Introduction to Civil Information Systems

Mark A. Austin

University of Maryland

austin@umd.edu
ENCE 688R, Spring Semester 2023

January 27, 2023

Overview

Part 1

Modern

Civil Infrastructure

Systems

Modern Civil Infrastructure Systems

Various Sources (Google, ScienceDirect):

- Civil Infrastructure Systems provide for human activity, ranging in scale from buildings to cities.
- Includes supporting infrastructure: water supply networks; energy networks; transportation systems, communication systems.

Support 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.

Modern Civil Infrastructure Systems

- 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 infrastructure environment have both system structure and system behavior ....

Decision makers use behavior modeling to understand:

- Levels of attainable performance.
- 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.

Framing the Opportunity

Premises of ENCE688R:

- Modern civil infrastructure systems can be modeled as graphs and networks – sometimes they are intertwined networks of networks – that will dynamically respond to events.
- These systems grow and fourish based on societal and economic stimulus, and fall into decay when stimulus is absent.
- Advances in computer software, sensing, and networking technologies can work together to expand the functionality and performance of systems.

Long-Term Need:

- To understand and manage interactions among infrastructure networks and organizational and societal factors.

A Little History

Pathway Forward $\rightarrow$ Look to the Past

What is Civil Engineering?

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

.

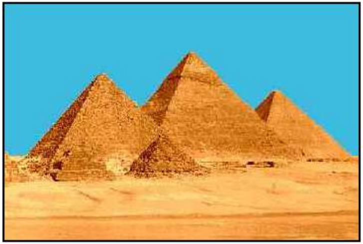
.. the design, construction, and maintenance of the physical and naturally built environment, including roads, bridges, canals, dams, and buildings.

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.

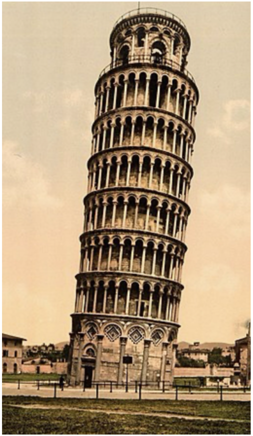
Exemplars of Early Work



- 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,

Exemplars of Early Work

Leaning Tower of Pisa (12th Century)



- Designed to be the tallest bell tower in Europe.
- Construction: Three stages over 199 years (1173-1372).
- Constructed from white marble.
- Tower leans because of weak unstable subsoil.
- It once leaned at 5.5 degrees.
- Currently leans at 3.99 degrees.
- Has survived 4 earthquakes –ironically, weak subsoil conditions work to protect Pisa from ground accelerations.

Industrial Revolution

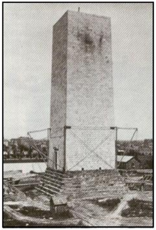
Fast forward to the Industrial Revolution: (1760 – 1840).

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

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

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

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.

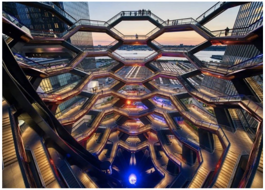
Skyscrapers → High-Density Urban Development

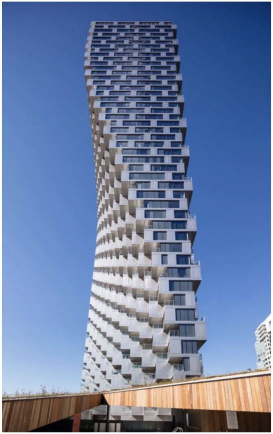
Urban Development in NYC

Urban Development in Shanghai

Advances in Computing and Analysis

Emergence of New Architectural Forms





Advances in Computing and Analysis

Parametric Architectural Design

Advances in Computing and Analysis

Convergence: Engineering-Architecture-AI

AI-generated art ...

AI-generated building architecture

References

- Array of Things: See https://arrayofthings.github.io
- Austin M.A., Delgoshaei P., Coelho M. and Heidarinejad M. , Architecting Smart City Digital Twins: Combined Semantic Model and Machine Learning Approach, Journal of Management in Engineering, ASCE, Volume 36, Issue 4, July, 2020.
- Bello J.P. et al., SONYC: A System for Monitoring, Analyzing, and Mitigating Urban Noise Pollution, Communications of the ACM, 62, 2, 2019, pp. 68-77.
- Coelho M., and Browning L.S., INL Digital Engineering: Model-Based Design, Digital Threads, Digital Twins, Artificial Intelligence, and Extended Reality for Complex Energy Systems, INL/CON-22-69247, Idaho National Laboratory, Idaho Falls, Idaho 83415, September, 2022.
- Leveson N.G., A New Approach to Software Systems Safety Engineering, System Safety Engineering: Back to the Future, MIT, 2006.
- Tien J.M., Toward a Decision Informatics Paradigm: A Real-Time Information-Based Approach, to Decision Making, IEEE Transactions on Systems, Man, and Cybernetics – Part C: Applications and Reviews, Vol. 33, No. 1, February, 2003.