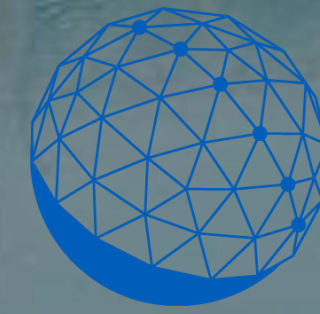




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Urban Climate Resilience Master Class

Module 4

Ensuring Climate Resilience of Urban Infrastructure

UCRMC Course Overview

Welcome to the Urban Climate Resilient Master Class! You are about to start **Module 4**.



Module 1

Introduction to
Climate
Change and
Urban
Resilience



Module 2

Understanding
Climate Risks
in Your City



Module 3

Locally Led
Adaptation for
Urban
Resilience



Module 4

Ensuring
Climate
Resilience of
Urban
Infrastructure



Module 5

Step-by-Step
Guidelines for
Delivering
Climate
Resilient
Infrastructure



Module 6

Financing
Climate
Resilient Urban
Infrastructure

Acknowledgements

Welcome to the Urban Climate Resilience Masterclass!

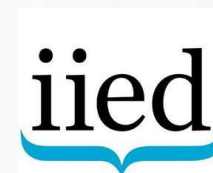
This training has been developed by the Global Center on Adaptation (GCA) as a learning resource under Improving Urban Governance and Infrastructure Program (IUGIP) to strengthen the capacity of municipal officials to integrate climate adaptation and resilience into urban infrastructure and planning.

Thank You!

We would like to acknowledge the following partners and funders involved in designing and delivering this training:



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Summary



Korail slum, Dhaka; Photo by William Veerbeek, Flickr

Housekeeping

Listen



Listen carefully, follow along and make your own notes.

Ask



Ask the trainers questions or clarifications at any time.

Share



Your own experience is valuable and we encourage you to share it.

Discuss



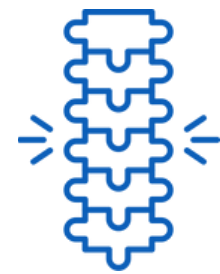
Share and discuss with others during exercises, breaks and reflections.

01 | Why This Topic Matters



Photo by Aleksandar Pasaric, Pexels

Why This Topic Matters



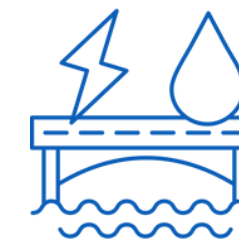
Infrastructure is the backbone of urban systems. Infrastructure & services are vital for ensuring the necessities of life and promoting economic activity.



Climate change poses risks to urban infrastructure including loss, damage and service disruption, leading to cascading impacts across sectors.



City planners need to understand how to make sure that urban infrastructure and services are resilient to climate change so that they are not damaged and disrupted by climate hazards.



Investing in climate resilient infrastructure makes economic sense, reduces post-disaster expenditure, and ensures continuity of urban services during disasters, helping minimise losses.



This module introduces a range of approaches to building climate resilience of urban infrastructure, including structural measures, non-structural measures and Nature-based Solutions (NbS).

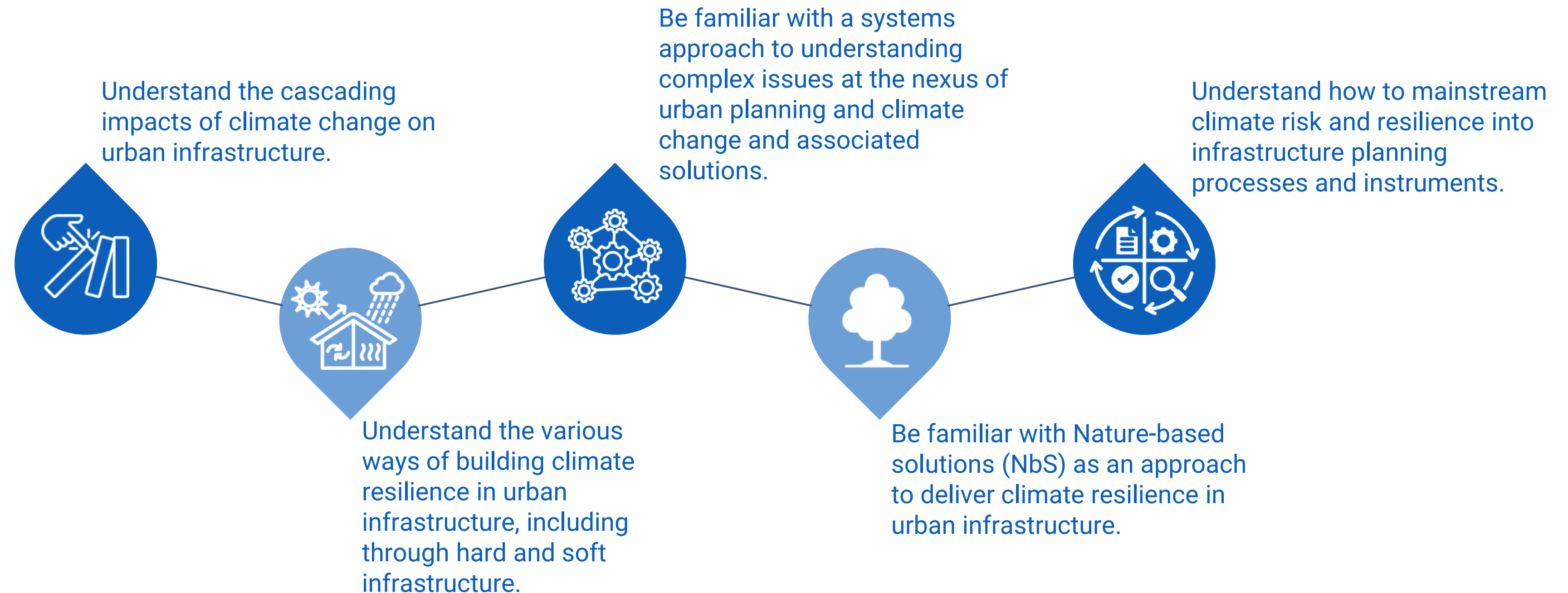
02 | Learning Objectives



Photo by Safari Consoler, Pexels

Learning Objectives

By the end of Module 4 participants will be able to:



03 | Concepts & Definitions



Nairobi; Photo by Nina R, Wikimedia

Concepts & Definitions



Resilient Infrastructure

Infrastructure systems and networks, and the services they provide, that can resist and absorb disaster impacts, maintain adequate levels of service continuity during crises, and swiftly recover so that future risks are reduced or prevented.



Structural Measures / Grey Infrastructure

Physical systems required for a city's operation; including roads, bridges, telecommunications, transportation networks, energy generation and distribution systems etc.



Non-Structural Measures / Soft Infrastructure

Human capital and institutions required to maintain a society and economy, including laws, rules, systems and the people, inputs and outputs involved in delivering services such as healthcare, financial institutions, law enforcement, and education.



Ecosystem Services

The benefits that nature provides to people. They include carbon storage and sequestration, biodiversity maintenance, food and water provision, recreation and tourism, opportunities for income etc.



Ecosystem-based Adaptation (EbA)

A nature-based solution that harnesses biodiversity and ecosystem services to reduce vulnerability and build resilience to climate change.

Concepts & Definitions



Nature-based Solutions (NbS)

Actions that address societal and environmental challenges through the protection, sustainable management and restoration of ecosystems, benefiting both human well-being & biodiversity. NbS have the potential to enhance resilience to climate change and reduce the impact of disasters. NbS can include green, blue and blue-green infrastructures.



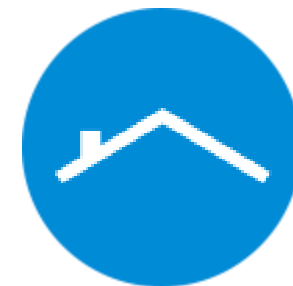
Green Infrastructure

Characterized by well-functioning biophysical systems, mostly related to green spaces that support biodiversity and natural ecological processes, such as mangroves, coastal salt marshes, coral reefs, sea grasses, sand beaches, dunes, forests, street trees, grasslands.



Blue Infrastructure

Characterized by natural and artificial water systems, including wetlands, ponds, lakes, streams rivers, riverbank and storm water provision.



Blue-Green Infrastructure

Nature-based (structural) infrastructure using the capacities of green space and water; includes green roofs for stormwater runoff management, coastal reforestation of mangroves.

04 | How Climate Change Impacts Urban Infrastructure



Kibera; Photo by Nina R, Flickr

Infrastructure is the backbone of a city's development

- Infrastructure systems consist of interconnected networks of assets that deliver vital services to support urban lives and economies.
- Physical assets form the building blocks of urban infrastructure upon which all urban services are built.
- Some critical infrastructure for cities include roads and transportation networks, energy systems, telecommunications networks, buildings and housing, water supply systems, sewage and waste management facilities, healthcare facilities, and public spaces.
- In addition to assets, infrastructure systems also include operational organizations and regulatory authorities responsible for governing service provision at various levels.



Transportation



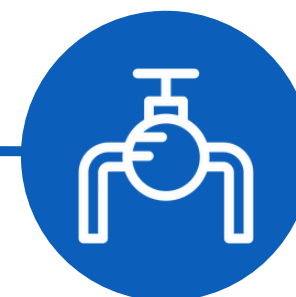
Energy



Telecoms



Buildings



Water



Waste

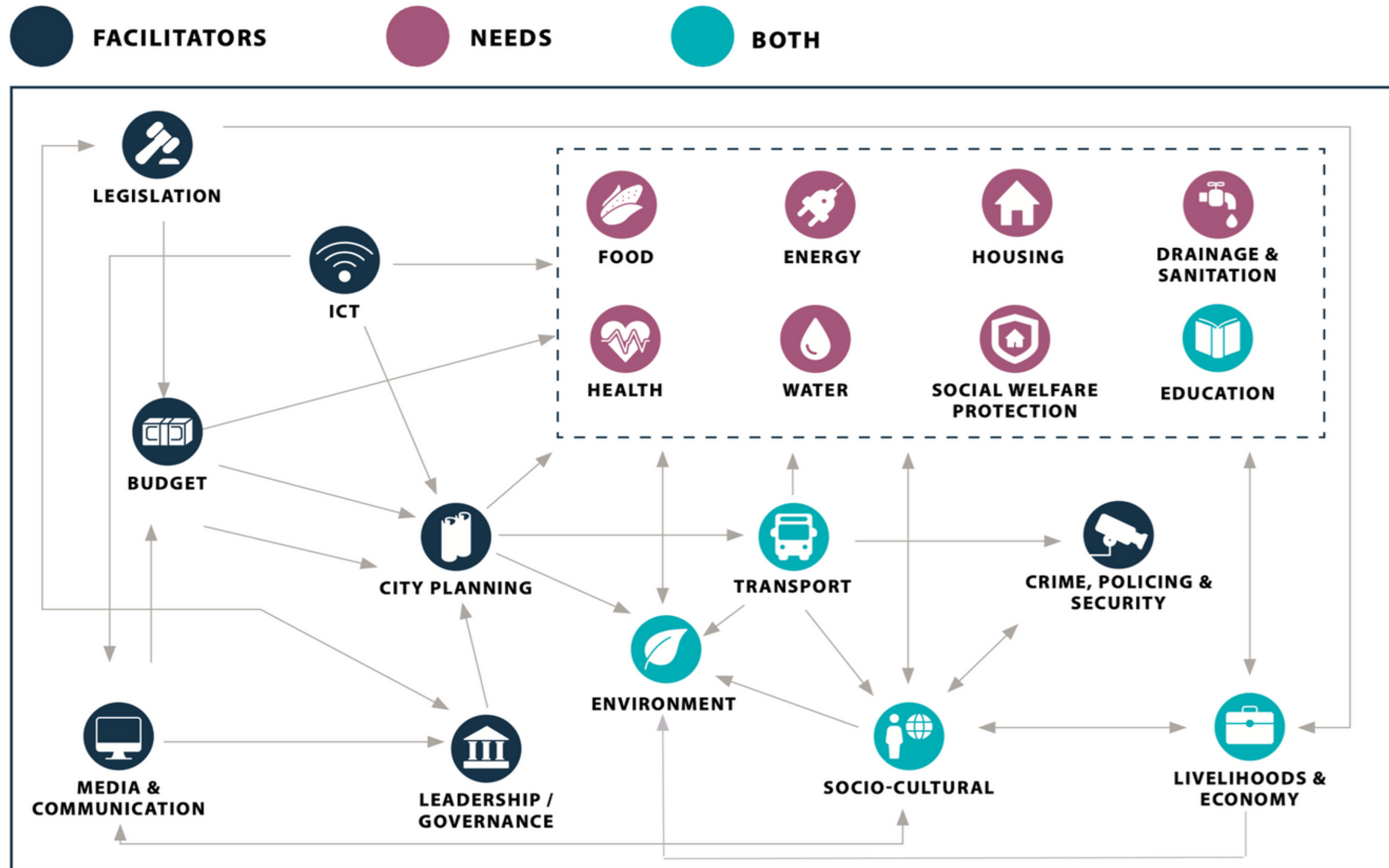


Health & Sanitation



Public Spaces

Infrastructure & services are critically interconnected



Review Exercise

Test your knowledge, and challenge those around you:

→ Choose one of the definitions.

→ In 2 mins, draw a simple sketch of what you think this concept would look like in real life.

→ Challenge someone else on your table to guess which of the definitions you have drawn.

Do you have any questions on the definitions or concepts?



Resilient Infrastructure



Grey Infrastructure



Soft Infrastructure



Ecosystem Services



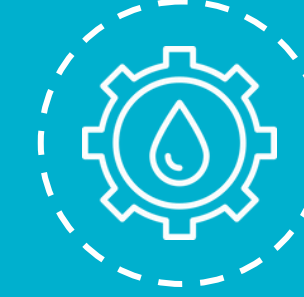
Ecosystem-based Adaptation (EbA)



Nature-based Solutions (NbS)



Green Infrastructure



Blue Infrastructure



Blue-Green Infrastructure

Recap: Climate resilient infrastructure

Cities need to climate proof existing and future infrastructure & services so that they are resilient to climate change.



How climate change impacts urban infrastructure



Asset damage

Climate change can cause direct physical damage to infrastructure assets. Asset damage leads to additional costs and deterioration in the performance and value of the asset and the services it provides.

Examples

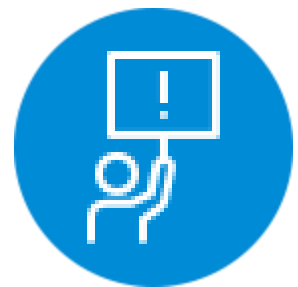
Heatwaves lead to overheating of power generation equipment, causing failure.



Service disruption

Climate change can cause disruptions in the provision of infrastructure services. This can cause additional costs to maintain the same level of service under different climatic conditions (e.g. larger reservoirs are needed to address more variable precipitation).

Flooded and washed-out roads, bridges, ports and railways cause disruption to public transport services and impact supply chains.



Changing demand for infrastructure services

Climate change impacts the demand for infrastructure services, putting pressure on service providers.

Increased electricity demand for cooling due to increased temperatures, which can lead to power outages and grid overloads.

How climate change impacts urban infrastructure

	Heatwaves	Storms & Cyclones	Flooding	Sea-Level Rise
 Transportation	• Overheating of road surfaces and rail tracks, leading to deformations and service disruptions. • Thermal expansion causes vehicle engines and transit system components to overheat and malfunction.	• Damage to bridges, roads, and transit facilities from strong winds and flying debris. • Disruptions in air and sea port operations due to high winds and severe weather.	• Waterlogged roads and transit systems leads to service disruptions, particularly in low-lying areas. • Sediment and debris accumulation on transport routes, hinders movement.	• Coastal erosion damages roads and rail lines near shorelines. • Submergence and saltwater corrosion of coastal transportation infrastructure
 Energy	• Overheating of power generation equipment reduces efficiency and increases risk of outages. • Increased electricity demand for cooling leads to power outages and grid overloads.	• High winds damage power lines and energy production facilities. • Disruption of energy supply chains due to damage to substations, transmission towers and lines.	• Flooding disrupts power production and distribution, affecting substations and grid connections. • Contamination of fuel supplies leading to generator and power station failures.	• Submergence of low-lying power plants and transformer stations due to rising sea levels. • Accelerated corrosion and wear of energy infrastructure in coastal zones.

How climate change impacts urban infrastructure

	Heatwaves	Storms & Cyclones	Flooding	Sea-Level Rise
 Telecoms	• Additional burden to cool equipment in exchanges and base stations, resulting in increased failure rates and impacting service delivery. • Increased burden on telecoms for emergency response exacerbates system loads.	• Structural damage to antennas and satellite dishes impairs communication services. • Power outages during storms lead to loss of telecom services when backup systems fail.	• Water damage to underground cables and telecom equipment disrupts services. • Inundation of key network nodes disrupts telecom services.	• Corrosion and functional degradation of telecom equipment in coastal areas due to saltwater exposure. • Rising maintenance and repair costs for infrastructure exposed to marine environments.
 Buildings	• Increased energy demand for air conditioning strains electrical systems, risking outages, • Heat exacerbates deterioration of building materials, leading to faster degradation.	• Structural damage to buildings from wind, impacting roofs and windows. • Frequent need for structural repairs and reinforcements in buildings in cyclone-prone areas, increasing costs.	• Flooding causes significant damage to lower floors and basements, necessitating costly repairs. • Moisture and mold problems persist long after initial floodwaters recede.	• Soil erosion and instability lead to foundational issues in coastal buildings. • Risk of higher insurance premiums and challenges in maintaining property values in coastal areas.

How climate change impacts urban infrastructure

	Heatwaves	Storms & Cyclones	Flooding	Sea-Level Rise
 Water	• Increased evaporation rates reduce water supplies, impacting availability. • Higher water temperatures affect water quality, increasing treatment challenges.	• Damage to water infrastructure such as pipes and treatment plants during storms. • Storm runoff contaminates water supply with pollutants and debris.	• Damage to water distribution systems, such as burst pipes leading to disrupted services. • Flooding overwhelms water treatment facilities, leading to contamination of water supply.	• Loss of coastal water infrastructure and natural water buffers like wetlands. • Saltwater intrusion compromises the quality of freshwater resources.
 Waste	• Higher temperatures increase the risk of waste combustion and fires in disposal sites. • Increased waste generation from disposables used during heatwaves, such as plastic water bottles and cooling products.	• Damage to waste management infrastructure like recycling centers and landfills. • Storms disrupt collection and processing, leading to waste accumulation across communities.	• Disruption of waste collection routes due to flooded roads and damaged infrastructure. • Floodwaters spread waste and hazardous materials, complicating cleanup efforts.	• Sea-level rise leads to inundation of landfills near coastlines, risking the release of contaminants into surrounding areas and water bodies.

How climate change impacts urban infrastructure

	Heatwaves	Storms & Cyclones	Flooding	Sea-Level Rise
 Health & Sanitation	• Heatwaves lead to a surge in heat-related illnesses, overloading healthcare facilities. • Increased demand for emergency services and medical care during periods of extreme heat.	• Damage to healthcare infrastructure hampers emergency response. • Disrupted access to healthcare services due to damaged transport routes and facilities.	• Flooding compromises sanitation systems, escalating the risk of waterborne diseases. • Damage to health care facilities, for example due to water ingress.	• Sea-level rise leads to saltwater intrusion into freshwater systems, compromising water quality and sanitation facilities at coastal medical centers.
 Public Spaces	• Extreme heat reduces the usability of outdoor spaces, affecting citizen health and decreasing community engagement.	• Damage to landscaping, trees, and recreational facilities reduces the availability of public spaces. • Increased maintenance and restoration costs for public spaces after storm events	• Parks and public gardens become waterlogged, restricting recreation and community events. • Long-term impacts on the ecological health of public spaces due to repeated flooding.	• Permanent inundation of low-lying public areas like parks and beaches, reducing available recreational space and altering the landscape. • Erosion of coastal public spaces resulting in loss of land and damage to infrastructure.

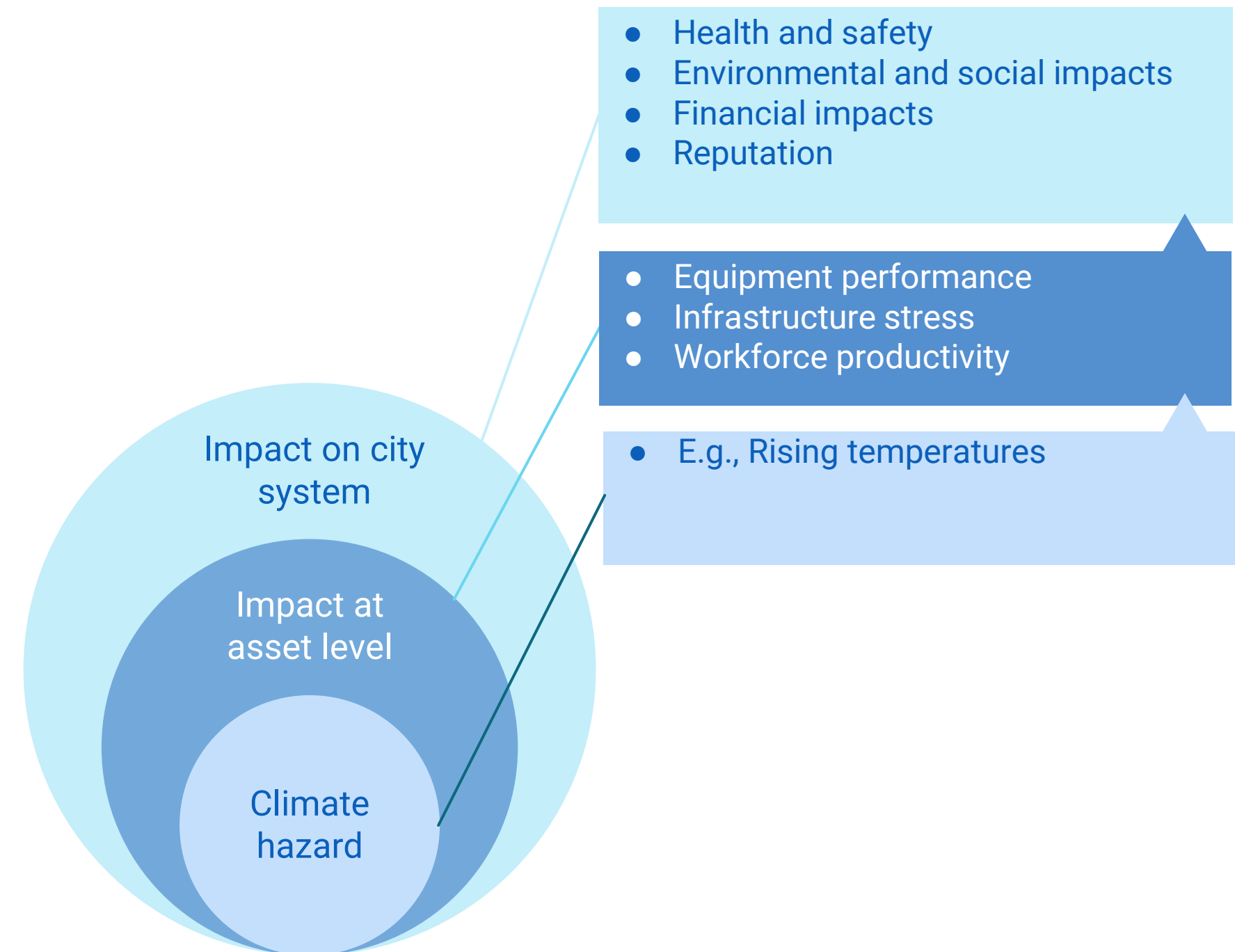
Cascading Impacts of Climate Change

Cascading impacts of climate change

Infrastructure increasingly operates as an interdependent “system-of-systems”, meaning infrastructure assets depend on each other for delivering urban services

However, this also means there is potential for cascading failures and systemic risks due to climate impacts

A single climate impact on one infrastructure asset or service in a city can cause a cascade of impacts across other assets & services, leading to more severe and pronounced negative consequences for a city.



Cascading Impacts of Climate Change

Case Study | Ghana Flooding

Climate risks to Ghana's transport sector from floods and landslides, could cause USD \$3.9 billion in damages by 2050, nearly triple the USD \$1.3 billion invested in transport infrastructure in 2019.

The impact of flooding could severely damage roads and transportation infrastructure in Eastern, Central and Western districts in Ghana. This could lead to cascading impacts on healthcare systems. It could isolate over 80% of the population from accessing healthcare, which would disproportionately affect women who are frequent users of these services.

Building the climate resilience of infrastructure & services should be viewed in the context of the entire system, rather than focusing on a single asset or service.



UGC photo

Climate Impacts on Vulnerable Groups

People Living in Informal Settlements

- Increased temperatures put pressure on an already-stressed water supply, which has a disproportionate effect on urban poor living in informal settlements. They have to pay high prices to buy water from informal vendors when it is not available.
- Heat-related illnesses, especially of children and the elderly, increase living costs as public health facilities have limited capacity to provide care at affordable cost.
- Insecure tenure of informal settlements restricts household access to electricity to cope with heat. They experience load-shedding more often and need to rely on services from informal vendors.

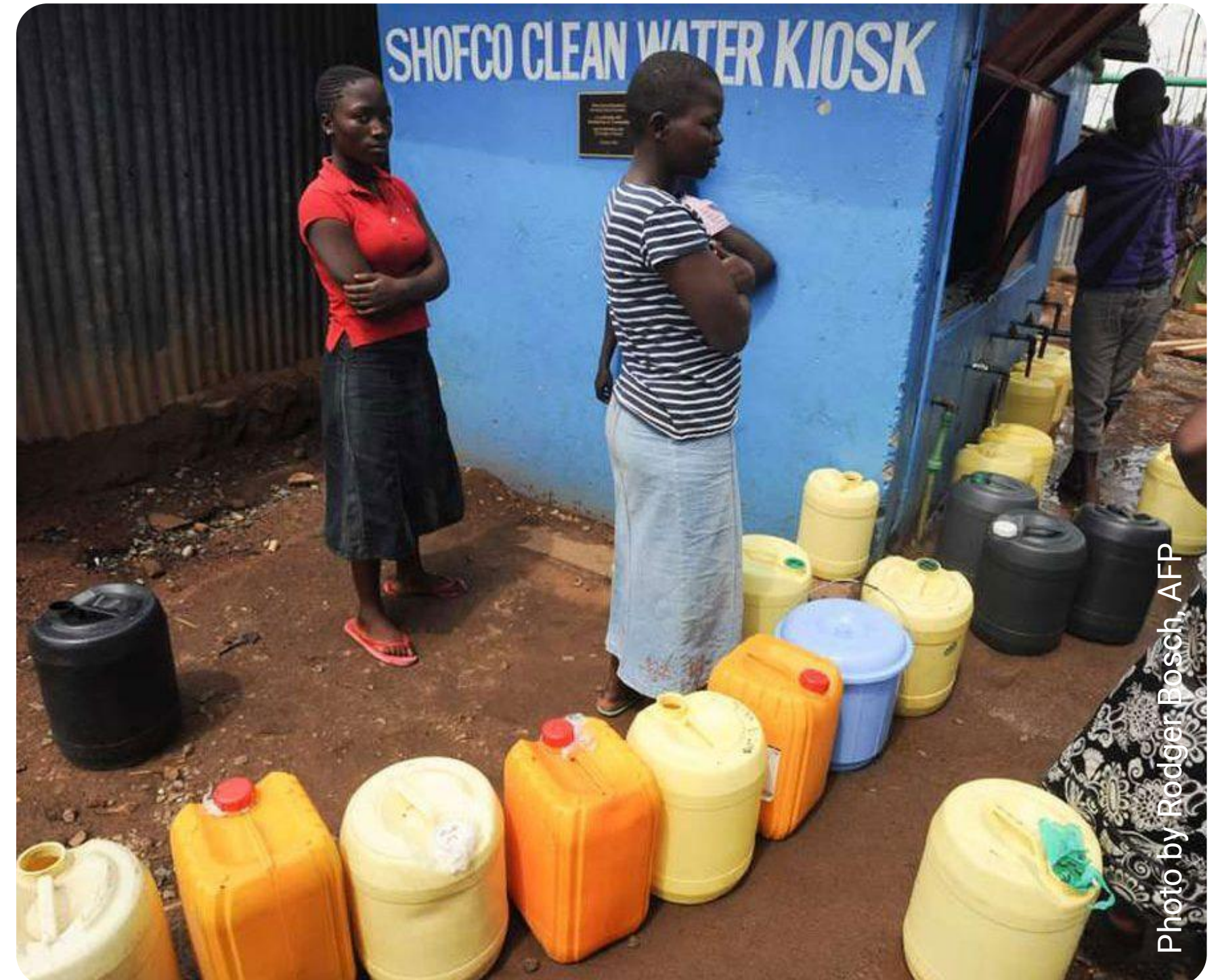


Photo by Rodger Bosch, AFP

Climate Impacts on Vulnerable Groups

Informal Settlement Riverine Communities

- Communities in informal settlements, are often located near rivers.
- Climate change has increased the risks they face owing to their location.
- Heavy rainfall and flooding due to extreme weather events have damaged or washed away houses in riverine communities and put lives at risk.
- Informal workers who run their businesses on the roadside and open spaces lose businesses during intense rainfall and waterlogging.



Nairobi; Photo by AP

Climate Impacts on Vulnerable Groups

Women and Girls

- Women and girls often suffer the impact of climate impacts on infrastructure.
- Increased drought can lead to water scarcity, which disproportionately puts burden on women who often spend significant time collecting water if they do not have access to piped water.
- Changing rainfall patterns leading to waterlogging and flooding of roads make women's and children's mobility difficult and unsafe. The cost of travelling for work increases when roads are flooded. Women, who often use public transport and walk to work, suffer most.



05 | Climate Impacts on Infrastructure in Bangladesh



Bihari Refugee Camp, Dhanka;
Photo by SkipAudio, Getty Images (licensed via Canva)

Impacts of climate change on critical infrastructure



Transportation

- **Extreme rainfall causes flooding**, exceeding the capacity of the urban drainage system to cope with the additional stormwater causing water-logging. Dhaka and Chattagram face extreme disruption of urban life after any extreme rainfall event.
- **Flash flood and long-term flooding** destroys roads and bridges.
- **Increased temperature** causes road surfaces to melt. **Heatwaves** significantly impact pedestrian mobility and operation of informal transport such as cycle rickshaws and shared taxis.
- **Salinity due to sea level rise** increases the cost of construction for roads in coastal areas.

If flood levels from 2004 repeated in Dhaka under the influence of future climate change by the 2050s, damages would rise to **US\$23 million** assuming present-day infrastructure and economic values.



Photo by AFP

Impacts of climate change on critical infrastructure



Energy

- **Rising temperatures** increases demand for energy (e.g. for cooling), especially in urban areas due to high density of people and built environment.
- The country experiences power-cut/ load shedding during hot summers that significantly impacts commercial activities and makes living conditions difficult.
- People and businesses use more fossil-fuel dependent alternatives that increases the costs, especially for the poor.
- In 2023, Bangladesh experienced partial load shedding on 225 days which means there was **an uninterrupted power supply every three out of ten days**.



Photo by Mahmud Hossain Opu, AP

Impacts of climate change on critical infrastructure



Telecoms

- **High winds from more frequent and intense cyclones** cause damage to above-ground transmission infrastructure, such as telephone towers.
- Power outages affect all digital communications, causing disruptions in service; this can be exacerbated by delays in tackling power outages due to adverse weather conditions during and after disasters such as cyclones and flooding.
- Fibre optic cables in coastal areas often are damaged causing disruption in broadband Internet.
- In October 2022 Cyclone Sitrang downed 7,343 mobile towers in 19 districts in Bangladesh.



Impacts of climate change on critical infrastructure



Buildings

- Use of high heat-absorbing and heat-emitting building materials, and the adoption of building techniques that are inappropriate for a warm-humid country, has increased dependency on energy-based cooling systems. This in turn traps heat and create **heat islands** in cities.
- **Water-logging, flooding and windstorms** cause damage to buildings and structures, particularly poorly constructed houses in informal settlements.
- **Salinity due to sea level rise** increases construction costs of building in coastal cities.

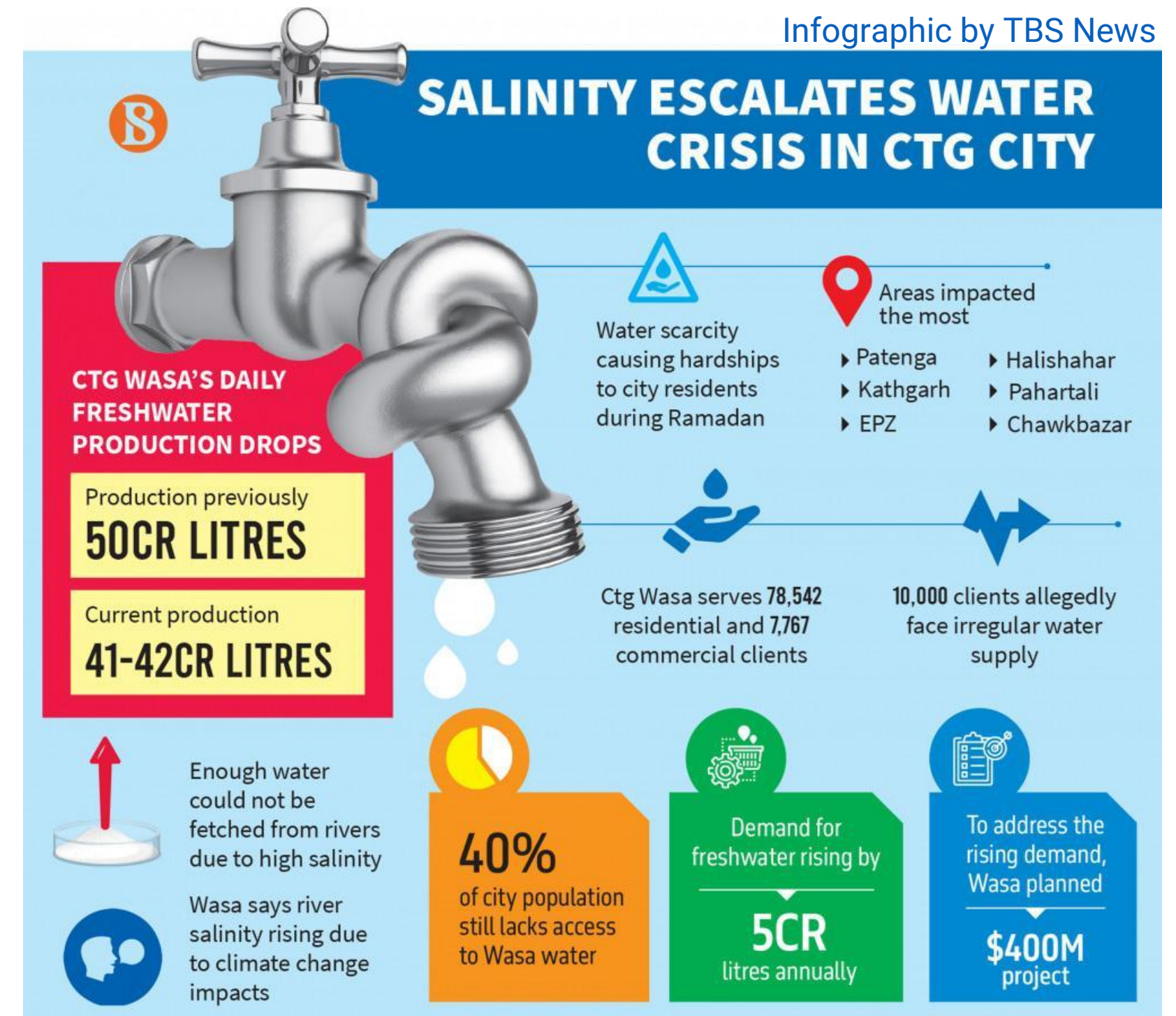


Impacts of climate change on critical infrastructure



Water

- **Increased temperature** increases demand for water in cities of Bangladesh, most of which are not fully covered by the supply network.
- This compounds an existing issue: over-dependency on extraction of groundwater by individual households through pumps, causing water levels to reduce every year.
- **Waterlogging and flooding** cause contamination of the poorly maintained supply infrastructure and increases exposure to water-borne diseases.
- **Increased salinity from sea level rise** impacts the availability of surface water from natural sources to treat and use in urban areas.



Impacts of climate change on critical infrastructure



Waste

- **Increased rainfall can lead to waterlogging and urban flooding** by blocking drainage systems with solid waste that is dumped in the open and not collected.
- **Flooding** disrupts solid waste collection and sorting services, as it is difficult to operate vehicles on flooded roads.
- Landfills are usually located close to residential areas, bodies of water, and agricultural regions, exposing people to a variety of health and environmental concerns through leachate percolation, trash combustion, and vector breeding. **Flooding and waterlogging** can exacerbate these risks.

On an average **half of all waste remains uncollected** and all waste is **dumped in open spaces in an unsanitary manner**.



Impacts of climate change on critical infrastructure



Health & Sanitation

- Recent **heat waves** have overwhelmed hospitals and health centers especially in secondary cities.
- The spread of water- and vector-borne diseases may increase due to **flooding** and **waterlogging**, compounded by inadequate water supply infrastructure, inadequate management of natural water bodies and poor drainage infrastructure.
- **Increased temperatures** lead to heat-related illnesses such as heat stress and heat strokes, which puts pressure on the health sector.
- 57 diarrhoea patients are admitted to International Centre for Diarrheal Disease Research, Bangladesh every hour in a day.
- In late March 2022, in the pre-monsoon season, the daily patient count for Dhaka Hospital exceeded 1,300 per day.



Photo by Waterdotorg, Flickr

Impacts of climate change on critical infrastructure



Public Spaces

- Public spaces with hard surfaces without adequate shading and greenery **reduces their usability**, especially during heat waves.
- **Irresponsible planning** to increase hard surfaces in public open spaces can reduce vegetation coverage, damage natural environment and ecology adding to the heat gain of the surrounding areas.
- Increased use of concrete and other grey infrastructure that reduces natural vegetation can lead to **waterlogging and flooding**, which can cause physical damage as well as lead to contamination of water bodies and increased spread of diseases.
- Public spaces, especially those that are located along rivers now face the challenge of constant **flooding** and encroachment from communities living near the rivers.



Photo by: News Bangla 24

Experience Share

Open Floor

→ Do you have any examples or stories of the impacts of climate change in your city?

→ Consider the infrastructure, communities, and environments that may have been affected.

→ Raise your hand if you have an example or story to share with the room.



06 | What Makes Urban Infrastructure Resilient?



Photo by Tuu Sithikorn, Canva

Why it is important to make infrastructure resilient

Climate resilient infrastructure positively impacts the social and economic wellbeing of urban populations. By building resilience of infrastructure cities can ensure:



Increased Reliability of Service Provision

Ensures consistent access to essential services, even during climate-related extreme weather events including floods and heatwaves



Increased Asset Life

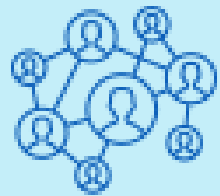
Prolongs the lifespan of infrastructure assets, maintaining their functionality and service provision capabilities over time



Improved Efficiency of Service Provision

Optimizes resource allocation and streamlines service delivery, leading to more effective and equitable delivery of essential services

Why it is important to make infrastructure resilient

	Increased Reliability of Service Provision	Increased Asset Life	Improved Efficiency of Service Provision
 Social	• Enhanced public health and well-being, particularly in vulnerable communities during emergencies • Reduced vulnerabilities of human life and livelihoods by providing continued access to vital services	• Preservation of public health and safety through preventing infrastructure failures and service interruptions • Promotion of social stability and resilience by ensuring continued functionality of infrastructure assets	• More equitable access to essential services, reducing disparities in service delivery and promoting social inclusion • Greater public satisfaction and trust in urban infrastructure systems through streamlined service provision processes
 Economic	• Economic stability and resilience in urban areas, with businesses able to operate without interruption • Attraction of investment and support for economic growth by providing a conducive environment for businesses to thrive	• Economic savings and efficiencies through reduced frequency of asset replacements and repairs • Maximization of benefits derived from infrastructure development, supporting long-term economic sustainability	• Reduces financial burden on governments and taxpayers through cost-effective operation of infrastructure systems • Fosters innovation and competitiveness by attracting investment and supporting economic growth in urban areas

What makes urban infrastructure climate resilient?



What makes infrastructure climate resilient?



It is planned, designed, built and operated in a way that anticipates, prepares for, and adapts to changing climate conditions.



It can withstand climate-related disruptions and continue to provide services such as power, water, and healthcare services even during crises.



It can recover rapidly from climate-related disruptions without rebuilding the vulnerabilities of the past.



It considers interdependencies and how changes in one infrastructure system may affect risk elsewhere e.g. an increase in paved surfaces for improved road networks may increase flood risk.



It supports inclusive social and economic resilience so that people are less vulnerable to climate hazards.



Dhaka; Photo by Lepot Nicolas, Flickr

Two approaches to climate resilient infrastructure

01

Climate Proofing Infrastructure: When building new infrastructure or upgrading existing infrastructure, ensure that the design of the asset can withstand current and future climate impacts

Example: Upgrade road networks in floodplains using climate resilient design standards and materials, so they can withstand more frequent flooding caused by climate change.

02

Infrastructure that Addresses Underlying Vulnerabilities: Make infrastructure investments to address peoples' underlying vulnerability so they are less severely affected by climate impacts

Example: Provide better access to reliable electricity, so that when extreme heatwaves occur, they are not as vulnerable to heat stress and can cool their homes effectively.



Dhaka; Photo by Bobulix, Flickr

Design Principles for Climate Resilient Urban Infrastructure



01 | Systems Approach



02 | Adaptive Management



03 | Equity & Inclusion



Photo by Luis Tato, AFP

01 | Systems Approach



A systems approach is used to address the interdependencies across different infrastructure assets and services within a city. It considers how individual assets influence one another and how they interact with the overall system.

A systems approach identifies risks to the entire system, including cascading impacts. It also considers that resilience building interventions should increase resilience of the entire system, not just a single asset or sector.

Example: Road infrastructure is interconnected with water management infrastructure, for managing run-off water during rainfall. To increase the climate resilience of road networks, city planners must consider this interconnection. Making drainage systems more resilient will help ensure that roads can cope with future flooding events.



01 | Systems Approach



Case Study | Rosario, Argentina

Background: Since 2001, Rosario, Argentina has demonstrated systems-level change by integrating agriculture into the city's environmental and land use policies, accompanied by social programs. This helps the city be resilient to flooding and heat events.

Interconnected issues: Food production, land use, social benefits. The city faced economic crisis, record-breaking rainfall and flooding, along with food insecurity, unemployment, displacement and poverty.

Intervention: Initially the city equipped citizens with the resources to grow produce on vacant land and sell it at local markets. After major floods in 2007, the city identified flood risk zones to convert into “vegetable garden parks” for urban agriculture.

Benefits: These land use changes limit urban sprawl, provide cooling, and absorb excess rainfall. This also provides other linked benefits including green jobs, composting and renewable energy.



Rosario, Photo by WRI

02 | Adaptive Management



Adaptive management is a strategy that helps handle the uncertainties linked to climate change over the lifetime of an infrastructure investment. Sources of uncertainty include climate model projections, especially at the local scale, and socioeconomic changes linked to urban growth.

This means **integrating flexibility from the start**, so that infrastructure plans can respond to changing circumstances and multiple possible climate scenarios across the life of the investment. This also reduces costs, avoiding locking in large up-front investments.

Requires **monitoring and evaluating performance** over the lifetime of the investment, which allows decisions to be made at later points in time, according to performance, updates to climate science and attitude to risk. Climate risk assessments (CRAs) are an important input to these decisions.



Khulna Dacope Koira, Bangladesh; Photo by Emdadul Islam Bitu, UNDP Bangladesh

02 | Adaptive Management



Case Study | Thames Estuary 2100 Plan, UK

TE2100 Plan outlines how increasing flood risk in the Thames estuary will be managed up until 2100, adopting a flexible approach to manage uncertainty.

The Plan monitors ten change factors: sea level, peak surge level, peak river flows, flood defense condition, barrier operation, economic development, erosion and deposition, natural habitat, land use plans, attitude to risk.

If rapid change is detected in these factors (for example sea level rise), the plan will be adjusted and a new adaptation pathway followed

This could include allowing flood defense interventions to be brought forward in time, designing structures to allow for modifications, and securing land for new defenses.



Westminster Bridge in London; Photo by Tom Arthur, Flickr

03 | Equity & Inclusion

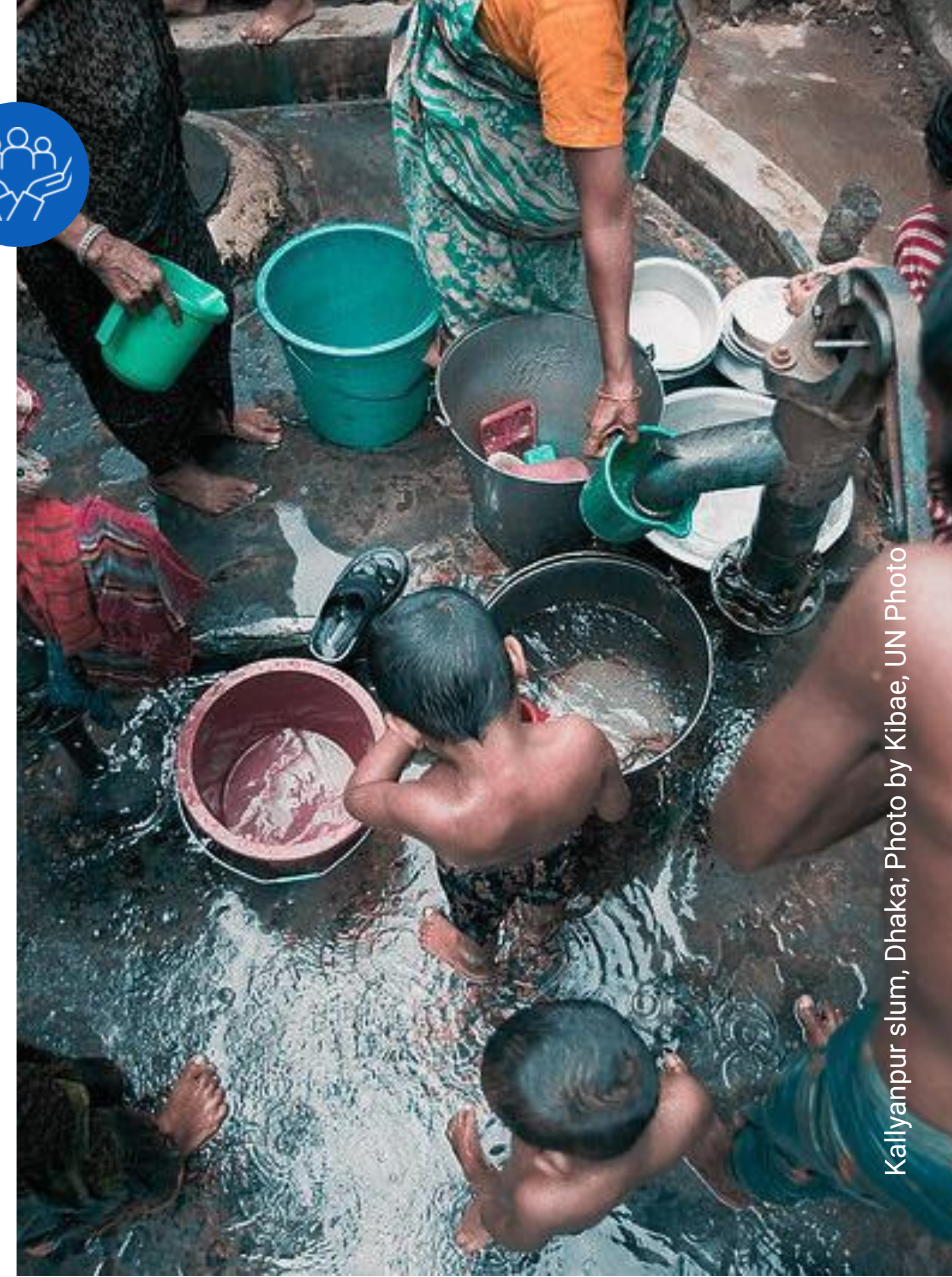
Equitable & Inclusive Access to Services

Effective urban infrastructure planning must ensure accessible, reliable and quality services for all. By 2050, urban areas are expecting an influx of 2.5 billion people, mainly in Asia and Africa. By the same year, up to 85% of urban poor neighborhoods are projected to be at risk of flooding, compared to about 60% of the broader urban landscape.

Disparities in access to climate resilient urban infrastructure, especially among the urban poor lacking basic services, compounds their existing vulnerabilities.

Social factors like gender and age result in differential vulnerabilities from poor access to services, even within vulnerable groups.

For example, in urban poor settlements, women bear the brunt of climate-related water scarcity as they fetch water for households. Reliable piped water infrastructure at the household level can help relieve this burden and contribute to women's well-being.



Kallyanpur slum, Dhaka; Photo by Kibae, UN Photo

03 | Equity & Inclusion

Equitable & Inclusive Decision-Making

Prioritizing equitable access involves engaging women and marginalized communities not only as end beneficiaries but also as active participants in shaping urban infrastructure development.

Community-based development processes are pivotal in integrating diverse perspectives, especially from vulnerable communities. This is crucial for fostering holistic resilience-building by ensuring equitable distribution in urban service delivery

For urban service planners and providers, adopting inclusive and participatory methods for climate risk assessments and infrastructure planning offers a starting point for engagement that integrates unique needs of diverse groups



Madogo, Tana River County, Kenya; Photo by IOM

03 | Equity & Inclusion

Case Study | Kibera, Kenya

Where is Kibera: In the centre of Nairobi, one of the world's largest informal settlements, home to over 300,000 people

Problem: Poor drainage and sanitation infrastructure and unsafe housing make residents of Kibera vulnerable to extreme flooding.

Intervention: Developed a network of community-designed and managed public spaces where flood protection combines green and grey infrastructure with core services. 5,000 residents were involved in the design.

Impact: Improved service access and flood protection for over 125,000 residents, particularly benefiting women and youth. This included: 11 new climate resilient spaces, 520m of flood protection installed, and 840m of drainage infrastructure installed.



Kibagare Slum, Nairobi; Photo by Ninara, Flickr

Questions

Open Floor

Does anyone have any questions about what makes climate resilient infrastructure?



Photo by Brian Inganga, AP

07 | Ways to Build Resilient Urban Infrastructure

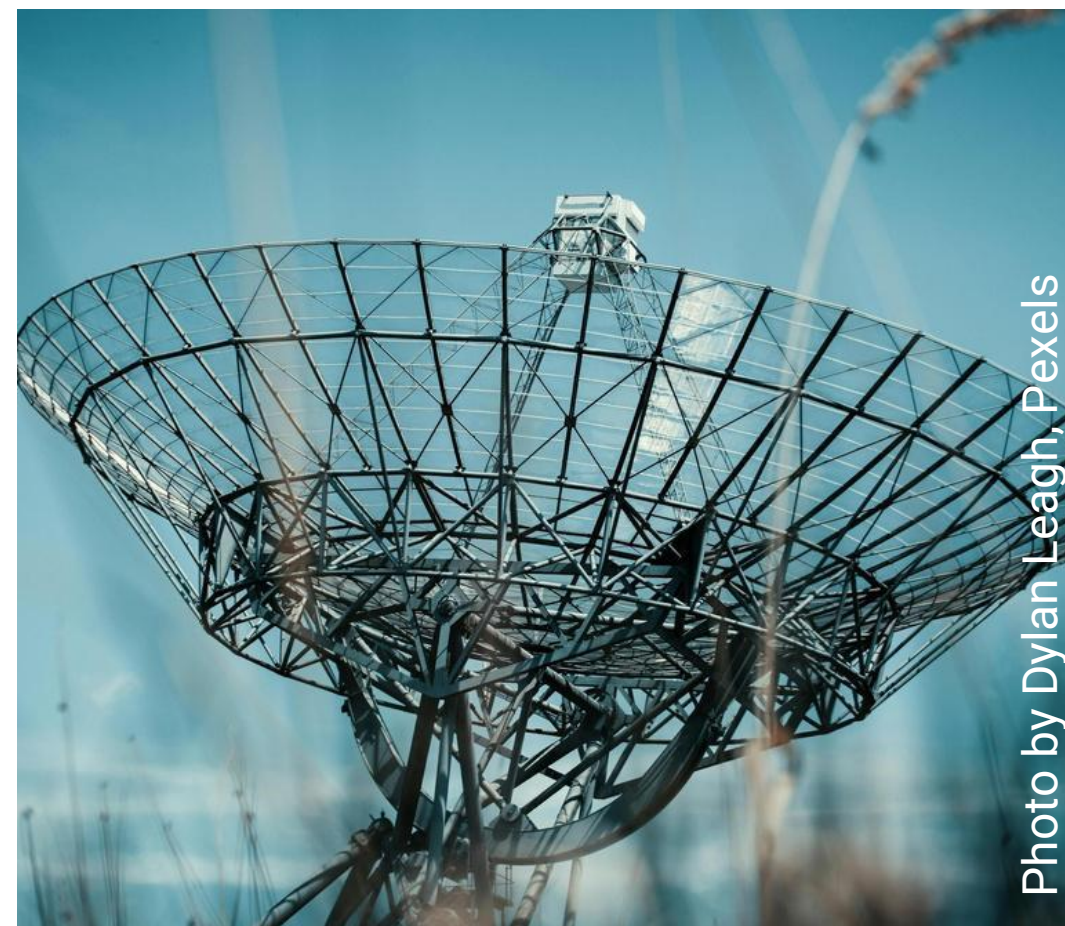


Photo by Daniel Irungu, EPA-EFE

Three ways to build resilient urban infrastructure



01 | Structural Measures



02 | Non-Structural Measures



03 | Nature-based Solutions

01 | Structural Measures

Structural measures are physical constructions and assets that are built to reduce or avoid the impacts of climate hazards.

They are also known as 'hard' or 'grey' infrastructure, since they are often made of concrete or other long-lasting materials.

Examples of structural measures include:

- Building a sea wall or using permeable paved surfaces to reduce run-off during heavy rainfall
- Retrofitting existing infrastructure e.g. raising the height of a bridge to protect against sea level rise



Photo by Edmundo_Cruz, Getty Images (licensed via Canva)

01 | Structural Measures

Case Study | Da Nang, Vietnam

Problem: Poor people live in inadequately built houses, at high risk to storm-related damage. As a result, many face financial stress and struggle to recover from crises.

Intervention: Da Nang implemented a project that provided 300 loans to low-income households in 8 disaster-prone wards. Loans were administered via Da Nang's Women's Union and supply technical assistance to construct disaster-resilient houses, made from brick, cement and steel (structural measure).

Impact: As of 2022, support was provided to 4,100 low-income households in the central coastal areas. All homes survived the multiple storms and significant flooding that hit Vietnam in 2020. They protected lives and means of subsistence and, in many communities, further protected adjacent neighbours.



Vietnam; Photo by Nhac Nguyen, AFP

01 | Structural Measures

Case Study | Malindi, Kenya

The Vasco da Gama pillar is a historic landmark in Malindi which attracts thousands of domestic and foreign tourists.

Problem: Coastal erosion and sea level rise weakens the physical fabric of the site and structural integrity of the monument

Intervention: Construction of sea wall to curb further erosion and protect the historic site from collapsing (structural measure)

Impact: Protecting a historic monument against climate-related impacts, preserving an economically important tourist site



Malindi; Photo by Kelvin Karani, The Standard

02 | Non-Structural Measures

Non-structural measures are ‘soft’ measures that reduce climate risks. They focus on improving institutional, organizational and human capacity to respond to climate change.

These non-physical measures include policies, plans, capacity building, investment in data collection and technology, awareness raising, monitoring and evaluation (M&E), etc.

Examples of non-structural measures include:

- Establishing inclusive early warning systems that collect data on climate risks.
- Building capacity of urban actors to ensure basic understanding of climate information and implications on key urban sectors
- Developing policies & building codes to reduce climate risks and promote resilience of urban infrastructure.



Photo by GCA

02 | Non-Structural Measures

Case Study | Punjab, Pakistan

Problem: Punjab province in Pakistan, predominantly in a floodplain, is vulnerable to flooding as well as periods of drought and water scarcity; this negatively impacts economic development and leads to loss of lives.

Intervention: The government of Punjab passed an order that every publicly funded project with a budget of over 1 billion Pakistani rupees undergo a risk screening and resilience mainstreaming protocol. They adopted an online risk screening tool, designed to fit within the province's existing project development cycle, to help departments (initially energy, irrigation, and agriculture) identify and integrate climate risk into project design (non-structural measure)

Impact: Building government capacity and institutional architecture for embedding resilience within projects and programmes



Pakistan; Photo by AP

Combined Structural & Non-Structural Measures

Cities can **combine structural and non-structural measures** for more holistic resilience solutions.

Building resilience of infrastructure has conventionally focused on structural or 'hard' measures (e.g. engineering practices). However, deploying non-structural or 'soft' measures is equally important – urban actors need appropriate information, capacity and enabling policy environment to take action.

In many cases, the two types of measures are integrated into a resilience intervention. Examples of combined measures could include:

- Physical flood protection measures such as dams and flood defenses, combined with hydrological catchment modelling.
- Water distribution infrastructure and community water management committees that monitor groundwater availability and quality.



Demonstration of the use of a Tromino, a passive seismic tool used for stratigraphy and bedrock mapping, to local water officials, Kenya; Photo by USGS

Combined Structural & Non-Structural Measures

Case Study | Gorakhpur, India

Problem: Gorakhpur (population 670,000 and growing quickly) faces frequent **flooding, seasonal waterlogging**, and related **health and mobility challenges**. Poor communities are most affected.

Intervention: Gorakhpur has established a ward-level committee to ensure ongoing provision and maintenance of municipal services. They have made investments in storm water drainage, hand pumps, and better toilets (structural measures). They have also established community-level monitoring of solid waste and better maintenance of drainage channels (non-structural measure) to minimize flood risks.

Impact: Almost 6000 people have benefited from new drains in Mehewa Ward. September 2012 saw record rainfall when 423mm fell in one month, yet Mehewa ward did not experience waterlogging.



Gorakhpur; Photo by Dainik Bhaskar

Combined Structural & Non-Structural Measures

Case Study | Semarang, Indonesia

Problem: Semarang is at risk from sea level rise and river inundation, with the expected number of households in flood-prone areas to increase to 50% by 2050.

Intervention: The city government implemented a Flood Early Warning System (FEWS) project between 2012 and 2014. It included flood shelters (structural measure) and evacuation plans to alert vulnerable communities. This was accompanied by disaster risk management training to educate communities in flood-prone areas to be more prepared (non-structural measure).

Impact: Vulnerable communities residing in coastal areas were more capable to respond to emergencies and minimize risk, injury, and casualties. Local government agencies benefited by understanding where infrastructure capacity should be strengthened to minimize the impact of flood on major water infrastructure.



Tawang train station, Semarang; Photo by Aji Styawan, WSJ

03 | Nature-based Solutions

Nature-based solutions (NbS) is an umbrella term referring to “actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.”

NbS use the benefits of natural processes to support resilience. This can include natural flood defenses, urban cooling, access to water, and many more services that provide benefits to people living in cities .

NbS approaches that integrate natural ecosystem processes into infrastructure planning offer an effective alternative or addition to traditional built/grey infrastructure

Nature-based solutions are often more cost-effective than grey infrastructure. Recent estimates suggest that the average cost of implementing NbS for infrastructure is half of their traditional grey infrastructure counterparts



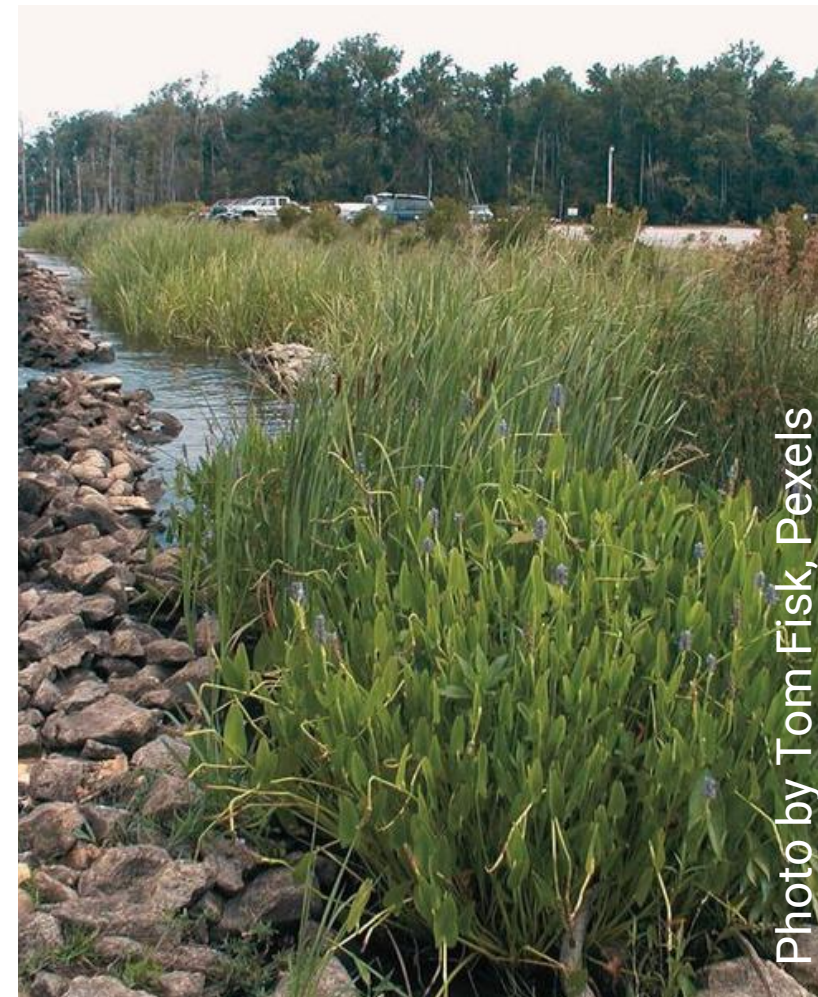
Photo by Jomphong, Getty Images (licensed via Canva)

03 | Nature-based Solutions



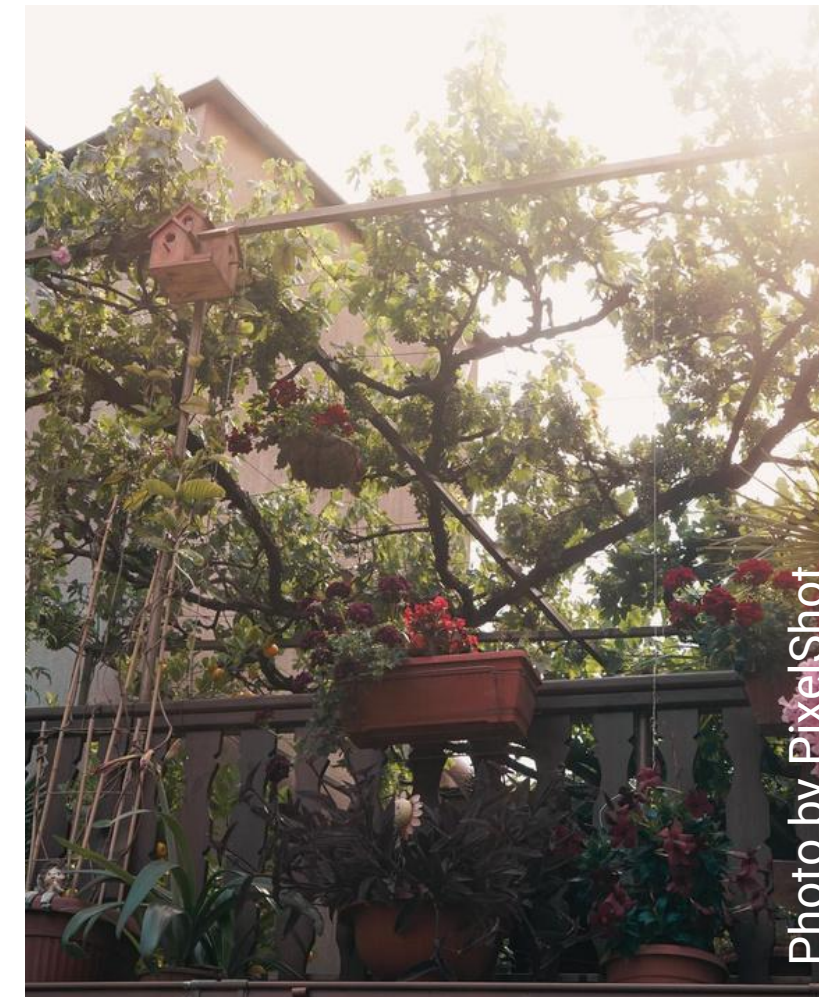
Natural

Restoration and conservation of natural habitats, with active management



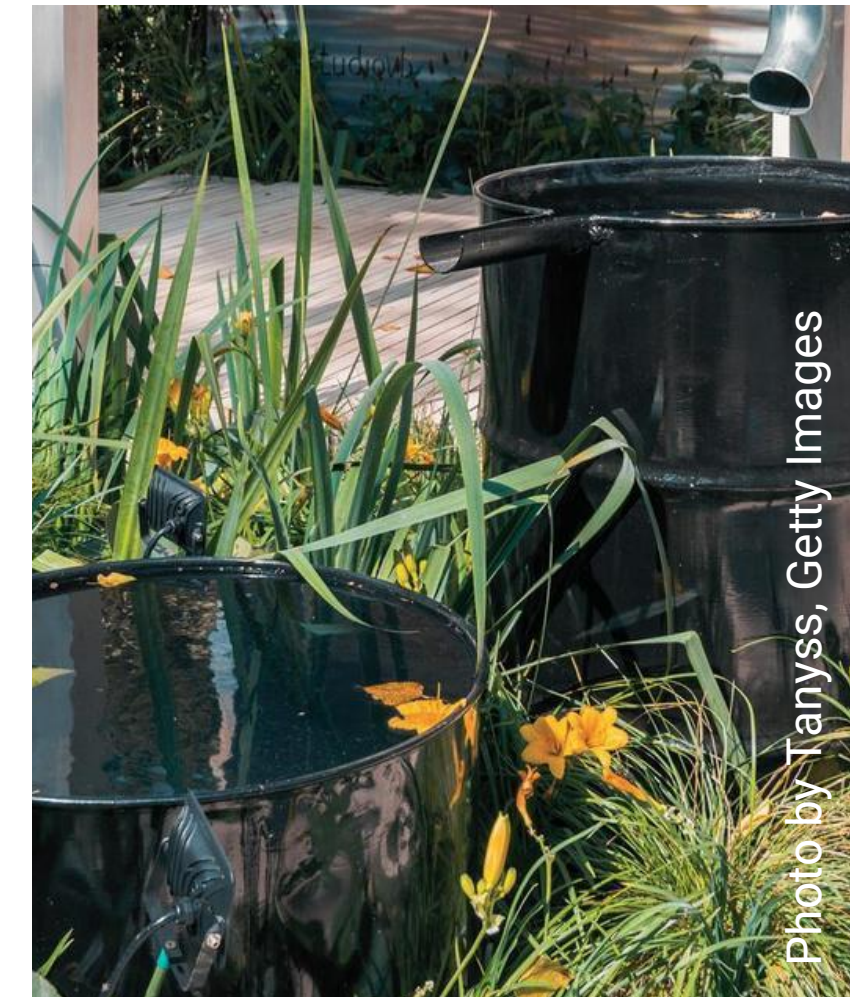
Semi-cultivated

Living shorelines
Constructed wetlands
Hybrid reefs
Riparian buffers



Cultivated

Bioswales
Rooftop gardens
Urban forests
Green alleys



Engineered

Permeable pavements
Rainwater harvesting
Groundwater recharge wells

03 | Nature-based Solutions

Nature-based solutions are important because they can reduce some of the negative impacts of grey infrastructure in cities:



The expansion of built-up areas and impermeable surfaces, often at the cost of green and blue (water-based) spaces, heightens the risks associated with climate change including heatwaves and floods.



Urban areas can be 10-15°C hotter than their rural counterparts. Concrete surfaces like roofs and pavements absorb more heat and are resistant to cooling, contributing to the urban heat island effect.



Urban expansion in reclaimed blue spaces, such as degraded lakes and wetlands, disrupts natural drainage patterns, leading to higher instances of urban flooding during heavy rainfall.



NbS approaches that integrate natural ecosystem processes into infrastructure planning offer an effective alternative or addition to traditional built/grey infrastructure.



Photo by Radu Bercan, Canva

03 | Nature-based Solutions

Nature-based solutions can complement, substitute for, or protect traditional grey infrastructure to enhance the resilience of urban service delivery to climate change.



Complement: Restoring watersheds, which serve as ecological infrastructure supplying water to reservoirs, plays a vital role in regulating hydrological processes and maintaining water quality.



Substitute: Using deep-rooted vegetation for slope stabilization offers a cost-effective alternative to building concrete retaining walls, and is estimated to save up to 90% in implementation costs.



Safeguard: Afforesting mangrove forests could protect shorelines from erosion, thus safeguarding nearby roads, buildings, and utilities from wave damage during storms and sea surges.



ICBAAR Project Bangladesh, Photo by UNDP Bangladesh

03 | Nature-based Solutions

Benefits of Nature-based Solutions

They provide a range of climate adaptation and mitigation benefits



Temperature regulation



Improved air quality



Flood risk reduction



Stormwater regulation



Water security



Biodiversity and regeneration



Carbon sequestration

They additionally offer multiple social benefits



Tourism and recreation



Stimulate local economies



Contribute to public health



Spaces for interaction



Contribute to mental health



Eco-cultural heritage



Climate education

03 | Nature-based Solutions

Case Study | Dhaka, Bangladesh

Dhaka's rapid urbanization has led to the destruction of wetlands, causing poor drainage and water stagnation, leading to frequent flooding.

Waterlogging is also a problem due to poor drainage, impacting transportation, telecoms, water supply and electricity.

The Hatirjheel basin was restored over 6 years with the aims of: retaining stormwater, transforming a wastewater canal into a freshwater lake, connecting 2 major roads.

The initiative has reduced flood risk, enhanced city-wide connectivity and revitalized the cityscape through a grey-green approach to infrastructure



Dhaka; Photo by Shadman, Pexels

08 | Climate Resilient Infrastructure in Bangladesh



Dhaka; Photo by eGuide Travel, Flickr



Ministry of Environment, Forest and Climate Change
Government of the People's Republic of Bangladesh

Climate Resilient Urban Infrastructure Needs

Bangladesh's NAP outlines 12 areas of investment and action relevant for climate resilient urban infrastructure.

For example:

- Improvement of natural and artificial stormwater drainage networks for reducing vulnerabilities to urban flooding and drainage congestion (CRC1, NAP)
- Increase access to water supply, sanitation and hygiene services in cities for reducing exposure to flooding and waterborne diseases during or after extreme weather events (CRC6, NAP)
- Establishment of climate resilient health-care facilities in urban areas (CRC11, NAP)
- Development of heatwave and disease outbreak advisory services for city dwellers (CRC12, NAP)

National Adaptation Plan of Bangladesh (2023-2050)

October 2022



Guidelines for Climate Resilient Infrastructure in Bangladesh

Bangladesh National Building Code contains “Requirements for Buildings in Flood Prone and Coastal Regions of Bangladesh”. This provides general design and construction specifications for walls, floors, electrical, sewerage systems etc. to cope with flooding, salinity and seismic risks for buildings.

The Local Government Engineering Department (LGED) has established the Climate Resilient Local Infrastructure Center (CReLIC) under its Climate Resilient Infrastructure Mainstreaming Project (CRIMP) to mainstream climate resilience guidelines in designing, planning, constructions, operation and maintenance of all infrastructure at the local level. It will also act as a knowledge hub and resource centre.

BRAC’s Low-Cost Climate Resilient Urban Housing handbook outlines a set of technical approaches and construction techniques for houses based on 4 main climate hazards: strong wind, salinity, heat stress, and flooding / water-logging.



Photo by West Africa Biodiversity and Climate Change

Guidelines for Climate Resilient Infrastructure

Guidelines on the utilization of development programme funds allocated to City Corporations and Pourashavas state:



The impact of the environment and climate change must be considered in the construction and use of infrastructure.



At least 10% of development funds provided to City Corporations and Pourashavas must be spent for the implementation of Green and Climate Resilient priority activities. The next slide will cover a list of eligible sectors.



Barindh Tract; Photo by Anowarul Haq, Flickr

Guidelines for Climate Resilient Infrastructure



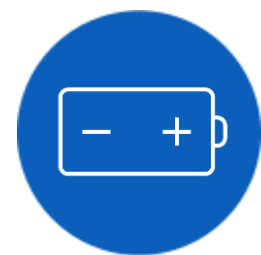
Construct, renovate and develop climate resilient and flood-resistant infrastructure.



Make cities flood-resilient with proper drainage and sewerage systems.



Increase access to safe water, sanitation, and hygiene (Water, Sanitation and Hygiene-WASH) facilities.



Enhance the use of energy-efficient appliances in official, residential, and commercial buildings under city corporations.



Promote environmental and ecological restoration and protection of forest and water bodies.



Create access for city-dwellers to climate-resilient housing and other critical infrastructure.



Construct sustainable and climate-resilient shelters.



Strengthen climate-resilient urban infrastructure and services.

Guidelines for Climate Resilient Infrastructure

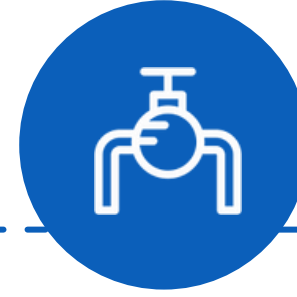
In the guidelines for development fund utilisation for pourashavas, climate resilience is also integrated into activities under sectoral expenditure heads:



Public Health

Construction and maintenance of hygienic and climate resilient public toilets.

Construction, renovation and maintenance of climate resilient health infrastructure (hospitals, immunization centers, children and maternity homes, day-cares, dispensary buildings) operated under the management of Pourashava.



Drinking water and Sewerage

Construction, renovation and maintenance of sewerage/drainage system to mitigate waterlogging, and floods.



Roads & Infrastructure

Building sustainable and climate-resilient shelter homes

Development of climate-resilient cemeteries and crematoriums

Rehabilitation and conservation water bodies for public use owned by pourashavas and restoration of natural habitats

Avoiding unnecessary roads, especially in hoar areas.

Guidelines for NbS in Bangladesh

Use of NbS for infrastructure in urban areas of Bangladesh is currently limited. This is primarily due to high density of development in urban areas and private ownership of land.

However, there are many opportunities to use NbS in urban areas,

- Development of climate resilient urban drainage infrastructure through eco-engineering or bioengineering measures
- Expanding green and blue infrastructures such as green buildings, urban green parks, schoolyards, and playgrounds.
- Conservation of urban wetlands and biodiversity.
- Managing urban heat islands with planned urbanization and keeping green areas at 25%.
- Ensuring areas adjacent to roads are planted with greenery.
- Floating vegetable cultivation along riversides.



Dhaka; Photo by Kabir Uddin; Getty Images (licensed via Canva)

Guidelines for NbS in Bangladesh

The urban development planning process in Bangladesh takes two types of approaches to guide building and neighbourhood development.



Location approach: Formulates spatial plans (e.g., master plan, land use plan)

NbS can be integrated into land use plans with specific indications for conserving, preserving and rehabilitating natural elements, such as water bodies, parks and natural open spaces. Land use planning can help create networks of green and blue open spaces to preserve and interweave nature with the built environment.



Design approach: uses regulatory frameworks (e.g., building codes and standards)

Infrastructure design guidelines, especially for roads, footpaths and drains can be revised to encourage use of environment-friendly materials and materials. A similar approach can be taken in building design rules and guidelines, for example, introducing rainwater harvesting, solar energy, using reflective roof paints, natural ventilation, etc.



Dhaka; Photo by Michael Foley, Flickr

NbS in Bangladesh

Case Study | Rasulbagh Children's Park, Dhaka, Bangladesh

Dhaka South City Corporation started converting a derelict area with **waterlogging** problems in 2018 into a children's park in the one of the mostly densely populated areas of Dhaka.

The designers followed a **participatory approach** to engage the community in identifying the needs for the 2500m² park.

The park includes a **rainwater filtration system** created by digging a trench covered by walkways. Rainwater runoff is collected, filtered (at a capacity of 8000L per hour), stored and distributed to the community for various uses.

New trees planted by local children enhanced air quality and biodiversity. The playfields improved the children's mental and physical health.



NbS in Bangladesh

Case Study | Floating Vegetable Gardens, Gopalganj, Bangladesh

Floating vegetable gardens in **peri-urban area** of the Gopalganj, Barisal and Pirojpur and other districts **exposed to higher risks of flooding** provide opportunities to reduce food insecurity and preserve local flora, fauna and ecosystems.

The process adopts an **age-old traditional method** of cultivation called dhap (known locally as baira), in creating floating vegetable garden beds.

These beds simply rise and fall with the swelling waters, reducing risk to agricultural livelihoods from flooding and waterlogging.

The floating gardens combine agricultural biodiversity, resilient ecosystems and cultural heritage.



Gopalganj; Photo by Urban Nature Atlas

NbS in Bangladesh

Case Study | Urban Greening | Rajshahi City, Bangladesh

This pilot project aimed to **improve and manage open green spaces**, generate awareness among stakeholders about local biodiversity and ecosystem services, and promote outdoor activities.

Key climate-related benefits include: mitigating the impact of **increased temperatures**; providing **ecosystem services** such as improving air, soil and water quality; **reducing surface runoff during heavy rains**.

A local nursery was engaged to maintain the pilot-scale plantation using **local and naturalized plant species**.

Stakeholder participation in planning and implementation helped in generating ownership.



Rajshahi; Photo by Atik Hossain Zisan, The Business Standard

09 | Interactive Exercise



Photo by Dbldy, Getty Images (licensed via Canva)

Decisions for the Decade

→ Investing in infrastructure for the future is full of uncertainty

→ Let's play a game to discuss the level of uncertainty in which we must operate.

→ Are you ready?



Source: Red Cross/Red Crescent

Decisions for the Decade



Umbrella Flood Protection



Thumbs Up Development



Bucket Drought Protection

Practice Run



Umbrella Flood Protection



Thumbs Up Development



Bucket Drought Protection

Decisions for the Decade

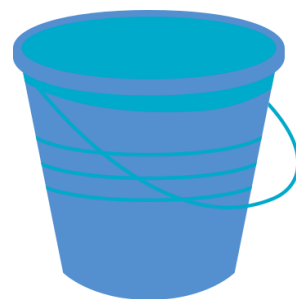
Strategy: Where should we invest?



Umbrella Flood Protection



Thumbs Up Development



Bucket Drought Protection

Decade 1



Too much flood disaster



Just right
It's okay for development

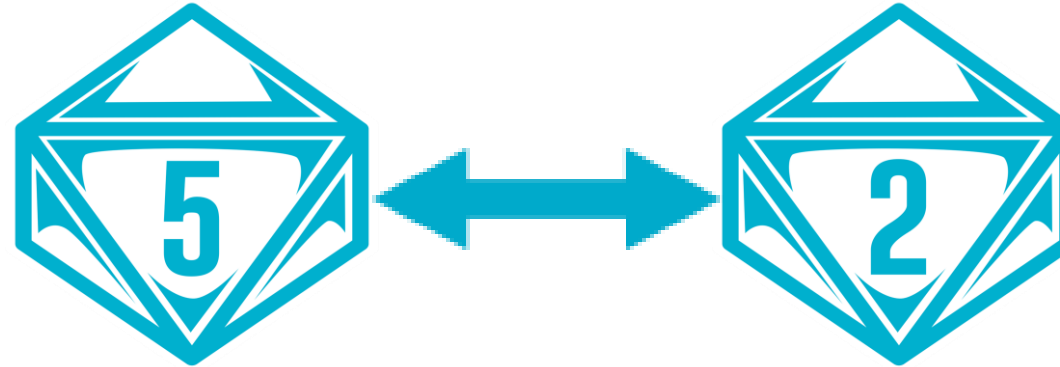


Too little drought disaster

Decade 2



Too much flood disaster



Just right
It's okay for development



Too little drought disaster

Decade 3



CONE OF UNCERTAINTY



Too much flood disaster

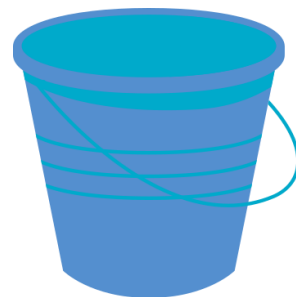


Just right
It's okay for development



Too little drought disaster

Discussion



Did your team make good decisions?

What is a good decision?

How did the decision making change over time as the risk levels changed?

Were you too cautious or too ambitious?

What other strategy could you have deployed?

10 | Summary



Photo by Seapya, Getty Images (licensed via Canva)

Summary & Next Steps

Congratulations on completing Module 4: Ensuring Climate Resilience of Urban Infrastructure!



Module 1

Introduction to
Climate Change
and Urban
Resilience



Module 2

Understanding
Climate Risks in
Your City



Module 3

Locally Led
Adaptation for
Urban
Resilience



Module 4

Ensuring
Climate
Resilience of
Urban
Infrastructure



Module 5

Step-by-Step
Guidelines for
Delivering
Climate Resilient
Infrastructure



Module 6

Financing
Climate
Resilient Urban
Infrastructure

The next module in the UCRMC is **Module 5: Step-by-Step Guidelines for Delivering Climate Resilient Infrastructure.**



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