



Engineering Systems Symposium March 2004

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**Sustainability**  
**as an**  
**Organizing Design Principle**  
**for**  
**Large-Scale Engineering Systems**

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## *Sustainability as an Organizing Design Principle for Large Scale Engineering Systems*

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- What is an Organizing Design Principle?
  - › Above the models and analysis – to guide their use
  - › Examples: Cost, Reliability, Safety, Robustness
- What is Sustainability at this Level?
  - › Trade-offs among **Economic Development, Social and Environmental Goals.**
  - › Broad: “Not just the Environment anymore”
  - › Not in itself an implicit, analytic, measureable property but does require a systems treatment



## Core Concerns for Sustainability

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- Flexibility in strategies, organizations, institutions
- System boundaries
- Goals, metrics and tradeoffs
- Cause and effect
- Stakeholders
- Openness of process
- Scale of analysis
- Interaction among sub-systems



## Why Sustainability?

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- Sense of urgency – rise in population, resource consumption, urbanization, globalization
- It's hard to redesign present systems
  - » Institutional barriers, complex cause and effect relations
- Imbed this notion in all we do
  - » Education - Professionals (a few) and Literate Practitioners (all)
- Top-Down or Bottom-Up? Both
- What are the core engineering systems methods to guide this?

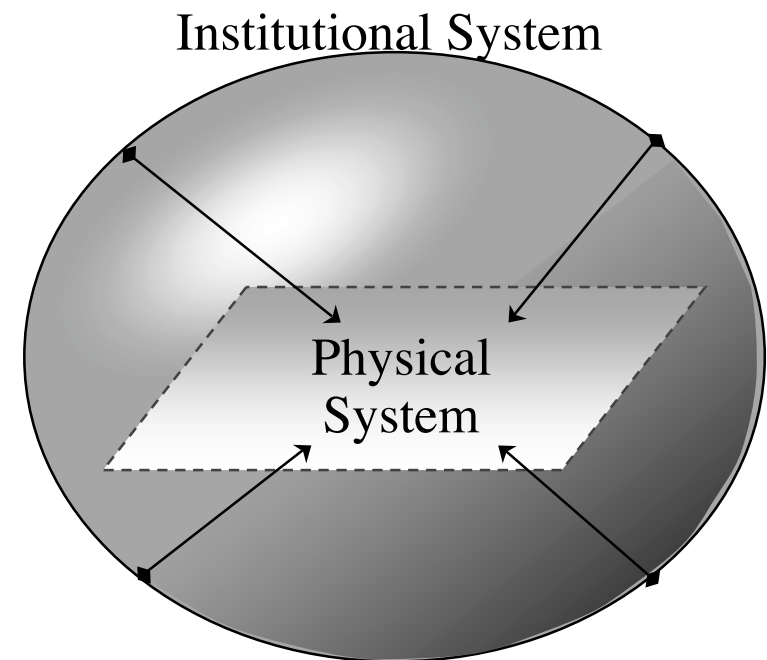


# Four Case Study "Vignettes"

## **1. Sustainability in a developing world megacity: The Mexico City case**

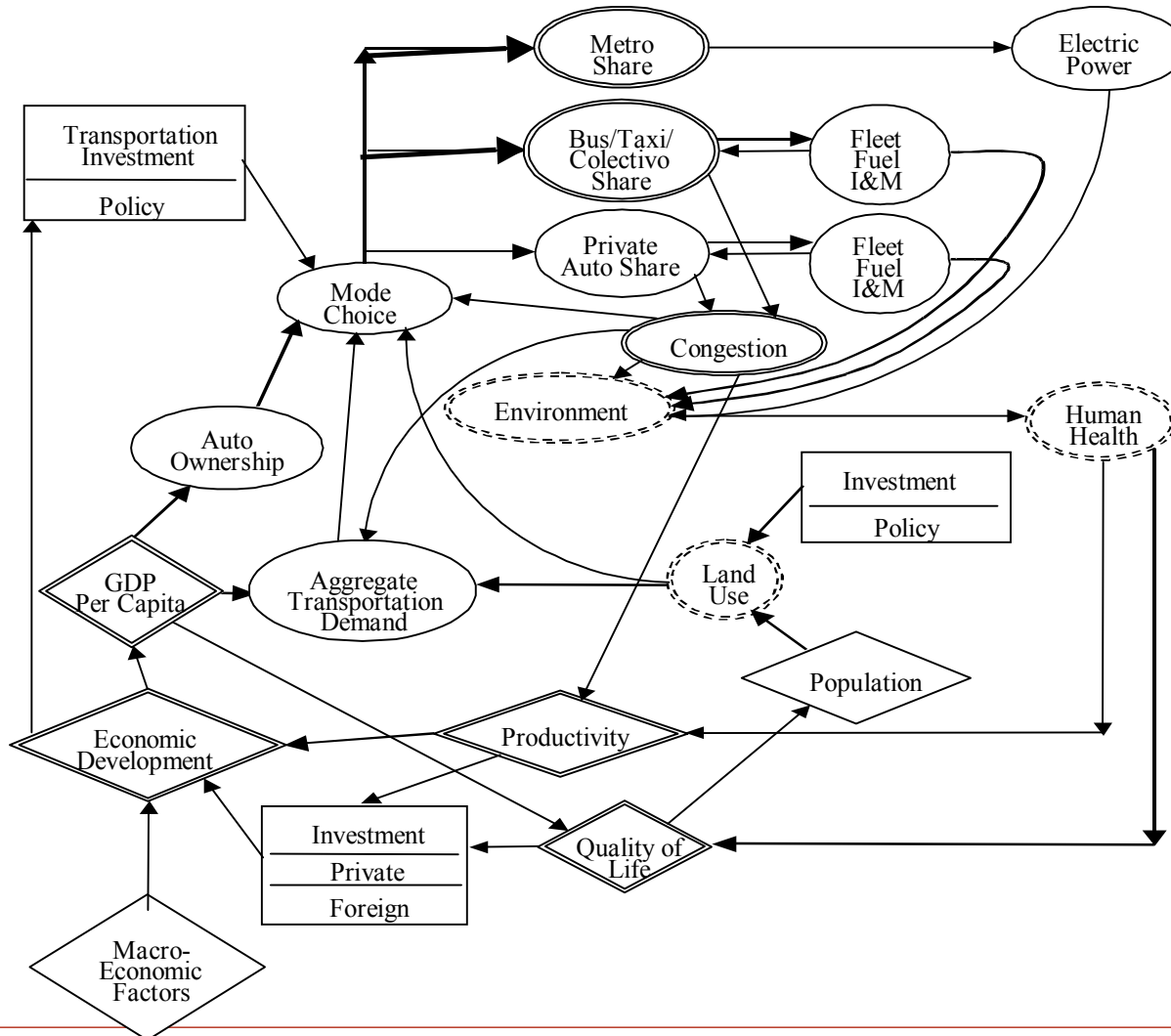
- » How to improve urban air quality without excessive damage to mobility and economic development?
- » CLIOS systems representation
- » Representation, Evaluation, Implementation
  - > Where are the necessary institutions?
- » Nested Complexity

COMPLEX, LARGE-SCALE,  
INTEGRATED, OPEN  
SYSTEMS (CLIOS)





# CLIOS Representation of Mexico City





## Four Case Study "Vignettes"

### **2. Ford Heritage Sustainable Manufacturing Model**

» Voluntary Private Sector Approach to sustainability in manufacturing – Expanding scope to include:

<b><i>Key Aspects of Manufacturing</i></b>	<b><i>Corresponding Aspects of Sustainability</i></b>
Facility design	Simplicity & Transformation
Manufacturing operations	Stability & Continuity
Stakeholder relations	Transparency & Partnership
Underlying mode of thought	Balance & Evolution



## Four Case Study "Vignettes"

### **3. Hierarchy of Levels of Analysis in Automotive Aluminum**

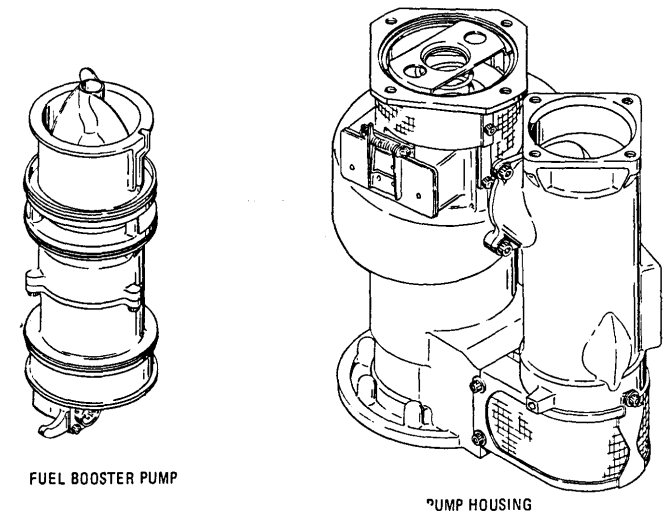
- » Broadening of scope of engineering problems requires a broadening in the scale of the system taken into consideration when issuing design development guidelines.
- » Leads to an hierarchy of analysis
- » A Close look at the "base case" for use makes it possible to derive "shadow prices" for different types of aluminum
  - › Examining use in: Bumpers, Body Sheet, Wheels, Brakes, Heat Exchange, All Al Engine & Transmission, Non-Al Engine & Transmission, Media scrap



## Four Case Study "Vignettes"

### **4. Lean Sustainment Initiative for the US Air Force: Tracing the Repair of an Aircraft Fuel Pump**

- » Organizations making procurements of large scale very long-lived products such as aircraft or infrastructure must move beyond simple concepts of life-cycle analysis
- » Sustainment Concept - Breech the fire walls between procurement/acquisition and long-term use



**Figure 8: Fuel Booster Pump  
and Pump Housing**



# *Sustainability, Efficiency, Uncertainty, and Adaptation*

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- Uncertainty and inevitable, unexpected effects
  - » Perverse reverse incentives, for example
- Tactical and Operational Implications:
  - » Fix the specific problems
- Strategic Implications:
  - » Designing policies to generate use and information, including:
    - › Broadening the scope of information acquisition and review to permit earlier detection of side effects
    - › Establishing independent units for reevaluation and reassessment of corporate strategies or public policies
    - › Analyzing retrospective examples of successful and unsuccessful business and government adaptation



## Conclusions

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- Sustainability as an Organizing Design Principle for Large-Scale Engineering Systems
- It is already influencing our thinking in research and education
- Now we need to formalize treatment of Sustainability as an Organizing Design Principle and the systems-oriented methods and metrics to implement this principle
- This is a Major Challenge for Engineering Systems as a Discipline