CIRI | CRITICAL INFRASTRUCTURE RESILIENCE INSTITUTE

A DEPARTMENT OF HOMELAND SECURITY CENTER OF EXCELLENCE

Annual Review:
Enhancing Water Distribution Networks Resilience with Scalable AI-based Planning

Bistra Dilkina
University of Southern California

The Problem

A water main break following a 6.0 earthquake in Napa, California.
https://www.cbsnews.com/pictures/strong-earthquake-knocks-napa-valley/17/

- In US, average age of a current water pipelines is **45 years old**; **C- on Infrastructure Report Card** from the American Society of Civil Engineers
- 143 million Americans live in areas vulnerable to earthquakes
  - Earthquakes disrupt critical infrastructures, and specifically water infrastructure.
  - Water Service Disruption compromises public access to water and reduces effectiveness of disaster response (fire departments, hospitals, disaster recovery centers)
- **Critical water customers**
  - hospitals, fire/police stations, emergency evacuation centers, power, sanitation, etc need resilient water supply to provide life-saving services during and post disasters.
- Relevant DHS Components: FEMA, USCG among others
- Proposed solution: data-driven AI-based decision support for water infrastructure mitigation planning to inform strategic infrastructure network fortification before the disaster strikes

Pipes in New Zealand's capital are leaking a million litres (220,000 gallons) of water a day as a result of the powerful November 2016 earthquake.

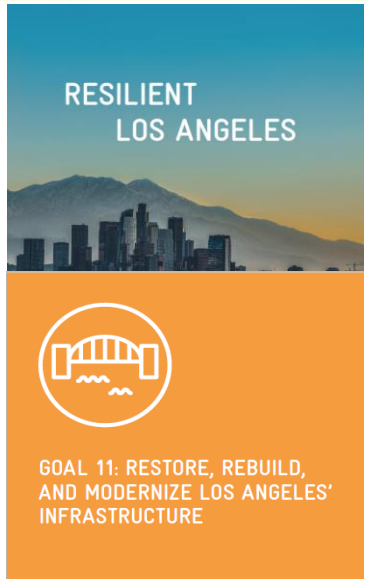
M 7.8 earthquake on San Andreas Fault, CA could cause **$24 billion in business interruption losses due to water supply interruption alone** (>13% of the total estimated costs)

What Will Success Look Like?

- Develop decision-support tool to strategically target infrastructure upgrades in water distribution networks
  - enable for the first time capability to **(automatically) generate** optimized service-zone-scale **master plans** for disaster-resilience mitigation planning
  - to meet the **resiliency requirements** of the local communities
  - **data-driven and cost-effective** by design
- **Modular, usable, robust software tool**
- Transition of our approach/tool to be **incorporated with existing data platforms and planning workflows used by a spectrum of end-users**

Benefits to end-users

- Los Angeles Department of Water and Power
  473 square miles, over 4 million residents, 733,900 active service connections
  - 23% of 2,742 critical customers at earthquake risk
  - 34% of 267,084 total pipes at earthquake risk
  - Pilot program using hand calculations – slow



Action 61: Advance seismic safety, prioritizing the most vulnerable buildings, infrastructure, and systems

"**Expand Seismic Resilient Pipe Network**
The City will expand development of the seismic resilient pipe network. … Resilient pipeline planning, design, and construction **requires the development of new informational tools and mapping of geohazards** …."

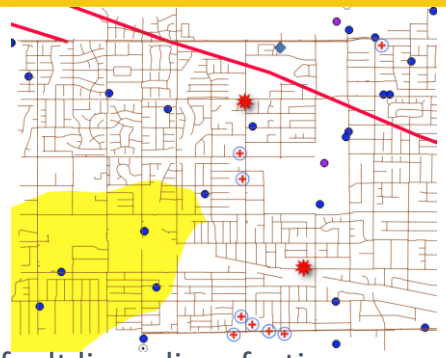
- Provide owners and operators of water infrastructure with data-driven hazard assessment and cost-effective planning tool
  - **Hazard assessment**: in addition to pipes, which critical customers are at risk?
  - **Automated planning**: coordinated upgrades across the network wrt joint needs and costs
  - **Faster speed** at developing mitigation plans
  - Ability to plan on a **larger scale** (thousands of pipes, 10s of sq miles)
  - More **cost-effective** plans by using algorithms to search for optimal upgrades
  - Agility to **re-calculate, re-optimize, what-if analysis**

Benefits to DHS

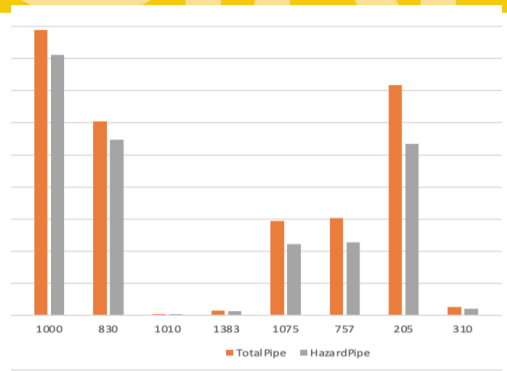
- Enhances the ability of local and state decision makers across the nation to perform mitigation planning
  - Enhances resilience by minimizing likely disaster disruptions
- Ways to show cost-effectiveness of planning – FEMA grant applications
- Help Disaster Response
  - Services critical to disaster response (hospitals, evacuation centers, fire/police departments) less likely to be compromised by water disruption
- Public Health and Damages
  - minimizes risks to public health and property damage (fire, water) through increased availability of water during earthquakes

Accomplishments

- **Flexible tool to aid in resiliency planning**
  - Highly parametrized: definition of hazards, costs, resilience needs
- **Map risk exposure:** hazard, infrastructure and customers
- **Master Plan**
  - Identify set of pipes that minimize costs to meet all resilience requirements
  - Showed NP-hard, developed **Mathematical Model**
  - **6%-23% more cost effective than baseline approach**
  - Scales to 1-3 service zones at a time
- **Sequential Planning** subject to yearly budget
  - Year by year pipes to be replaced that maximize resilience benefits as early as possible
  - **Dynamic Programming approach (optimal)**
  - **Cost benefit analysis** with various replacement budgets (miles/year) to quantify opportunity cost
- **Stakeholder engagement and requirement elicitation**
  - Los Angeles DWP, Seattle Public Utilities, East Bay Municipal Utility District (EBMUD)
  - Metropolitan Water District of Southern California, FEMA IX
  - C A Davis Engineering, Kubota Membrane USA
- **RTI Screening assessment completed**



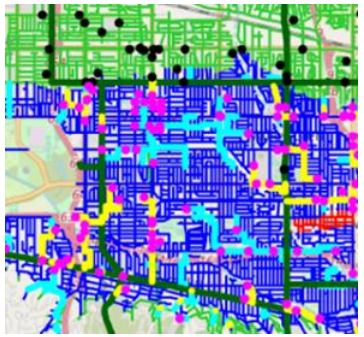
fault lines, liquefaction zones, pipes and critical customers



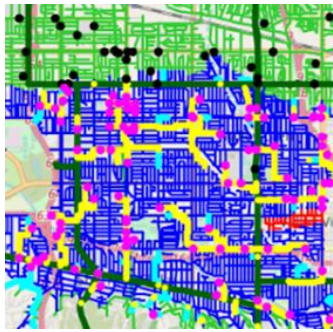
Pipes at risk in each service zone

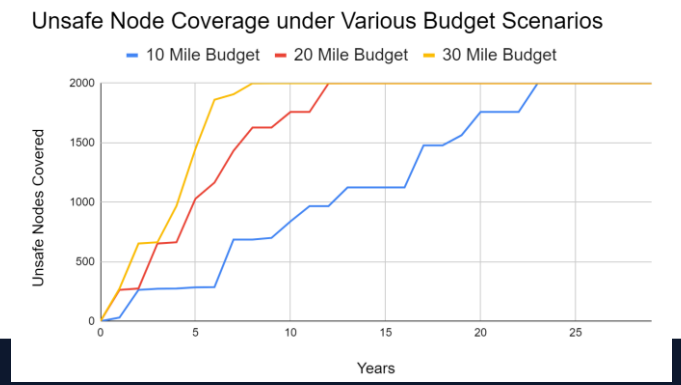
Master Plan

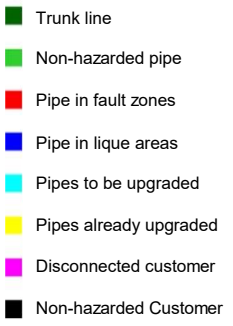
By Year 5



By Year 9







Activities Remaining

- **Package** into a standalone tool with robust error checking, compatibility and documentation – improve usability
- **Pilot in-house training** and usage at LADWP with 5-10 engineers on site
- Address **requirements gaps** and design based on pilot feedback
- Continue to **engage with customers** and potential partners
- Explore pathways forward (funding, piloting, IP)