2.6.0

SERIES 2
Understanding Vulnerability & Risk

CLIMATE RESILIENCE FRAMEWORK
ISET-INTERNATIONAL

Contents of Set

TRAINING.I-S-E-T.ORG

SYSTEM FRAGILITY

Urban systems include infrastructure and ecosystems that support the high density of human occupation and economic activity in cities. They are essential in creating the productive opportunities central to urban life. When these systems are fragile—when their functioning is easily disrupted—the people reliant on them are put at risk. Resilience of vulnerable groups can frequently be increased by improving the resilience of the systems on which they depend.

IN THIS SET YOU WILL:

- ✓ Be introduced to the idea of fragile and resilient systems;
- ✓ Consider how urban systems differ from rural systems and what this means for vulnerability and entry points for building resilience; and
- ✓ Explore the underlying fragilities and exposure—such as dependence on only one avenue for delivering a service, construction in a floodplain, or ecosystem degradation—that might make a particular system, service or function susceptible to suffering harm from climate hazards.

What is System Fragility? 

Urban systems include infrastructure and ecosystems that support the high density of human occupation and economic activity in cities. They are essential in creating the productive opportunities central to urban life. Urban systems include infrastructure, services, and functions (such as water supply and wastewater treatment systems, roads, power lines, food distribution, health, education, finance) and ecosystems (such as agricultural land, parks, wetlands, fishing grounds). Systems are designed and/or managed by people, but their performance depends on a multitude of factors that are difficult to manage, including human behavior and institutional context. Systems are fragile if they are easily disrupted or broken, though their basic functioning may look very stable.

City systems are susceptible to harm from past and current climate hazards in a different manner than people simply because systems cannot make decisions or take actions. Ecosystems are reactive. They respond to changes caused by people or the climate, but do not think about their responses or actively choose to evolve the way they do. Other systems, like water management, roads, electricity production and distribution, or food production and distribution, depend on people for their maintenance and functioning.

City systems, services, functions and infrastructure are vulnerable because we make them vulnerable in how we conceive of, build, and maintain them. Systems suffer harm because of:

- Exposure, or location in hazard prone areas;
- Inappropriate construction materials and techniques and/or lack of maintenance;
- Construction and location of surrounding infrastructure, which if improperly placed or constructed can increase the hazard intensity. For instance, road construction often changes drainage patterns, creating new flooding hazards;
- Ecosystem degradation; and
- Damage to one system causing damage to others. For example, failure of a dike causing flood damage to roads, homes and businesses.

Systems also suffer harm as a result of constraining and/or weak institutions:

- Laws, polices, and practices that encourage poor selection of systems (e.g. national construction mandates that are ill suited to the environment), poor construction, mismanagement or poor maintenance; and
- Cultural practices that shape the way systems, city services or functions are created and delivered. For instance, planning and constructing schools only for boys, or limiting access to food, jobs or housing based on ethnicity or religion.

Vulnerability and institutions are discussed further in set 2.7

When conducting an assessment of current vulnerability, you need to assess these factors in a qualitative or quantitative manner, or some combination of the two, depending on how your working group has set up your vulnerability framework. Capacities and fragilities are often measured or described as opposites—a river basin that has been damaged by people cannot adequately supply city water needs or filter city wastes; we would describe this as a fragile ecosystem. A healthy river ecosystem, however, might be able to supply city water, maintain a strong, health fishery, and filter waste; we would describe this as a resilient ecosystem.

The photo above shows fragile systems—drainage and roadways—during extreme rainfall in Gorakhpur, India.

Characteristics of Resilient Systems

Within the framework, building system resilience means strengthening systems to reduce their fragility in the face of climate impacts and to reduce the risk of cascading failures. Resilient systems differ from engineered, robust systems. Robust engineered systems rely primarily on hard protective structures (e.g. sea walls) or are designed in ways that emphasize the strength of specific individual components to ensure functionality. Resilient systems, in contrast, ensure that functionality is retained and can be rapidly re-instated through system linkages despite localized failures or operational disruptions.

Rather than relying on the strength of individual components, resilient systems retain functionality through:

- **Flexibility and diversity:** the ability to perform essential tasks under a wide range of conditions, and to convert assets or modify structures to introduce new ways of achieving essential tasks. A resilient system has key assets and functions physically distributed so that the entire system is not affected by a given event at any one time (spatial diversity) and so that the system has multiple ways of meeting a given need (functional diversity).
- **Redundancy, modularity:** spare capacity for congitency situations or to accommodate increasing or extreme surge pressures or demand; multiple pathways and a variety of options for service delivery; and/or interacting components composed of similar parts that can replace each other if one, or even many, fail. Redundancy is also supported by the presence of buffer stocks within systems that can compensate if flows are disrupted (e.g. local water or food supplies to supplement or replace imported food or water).
- **Safe failure:** designed to fail in predictable and/or planned ways that will minimize damage. Safe failure also refers to the interdependence of various systems that support each other; failures in one structure or linkage being unlikely to result in cascading impacts across other systems.

These characteristics of resilient systems are guidelines for thinking about complex urban systems, not technical prescriptions. Each technical context and system will be different. It is impossible to provide specific guidelines for all conditions. However, there is a growing body of research looking at the resilience of specific systems and the wider consequences and costs of disruption or failure due to climate change. Table 2.6.1 provides examples of

Table 2.6.1: Characteristics of Resilient Systems

SYSTEM CHARACTERISTIC	PERFORMANCE DESCRIPTION	EXAMPLES (FOR WATER SUPPLY)	OTHER EXAMPLES
Flexibility and Diversity	The system can meet service needs under a wide range of climate conditions. Key elements are spatially distributed and can substitute for each other but are functionally linked.	Multiple, geographically distributed water sources (ground and surface water). Pumping stations in multiple sites with overlapping service. Demand side management to ensure water is used efficiently. Expandable fleet of water tankers.	Transportation: multiple modes and capacities for transporting key goods and people. Food supply sourced from diverse geographic areas.
Redundancy and Modularity	Spare capacity to accommodate unexpected service demand or extreme climate events. System components and pathways provide multiple options or substitutable components for service delivery.	Reservoir storage capacity exceeds demand under drought conditions. Groundwater recharge exceeds withdrawal rate. Storage to buffer annual variability or other supply disruptions. Backup systems for water pumping. Rainwater harvesting systems to supplement water supply.	Transportation: multiple access routes. Communications: redundant transmission towers. Energy: backup generators for crucial services. Food and medicines: maintain high stock/flow balance in case of disruption.
Safe Failure	Failure in one part of the system will not lead to cascading failures of other elements or related systems. Key service delivery can be maintained even under failures.	Protection and monitoring of source quality under conditions of climate stress. Failure of one pumping station does not lead to distribution system failure. Distribution network interlinked so local failure will not cause major service interruptions.	Dikes can be opened to flood retention zones outside city, if threatened.

what resilience characteristics might look like for a series of water supply examples. From these examples, it can be seen that the resilience characteristics of a system are not mutually exclusive. In any given system, a particular desired service might be addressed under more than one resilience characteristic (in some systems, for example, modularity is similar to diversity, e.g. multiple water pumping stations in various locations).

SYSTEM FAILURE

Core or "critical" systems are essential to urban function (Figure 2.6.1). The failure of core systems puts human well-being at risk, and precludes higher order economic activity until core function is restored. Core systems include water supply, food supply and the ecosystems that support these, as well as energy, transport, shelter and communications.

Other urban systems support broader adaptive capacity of city residents. Markets, financial services, education, health care – these are the systems that differentiate the urban environment. They are the systems that enable greater prosperity and well-being. Systems such as early warning systems, emergency response services, and social safety nets provide security. Failure of these systems, or failure to

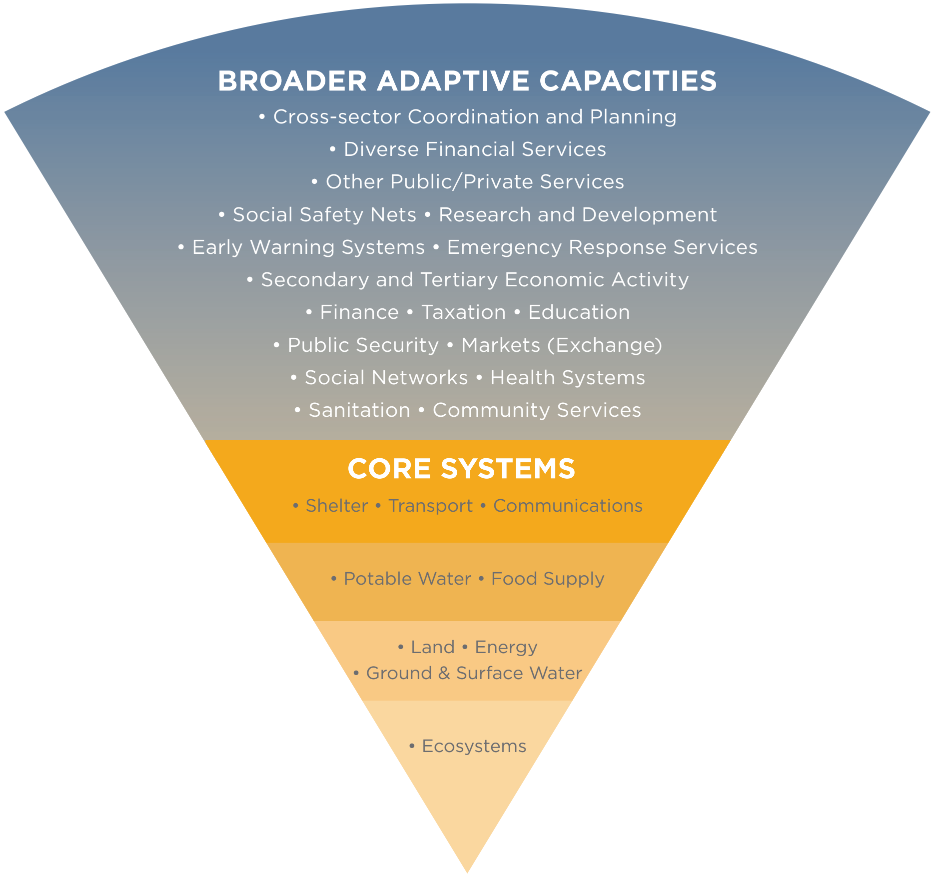
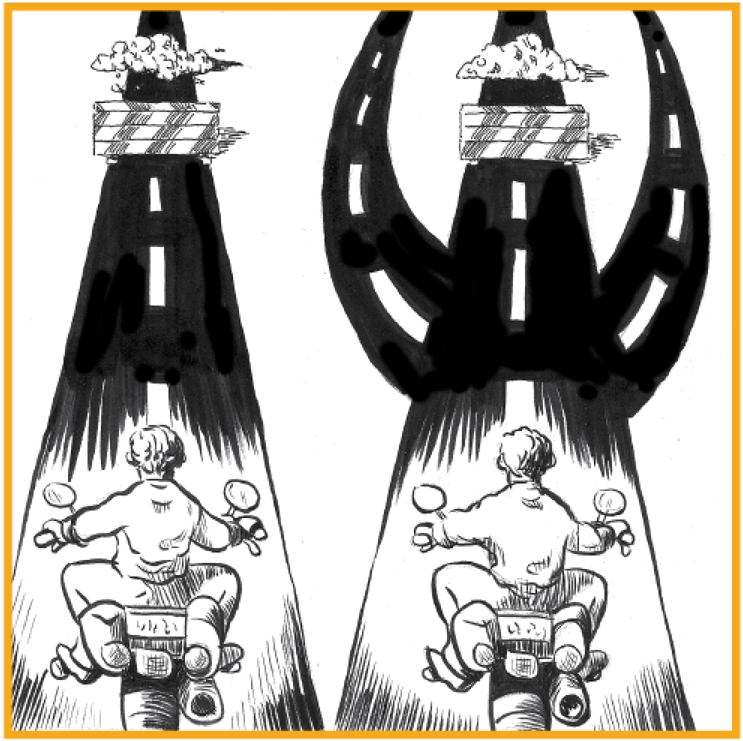


FIGURE 2.6.1 CRITICAL SYSTEMS DIAGRAM

access them, results in greater vulnerability and negates many of the expected benefits of urban residence.

The potential for any one of these urban systems to fail under climate-induced stress can be relatively easily assessed. However, more critical in an urban environment is to identify the interdependencies between systems. Unlike in rural environments, where systems can be relatively simple and straightforward, systems in urban environments are frequently complex and interlinked. As a result, the failure of one system often lead to failures in linked systems. The New York City Blackout case study presented in Section 2.6.2 illustrates the potential for cascading failures in systems.

Analyzing the potential for cascading failures is challenging. Scenario construction and "What if..." games are two ways to begin exploring the complexities of linked systems.



SYSTEMS
Flexibility & Diversity