnected, complex, and non-linear cause-effect relationships between the system's elements to identify appropriate responses. See also "Organizational learning" and "Infrastructure linkages".

Disasters in the readymade garment industry, Dhaka, 2013

An eight-storey commercial building, Rana Plaza on the outskirts of Dhaka collapsed on 24 April 2013. Around 1,100 people lost their lives and many more were left with life-long injuries. The building owners had refused to shut down the building inspite of being warned about cracks appearing in the building the day before. Garment workers had been ordered to return to work on the following day, and the building subsequently collapsed during the morning rush hour. The collapse was due to:

- The building was built on a filled-in pond, compromising structural integrity.
- The building had been converted from commercial use to industrial use, and heavy industrial machinery was installed which caused vibrations.
- Four floors had been added above the original permit.
- Substandard construction materials had been used.

Sources:

- *Government of United Kingdom. (2014, April 10). The Rana Plaza disaster. Foreign & Commonwealth Office. Department for International Development. Retrieved December 14, 2022, from https://www.gov.uk/government/case-studies/the-rana-plaza-disaster*
- *The Rana Plaza Accident and its aftermath. International Labour Organization. (2017, December 21). Retrieved December 14, 2022, from https://www.ilo.org/global/topics/geip/WCMS_614394/lang--en/index.htm*
- *Manik, Julfikar Ali; Yardley, Jim (24 April 2013). "Building Collapse in Bangladesh Leaves Scores Dead". The New York Times. Retrieved 25 April 2013.*
- *Blair, David; Bergman, David (3 May 2013). "Bangladesh: Rana Plaza architect says building was never meant for factories". The Telegraph. London. Retrieved 8 May 2013.*
- *"Power generators linked to Dhaka building collapse". BBC News. 3 May 2013. Retrieved 16 April 2017.*

T

65. Transboundary infrastructure

Infrastructure that provides services across territorial or spatial boundaries (international/regional/national/sub-national).

Notes:

1. May also be referred to as “Regional infrastructure”.
2. May also be referred to as “Global infrastructure”.
3. See also “Infrastructure linkages”.

2021 Suez Canal obstruction

The Suez Canal is an artificial waterway in Egypt connecting the Mediterranean Sea to the Indian Ocean via the Red Sea. The canal is an important pathway for transportation for gobal trade and commerce. On 23 March 2021, while the world was dealing with the COVID-19 pandemic, the Ever Given, one of the world’s largest container ships with a capacity of over 18,300 cargo containers, was driven off course while transiting the Suez Canal by high winds amid low visibility. The 400m wide ship ran aground, diagonally blocking the southern end of the canal and obstructing the passage of 300 ships that had queued up at both ends of the canal. Shipping rates nearly doubled and global supply chains, already strained by the COVID-19 pandemic, were disrupted. The alternate route for ships, which takes them around the Cape of Good Hope, takes around 15 days of extra travel time. Losses to the shipping industry were estimated to be upwards of US$9.6 billion. The Ever Given was finally refloated with the help of tugboats and dredgers on March 29, after being stuck for 6 days.

Source:

Singh, P. (2022, May 27). The Suez Canal Crisis of 2021: A case study: Boxxport. BOXXPORT BLOG. Retrieved March 17, 2023, from https://blog.boxxport.com/2021/04/28/suez-canal-crisis-2021/

U

66. Unintended consequences

In the context of disaster resilient infrastructure, unintended consequences are the set of outcomes of a policy or action that were not the direct intention of that policy or action.

Notes:

1. Unintended outcomes are often unforeseen or unexpected (and the terms are often used interchangeably). They can arise from the complexity of the system generating them, thus making them difficult to predict, or from the decision-makers' failure to adequately consider the full range of possible outcomes.
2. Unintended consequences may be positive, negative or neutral in their outcomes.
3. Unintended consequences are sometimes viewed as "externalities". The term "externality" is often used in a general sense to mean consequences outside the control of the bodies directly responsible for the policy or action (e.g., the operation of an infrastructure). However, the term "externality" has a more specific meaning in economics, where the costs or benefits of a consequence in a given context are borne by people outside the sphere of the decision-maker's assessment. Greenhouse gas emissions, the cause of climate change, are an example, where the emitters of these gases do not bear the full costs of their emissions (as the costs are spread globally).

Impact of Bangkok floods on the manufacturing supply chain (2011)

Bangkok, a delta city close to sea level and the capital of Thailand, generates much of its employment from small and medium-sized enterprises (SMEs). Many components essential to manufacturing are made in Bangkok. The impact of the 2011 Bangkok flood had some unintended consequences, triggering regional impacts on manufacturing supply chains in South-east and East Asia.

Western Digital produces a quarter of the world's computer hard drives. When their offices and facilities in Thailand were flooded, it took a year to resume production to pre-flood levels. This greatly disrupted computer manufacturers' supply chains. Most of the suppliers affected by the Thailand floods were SMEs that lacked flood resilience measures. Even SMEs that had contingency plans and alternative premises to relocate their stock or plant, had sensitive equipment and supplies at ground-level. Few had relevant insurance cover. Those without access to capital or recovery loans were unable to resume services.

Source:
UNDRR. (2019). Chapter 2: Systemic Risks, the Sendai Framework and the 2030 agenda. GAR. Retrieved December 15, 2022, from https://gar.undrr.org/chapters/chapter-2-systemic-risks-sendai-framework-and-2030-agenda.html

POSTSCRIPT

This Lexicon has been developed with the objective of providing a common and consistent set of reference definitions that apply the core concepts of resilience, sustainability, risk and disaster risk management (among others) to infrastructure. The principal concepts related to DRI are accounted for, in the Lexicon and its accompanying notes. There is a critical need, however, to discuss a few central concepts and the relationships between them in this brief epilogue because of their unifying and overall defining characteristics when dealing with resilience of infrastructure. These are the concepts relating to disaster and disaster resilience; sustainable development; and the cluster of terms relating to systems, systemic change and systemic impact.

There is an increasing acceptance of the idea that disasters are endogenously linked with development (or the lack of it). In the absence of adequate inclusion of risk considerations, development in general and more specifically infrastructure, can lead to increasing, more complex and new risks for different social and economic units. Therefore, disaster risk can be understood as a challenge for sustainable human development.

Disaster risk and impacts are by nature systemic and increasingly so, with evident shift towards globalization, internationalization and closer connections between societies, economies, ecosystems, and environment. The more connected we are, the more easily risk can cascade through the system. As a consequence, the need for building resilience infrastructure systems and societies has become critical.

The ever-increasing extent and depth of disaster risk and its relationship to processes such as climate change, environmental degradation, and urbanization, have necessitated the need to engage with the intersectionality between sectors and territories for promoting resilience. To this we must add the need to adapt to a changing climatic context, all working together in an integrated and holistic way. The recent developments in the DRM and CCA practice have increasingly been couched in terms of the resilience of societies encompassing essential enablers, including infrastructure, environment, and economy. However, the call for resilience as an all-encompassing goal in its own right, is sharpened by the very fact that historical development models have led to ever greater disaster and climate change-related impacts on society.

In this context, the call for resilience represents a search for a new equilibrium, and the constitution or reconstitution of sustainability in society. Most sustainability efforts have often been limited by prior economic models driving development and growth. Given the increasingly systemic nature of development processes and the risk they carry or construct, the search for resilience (including within disaster resilient infrastructure) there is a need to focus on systems, systemic change, and systemic challenges. Only by understanding and acting on a larger systems level, can we realize the potential for mutually shared prosperity that infrastructure offers.

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