WHERE TRANSPORTATION IS GOING: Transportation in the CLIOS System Era

SEMINAR

SMART Project

CARSS

U of Michigan

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Engineering Science → ENGINEERING SYSTEMS

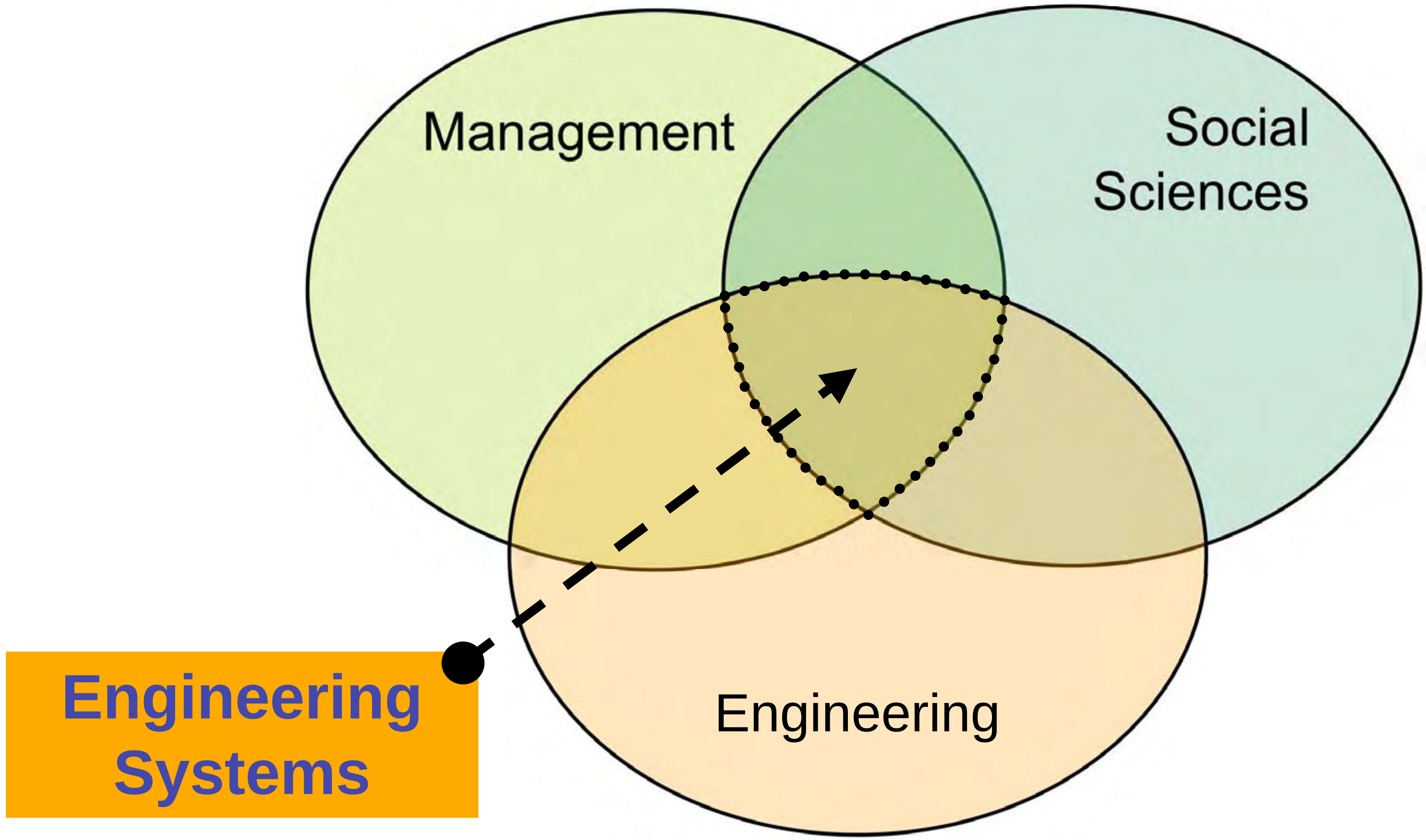
- Viewed as a distinct approach from the engineering science revolution of the late 1950s and early 1960s. Engineering science built on the physical sciences: physics, mathematics, chemistry, etc., to build a stronger quantitative base for engineering, as opposed to the empirical base of years past.
- This approach, while extraordinarily valuable, tends to be very micro in scale, and focuses on mechanics as the underlying discipline.

Engineering Systems

- Now *engineering systems* takes a step back from the immediacy of the technology and is concerned with how the system in its entirety behaves, for example, emergent behavior of complex systems.

ENGINEERING SYSTEMS

(at the interface of Engineering, Management, & Social Sciences)



<u>C</u> <u>L</u> <u>I</u> <u>O</u> <u>S</u> System

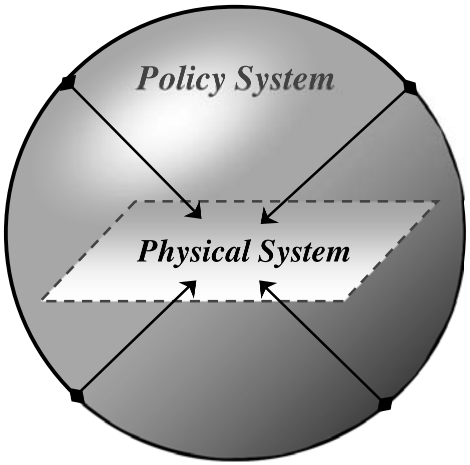
- Complex
- Large-scale
- Interconnected
- Open
- Socio-technical

C L I O S System

Complex

- *Structural complexity*
  - The number of components in the system and the network of interconnections between them
- *Behavioral complexity*
  - The type of behavior that emerges due to the manner in which sets of components interact
- *Evaluative complexity*
  - The competing perspectives of stakeholders who have different views of "good" system performance
- *Nested Complexity*
  - The interaction between a complex "physical" domain and a complex "institutional" sphere

Nested Complexity



- Physical system "layer"
  - More quantitative principles
  - Engineering & economic models
- Policy system "sphere"
  - More qualitative in nature and often more participatory
  - Stakeholder evaluation and organizational analysis
- Different methodologies are required
  - within the physical system
  - between the policy system and the physical system
  - within the policy system

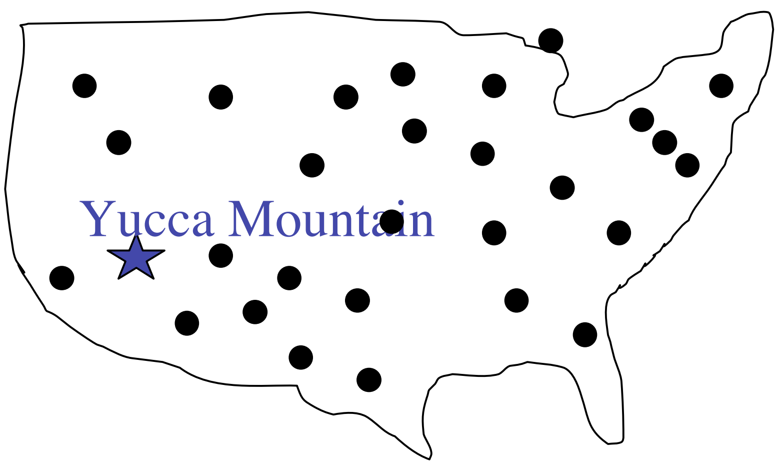
TRANSPORTING SPENT NUCLEAR FUEL

Complex

Large-scale

Large-scale in

- Geographic extent, and
- Impact



C L I O S System

Complex
Large-scale
Interconnected

TRANSPORTING SPENT NUCLEAR FUEL

Transportation interconnected with:

- **Energy**
- **Global Climate Change**

Complex
Large-scale
Interconnected
Open

TRANSPORTING SPENT NUCLEAR FUEL

- Social Factors
  - Risk
- Political Factors
  - Geopolitics
- Economic Factors
  - Development

C L I O S System

Complex

Large-scale

Interconnected

Open

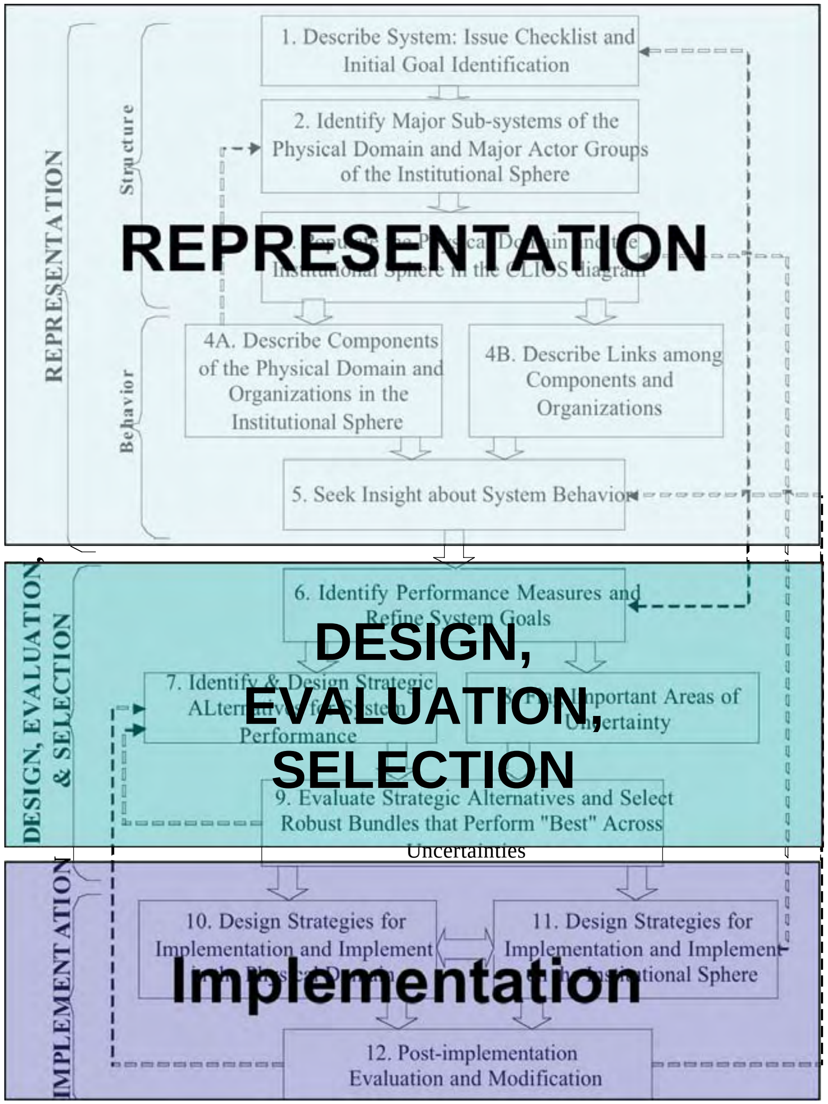
Socio-technical

An Example of a Socio-technical System:

TRANSPORTING SPENT NUCLEAR FUEL

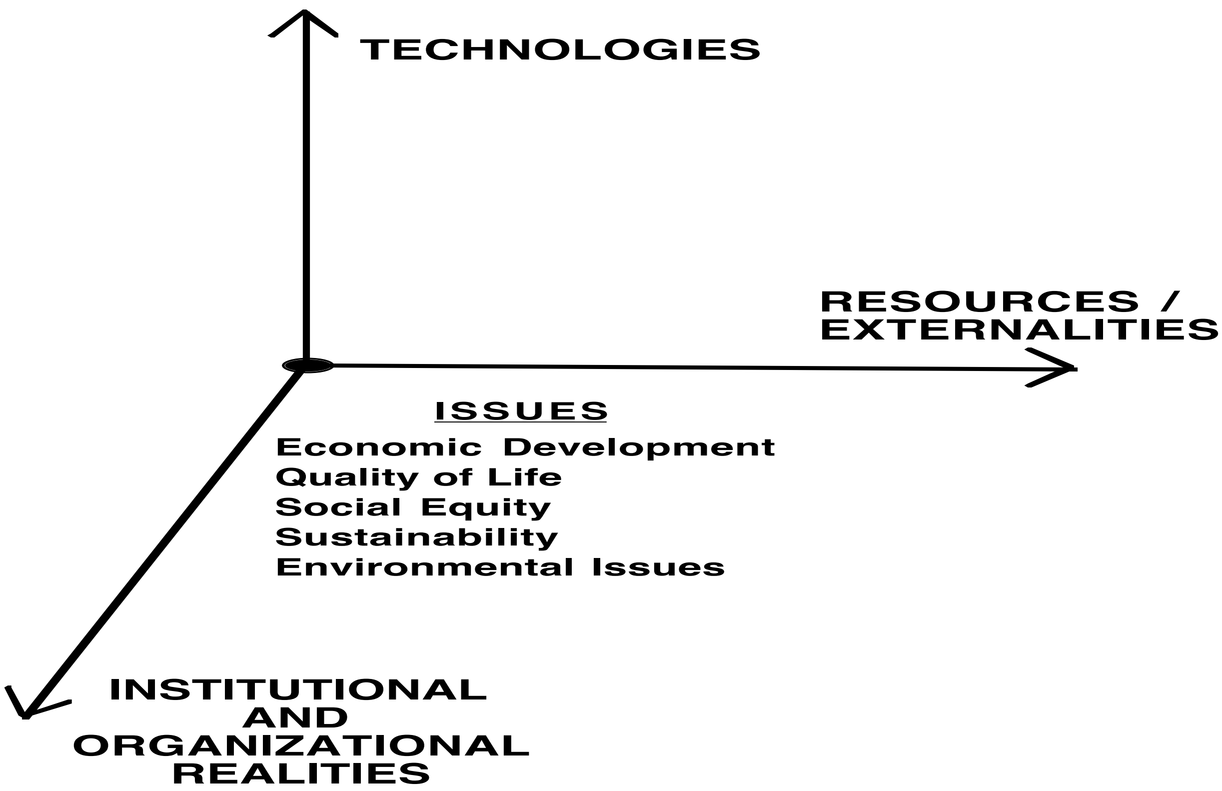
- **Complex Technology**
- **Important Social Impacts**

The C L I O S Process



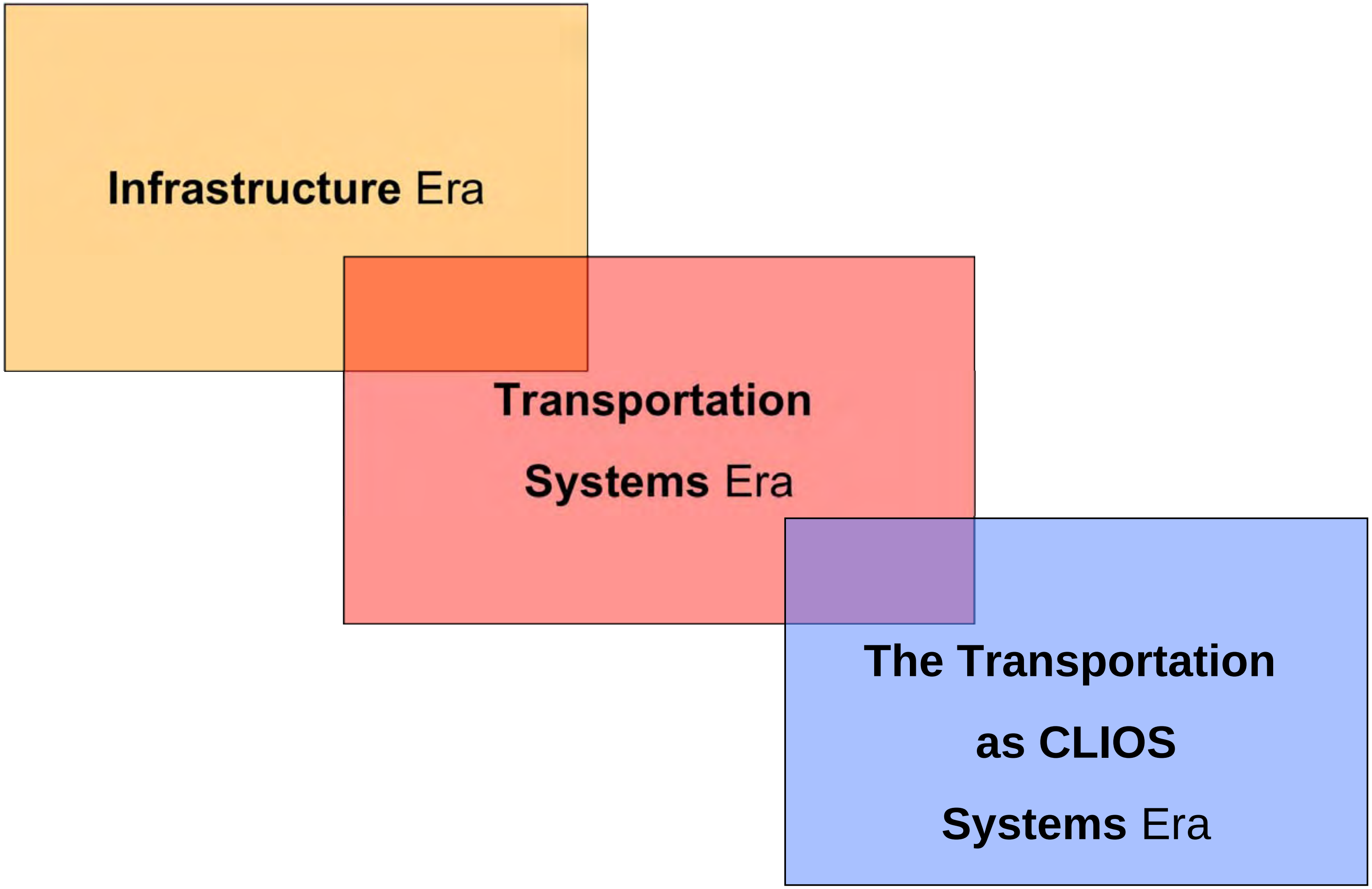
A 3-Stage, 12-step, iterative process used to study CLIOS Systems

DRIVING FACTORS IN TRANSPORTATION



Sussman, Joseph M., "The New Transportation Faculty: The Evolution to Engineering Systems", *Transportation Quarterly*, Eno Transportation Foundation, Washington, DC, Summer 1999.

Transportation Eras



Infrastructure Era

- –Build what “they” want
- –Focus on physical facilities
- –Focus on mobility
- –Focus on economic growth
- –Largely a modal perspective

Transportation Systems Era

- Economics-based framework
  - Supply
  - Demand
  - Equilibrium
  - Networks
- Focus on economic development and environmental concerns
- Focus on both mobility and accessibility
- Recognition of unpriced externalities as causing problems – congestion, air quality, sprawl
- Intermodal Perspective (largely limited to freight)

The Transportation as CLIOS System Era

Focused on transportation as a

Complex, **L**arge-scale, **I**nterconnected, **O**pen, **S**ocio-technical (**CLIOS**) System

Characterized by:

– Advanced Technology and Mathematics

– Institutional Change – the New Concept of Enterprise Architecture

– Transportation Connected to other Sociotechnical Systems

– Expanded Role for Stakeholders *and* a Broader Definition of Interested Stakeholders

– "Macro-design" Performance Considerations for the Transportation Enterprise – the "ilities"

The Transportation as CLIOS System Era is Characterized by:

Advanced Technology and Mathematics Enabling…

- Operations Focus
- Tailored Customer Service
- A Rich Information Environment
- A Higher and More Effective Level of Intermodalism Extending into Supply Chain Management
- Large-scale Optimization

The Transportation as CLIOS System Era is Characterized by:

Advanced Technology and Mathematics Enabling… (cont.)

- Disaggregate Demand Analysis
- Real-time Network Control and Provision of Traveler Information
- Vehicle Automation and a Crash-Avoidance Safety Perspective
- Sophisticated Pricing
  - Yield Management
  - Pricing of Externalities
- Regionally-scaled Transportation Operations and Management

The Transportation as CLIOS System Era is Characterized by:

Institutional Change—the New Concept of Enterprise Architecture

- Public Sector Change—among and within levels of government
- Private Sector Change – with new business models and players beyond the traditional ones
- Public/ Private Relationships/ Partnerships

The Transportation as CLIOS System Era is Characterized by:

Institutional Change—the New Concept of Enterprise Architecture (cont.)

- An International/Global Perspective

  and

  The Challenge of Operating Regionally and with Advanced Technology
- The Relationship of Logistics and Supply Chain Management to Regional Strategic Transportation Planning and the Idea of Transportation Investment and Operations as a Means to Enhance Regional Competitive Advantage

The Transportation as CLIOS System Era is Characterized by:

Transportation Connected to other Sociotechnical Systems

- Environment
- Energy
- Economic
- Global Climate Change
- National Defense/ Geopolitics
- Telecommunications

The Transportation as CLIOS System Era is Characterized by:

Expanded Role for Stakeholders *and* a Broader Definition of Interested Stakeholders

- In system definition and representation
- In developing performance metrics
- In developing strategic alternatives
- In considering implementation strategies
- In decision-making

The Transportation as CLIOS System Era is Characterized by:

"Macro-design" Performance Considerations for the Transportation Enterprise---the "ilities"

(in addition to traditional micro-design considerations such as cost, level-of service (LOS) variables such as price, travel time, service reliability, service frequency, safety….)

- Flexibility
- Adaptability
- Robustness

The Transportation as CLIOS System Era is Characterized by:

"Macro-design" Performance Considerations for the Transportation Enterprise---the "ilities"

- Resilience (the opposite of vulnerability)
- Scalability
- Modularity
- Stability …

The Transportation as CLIOS System Era is Characterized by:

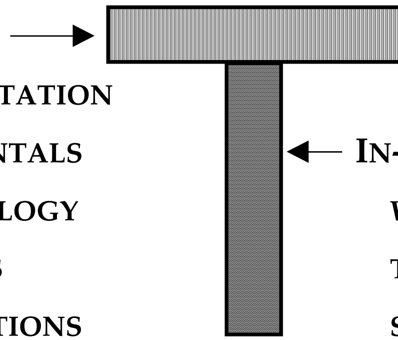
“Macro-design” Performance Considerations for the Transportation Enterprise---the “ilities”

… and, perhaps the most important “ility”

- **SUSTAINABILITY**

  as an overarching design principle–The 3 Es---Economics, Environment and Social Equity

THE "T-SHAPED" NEW TRANSPORTATION PROFESSIONAL



BREADTH IN:

- TRANSPORTATION FUNDAMENTALS
  - TECHNOLOGY
  - SYSTEMS
  - INSTITUTIONS

IN-DEPTH KNOWLEDGE WITHIN A TRANSPORTATION SPECIALTY

How Transportation Must Change in Academia

1. Reaching beyond engineering to management, social science, planning.

2. Recognizing the need for **qualitative** as well as quantitative analysis.

3. Eschewing narrow representations of complex systems that can be formally solved, but that have little relevance to real-world issues.

How Transportation Must Change in Academia

4. Realizing that "optimal" solutions are often beyond the pale; a small set of feasible solutions is often all we can hope for because of *evaluative complexity.*

5. Learning to approach with considerable humility, our intervention in complex socio-technical domains – remember that *behavioral complexity* makes predictions extraordinarily difficult.

6. Relating our work in education and research to those of colleagues in other domains – Energy, Manufacturing, Logistics, Telecommunications – these are all CLIOS Systems too.

Thanks for your attention!