Complexity of Socio-Economic Political Systems

Application of Functional Periodicity

Complexity of Socio-Economic Political Systems

- Axiomatic design and complexity theory appear to be equally applicable to non-technical fields such as economic development, government, and educational institutions.

Socio-Economic Political Systems

- Korean Economic Development Plan 1980-85
- National Science Foundation 1984-88
- MIT Department of Mechanical Engineering 1991-2001

Socio-Economic Political Systems

- Transformed a system with time-dependent combinatorial complexity to a system with time-dependent periodic complexity
- In some cases, introduced new FRs

Socio-Economic Political Systems

- Development of the Five-Year (1980-85) Economic Development Plan of the Republic of Korea

History of Industrialization of South Korea

- 1945 -- Liberation of Korea with the ending of the Second World War (no industrial output)
- 1948 -- Republic of South Korea under Syngman Rhee
- 1961 -- Military coup d'etat (General Park, Junghee)
- 1961 to 1970 -- Labor intensive industries (textile, apparel, shoes, etc.)
- 1970 -- Heavy industries (automobiles, shipbuilding, steel making, machine tools, earthmoving equipment, etc.)
- 1979 -- Assassination of President Park
- July 1980 --

Status of Industrialization in 1980

- Ambitious industrialization plan based on the success of the labor intensive business and overseas construction business
- Capital formation through the concentration of capital and privileges in a few business groups
- Government guaranteed loans
- Rapid pace of investment
- Corruption
- Lack of domestic market for automobiles, etc.
- Export oriented economy
- Lack of technologies
- Poor planning (duplication of efforts, market, etc.)

Status of Industrialization in 1980

- **Time-Dependent Combinatorial Complexity Spiral was created.**
  - **Heavily borrowed capital**
  - **Heavy losses**
  - **More borrowing by going into another business**
  - **Cash flow driven business**
  - **Unsustainable debt load**
  - **Under investment in some areas**
  - **Corruption created by the government approval and control of loans, etc.**

Development of the Economic Plan for 1980-1985

- Accepted the highest-level FR (FR= Develop heavy industries for Korea)

- Assessed the status of the following industries/sectors
  - Automobiles
  - Shipbuilding
  - Machine tools
  - Power plants and machinery
  - Earthmoving equipment
  - Small businesses
  - Research infrastructure

Development of the Economic Plan for 1980-1985

- Many of the FRs were not changed.
- Some FRs, DPs, and PVs were changed.
- Imposed Constraints
  - Automobiles
  - Shipbuilding
  - Machine tools
  - Power plants and machinery
  - Earthmoving equipment
  - Small businesses
  - Research infrastructure

Development of the Economic Plan for 1980-1985

- Changed DPs.
- Imposed Constraints

  - Automobiles
    - The domestic market must be large enough to support the industry. A country must have at least 30 million people.
    - Korea is large enough to support automobile industry.
    - Minimum production volume of 400,000 passenger cars/year
    - Volume too small to support three competing companies
    - One company should specialize in passenger cars, another in buses, and the third in trucks until the volume can justify expansion.
    - Increase the domestic demand rate.

Development of the Economic Plan for 1980-1985

- Changed DPs and PVs
- Imposed Constraints

  - Shipbuilding
    - Export oriented industry.
    - Korea can be competitive in shipbuilding -- labor intensive, human resource, etc.
    - Insufficient capital and too high debt load
    - Convert bank loans to equity.
    - Combine the businesses to create an internationally competitive firm.

Development of the Economic Plan for 1980-1985

- Changed FRs
- Imposed Constraints

  - Power Plant equipment
    - Korea cannot be competitive.
    - Too much investment for the available market.
    - Should convert the plant being built to other purposes.

Development of the Economic Plan for 1980-1985

- Changed FRs
- Imposed Constraints

  - Machine tool industry
    - Small market worldwide
    - Korea needs machine tool industry.
    - Needs more technology and human resource.

Development of the Economic Plan for 1980-1985

- Changed FRs
- Imposed Constraints

  - Research Infrastructure
    - Combine KIST and KAIST
    - KIST should specialize in a few fields, e.g., automobile related technology.

Development of the Economic Plan for 1980-1985

- Support small business
  - Low interest loans
  - Regional engineering experimental stations
  - Require large firms to subcontract government work
  - Simplify the government approval procedure

Socio-Economic Political Systems

- **Transformation of the National Science Foundation Engineering Directorate (1984-88)**

NSF Act of 1950, as Amended

- Promote progress of science and engineering
- To provide welfare, health and prosperity
- To secure national defense
- others

Organization of NSF Engineering

See Figure 10.1 in Suh, N. P. Complexity: Theory and Applications. New York, NY: Oxford University Press, 2005.

Problem Definition

- A wrong set of FRs.
- Even for the right FRs, there was time-dependent combinatorial complexity problem.
- Not enough fund for engineering research and education.
- Entrenched PVs.
- Greater presence of engineering in Federal Government
- Vicious cycle for universities and funding agencies

New Set of FRs

- Strengthen the engineering science base.
- Create the science base for fields in which the science base is absent.
- Support emerging technologies.
- Support critical areas of technology.
- Promote engineering systems research by supporting group efforts.
- Encourage innovative research.
- Strengthen undergraduate engineering education.

New (1985)
NSF Engineering Directorate Structure

See Figure 10.2 in Suh, N. P. Complexity: Theory and Applications. New York, NY: Oxford University Press, 2005.

The design equation may be written as

$$\begin{Bmatrix} \text{Goal a} \\ \text{Goal b} \\ \text{Goal c} \\ \text{Goal d} \\ \text{Goal e} \\ \text{Goal f} \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 & 0 & 0 & 0 \\ 0 & X & 0 & 0 & 0 & 0 \\ 0 & 0 & X & 0 & 0 & 0 \\ 0 & 0 & 0 & X & 0 & 0 \\ 0 & 0 & 0 & 0 & X & 0 \\ 0 & 0 & 0 & 0 & 0 & X \end{bmatrix} \begin{Bmatrix} \text{Eng. Sci. Divs.} \\ \text{Design, Mfg., Comp.-Int. Eng. Div.} \\ \text{Emer. Engr. Tech. Div.} \\ \text{Critical Engr. Systems Div.} \\ \text{Cross-discip. Res. Div.} \\ \text{Engr. Inf. Dev. Office} \end{Bmatrix}$$

Socio-Economic Political Systems

- **Transformation of the MIT Department of Mechanical Engineering (1991-2001)**

TABLE 1.2 Four Domains of an Academic Department

Customer Domain	Functional Domain	Physical Domain	Process Domain
CA_1: Customer Satisfaction	**FR_1: Quality**	**DP_1: Programs**	**PV_1: Academic People**
CA_{11} Undergraduates	FR_{11} Provide quality undergraduate education	DP_{11} Undergraduate program	PV_{11} Strong involvement of faculty
CA_{12} Graduates	FR_{12} Provide quality graduate education	DP_{12} Graduate program	PV_{12} Academically strong graduate students
CA_{13} Research Sponsors	FR_{13} Conduct trend-setting quality research	DP_{13} Research organization	PV_{13} Strong faculty
CA_{14} Public (society at large)	FR_{14} Promote active participation in public activities	DP_{14} Service function	PV_{14} Active support of external activities of faculty
CA_2: Cash Flow	**FR_2: Good Management of Resources**	**DP_2: Administrative Mechanisms**	**PV_2: Administrative People**
CA_{21} Teaching support	FR_{21} Use the general fund effectively	DP_{21} Budget and planning mechanism	PV_{21} Budget officer
CA_{22} Research support	FR_{22} Generate external research support	DP_{22} Research support infrastructure	PV_{22} Support staff for research
CA_{23} Capital investment	FR_{23} Solicit gifts	DP_{23} Fund-raising mechanisms	PV_{23} Department head and faculty fund generators
CA_{24} Human resource "protection"	FR_{24} Create chairs, support, etc.	DP_{24} Incentive system	PV_{24} Department head and association head
CA_3: Profit	**FR_3: Productivity (Intellectual and Financial)**	**DP_3: Means**	**PV_3: Methods**
CA_{31} Better teaching paradigms	FR_{31} Create effective pedagogical tools	DP_{31} Development of textbooks, videotapes	PV_{31} Support and reward mechanisms
CA_{32} Research infrastructure	FR_{32} Develop labs and centers	DP_{32} (Better) research organizations	PV_{32} Establish interdisciplinary research activities
CA_{33} New inventions and discoveries	FR_{33} Promote scholarship and creative activities: patents, monographs, prizes and awards	DP_{33} Active support, promotion, and nomination	PV_{33} Staff support
CA_{34} Better tools (equipment/ facilities)	FR_{34} Secure equipment and facilities	DP_{34} Investment in capital goods	PV_{34} Fund raising
CA_{35} Outstanding graduates: captains of industry, researchers, professors, government officials	FR_{35} Provide mentorship	DP_{35} Stronger faculty/student interaction	PV_{35} "Research teams" and commencement of thesis work at sophomore level
CA_4: Growth (Intellectual and Physical)	**FR_4: Innovation**	**DP_4: Environment/ Culture**	**PV_4: Resources**
CA_{41} Define ME of the twenty-first century	FR_{41} Create new pedagogical tools and disciplines	DP_{41} Creative, experimental educational programs	PV_{41} Faculty time and financial support
CA_{42} Define engineering of the twenty-first century	FR_{42} Pioneer new engineering tools, methods, and books	DP_{42} Active interaction with industry	PV_{42} "Manufacturing Institute"
CA_{43} Shape the society of the twenty-first century	FR_{43} Solve societal problems	DP_{43} Active interaction with industry, government	PV_{43} External participation
CA_{44} Strengthen the human resource of engineering	FR_{44} Entice minorities and women into engineering	DP_{44} Special programs	PV_{44} Financial resources

Objective of MIT's ME Department

Transformation of the field of mechanical engineering from a discipline that has been primarily based on

physics

into one that is based on

physics, information, and biology,

while maintaining a strong foundation in design.

New FRs for the Department

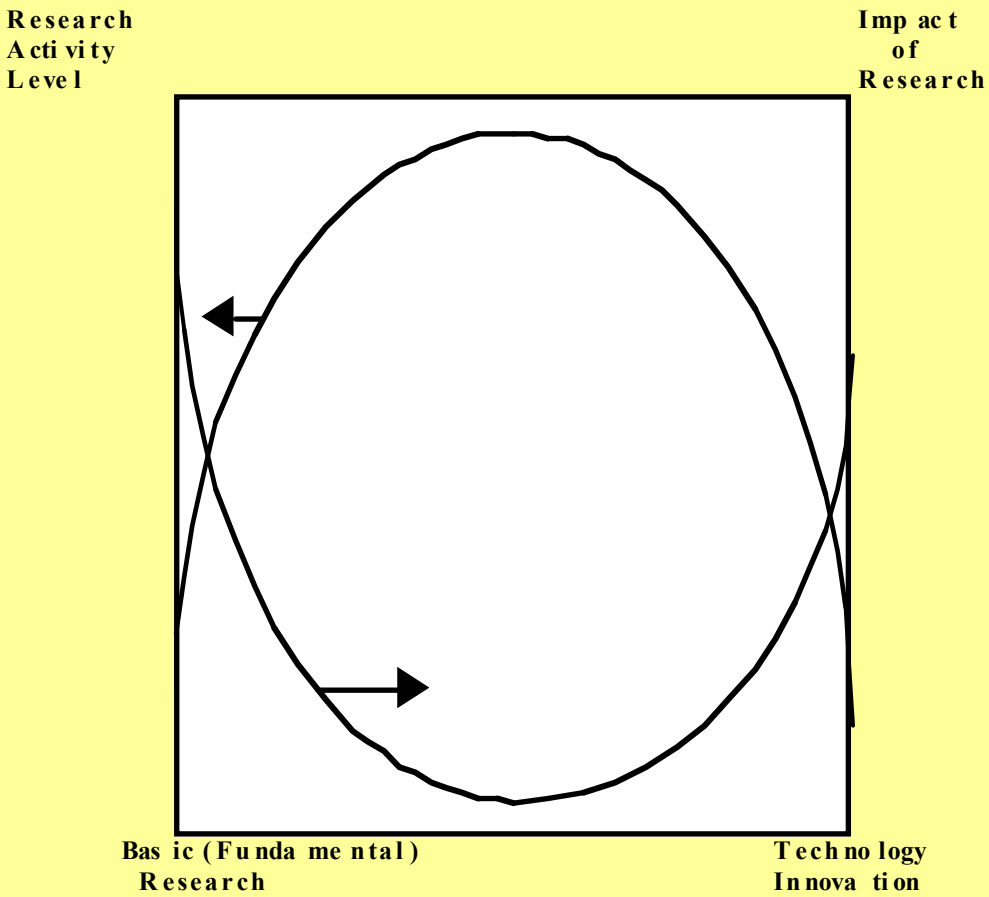
- Information technology
- Bio-Instrumentation
- Engineering systems (manufacturing systems)
- MEMS and nanotechnology
- Energy

Specific Goals of the Department

Research Emphasis

Near the Two Ends of the Research Spectrum

Research Emphasis of the ME Department



Characteristic of Academic Research

Academic research <u>often</u> deals with

"legitimate, well-understood problems within their disciplines"

rather than

"the exceptional, unorthodox work that creates revolutions" in science and technology"

-- From Chaos by Jame Gleick --

How did we manage the change?

- To deal with the challenges and the opportunities of our era, we established new goals and examined how we should manage the required changes.

- We identified the new fields/topics in which we should pursue excellence in education and research.

- We hired new faculty members with different expertise to complement the background of the existing faculty members.

How did we manage the change?

- Out of 26 or new faculty members hired, about 50% has degrees in physics, computer science, electrical engineering, applied mathematics, biology, chemistry optics, and materials.

- We created new research laboratories and facilities.

- We changed the undergraduate program.

New Laboratories and Facilities

- We were able to receive a number of large gifts for our programs and laboratories.
- We renovated 75% of the physical facilities.

- The AMP Material Laboratory
- Rohsenow Heat and Mass Transfer Laboratory
- Pappalardo Undergraduate Teaching Laboratories
- D'Arbeloff Laboratory for Information Systems
- Der Torossian Computational Laboratory
- Hatsopoulos Micro-Fluids Laboratory
- Laboratory for The 21st Century Energy
- Cross CAD/CAM Laboratory
- Cross Student Lounge
- The Park Lecture Halls

How did we manage the change?

- We created funds for a number of faculty chairs, textbooks, etc.

- MIT/Pappalardo Series of Mechanical Engineering Books by Oxford University Press

- We partially changed doctoral programs.