Data and Information Management in the Built Environment

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Overview

Part 1

Getting Started

Definition of Built Environment

Various Sources (Google, ScienceDirect):

- Human-made surroundings that provide for human activity, ranging in scale from buildings to cities.
- Includes supporting infrastructure: water supply networks; energy networks; transportation systems, communication systems.

Human Needs:

- Basic: Access to clean air and clean water.
- Health: Access to good medical services.
- Economic: Affordable low maintenance housing.
- Security: Protections against crime, environmental attack.

Definition of Built Environment

- Transportation: Good roads; parking; fast access to work.
- Educational: Access to good schools.
- Green Spaces: Access to parks, bike paths, etc.
- Retail: Access to shopping; reliable supply chains.
- Lifestyle: Access to social and recreational spaces.

Urban Planning and Engineering Concerns:

- Understand short- and long-term planning needs.
- Efficiency in design – aesthetically pleasing design.
- Efficiency in operations – better use of limited resources.
- Improved response to unexpected events.

Framing the Opportunity

We seek:

- Data-driven approaches to measurement of performance in the building environment and identification of trends and patterns in behavior.
- Solutions that account for unique physical, economic, social and cultural characteristics of individual cities.

Sources of Complication:

- Multiple domains; multiple types of data and information.
- Network structures that are spatial and interwoven.
- Behaviors that are distributed and concurrent.
- Many interdependencies among coupled urban subsystems.

Framing the Opportunity

Systems Perspective:

- Entities in the built environment have both system structure and system behavior ....

Decision makers use behavior modeling to understand:

- Sensitivity of systems to model parameter choices.
- Influence of resource constraints.
- Potential emergent interactions and propogation of cause-and-effect relationships.
- Identification of parts of the systems that are vulnerable.

Cannot play with a real building/city – so a reasonable first step is data-driven building science in gaming environments ...

Framing the Opportunity

Glassbox Simulation Engine (2012-2013):

Cities are modeled as resources + units + maps + globals, combined with sets of rules, all in a box.

Framing the Opportunity

Framing the Opportunity

Premise of this Class:

- Data mining and machine learning technologies can enhance (not destroy) the built environment.

Basic Questions:

- What are the challenges facing the built environment in the time frame 2020-2060?
- Is present-day technology where it needs to be to make a worthwhile contribution?
- What will the data mining do? What will the machine learning do?
- Are there opportunities for AI, data mining and machine learning to work as a team?

A Little History

Pathway Forward $\rightarrow$ Look to the Past

What is Civil Engineering?

Civil Engineering deals with (Civil Engineering, Wikipedia) ...

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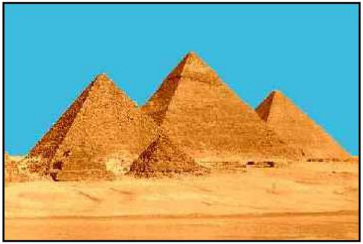
.. the design, construction, and maintenance of the physical and naturally built environment, including roads, bridges, canals, dams, and buildings.

After military engineering, civil engineering is the oldest engineering profession.

Goals during Early Civilization (4000 BC – 6000 BC)

- Problems of survival and basic systems were solved.
- Design and construction methods evolved.

Exemplars of Early Work



- Great Pyramid of Giza, Egypt (20 year construction; finished 2556 BC).
- The Parthenon in Ancient Greece (447-438 BC).
- Construction of the Great Wall of China (220 BC).
- The Romans developed civil structures throughout their empire, including especially aqueducts, insulae,

Industrial Revolution

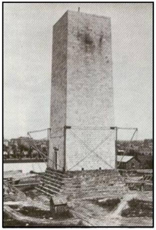
Fast forward to the Industrial Revolution

Year	Milestone
1692	Languedoc Canal. 240 miles long. 100 locks.
1708	Tull's mechanical seed sower → large-scale planting.
1765	Spinning jenny/wheel automates weaving of cloth.
1775	Watt's first efficient steam engine.
1801	Robert Trevithick demonstrates a steam locomotive.
1821	Faraday, electro-magnetic rotation → electric motor.
1834	Babbage analytic engine → forerunner of the computer.
1903	Wright brothers make first powered flight.
1908	Henry Ford mass-produces the Model T.

Industrial Revolution

Advances in Civil Engineering during the Industrial Revolution

Year	Milestone
1854	Bessemer invents steel converter.
1849	Monier develops reinforced concrete.
1863	Siemens-Martin makes steel available in bulk.



The Eiffel Tower - April 1888

Skyscrapers

- New materials → design of tall structures having large open interior spaces.
- Elevators (1857) → vertical transportation building occupants.
- Mechanical systems → delivery of water, heating and cooling.
- Collections of skyscrapers → high-density CBDs/commuter society.

Industrial Revolution

Industrial Revolution Actually Changed the World!

Characteristics	**Stage 1 Mechanical Era**	**Stage 2 Electrical Era**
Onset in the U.S.	Late 1700s.	Late 1800s.
Economic Focus	Agriculture/Mining	**Manufacturing**
Productivity Focus	Farming	Factory
Underlying Technologies	**Mechanical Tools**	**ElectroMechanical**
Product Lifecycle	Decades	Years
Human Contribution	Muscle Power	Muscle/Brain Power
Living Standard	Subsistence	**Quality of Goods**
Geographical	Family/Locale	Regional/National

Industrial Revolution (Mid-1900s)

New types of systems – planes, trains and automobiles – rely on human involvement as a means for sensing and controlling behavior, e.g.,

- Driving a car,
- Manual collection of road tolls,
- Traffic controllers at an airport,
- Manual focus of a camera.

Systems work, but:

- Humans are slow.
- Humans make mistakes.
- They also easily tire.

Transition to Information Era

Since 1990 we have been in an Information Era

Characteristics	**Stage 2 Electrical Era**	**Stage 3 Information Era**
Onset in the U.S.	Late 1800s.	**Late 1900s.**
Economic Focus	Manufacturing	Services
Technologies	ElectroMechanical	**Information**
Product Lifecycle	Years	Months
Living Standard	Quality of Goods	**Quality of Life**
Geographical Impact	Regional/National	**Global**

Design of Information-Age Systems

Premise of Information-Age System Design:

- Advances in computer software, sensing, and wireless networking technologies can work together to expand the functionality and performance of systems.

Trend toward Automation:

- New types of systems where human involvement for management of system functionality is replaced (or partially replaced) by software automation.

Civil Engineering Applications:

- Automated road toll collection (Rt. 200).
- Automated baggage handling systems at airports.

Transition to Information Era

Metrics of Good Engineering Design:

- A good engineering design works correctly, has good performance, and is economical.
- Functionality and performance are resilient to uncertainties.
- System can be easily upgraded to take advantage of new technologies.

Metrics of Good Systems Operation:

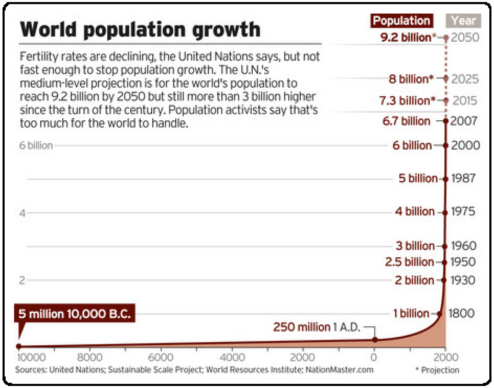
A well-run system has "situational awareness" and handles unexpected events:

- Sense the system state and surrounding environment,
- Look ahead and anticipate events, and
- Take action to control system behavior.

Near-Term Challenges

Civil Engineers need to create the infrastructure for citizens of the Information Era

Trends in World Population Growth



Increasing Population → Increased Demand on Limited Resources → Increasing need for Improvements to System Efficiency.

Urbanization and Sustainable Cities

Urbanization in America:

- In 2010, 82 percent of Americans lived in cities.
- By 2050 it will be 90 percent.

Cities are responsible for:

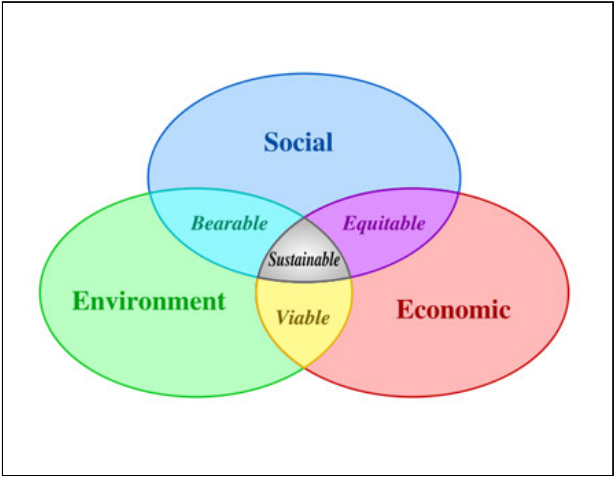
- Two thirds of the energy used,
- 60 percent of all water consumed, and
- 70 percent of all greenhouse gases produced worldwide.

Sustainable cities (SIEMENS, Sustainable Cities, USA):

- Environmentally friendly infrastructures;
- Improved quality of life for residents;
- Good economics.

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 ⇔ New York City Skyline).
- Cities grow and fourish 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 limit cascading failures.

Resilience of Urban Infrastructure

Example. Cascading Failures in Hurricane Katrina

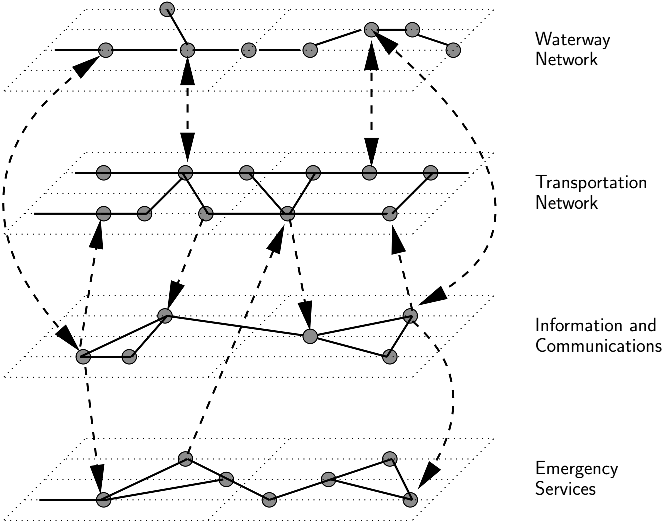
- Hurricane Katrina caused a storm surge which, in turn, resulted in the failure of levees around New Orleans.
- This is a failure in the waterway network.
- A more conservative (expensive) design might have prevented this failure.
- But the failure didn't stop there.

Resilience of Urban Infrastructure

Cascading Failures in Hurricane Katrina:

- **Waterway system failure.** The levees were insufficint 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.** Inhabits 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.** ...

Dependencies Among Urban Networks



Planning for Disaster Relief and Recovery

Lessons Learned

Cascading failures of this type indicate that:

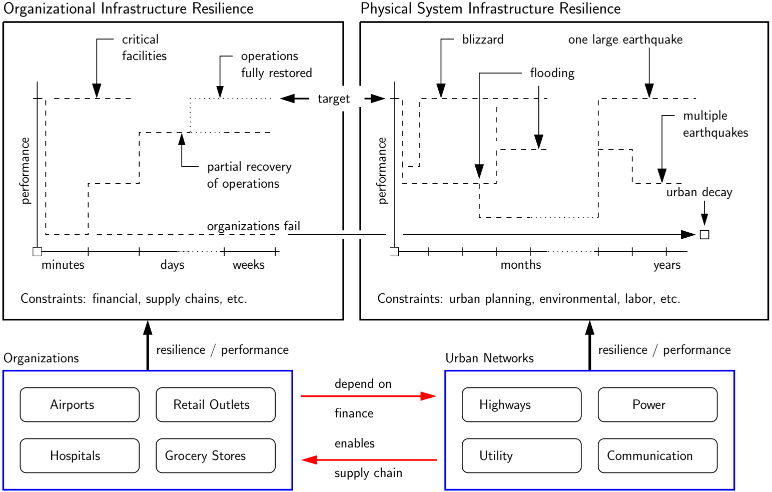
- There is a need to understand and manage interactions among infrastructure networks and organizational and societal factors.

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.

Planning for Disaster Relief and Recovery



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