BUILDING INNOVATION
Conference

Developing and Implementing Functional Recovery Framework for Lifeline Infrastructure Systems

Moderator:

Ronald T. Eguchi

Presenters:

Craig A. Davis

Katherine J. Johnson

Ayse Hortacsu

Kent Yu

Session Agenda (9:20am – 10:15am)

1. An Implementation Example of Oregon Resilience Plan for Functional Recovery
   - Kent Yu, SEFT Consulting
2. Developing Capacity for Collaborative Progress
   - Katherine J. Johnson, National Institute of Standards and Technology
3. Designing Lifeline Infrastructure Systems for Post-earthquake Recovery
   - Craig Davis, C.A. Davis Engineering
4. Strategies for Resilient Infrastructure
   - Ayse Hortacsu, Applied Technology Council
5. Audience Q+A

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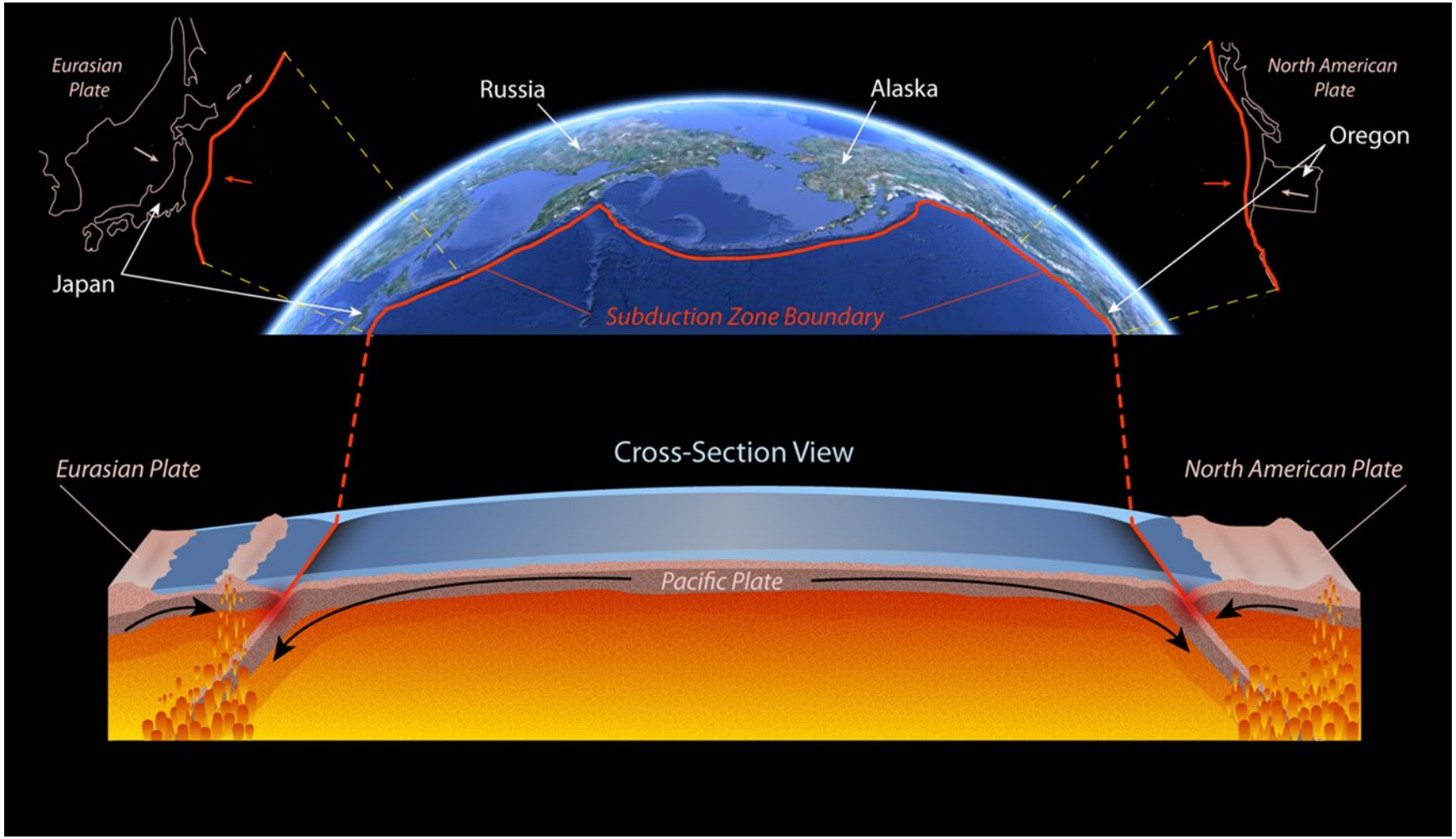
An Implementation Example of Oregon Resilience Plan for Functional Recovery

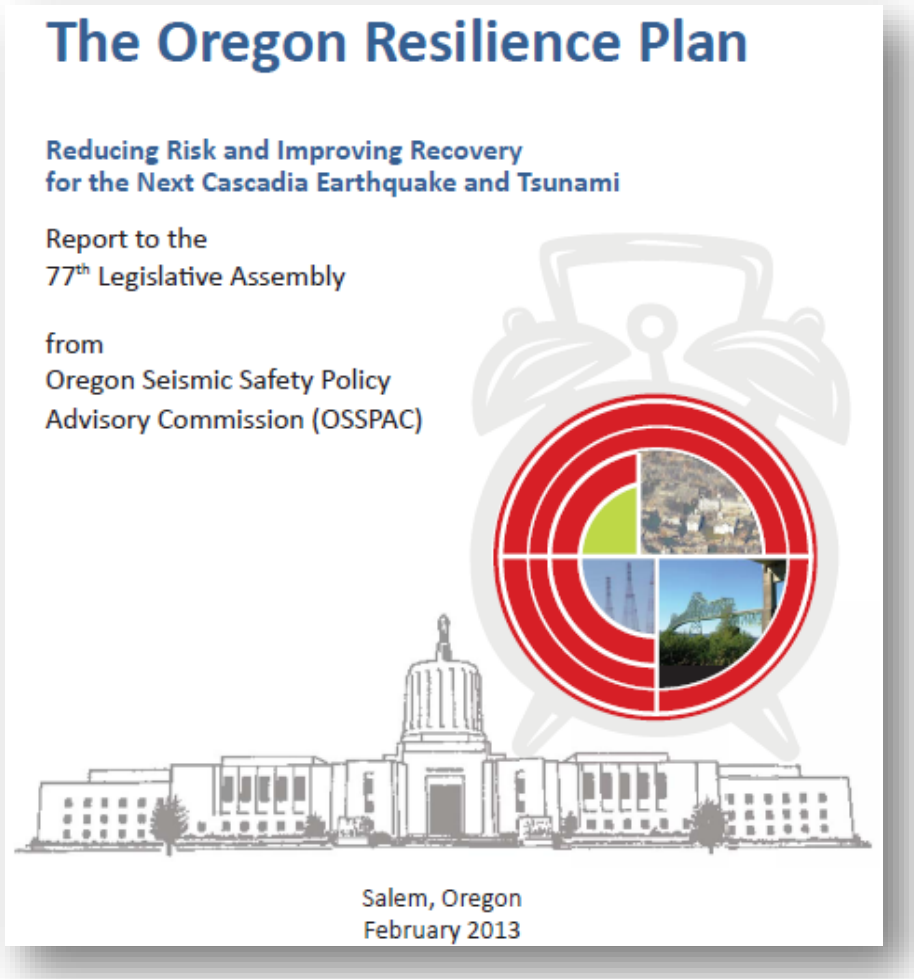
Kent Yu, PhD, PE, SE

SEFT Consulting Group

Cascadia Subduction Zone



Oregon Resilience Plan



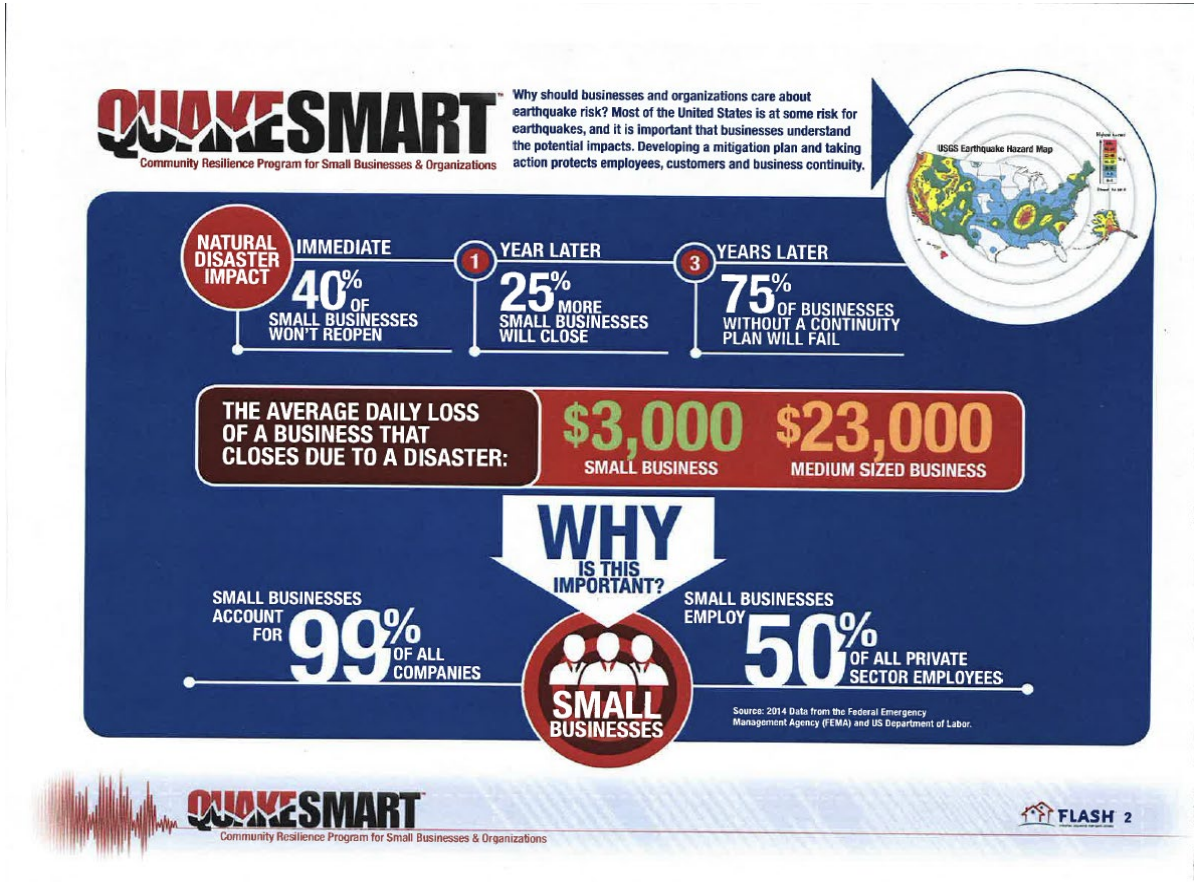
50-year Comprehensive Plan

- ❑ **Cascadia Earthquake Scenario**
- ❑ **Business/Workforce Continuity**
- ❑ **Coastal Communities**
- ❑ **Critical & Essential Buildings**
- ❑ **Transportation**
- ❑ **Energy**
- ❑ **Information and Communication**
- ❑ **Water & Wastewater**

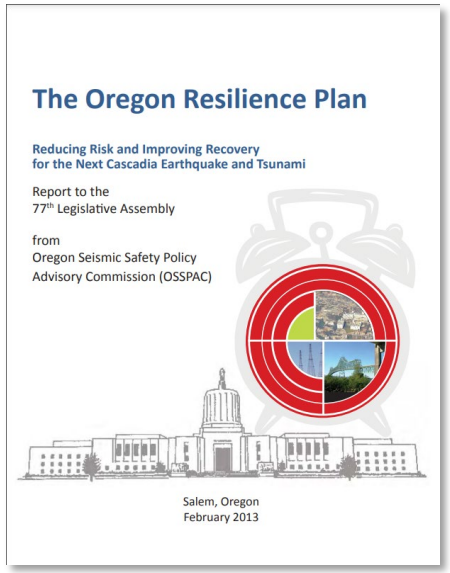
(*Download it from* http://www.oregon.gov/OMD/OEM/osspac/docs/Oregon_Resilience_Plan_Final.pdf)

Business and Workforce Continuity

- Business can only tolerate two to four weeks of disruption of essential services



Significant Resilience Gaps



Critical Services	Zone	Estimated Average Recovery Time
Electricity	Valley	1 to 3 months
Drinking Water	Valley	6 months to 1 year
Sewer	Valley	1 to 3 years +
Top-priority highways (partial restoration)	Valley	6 to 12 months

Critical Building Category	Zone	Estimated Average Recovery Time	Resilience Target
Healthcare Facilities	Valley	18 months	Immediate
Police and Fire Stations	Valley	2 to 4 months	Immediate
Emergency Shelters	Valley	18 months	72 hours
K-8	Valley	18 months	30 days
High Schools	Valley	18 months	30 days

ORP Level of Service Goals for Water

Event Occurs

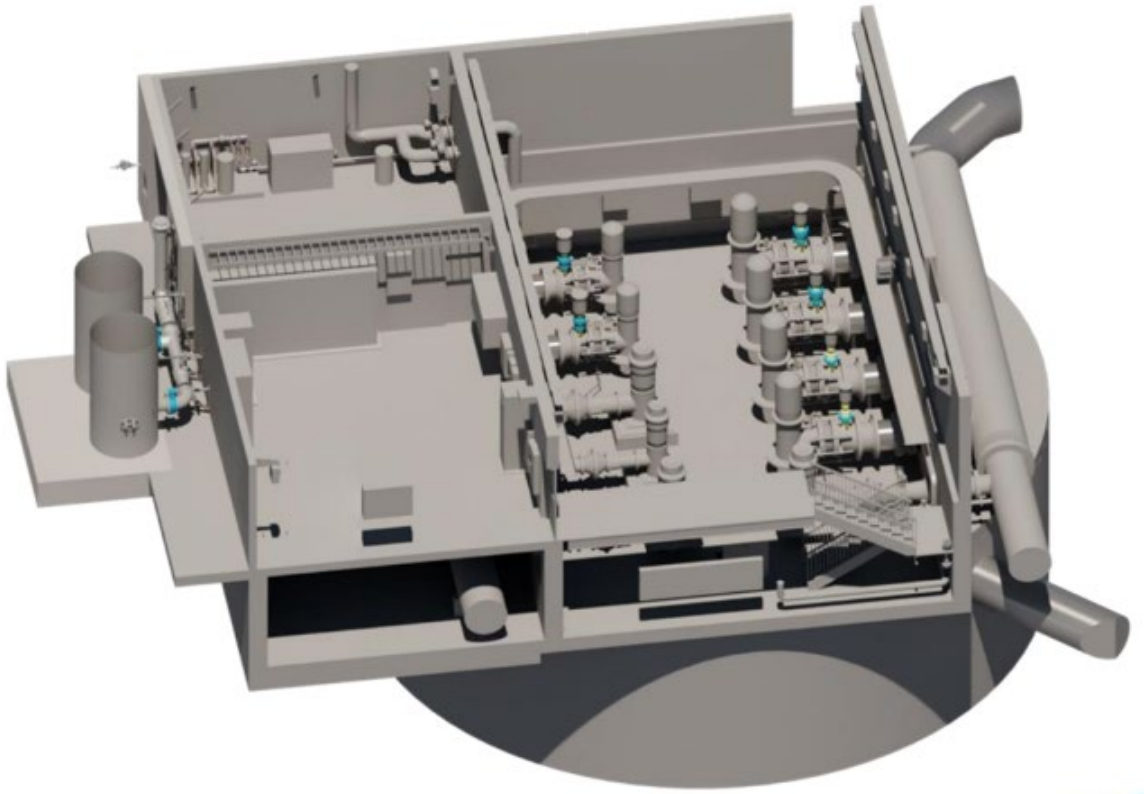
	0-24 Hours	1-3 Days	3-7 Days	1-2 Weeks	2-4 Weeks	1-3 Months	3-6 Months	6-12 Months
Potable water available at supply source (WTP, wells, impoundment)	R	Y		G			X	
Main transmission facilities, pipes, pump stations, and reservoirs (backbone) operational	G					X		
Water supply to critical facilities available	Y	G				X		
Water for fire suppression – at key supply points	G		X					
Water for fire suppression – at fire hydrants			R	Y	G			X
Water available at community distribution centers/points		Y	G	X				
Distribution system operational		R	Y	G				X

Legend:

80-90% Operational	G
50-60% Operational	Y
20-30% Operational	R
Current State/90% Operational	X

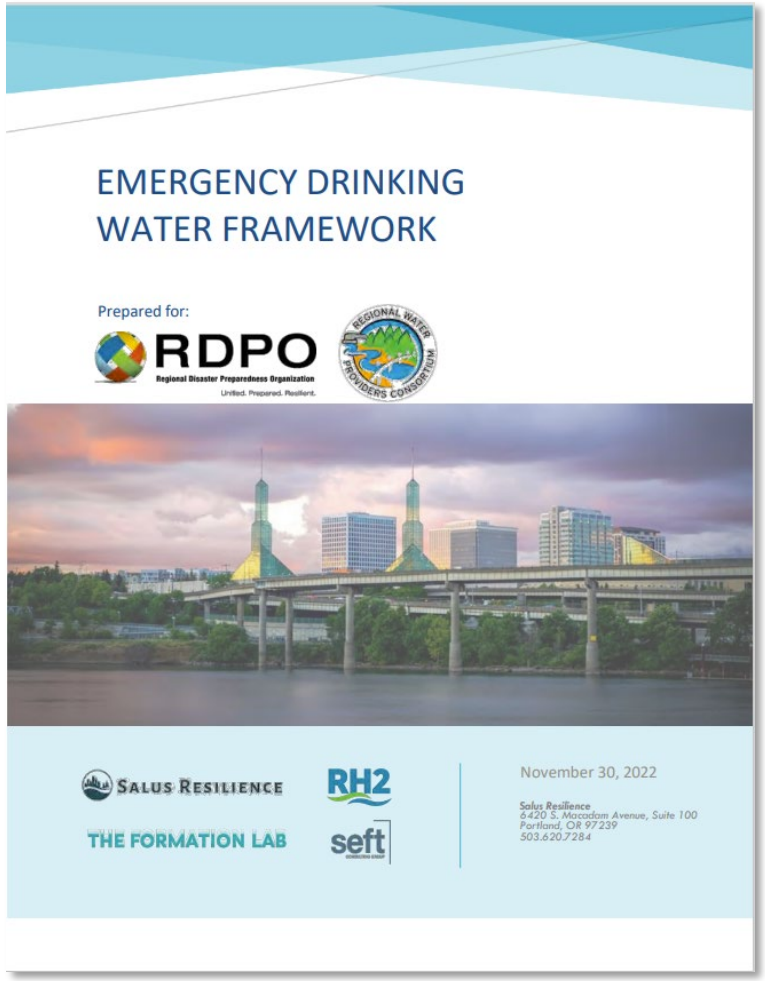
Raw Water Intake Pump Station

1. Performance Objective
   - Operational at 2,500-year Earthquake Hazard
2. Foundation
3. Buried Pipelines
4. Structural
5. Nonstructural
   - Seismic Certification
   - Seismic Bracing and anchorage
6. Dependencies
   - Local lifelines coordination

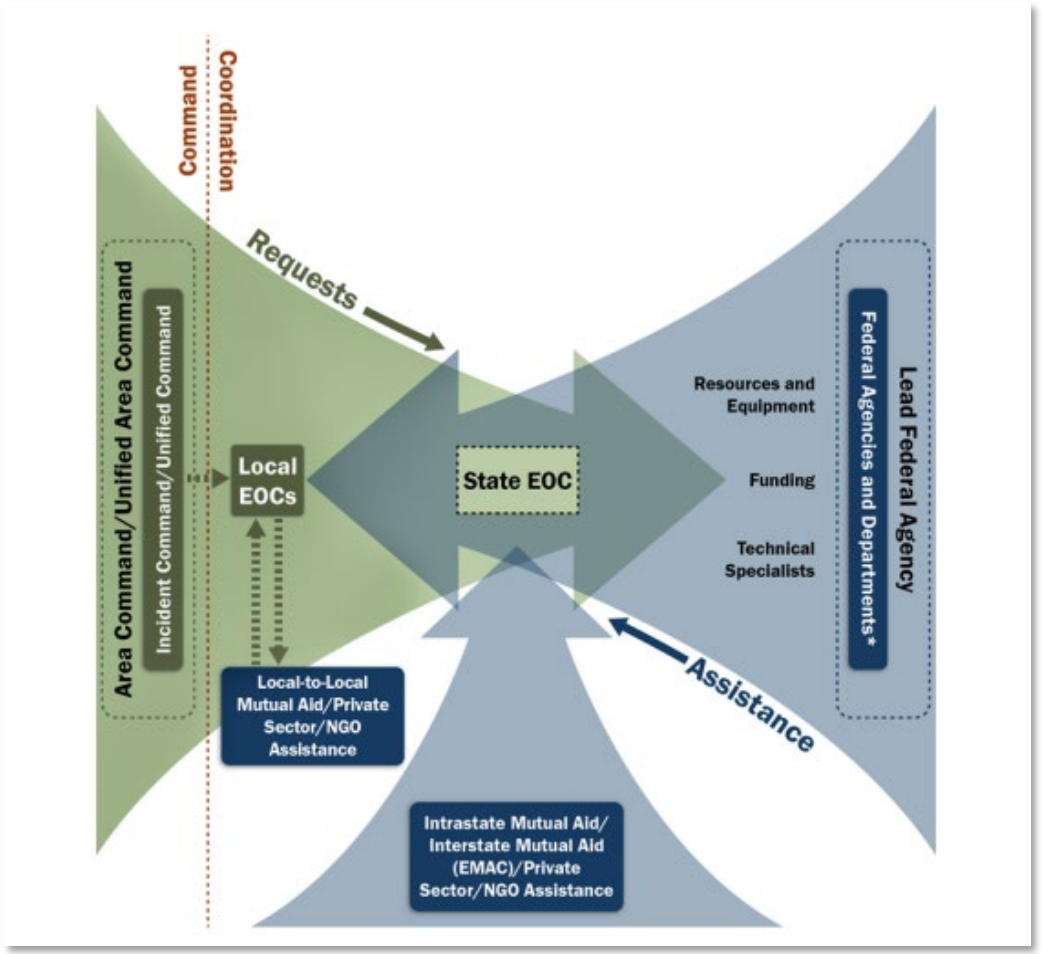


Source: Mike Britch, TVWD

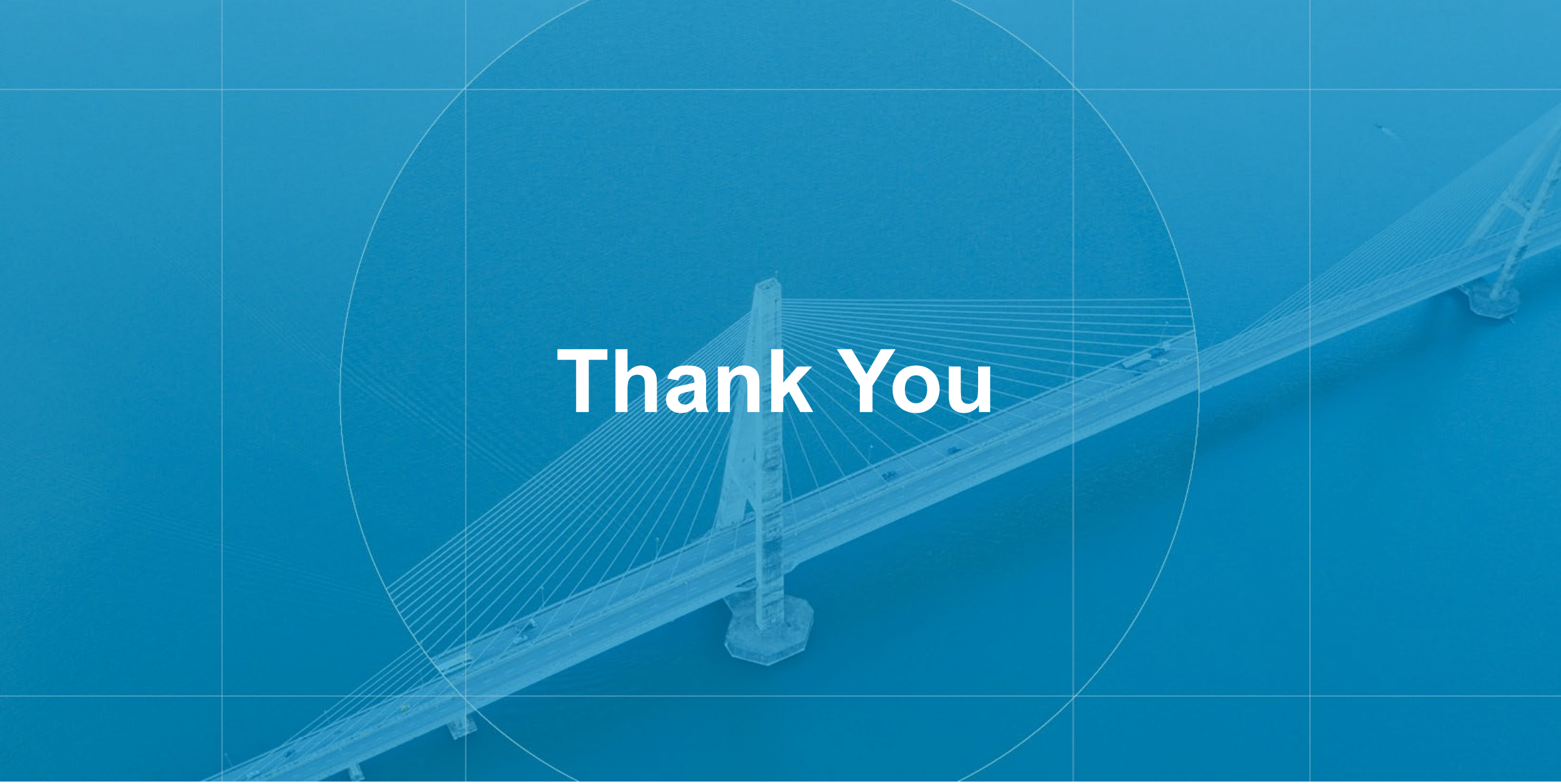
Portland Metro Emergency Drink Water Framework



2022



Source: National Incident Management System (2017)



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Developing Capacity for Collaborative Progress

Katherine J. Johnson, Social Scientist, National Institute of Standards and Technology **(NIST)**

May 20, 2025

Session: "*Developing and Implementing Functional Recovery Framework for Lifeline Infrastructure Systems*"

Co-Presenters: Craig A. Davis, Kent Yu, Ayse Hortacsu

Moderator: Ron Eguchi

Leading up to today:

AmericanLifelinesAlliance

A public-private partnership to reduce risk to utility and transportation systems from natural hazards and manmade threats

Protecting Our Critical Infrastructure: Findings and Recommendations from the American Lifelines Alliance Roundtable

2005
(est. 1998)

National Institute of Building Sciences
Washington, D.C.
2005

National Earthquake Resilience

RESEARCH, IMPLEMENTATION, AND OUTREACH

2011

NATIONAL RESEARCH COUNCIL

NIST Technical Note 1795

Developing Guidelines and Standards for Disaster Resilience of the Built Environment: A Research Needs Assessment

Therese McAllister

http://dx.doi.org/10.6028/NIST.TN.1795

2013

NIST National Institute of Standards and Technology U.S. Department of Commerce

NIST GCR 14-917-33

Earthquake-Resilient Lifelines: NEHRP Research, Development and Implementation Roadmap

NEHRP Consultants Joint Venture
A partnership of the Applied Technology Council and the Consortium of Universities for Research in Earthquake Engineering

2014

nehrp

NIST National Institute of Standards and Technology U.S. Department of Commerce

NIST GCR 16-917-39

Critical Assessment of Lifeline System Performance: Understanding Societal Needs in Disaster Recovery

By
Applied Technology Council

This publication is available free of charge from:
http://dx.doi.org/10.6028/NIST.GCR.16-917-39

2016

nehrp

Community Resilience

NIST National Institute of Standards and Technology U.S. Department of Commerce

SIX-STEP PROCESS TO PLANNING FOR COMMUNITY RESILIENCE

1. FORM A COLLABORATIVE PLANNING TEAM
- Identify leader
- Identify team members
- Identify key stakeholders

2. UNDERSTAND THE SITUATION

Social Dimensions
- Characterize social functions & dependencies
- Identify support by built environment
- Identify key contacts

Built Environment
- Identify and characterize built environment
- Identify key contacts
- Identify existing community plans

Link Social Functions & Built Environment
- Define clusters

3. DETERMINE GOALS & OBJECTIVES
- Establish long-term community goals
- Establish performance goals
- Define community hazards
- Determine anticipated performance
- Summarize results

4. PLAN DEVELOPMENT
- Evaluate gaps
- Identify solutions
- Develop implementation strategy

5. PLAN PREPARATION, REVIEW, AND APPROVAL
- Document plan and strategy
- Obtain feedback and approval
- Finalize and approve plan

6. PLAN IMPLEMENTATION AND MAINTENANCE
- Execute approved solutions
- Evaluate and update
- Modify strategy as needed

2015

NIST Author Manuscript

NIST Author Manuscript

NIST Author Manuscript

Author Manuscript

Accepted for publication in a peer-reviewed journal

NIST National Institute of Standards and Technology • U.S. Department of Commerce

Published in final edited form as:
Bridge (Wash D C). 2019 July 01; 49(2): 34–42.

Increasing Community Resilience Through Improved Lifeline Infrastructure Performance

2019

Christopher Rojahn,
Laurie Johnson,
Thomas D. O'Rourke,
Veronica Cedillos,
Therese P. McAllister,
Steven L. McCabe

Christopher Rojahn is director emeritus of the Applied Technology Council (ATC). Laurie Johnson is principal, Laurie Johnson Consulting | Research. Thomas O'Rourke (NAE) is the Thomas R. Briggs Professor of Civil and Environmental Engineering in the College of Engineering at Cornell University. Veronica Cedillos is president and CEO of GeoHazards International (GHI). Therese McAllister is leader of the Community Resilience Group and Steven McCabe is leader of the Earthquake Engineering Group, both at the National Institute of Standards and Technology (NIST).

Abstract

The concept of community resilience is complex and multidimensional, relying on engineering and other disciplines to help communities break the cycle of destruction and recovery and reduce the impacts of earthquakes and other hazards. This article presents proposed prioritized actions to improve lifeline infrastructure resilience based on an assessment of lifeline infrastructure performance commissioned and funded by the National Institute of Standards and Technology (NIST).

Introduction

Resilience involves the ability of people and communities to adapt to changing conditions and to withstand and rapidly recover from disruptions (White House 2011). At the community level, this concept is complex and multidimensional, relying on contributions from the social sciences, engineering, earth sciences, economics, and other disciplines to improve the ways communities prepare for, resist, respond to, and recover from disruptions due to either natural hazards or manmade causes. Resilience is intended to reduce both the impact of hazards by restoring community functions within a specified timeframe and the duration and cost of recovery. This requires planning for recovery and restoration prior to hazard events.

Disasters interfere with electric power, natural gas and liquid fuel, telecommunications, transportation, and water and wastewater infrastructure systems. Such systems are commonly referred to as "lifelines" because they are vital for the economic well-being, security, and social fabric of the people they serve (NIST 2014).

Check for updates

NIST Special Publication NIST SP 1295

NIST Transportation Systems and Functional Recovery Workshop Report

Christine Z. Beyzaei
Katherine J. Johnson
Sissy Nikolaou
Siamak Sattar
Jazalyn Dukes
Yalda Saadat

This publication is available free of charge from:
https://doi.org/10.6028/NIST.SP.1295

2023

Check for updates

NIST Grant/Contractor Report NIST GCR 23-037

Resilience for Critical Facilities

Donald R. Scott
A. Christopher Cerino
Robert G. Pekelnicky
Kent Yu

This publication is available free of charge from:
https://doi.org/10.6028/NIST.GCR.23-037

2023

National Institute of BUILDING SCIENCES

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AGING INFRASTRUCTURE REQUIRES NATIONAL PUSH FOR LIFELINE RESILIENCE

Friday, June 7, 2024

National Institute of Building Sciences Lifeline Infrastructure Hub to Advance Community Resilience and Recovery after Disasters

(WASHINGTON, DC, June 6, 2024) – The National Institute of Building Sciences (NIBS) is leading the charge to fortify the nation's resilience to climate-related disasters.

The NIBS Lifeline Infrastructure Hub recently held its inaugural meeting at the National Press Club attended by leaders from 35 organizations, including the White House, Congress, federal agencies, engineering community, business and academia, to assess the state of the nation's lifelines infrastructure resilience.

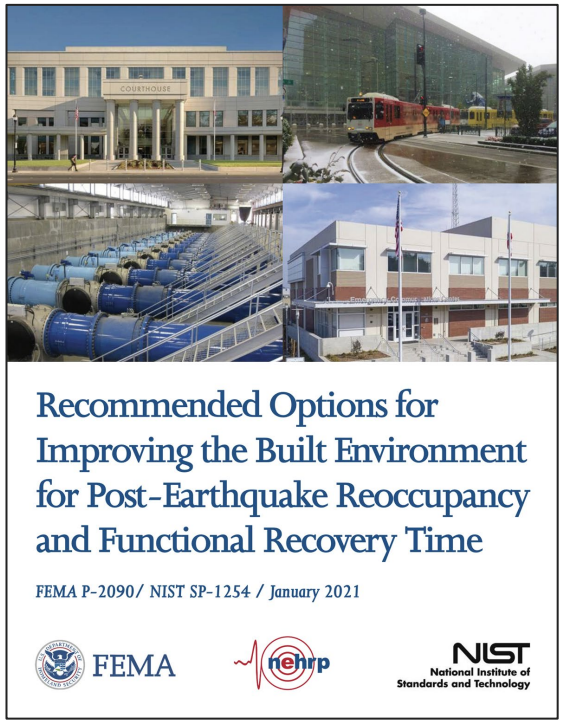
"Lifeline infrastructure is complicated and complex," said NIBS Interim President & CEO Stephen T. Ayers. "This needs to be a national collaboration across sectors and address multiple hazards. We invite all to join and support this important effort."

In April, the White House issued National Security Memorandum/NSM-22, urging immediate action to address critical national security concerns. The memorandum highlights the essential role of lifeline infrastructure in maintaining national security and calls for enhanced measures to protect and strengthen these vital systems.

"Enhancing our lifeline infrastructure not only protects people and supports our economy, it is also a national security priority," said Caitlin A. Durkovich, with the National Security Council at the White House. "With our nation's generational investment in critical infrastructure, we need to act now and the NIBS Lifeline Infrastructure Hub is a timely and needed

2024

Congressional Report & Focus on Target Recovery Times



2021

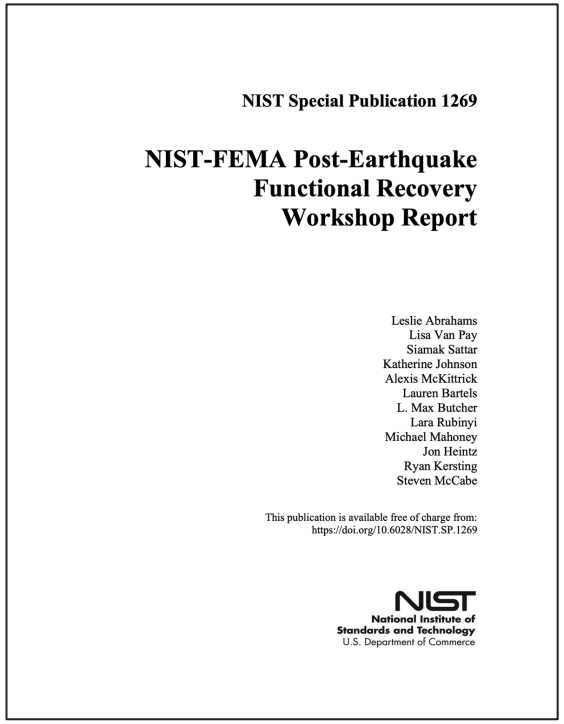


Table 2. Distribution of the Acceptable Recovery Times for Generalized Community Functions across All Workshop Breakout Groups.

Generalized Community Function	Hours	Days	Weeks	Months
Public Health and Safety				
Telecommunications/Information				
Healthcare				
Transportation Services				
Shelter/Housing				
Energy/Electricity				
Food and Water Resources				
Local Economy/Jobs				
Governance				
Entertainment/Recreation				
Social Support				
Education				
Cultural Identity				

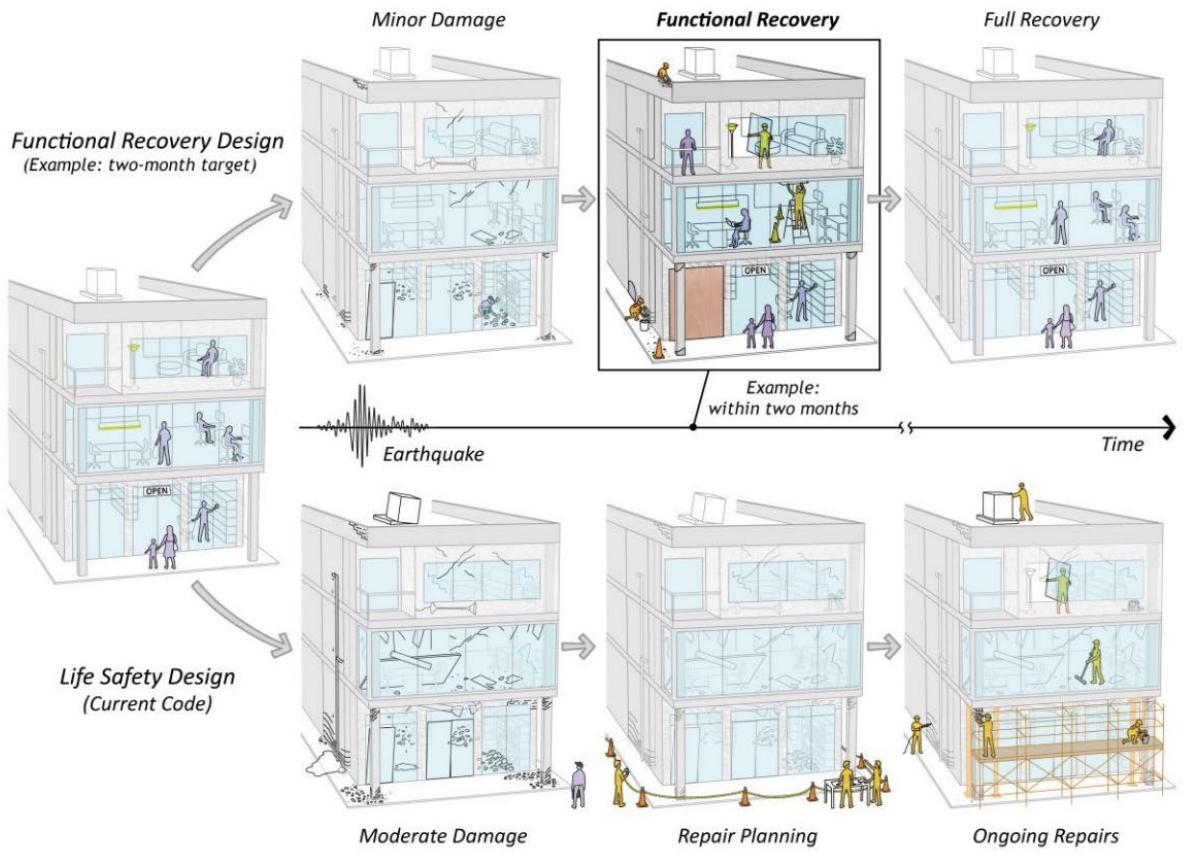
0 25

Darker color corresponds to the most often selected time category for a component that supports the generalized community function listed.

From NIST SP 1269

Functional Recovery at the Asset Scale

➢ *Design* enables an <u>asset</u> to be occupied and repaired/ reused more quickly than current code



Scenario Illustrating Functional Recovery Performance Compared to Life Safety Design

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY U.S. DEPARTMENT OF COMMERCE

Aher Structural Graphics

From NIST RB 4r1

Definitions of Functional Recovery *(emphasis for lifelines)*

- {basic intended functions or} basic services are *less than full pre-earthquake functionality, but more than what would be considered the minimum functionally sufficient {for reoccupancy of buildings, or} for temporary provision of lifeline services*

- the {building or} lifeline can be *maintained, or restored, to safely and adequately support {the basic intended functions, or} the basic services associated with {the pre-earthquake use or occupancy of a building, or} the pre-earthquake service level of a lifeline infrastructure system*

Developed from NIST SP 1254 and NIST SP 1310

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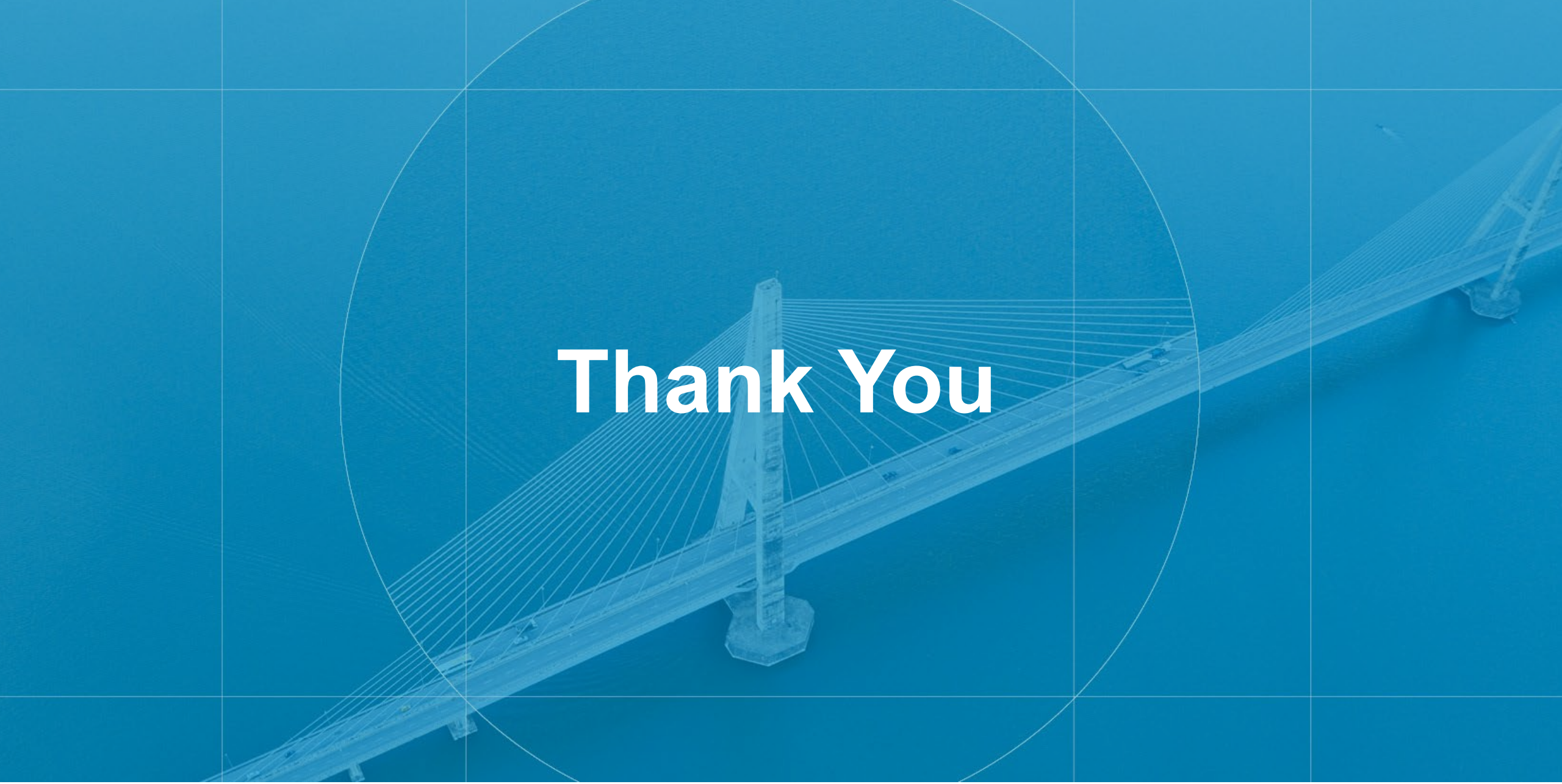
Ongoing Efforts

- Participating in NIBS Lifeline Infrastructure Hub
- Continuing work to implement the **Initial Framework for Lifelines Functional Recovery**
- Research and production of tools to support decision-making related to risk-reduction investments: TRIP$

Forthcoming Report
(expected July 2025)

Functional Recovery Performance Targets Workshop Report

Provides additional insights on "need-by" timeframes for functional recovery of functions/services by subject matter experts



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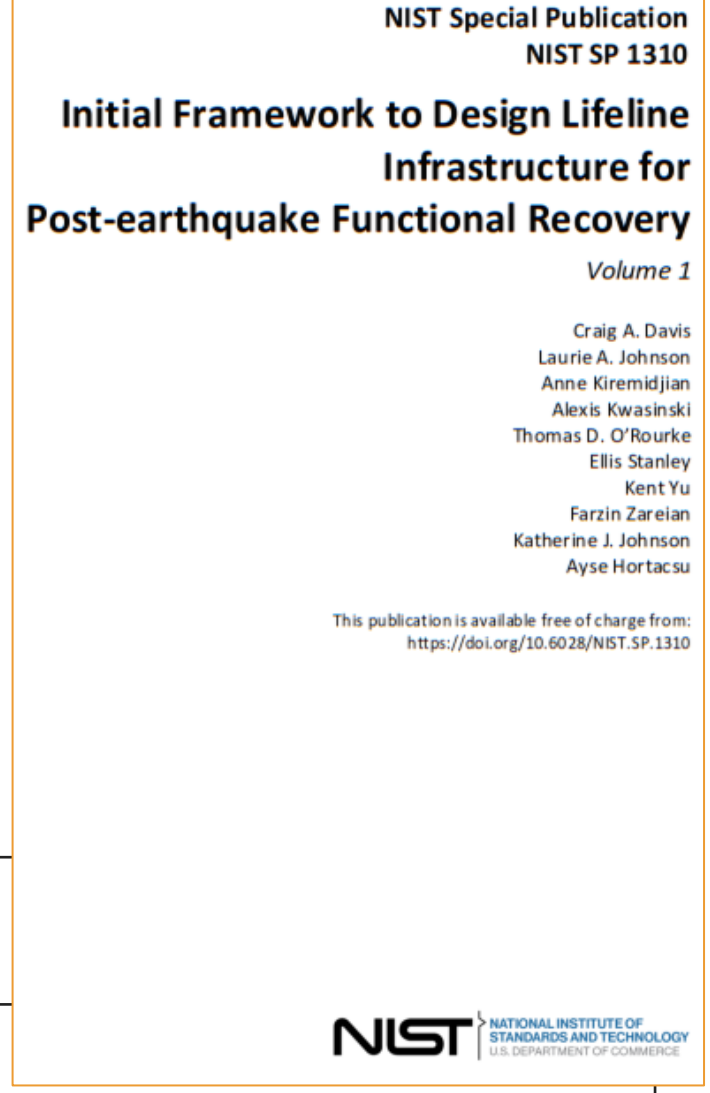
Designing Lifeline Infrastructure Systems for Post-Earthquake Recovery

Craig Davis, C. A. Davis Engineering

Katherine (Jo) Johnson, National Institute of Standards and Technology

Ayse Hortacsu, Applied Technology Council

NIST SP 1310 & 1311 “Initial Framework to Design Lifeline Infrastructure for Post-Earthquake Functional Recovery” Published March 2024

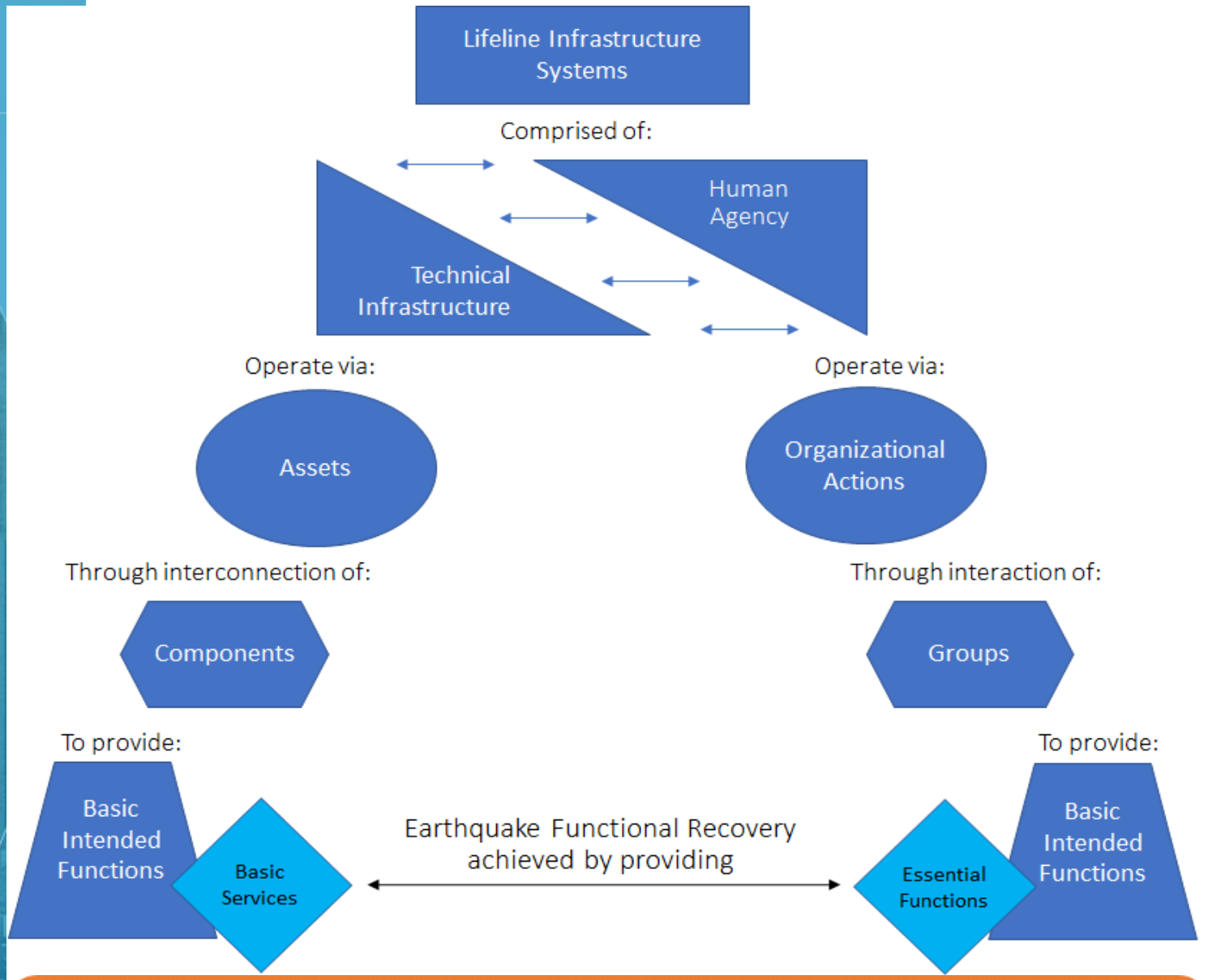


NIST project funding & guidance	Katherine (Jo) Johnson
Applied Technology Council	Ayse Hortacsu, Project Manager
Project Technical Committee	Craig Davis, Laurie A. Johnson, Anne Kiremidjian, Alexis Kwasinski, Thomas D. O’Rourke, Ellis Stanley, Kent Yu, Farzin Zareian
Project Review Panel	Don Cutler, Leon Kempner, Ryan Kersting, Katie Miller

Process Summary
Applicable to all Lifeline Infrastructure Systems

- After deciding to address functional recovery,
- Identify the basic service recovery time objectives
- Design each component to withstand levels of damage against the seismic hazards to which they are exposed (e.g., shaking, landslide, liquefaction, …)
- Prepare organizational policies and strategies to meet the targeted objectives
- The components making up the supply/collection chain to the more critical customers are designed to have lower possibility of damage
- Component and system-level performance incorporates the dependencies upon services from other systems
- Perform an assessment of the system, including recovery modeling, to determine if the objectives can be met
  - If not, make changes
  - If so, the component and system designs + organizational/group policies and strategies are assumed to be sufficient

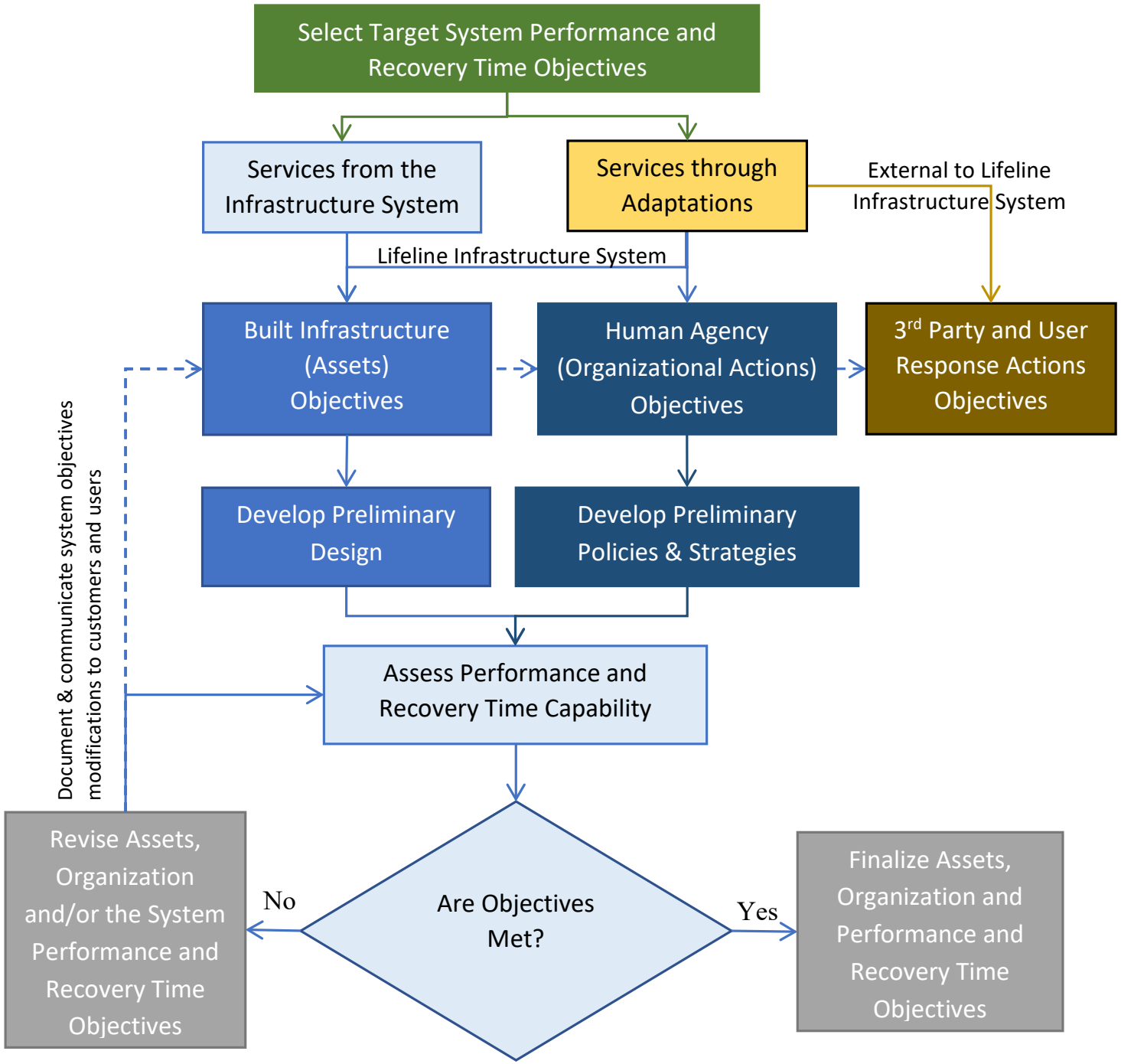
Prepare the systems to Meet Recovery Objectives Through Physical Assets and Organizational Actions Using Performance-Based Procedures



The effectiveness of assets and organizations to provide basic services and essential functions depends on performance of the **designs** and **plans** in the face of earthquake-induced **damage** and **disruption**.

NIST SP 1310

May 17, 2025



Performance-Based Procedures for Assets and Organizational Actions

Recovery Based Objectives

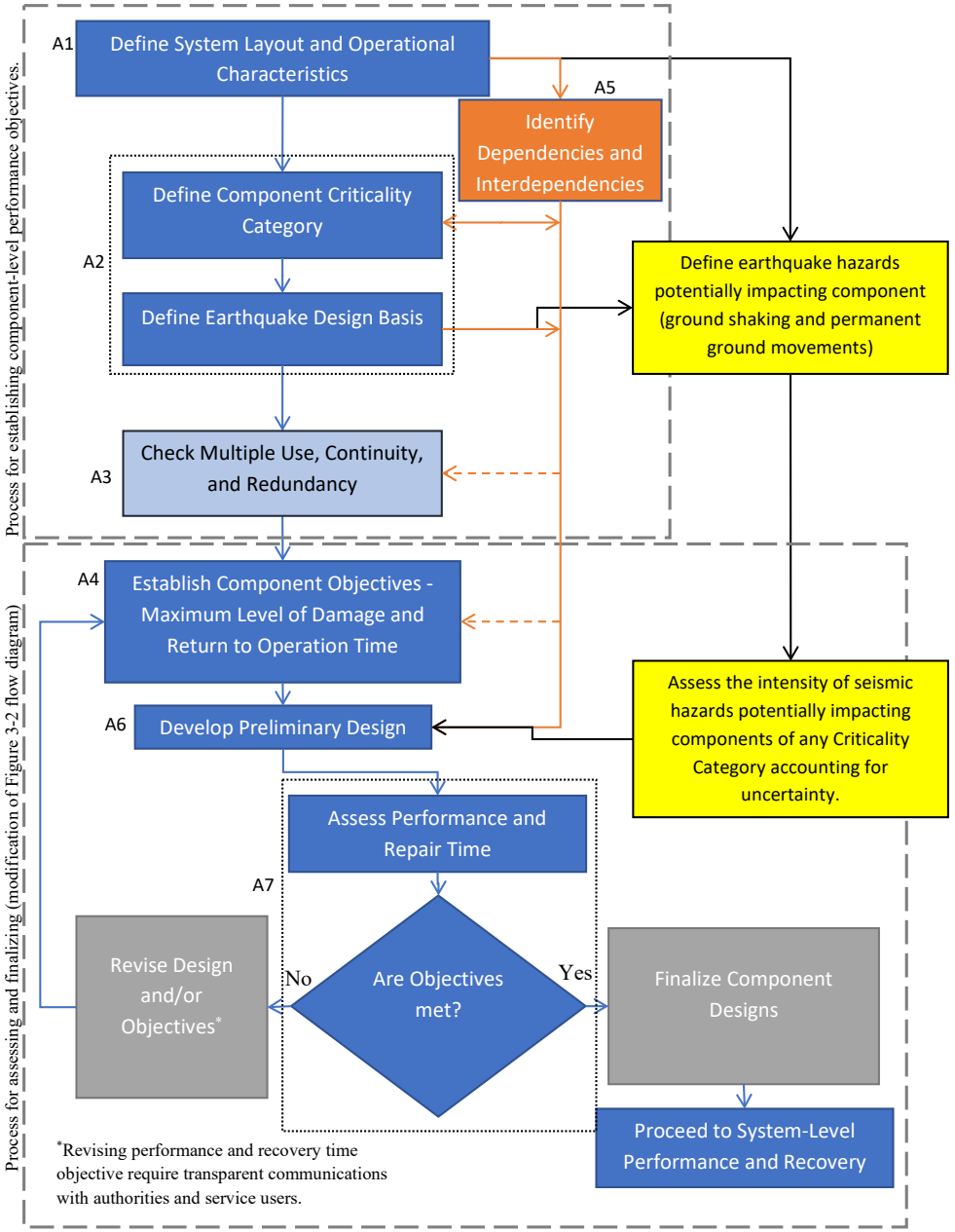
The basic service recovery objectives

- defined by the needs of the communities served, not from the existing lifeline infrastructure layout or functionality.
- Establish the future resilience improvements in the systems

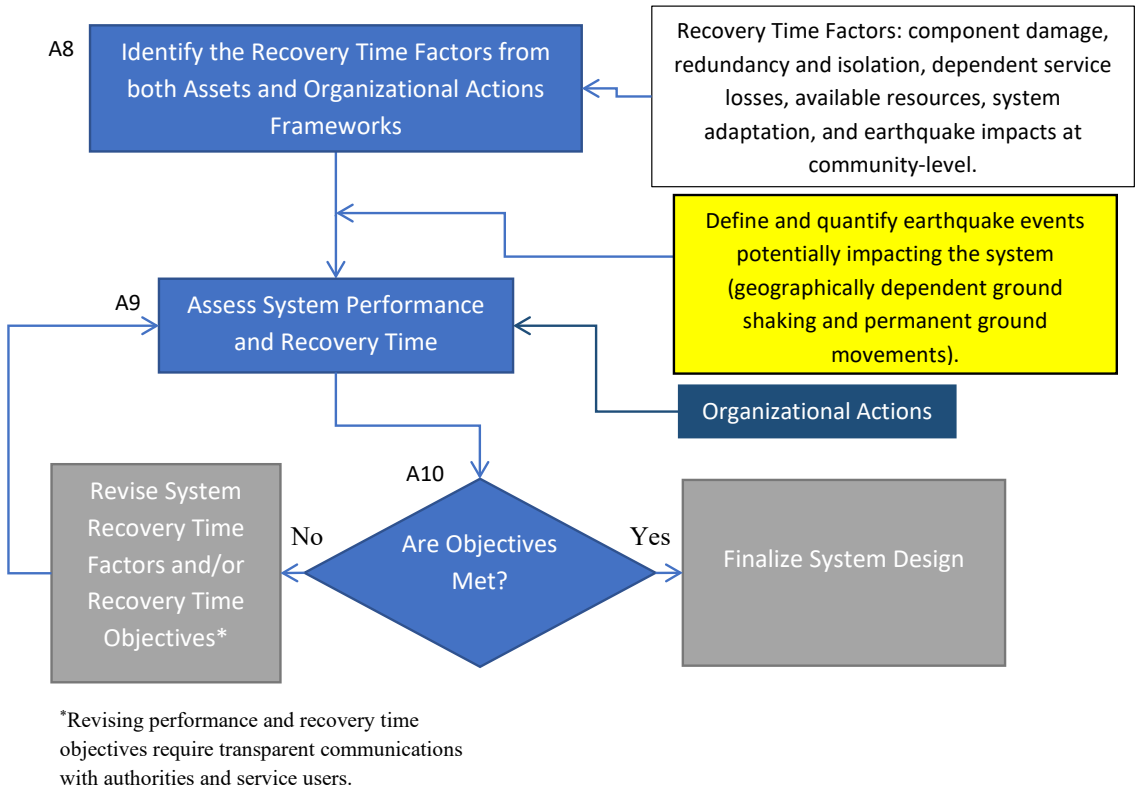
FEMA report P-2234 (soon to be published) provides a methodology to identify target basic service recovery objectives for user types with consideration of necessary user adaptations.

Assets Framework

Component-level design process flow



System-level assessment validation process



*Revising performance and recovery time objectives require transparent communications with authorities and service users.

See NIST SP 1310 for more description

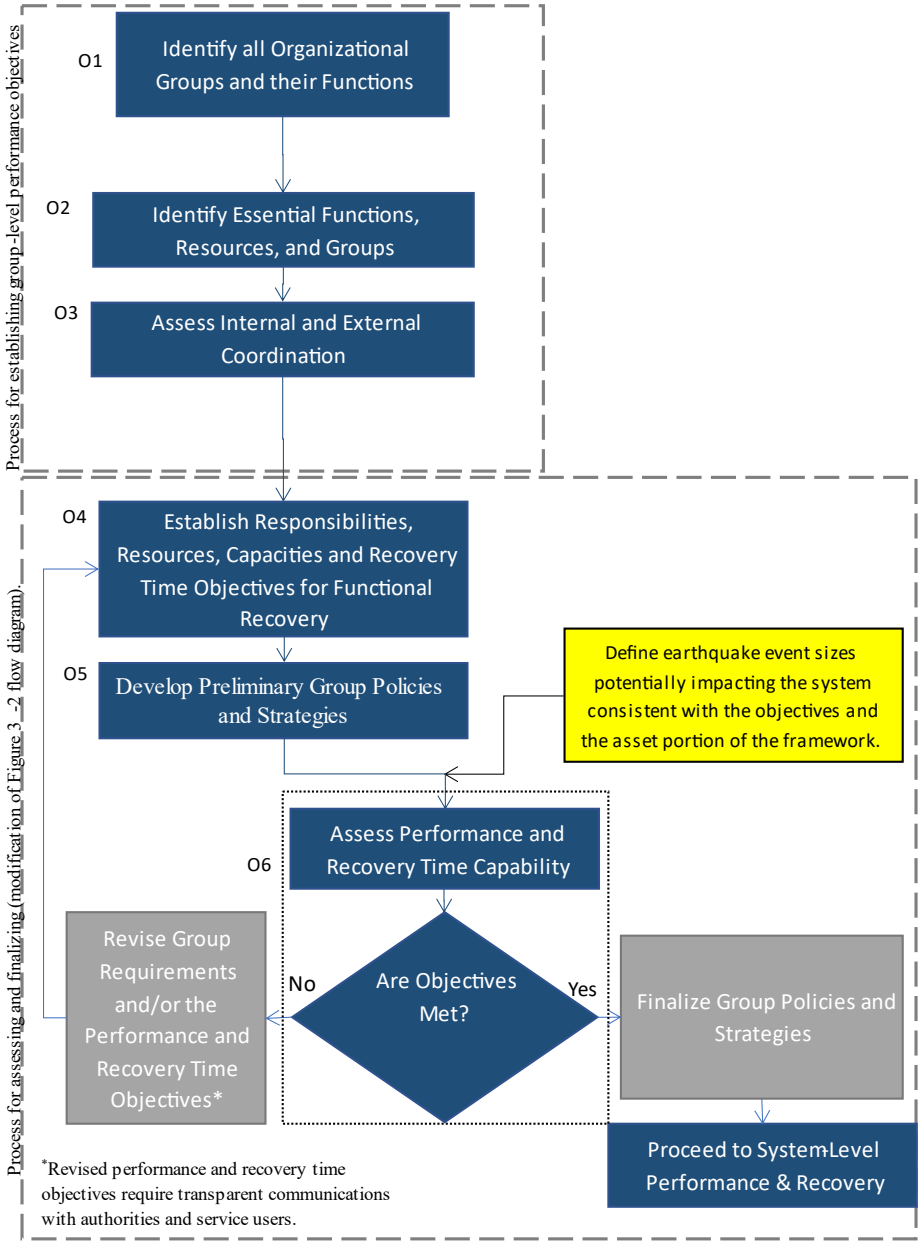
- The System is to be designed to meet targeted objectives
- Components are designed to prepare the system to meet the targeted objectives

NIST (2024) Steps for Assets Framework

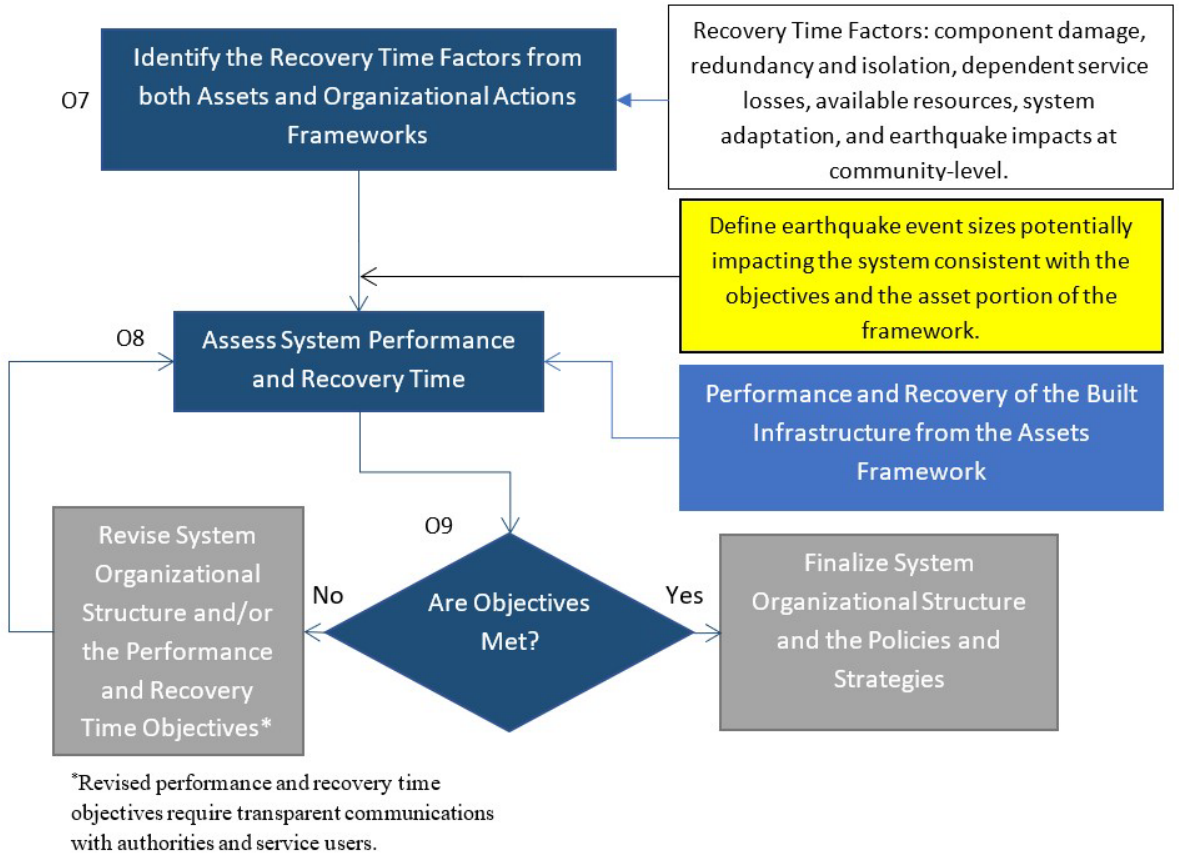
- Step A1: Define System Layout and Operational Characteristics
- Step A2: Define Criticality Category and Earthquake Design Basis for System Components
- Step A3: Check Multiple Use, Continuity, and Redundancy
- Step A4: Establish Component Objectives - Maximum Level of Damage and Repair Time
- Step A5: Identify Dependent Services
- Step A6: Develop Preliminary Design
- Step A7: Assess the Component Performance and Repair Time, Compare with Target Objectives
- Step A8: Identify Recovery Time Factors
- Step A9: Assess System Performance and Recovery Time
- Step A10: Compare System Assessment Results with Target Objectives
- Step A11: Report System Assessment Results

Organizational Actions Framework

Group-level design process flow



System-level assessment validation process



See NIST SP 1310 for more description

- The System is to be designed to meet targeted objectives
- Group policies and procedures are to prepare the system to meet the targeted objectives

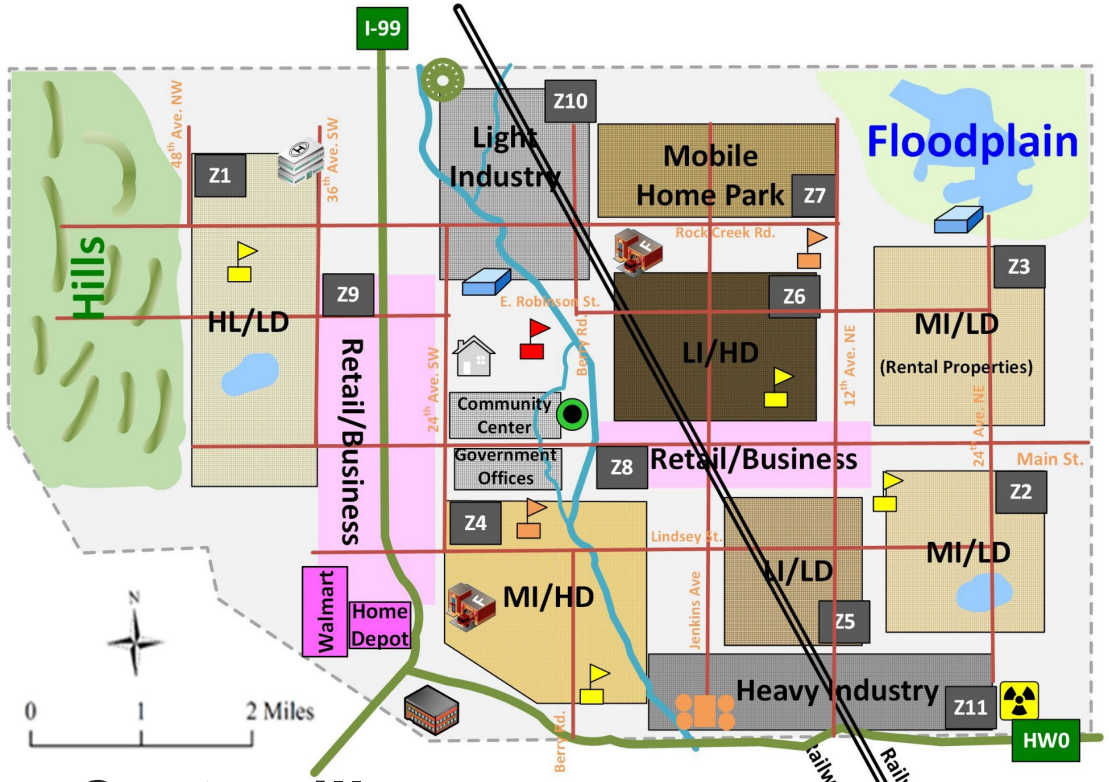
NIST (2024) Steps for Organizational Actions Framework

- Step O1: Identify Groups within the Organization and their Functions
- Step O2: Identify Organizational Essential Functions, Resources, and Groups
- Step O3: Assess Internal and External Coordination
- Step O4: Establish Responsibilities, Resources, Capabilities, and Recovery Time Objectives
- Step O5: Develop Group-Level Policies and Strategies
- Step O6: Assess Group Performance and Recovery Capability and Compare with Group's Target Objectives
- Step O7: Identify Recovery Time Factors
- Step O8: Assess System Performance and Recovery Time
- Step O9: Compare System Assessment Results with Target Objectives
- Step O10: Report System Assessment Results

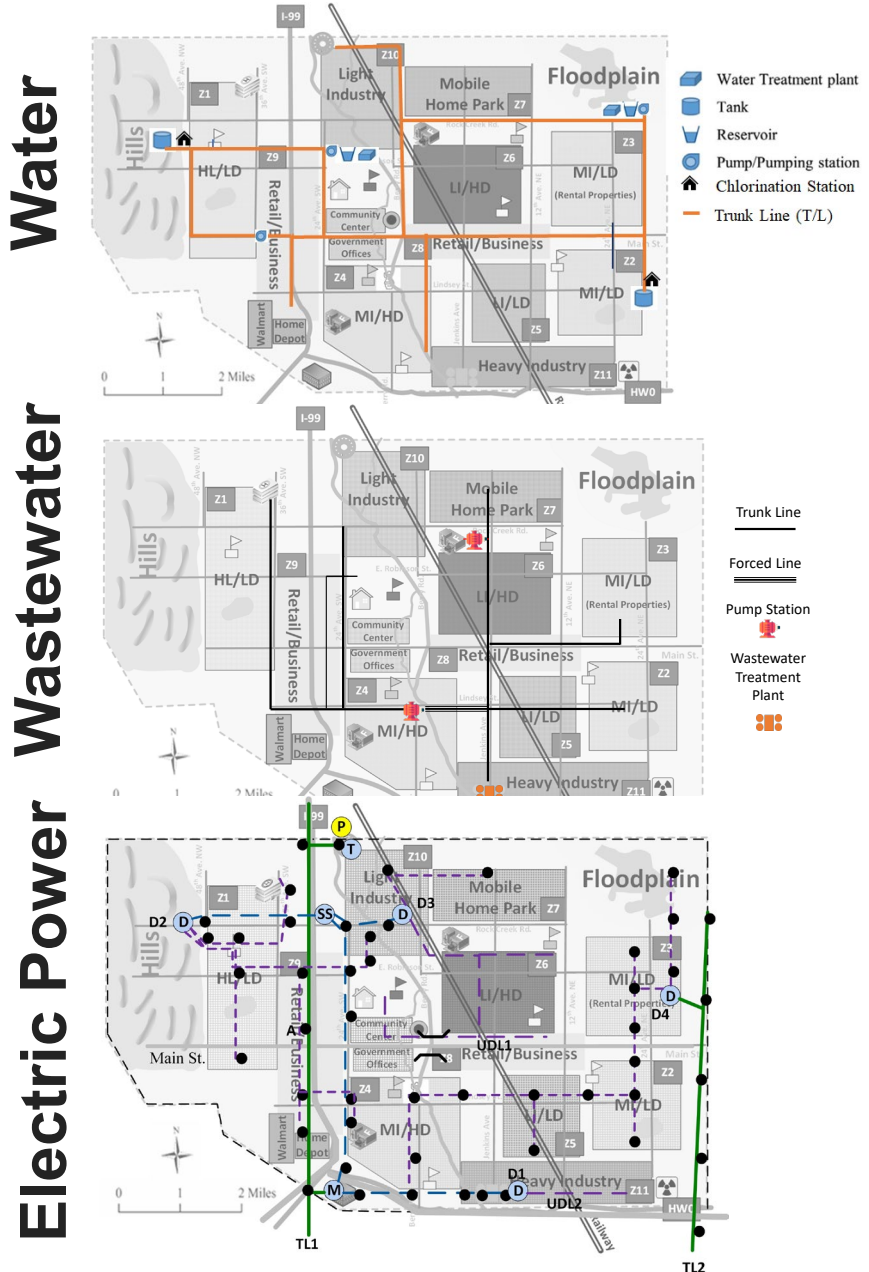
Example applications to Water, Wastewater, and Electric Power Systems - Hypothetical City

In Vol. 2, NIST SP 1311

Shows how the framework is relevant to multiple lifeline infrastructure systems



Centerville (Credit: NIST Center of Excellence)



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https://doi.org/10.6028/NIST.SP.1310
https://doi.org/10.6028/NIST.SP.1311

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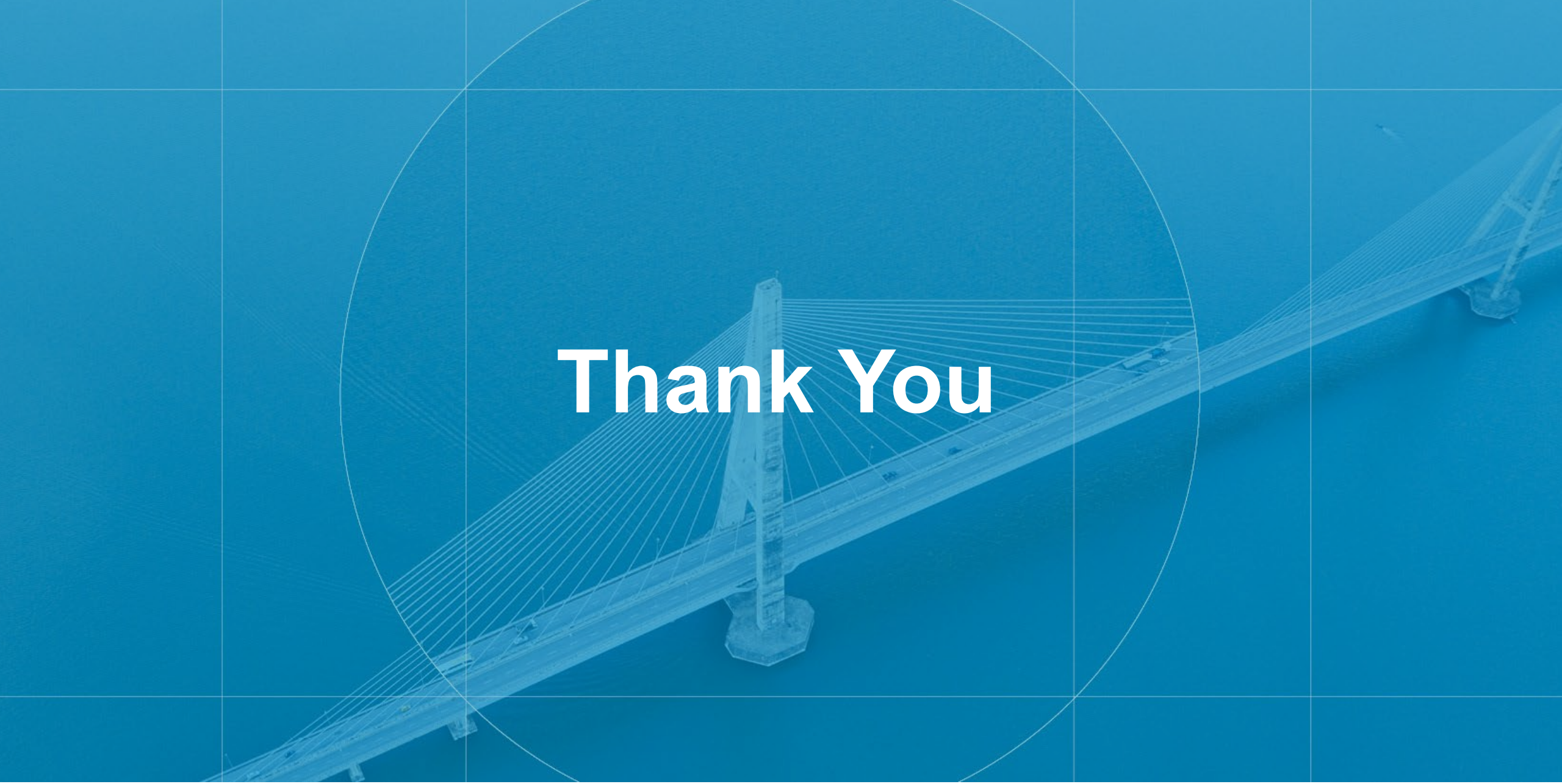
https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1254.pdf



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Strategies for Resilient Infrastructure

Ayse Hortacsu
Director of Projects, Applied Technology Council (**ATC**)

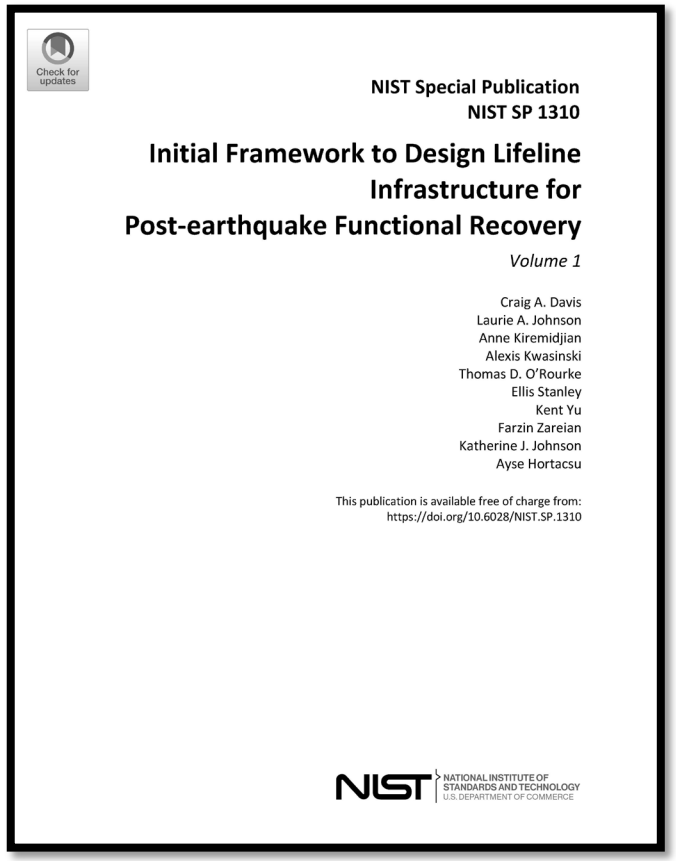
May 20, 2025

Session: "*Developing and Implementing Functional Recovery Framework for Lifeline Infrastructure Systems*"

Co-Presenters: Jo Johnson, Craig A. Davis, Kent Yu

Moderator: Ron Eguchi

NIST SP 1310 Initial framework


NIST Special Publication
NIST SP 1310

Initial Framework to Design Lifeline Infrastructure for Post-earthquake Functional Recovery

Volume 1

Craig A. Davis
Laurie A. Johnson
Anne Kiremidjian
Alexis Kwasinski
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Ellis Stanley
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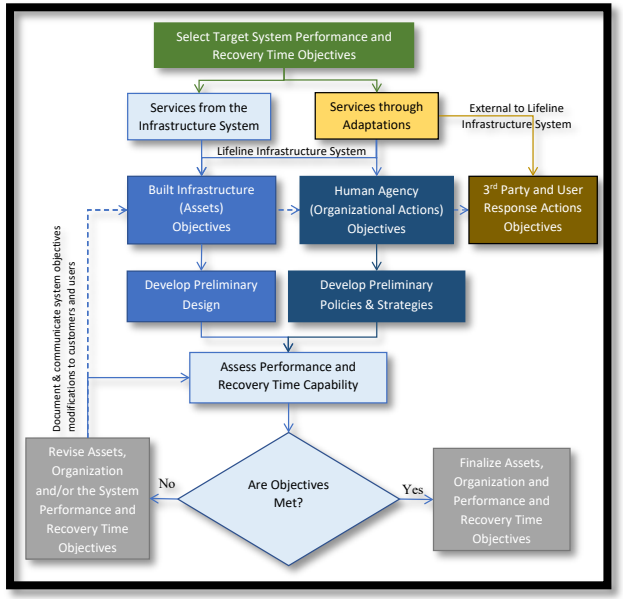
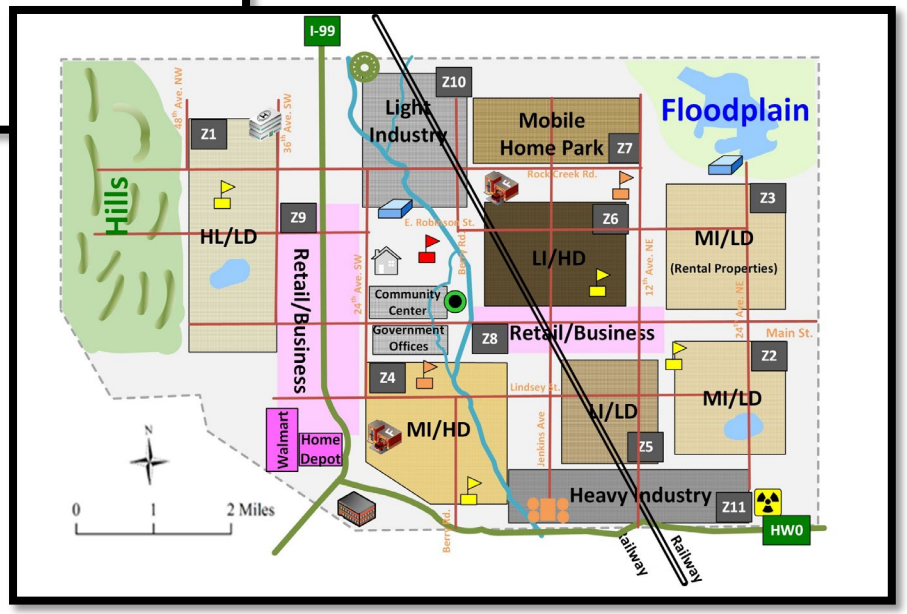
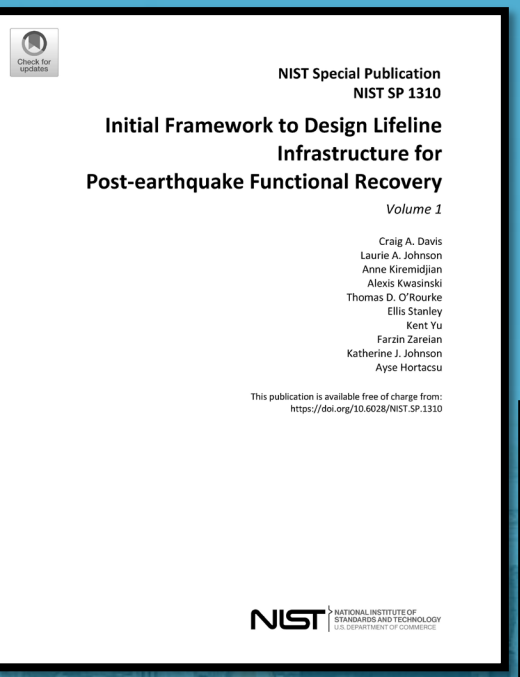
- Step A1: Define System Layout and Operational Characteristics
- Step A2: Define Criticality Category and Earthquake Design Basis for System Components
- Step A3: Check Multiple Use, Continuity, and Redundancy
- Step A4: Establish Component Objectives - Maximum Level of Damage and Repair Time
- Step A5: Identify Dependent Services
- Step A6: Develop Preliminary Design
- Step A7: Assess the Component Performance and Repair Time, Compare with Target Objectives
- Step A8: Identify Recovery Time Factors
- Step A9: Assess System Performance and Recovery Time
- Step A10: Compare System Assessment Results with Target Objectives
- Step A11: Report System Assessment Results





“Initial Framework”



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Initial Framework to Design Lifeline Infrastructure for Post-earthquake Functional Recovery

Volume 1

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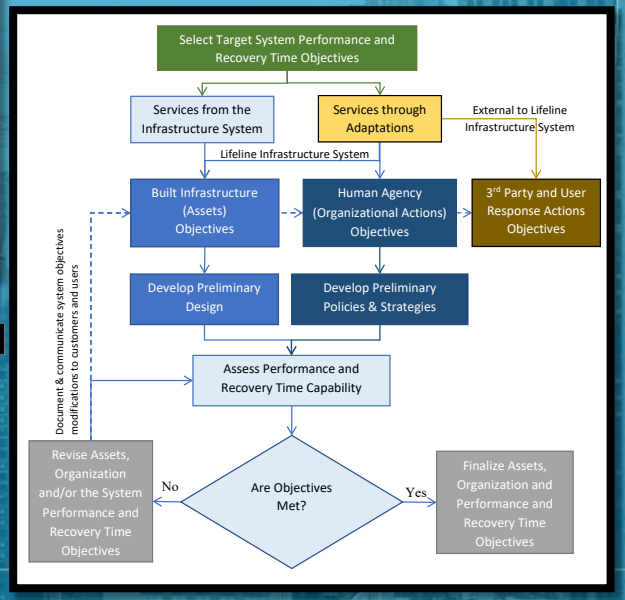


The processes apply to all lifeline infrastructure systems

The format is set up to allow more detailed information to be created for each infrastructure system

The process is useful for establishing consistent performance-based procedures for every component within each system

Also:

To accomplish consistency there needs to be a common method for establishing service recovery time objectives for all infrastructure systems

Supply and Demand

Analytical Modeling

- hazard scenario
- system information
- dependencies
- parameters for measuring services

What can the system provide?

=

What does the community need?

Community Engagement

- types of users
- types of uses
- availability of adaptations
- organizational actions
- consequences due to lack of services

ACTION PLAN

- enact policies
- mitigate assets
- establish organizational actions
- communicate

…iterate!

Future needs:

MORE RESEARCH

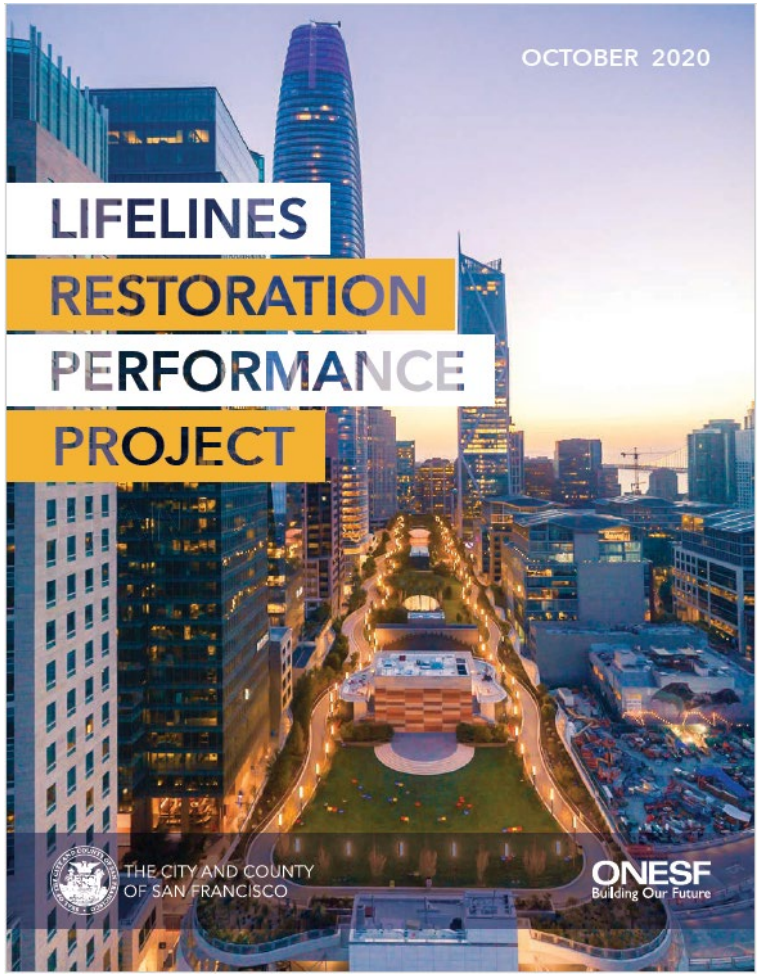
- Hazard definition
- Component and system fragility
- Translating asset-level design to system-level performance
- Improved models for assets and organizational actions
- Interdependencies
- Post-disaster data collection
- Cost and time estimates for repairs
- Recovery time factors

Future needs:

POLICIES AND PROCEDURES

- There are currently no policies requiring lifeline infrastructure systems to be prepared to recover services in a timely manner following any major natural hazard event.
- Lifeline infrastructure systems are owned and operated by many different types of agencies and organizations.
- Lifeline infrastructure system owners and operators need to first commit to the concepts for functional recovery and then implement them over time.

Implementation



May 17, 2025

FIGURE 2: SUMMARY RESTORATION TIMELINES

Sector	Organization	Emergency Response		Short-term Restoration		Long-term Recovery		
		0 hours	72 hours	2 weeks	2 months	6 months	1 year	3 years
Electric Power	PG&E			+				
	SFPUC					+		
Fuel	Kinder Morgan[1,2]					+		
Communications	AT&T Wireless		+					
	Comcast				+			
	Verizon Wireless		+					
	SF Dept of Technology			+				
Highways & Local Roads	Caltrans[2]							+
	Golden Gate Bridge					+		
	Public Works							
Potable Water	SFPUC							
Transit	MUNI							
	BART[2]							
Natural Gas	PG&E							
Wastewater	SFPUC							
Solid Waste	Recology							
Port	Port of San Francisco							
Airport	SFO							
Firefighting Water (EFWS)[3]	SFPUC			+				

FIGURE 5: SUMMARY INTERDEPENDENCIES TABLE

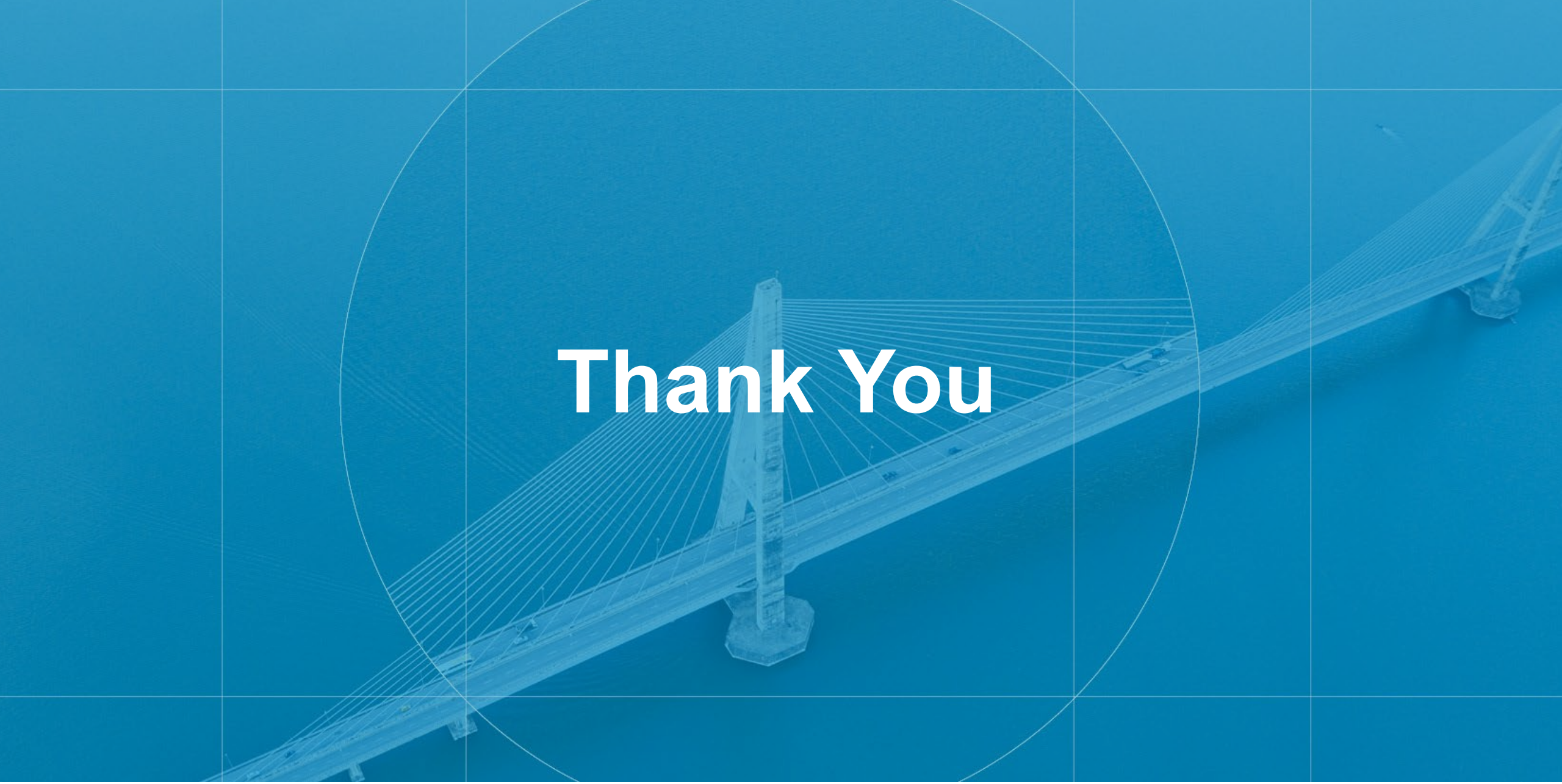
A. Lifeline Sectors

Sector	Electric Power	Natural Gas	Water	Wastewater	Communications	Highways and Local Roads	Fuel	Transit	Solid Waste	Airport	Port	Firefighting Water
Electric Power												
Natural Gas												
Water												
Wastewater												
Communications												
Highways and Local Roads												
Fuel												
Transit												
Solid Waste												
Airport												
Port												
Firefighting Water (EFWS)												

None	No reliance on sector
Low	Minimal reliance on sector
Moderate	Large reliance on sector with significant backup available, or moderate reliance on sector with no back up available
Significant	Large reliance on sector with limited backup available

Reading the matrix across each row shows which sectors a particular sector relies on. For example, electric power has a significant reliance on natural ga but a low reliance on the Port.

Reading the matrix down each column shows which sectors rely on the designated sector. For example, a systems, except for EFWS have a significant dependence on electric power.



Thank You

Questions for the Panel