



# Overview

- 1 Modern Civil Infrastructure Systems
  - Industrial Revolution
  - Post- Industrial Revolution
  - Transition to Information Era
- 2 Near-Term Challenges (2020-2060)
  - Crisis in US Infrastructure Investment
  - Urbanization and Sustainable Cities
- 3 Features of Modern Computing
- 4 Urban and Global Applications
- 5 Summary (Connections to Scientific Computing)





# Crisis in US Infrastructure Investment

## Universal Observations:

- Aging infrastructure becomes expensive to maintain.
- New (replacement) infrastructure is very expensive.
- Politicians are eager to talk up Infrastructure Investment , but slow to deliver ....

## Bottom line:

- Critical infrastructure is taken for granted and not a national priority (ASCE, IEEE).

Delay, delay, delay ....



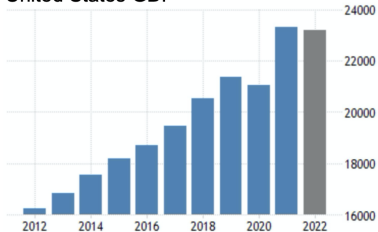
Bangkok, Thailand

# Crisis in US Infrastructure Investment

## Statistics:

- US: Post World-War II (1950-1970): 3% of Gross Domestic Product (GDP)
- US: 1980-present: 2% of GDP.
- China: 5% GDP.
- India: 9% GDP.

United States GDP



## Infrastructure Investment and Jobs Act (2021).

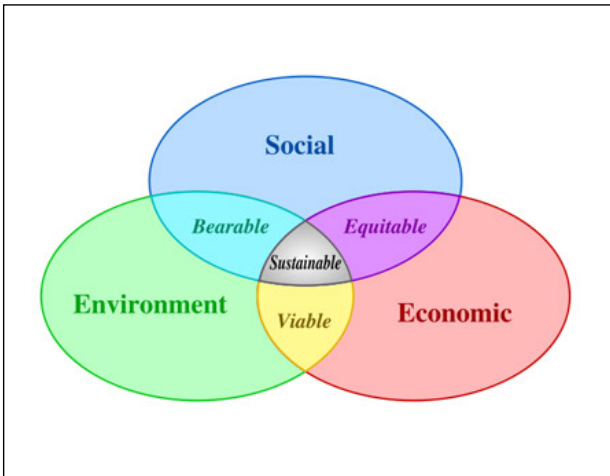
- Invest \$1.2T over 10 years.
- Sounds like a lot – but is it too low, too high?
- Increases investment by 0.5% of GDP.





# Sustainable Urban Systems

Sustainability involves **physical**, **organizational** and **social** systems.



# Sustainable Urban Systems

Urban systems are like plants in your garden:

- Cities are defined by their **emergent properties** (e.g., beautiful flower  $\Leftrightarrow$  New York City Skyline).
- Cities **grow and flourish** based on societal and economic stimulus, and **fall into decay** when stimulus is absent.

But sustainability is a tough problem:

- Many of the world's large urban areas – so-called **mega-cities** – are in **poor economic shape**.

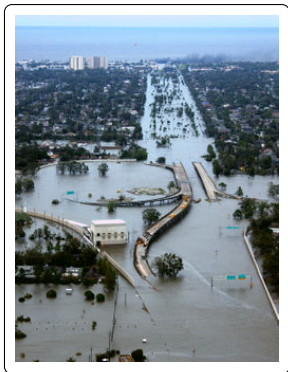
Cities are **system of systems**:

- Subsystems have a preference to **operate** as **independently as possible** from the other subsystems.
- Strategic **collaborations needed** to raise levels of **attainable performance** and **limit cascading failures**.

# Urban Infrastructure Protection and Recovery

## Case Study. Cascading Failures in Hurricane Katrina (2005)

- Hurricane Katrina caused a storm surge which, in turn, resulted in the failure of levees around New Orleans.
- This is a failure in the waterway network.
- A more conservative (expensive) design might have prevented this failure.
- But the failure didn't stop there.



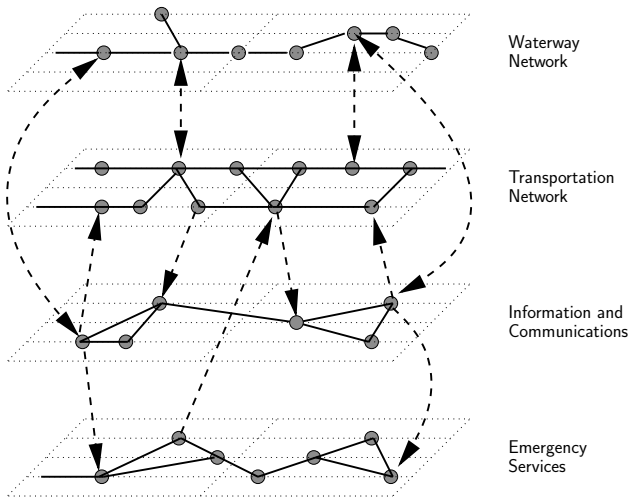
# Urban Infrastructure Protection and Recovery

## Cascading Failures in Hurricane Katrina:

- **Waterway system failure.** The levees were insufficient to resist the storm surge.
- **Highway and electrical power system failures.** Flooding resulted in failure of the electrical power and highway systems.
- **Federal emergency failures.** Inhabitants had to flee their homes, but few plans were in place for their orderly evacuation.
- **Social network failures.** After the inhabitants left their homes, looters stole property from evacuated properties.
- **Political system failures.** ...

# Urban Infrastructure Protection and Recovery

## Dependencies Among Urban Networks:



# Urban Infrastructure Protection and Recovery

## Lessons Learned:

Cascading failures of this type indicate that:

- There is a need to **understand** and **manage interactions** among **infrastructure networks** and **organizational** and **societal factors**.

## Basic Questions

- What kinds of dependencies exist between the networks?
- How will a failure in one network impact other networks?  
These are so-called **cascading failures**.
- What parts of a system are most vulnerable?

We need to look at **interactions between network models**.

