Understanding the Infrastructure Resilience Framework: Interactions Between System Functionality, Operability, Service Provision and Economic Activity

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ASCE | INFRASTRUCTURE RESILIENCE

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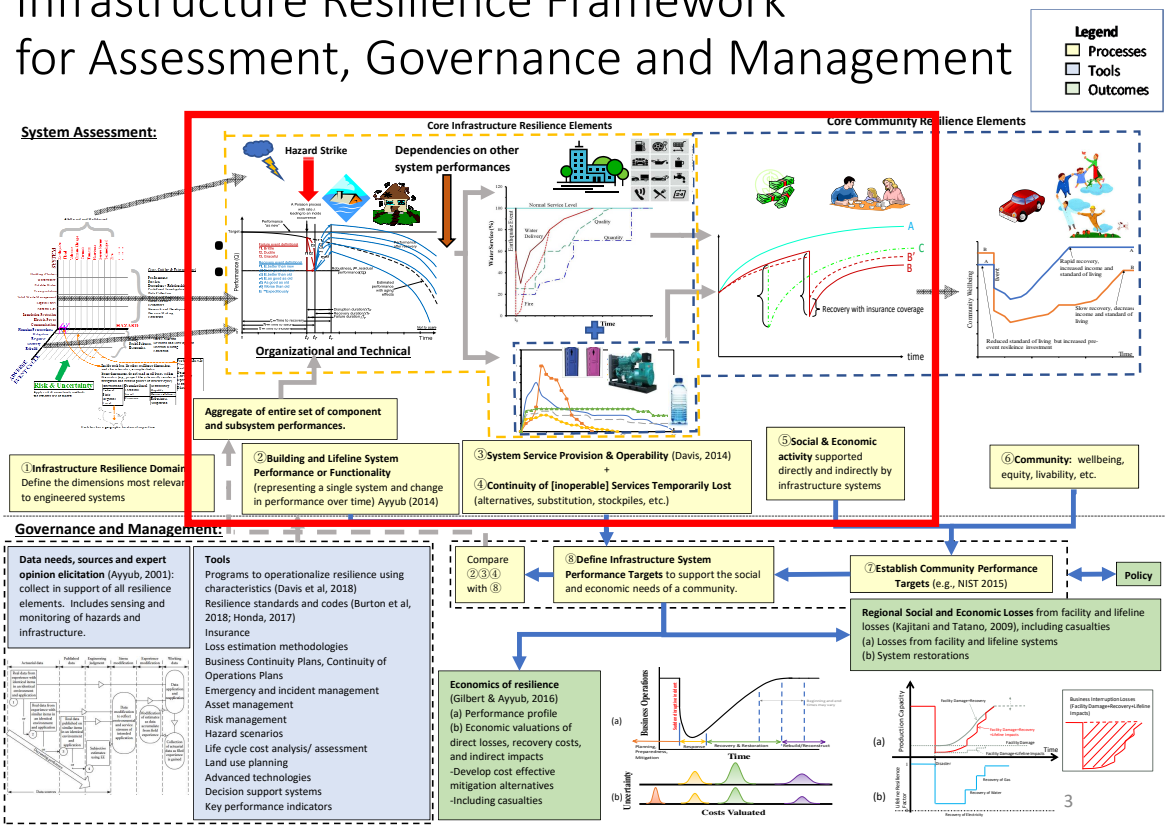
Introduction

- This presentation will focus on
  - The difference between Functionality and Operability (Infrastructure Resilience Framework Elements 2 and 3)
  - How Functionality, Operability and emergency accessibility services (IRF Elements 2, 3, and 4) support economic activity
  - Social-economic adaptations and objectives needed for a resilient community

Infrastructure Resilience Framework for Assessment, Governance and Management



Resilience Definitions

- Bruneau et al. (2003) defines resilience as the ability of social units (e.g., organizations, communities, etc.) to **mitigate hazards**, **contain the effects of disasters** when they occur, and carry out **recovery activities** in ways that **minimize social disruption** and mitigate the effects of future earthquakes [or other hazard strikes].
- Rockefeller Foundation (2018) defines resilience as the capacity to **survive, adapt, and thrive** in the face of **chronic stresses** and **acute shocks**, and even **transform** when conditions require it.
- Obama Administration (2013) defined resilience as the ability to **prepare for and adapt to changing conditions** and to **withstand and recover rapidly from disruptions**. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents.

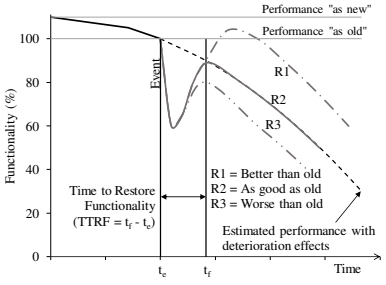
Infrastructure Resilience

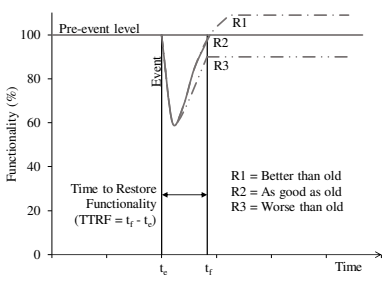
Definition *(Davis et al., 2019)*

"A resilient infrastructure system as one that is managed to provide safe and reliable services to customers, cope with chronic stressors, and accommodate hazard-related impacts with ability to continue providing services or limit service outage times tolerable for community recovery efforts."

Functionality

- Functionality (quality or performance) is the most commonly used metric for describing system resilience.
- In research and practice the term "functionality" is used in two different ways
  1. the amount of damage and system restoration through repairs
  2. loss and restoration of services provided by the system





Infrastructure Resilience Targets and Measures

- Infrastructure system functionality needs to distinguish between the time to:
  a) Return to performing its intended purpose (everything it did prior to an event), and
  b) An operational level that allows social institutions to provide services

- Social institutions include family, economic, government, health, education, community service, religious, cultural, and media organizations (NIST, 2015).
- For simple linear systems (a) and (b) may be the same.
- For large complex systems (a) and (b) may be significantly different

Infrastructure Resilience Targets and Measures

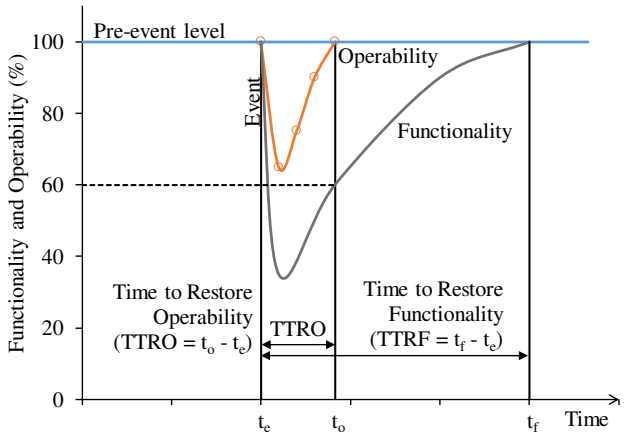
- The differences between targets (a) and (b) require 2 different measurements
  1) The performance of the entire infrastructure system serving its intended purpose at, or as close as possible to the level it did prior to an event (the percentage of the infrastructure system working at pre-event levels), and
  2) The operational level that provides infrastructure services adequate to allow social institutions to perform their functions (the percentage of customers receiving accustomed pre-event services from the infrastructure system).
- Measurements (1) and (2) have end targets (a) and (b), respectively.
- Both measurements are important to infrastructure resilience

Functionality

- The dual use of the word “Functionality” causes confusion in research and practice
- As a result, definitions for system “Functionality” and “Operability” are presented to clarify the measurements and end targets necessary for understanding infrastructure resilience

Proposed Functionality & Operability Definitions

- Functionality: The quality or state of working properly to provide a regular reliable service capable of serving the intended purpose. The regular reliable service and intended purpose are those, or as close as possible to, which the infrastructure system provided prior to an event.
- Operability: The fitness, capacity or ability to use to provide services allowing customers to receive normal, or near normal, amenities from the infrastructure system.
- Time to restore functionality (TTRF): How long it takes before an infrastructure system is functioning at a relatively constant post-event state, which may be less than or equal to the level that existed prior to the event.
- Time to restore operability (TTRO): How long it takes for customers to resume receipt of their accustomed services.



TTRO ≤ TTRF

Understanding Operability (Element 3)

- Need to classify the basic service categories the infrastructure system must provide in a disaster.
- The basic services are those adequate to allow customers and users to proceed with or resume activities in a relatively normal manner in relation to these amenities.
- The aggregate of basic services defines operability.
- The system is considered to have 100% operability when all the basic services are provided throughout the infrastructure system service areas.

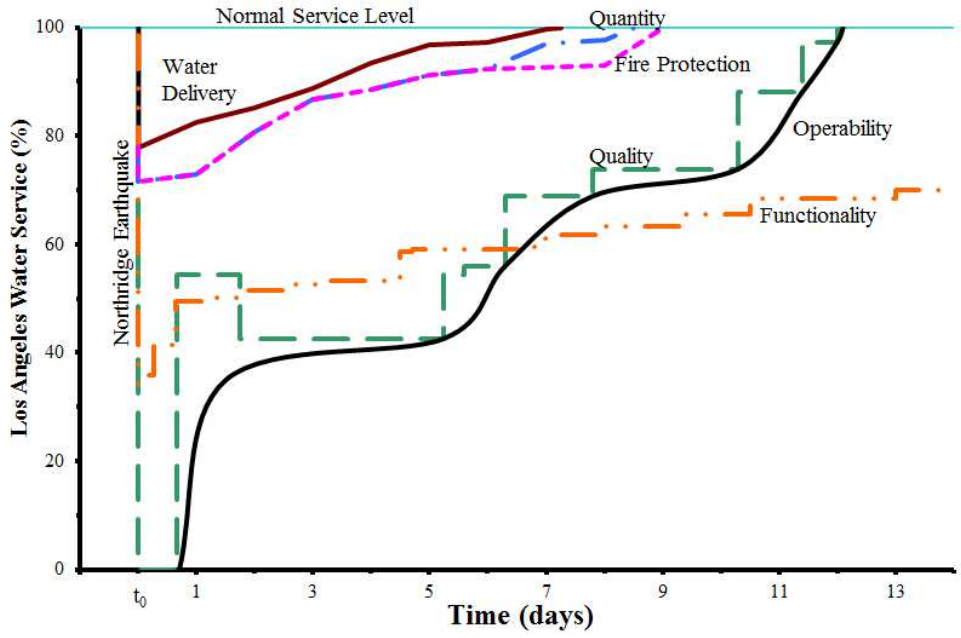
Basic Lifeline Service Categories

Lifeline System	Basic Service Category									
	Delivery	Collection	Connectivity	Quantity	Quality	Duration	Disposal	Fire Protection	Protective Barrier	Emergency
Water	X			X	X			X		
Wastewater[1]		X		X	X		X			
Inundation Protection[1]		X		X	X		X		X	
Electric Power	X			X	X					
Communications			X	X	X	X				X
Transportation			X	X	X	X				X
Gas and Liquid Fuels	X			X	X					
Solid Waste Management[1]		X		X	X		X			

Basic Lifeline Service Category Descriptions

Service Category	Description
Delivery	The system can distribute product to customers, but the product delivered may not meet quality standards, pre-event volumes (may require rationing), fire flow requirements for water systems.
Collection	The system can collect and remove waste and/or debris, but the system may not be able to treat, process, or properly dispose collected materials.
Connectivity	Connection can be made to access the system, but the transportation or communication mode may not provide the pre-event emergency, quality, volume, or timely services.
Quantity	The product can be served at pre-event demand volumes.
Quality	The product being served, or service provided when dealing with waste and disposal, meets pre-event quality standards.
Duration	The speed for transport or information transfer meets pre-event conditions, including access and transfer between modes.
Disposal	Entire collected volumes can be properly disposed, protecting the environment, and meeting public health standards.
Fire Protection	The water system can provide pressure and flow of a suitable magnitude and duration to fight fires.
Inundation Defense	The system can defend regions against inundation hazards by collecting, storing, removing, and/or providing containment and barriers to protect life and property, but some regions may be more vulnerable to inundation than prior to the event.
Emergency	The mode is capable of handling and connecting emergency calls and transport but may require removing other non-emergency services.

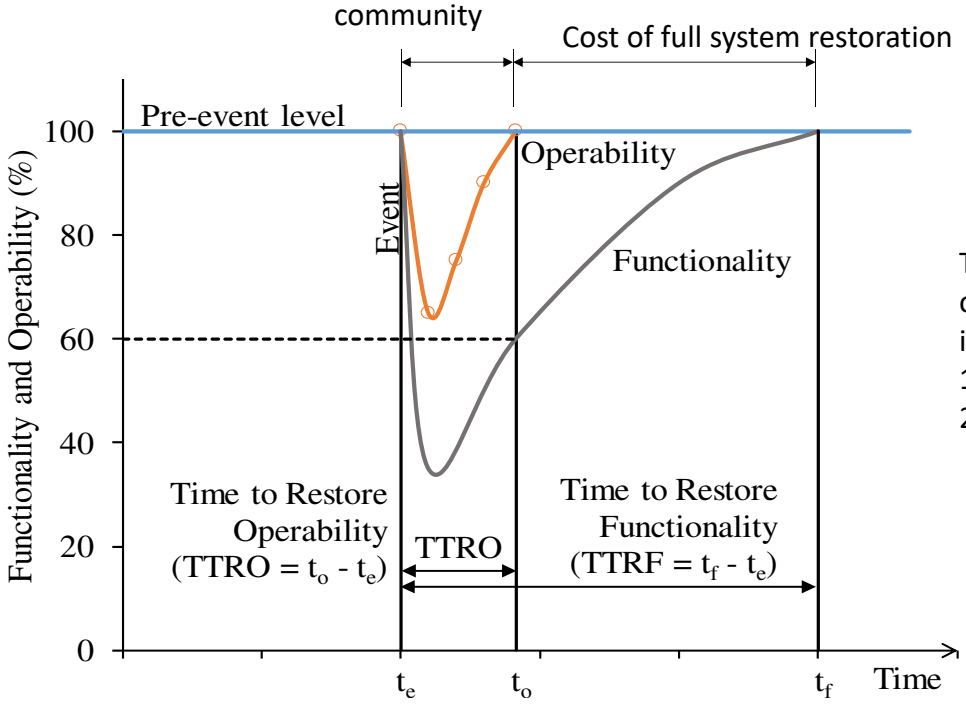
Example Operability for Potable Water System Los Angeles Water System 1994 Earthquake



Basic Building Cluster Service Categories

- Most buildings provide the following basic service categories:
  - Shelter (occupiable and having protection against external elements),
  - Safety and security, and
  - Space for social institutions to undertake their functions and provide services.
    - Many social functions require
      - climate and air quality controls (e.g., heating, ventilation, air conditioning),
      - sanitation,
      - energy,
      - connectivity (communication and transportation) with others, and
      - additional non-structural elements (including equipment, storage, etc.).
    - The building space is used for countless activities

1. Emergency Accessibility Services (Element 4)
2. Economic losses to community



The functionality and operability of each system inherently includes:

1. Cascading effects, and
2. dependencies on other infrastructure systems

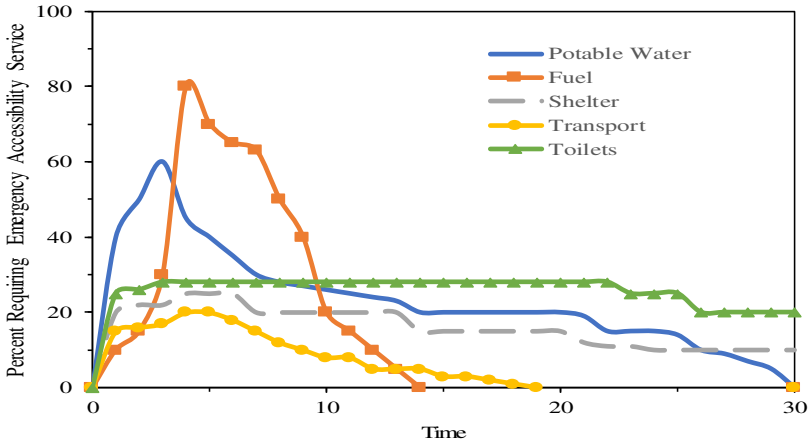
Emergency Accessibility Services

- When services are not provided in a disaster by normal means, there needs to be an alternate way to get the community access to basic services
- System owners and operators have a responsibility for informing the community of expected loss and duration of restoration (TTRO) for the basic services relative to different hazard levels
- If basic services are not provided to the community within the needed amount of time, then people will depart the area/region
- **Mass departure has serios social impact and significant effects to regional economics**

Emergency Accessibility Services

- Examples include
  - Emergency shelter
  - Bottled water
  - Electric power generator
  - Portable toiles

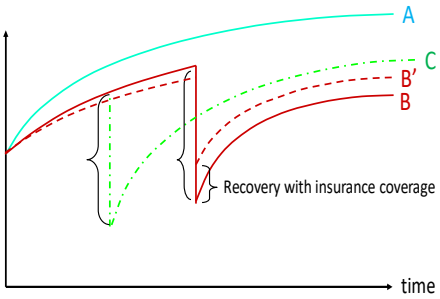


- Community is also responsible for preparing for service losses
  - Best if they have an understanding on what to expect

Social-Economic Adaptations and Objectives

- Objectives are to survive disaster with minimal impacts, and possibly even thrive. Examples of preparedness include:
  - Organizational resilience
  - Business continuity
  - Insurance
- Relative to infrastructure system service losses
  - Store essential needs (water, food, medicine, etc.)
  - After event, defer production
  - Work multiple shifts
  - Identify redundant sources
- These are just examples, there are numerous other adaptations individuals and businesses can undertake to be resilient



Conclusions

- Important to understand difference between system Functionality and Operability
  - New definitions presented to improve understanding and measuring of infrastructure resilience
- Need to define basic services provided by each infrastructure system
  - Common examples presented for use
  - Aggregate of these services define operability
- Infrastructure system owners and operators need to inform the community of potential amount of service losses and duration to restore relative to different hazard levels
- Community and infrastructure systems work together to provide emergency accessibility services until normal services restored
- Regional social and economic losses can be contained to acceptable levels with proper planning and personal and business level adaptations with input from infrastructure service providers