

Large-Scale Technological Systems

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Technological Systems

- One of the defining characteristics of modern society is the ubiquitousness of **large-scale technological systems**, or networks.
- Over time, systems may rise and go into decline: Canals, gas light, pneumatic tubes, trains, the highway system, the electrical grid, the internet, the global positioning system (GPS), etc.
- Of course, ancient and medieval civilizations also had complicated systems of administration and taxation, irrigation and food production, water supply and sewage disposal, transportation and trade, etc.
- So what is so different about the modern situation?
- A number of commentators on the current situation describe the modern systems as *ways of restructuring and reordering the world itself*, so that it becomes a kind of reserve, a means to an end.

The systems era

- The second industrial revolution led to a new type of technological system, beginning with the electrification of cities like Berlin, London, New York and Shanghai.
 - Henry Ford: “System, system, and more system.”
- During WWII, engineers began to think of the modern world as shaped not so much by machines but rather by systems.
 - Systems, unlike, unlike machines, cannot be understood in a linear, analytical fashion, we need new ideas, such as feedback, balance, etc.
- Engineers, scientists, social scientists, historians and philosophers began to consider the difficulties involved in controlling these complex systems.
 - Modern systems have subsystems and components whose purpose has been forgotten; they cannot be completely mapped: cascade effects, feedback effects, knowledge loss, black-boxed subsystems, etc.

Technological systems

Definition

Technological systems use whatever means are available and appropriate to *reorder* the physical world in ways considered useful or desirable.

- They contain: artifacts, organizations, scientific components, legal components, resources, and people (inventors, industrial scientists, engineers, managers, financiers, workers, etc.).
- They have some *input* and some *output*.
- They are messy and complex and exist in an environment of a network of other systems constantly interacting with them.
- Nevertheless, technological systems are treated as objects by **system builders**, who are able to force unity from diversity, often at the expense of alternative systems.

Invention

- Different types of invention are involved in these systems.
 - Artifacts like light bulbs, structures like power plants, organizations like holding companies, legal components like patents and copyrights, scientific components like encryption algorithms, etc.
- There are both **radical inventions**, which introduce new systems, and **conservative inventions**, which facilitate the development of an existing system.
 - Radical inventions are more often introduced by independent inventors, while conservative inventions are more often produced by government or corporate employees.
- Independents have more freedom to chose their direction.
- There was a concentration of radical inventions around the turn of the 20th century, and again around the turn of the 21st.

Development

- In order to become part of real-world production, an invention must be transformed into an innovation, a reproducible product.
- The invention changes from a simple idea that can function in the environment of the workshop into a something that can be mass-produced and function in a complex system.
- **Development** is the process in which inventor-entrepreneurs mold their ideas to match the social, economic and political realities in which their products must survive.
 - Elmer Sperry and gyro ship stabilizer, Edison and electric light system, Steve Jobs and the Apple computer, Kozo Ohson and the Walkman.
- A large organization inventing and developing a new system may assign subprojects and problems to different types of professionals.

Innovation

- In the final phase of this process, the invented and developed physical components are integrated into a complex system consisting of manufacturing, sales and service facilities.
- This can be called **innovation**.
- Very often, inventor-entrepreneurs form their own companies because they want to introduce manufacturing processes systematically related to their products.
- System builders use innovation to try to increase the size of the system that is under their control and reduce the size of the environment that is not.
- This often involves owning multiple companies related to the system.

Technology transfer

- A technological system has embodied in it characteristics suitable for survival in a particular place and time, hence transfer to another environment requires the solution of a number of new problems.
- Transfer is often associated with scaling and adaptation.
 - Ex.: The transformer was originally made to work with small systems in Britain. It was then adapted to work with the system in Hungary, but this was unsuitable for the safety standards in other regions. It was then adapted for the American situation and made suitable for mass-production.
- There are a number of factors involved in transfer such as legislation, market conditions, geography and social norms.
- Technological transfer often involves the transfer of legal ideas and organizational models as well as artifacts.

Technological style

- In technology, as in art, architecture and fashion, engineers express personal and local styles.
- Historians and sociologists use the concept of style to suggest that system builders have creative latitude.
 - Merz, consultant engineer (1908): “The problem of power supply in any district is ... completely governed by local conditions.”
- This, again, counters the notion that technology is simply applied science and economics.
 - The laws of physics along with factor inputs and unit costs are not a sufficient explanation for the *shape of technology*.
- Natural geography, regional and national historical experiences all play a role in shaping technological style.

Growth and consolidation

- Over time, *successful* technological systems have a tendency to grow and consolidate.
 - This is not always explicable in terms of the economies of scale and a drive for power, since many processes do not scale simply and individual initiative may be lost.
- Two of the main reasons why systems grow and consolidate is (1) to bring up the overall **load factor** of the system and (2) to bring more of the environment under control.
- Overtime, as a system expands, reverse salients (bottlenecks) appear. Resolving these then becomes a project for system builders.

Definition (Load factor)

Load factor is the ratio of the average output, or usage, to the maximum during a given period. (This concept is pertinent to many systems: electrical grid, the internet, highway systems, aviation, etc.)

Momentum

- Mature technological systems, as we saw in a previous lecture, never become fully autonomous. They do, however, acquire **momentum**.
 - They have a mass of technical and organizational components, they possess direction (goals), and they display a rate of growth.
- The momentum of a technological system is increased by the number of actors involved.
 - Manufacturing corporations, utility companies, industrial and government labs, financial firms, technical and scientific societies, educational institutions, regulatory bodies, etc.
- Durable physical artifacts project into the future the characteristics acquired when they were designed.
- High momentum systems can still change quickly or vanish all together.
 - Ford's system in Detroit, the Los Angeles trolley system, Jamaica's dairy industry, etc.

Show scenes from *Manufactured Landscapes*

The systems approach

- Due to the expansion of the US military-industrial complex, following WWII, leaders experienced a number of command and control problems.
- The systems they were trying to manage were too messy and complex for previous methods of command.
- This led to the development of a **systems approach**; that is, methods for taking in information from thousands of different sources and coordinating it for review and decision making.
- Tens of thousands of American technoscientists began to see their work through a systems approach.
 - An airplane became a component in a system involving airfields, air controllers, fuel depots, and maintenance facilities. A highway fits into a network of cars, service stations, traffic controls, maintenance crews, legislation, etc.

Failure and backlash

- During the 60s, there was a general backlash against technological systems among the young and the counter culture.
 - R. Carsons' *Silent Spring* (1962), *The Whole Earth Catalog* (1968).
- During the second half of the 20th century there were a number of striking, but **routine**, failures of systems control – what have been called **normal accidents** (Perrow, 1984).
 - The US and the USSR almost went to war a number of times over computer errors, Three Mile Island (1979), Chernobyl (1986), The *Challenger* explosion (1986), Fukushima (2011), etc.
- Accidents raise doubts among the public about the ability of technoscientists to control the technology they produce.
 - Recently, the BP oil spill in the Gulf of Mexico (2010) and the Fukushima power plant (2011).

Cybernetics: Control and information

- Technoscientists began to study the links between control and information.
 - Norbert Wiener, *Cybernetics; or, Control and Communication in the Animal and the Machine* (1948). 17th century: clocks. 18th–19th: steam engines, 20th: communication and control.
- Wiener and a number of others met for a series of seminars. The cyberneticists took a systems approach to understanding machines and animals.
- They used metaphors – such as control, communication, feedback, input, output, processing, etc. – to find similarities between various disciplines.
 - Ex.: Negative feedback was conceived of as the use of controlling signals to modify the output (behavior) of the machine or organism. Neurons were related to digital switches. Relating machines to the organization of the frontal cortex of the brain.

The information revolution

- Following WWII, there was an explosion in the amount of information produced in all fields. Storing, organizing and searching this information became major problems.
- By 1958, F. Machlup noted that the “information sector” of the US economy accounted for 29% of GDP and 31% of the workforce.
- The technical production of the semiconductor (1947), integrated circuit (1959) and microprocessor (1971), allowed for the production of small, cheap computers.
- ARPANET (Advanced Research Projects Agency Network) was made into the core of a network of computers (1971). The World Wide Web was developed at CERN (1991).
- New styles of management and control were developed.
- The public reaction has been almost entirely positive, despite the fact that this revolution is also deskilling.

Show scenes from *Our Daily Bread*

Final Remarks

- We have looked at the rise of large technological systems as a characteristic of modern technology, focusing on the electrical grids and the internet.
- We have tried to characterize their general characteristics.
- We have looked at the rise of a systems approach.
- We have touched briefly on the information revolution.