



WHERE TRANSPORTATION IS GOING: Transportation in the CLIOS System Era

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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

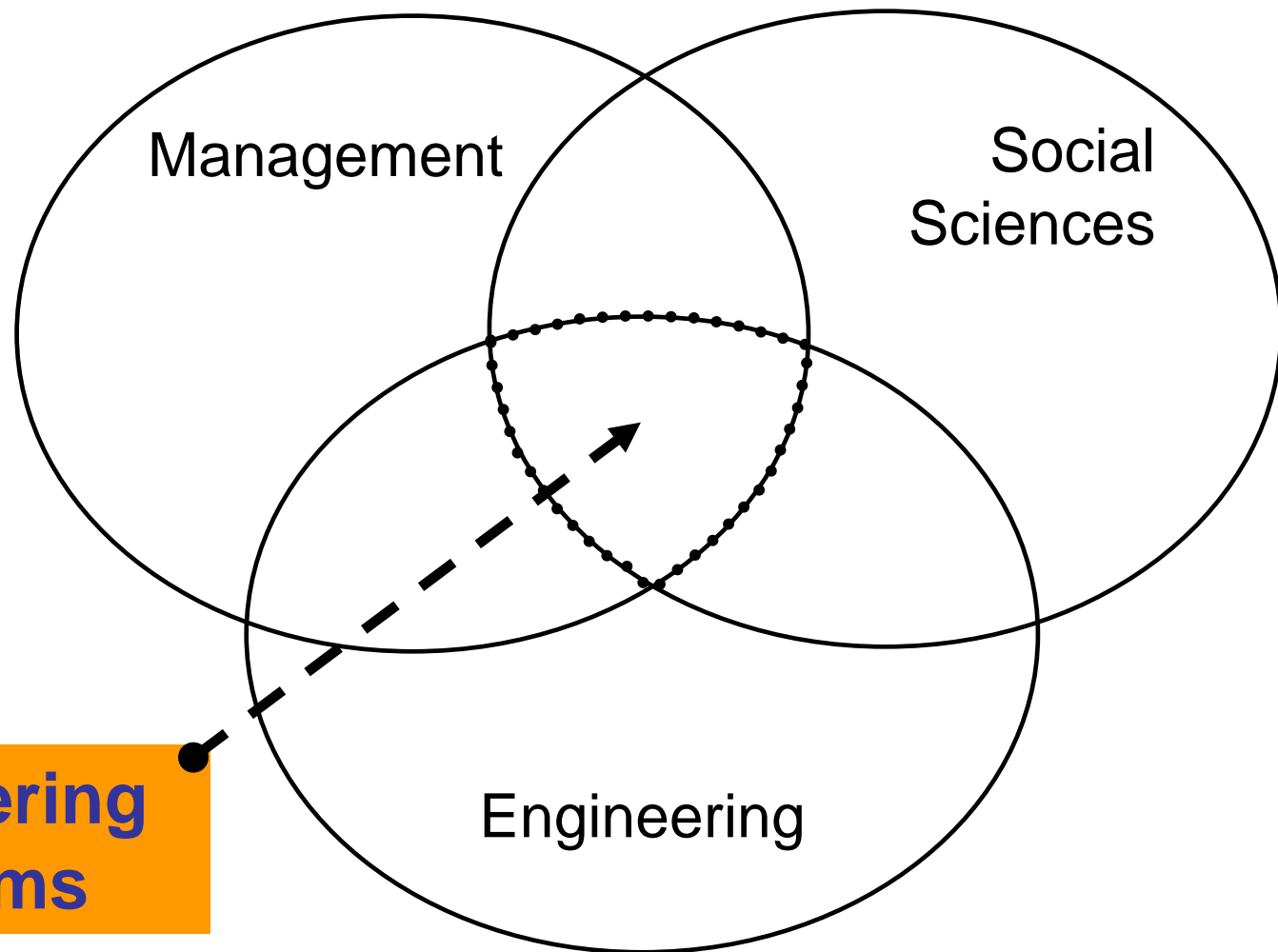
- Now *engineering systems* takes a step back from the immediacy of the technology and is concerned with **how the system in its entirety behaves**, for example, emergent behavior of complex systems.





ENGINEERING SYSTEMS

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



**Engineering
Systems**





C L I O S System

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





C L I O S System

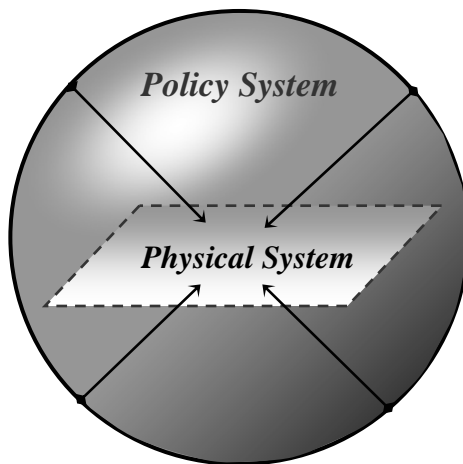
Complex

- *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 **actions of decision makers** in the system who have alternate 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



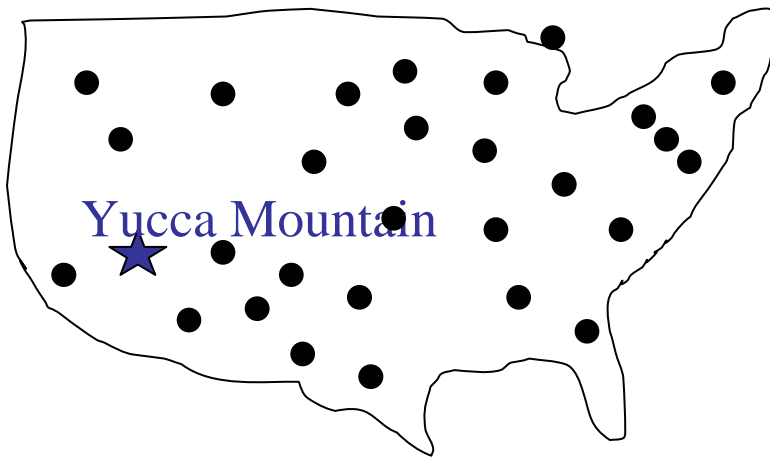
CLIOS System

Complex
Large-scale

TRANSPORTING SPENT NUCLEAR FUEL

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**



C L I O S System

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:

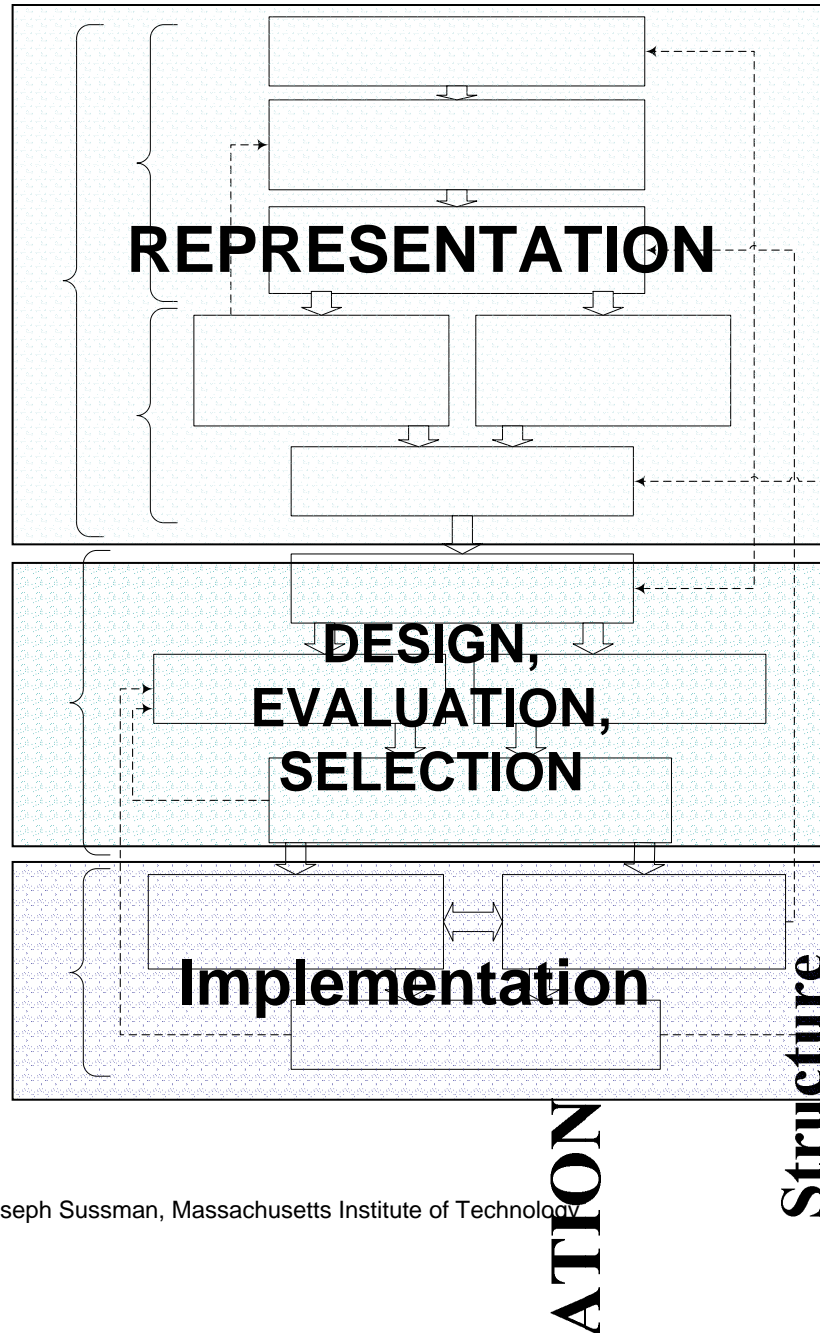
TRANSPORTING SPENT NUCLEAR FUEL

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





The CLIOS Process



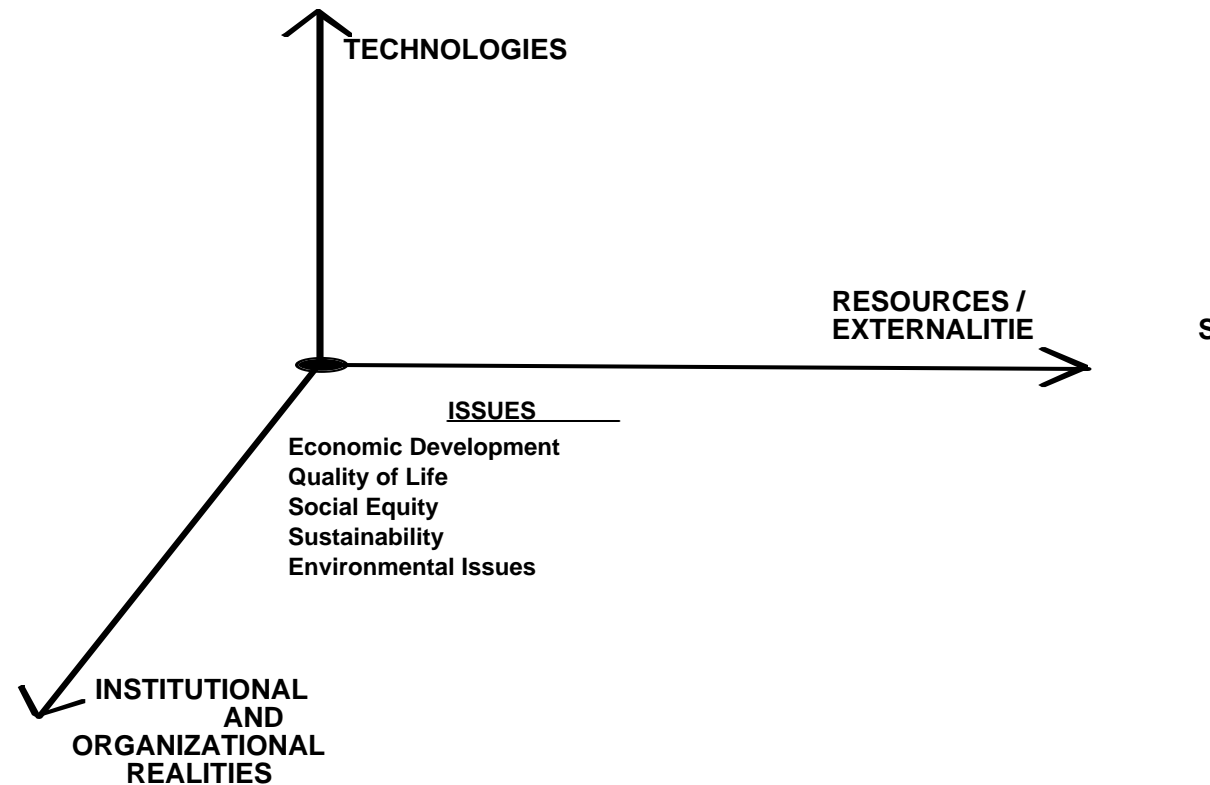
A 3-Stage, 12-step, iterative process used to study CLIOS Systems

1. Describe System: Is...
Initial Goal Ide
2. Identify Major Sub...
Physical Domain and M...
of the Institution
3. Populate the Physical





DRIVING FACTORS IN TRANSPORTATION

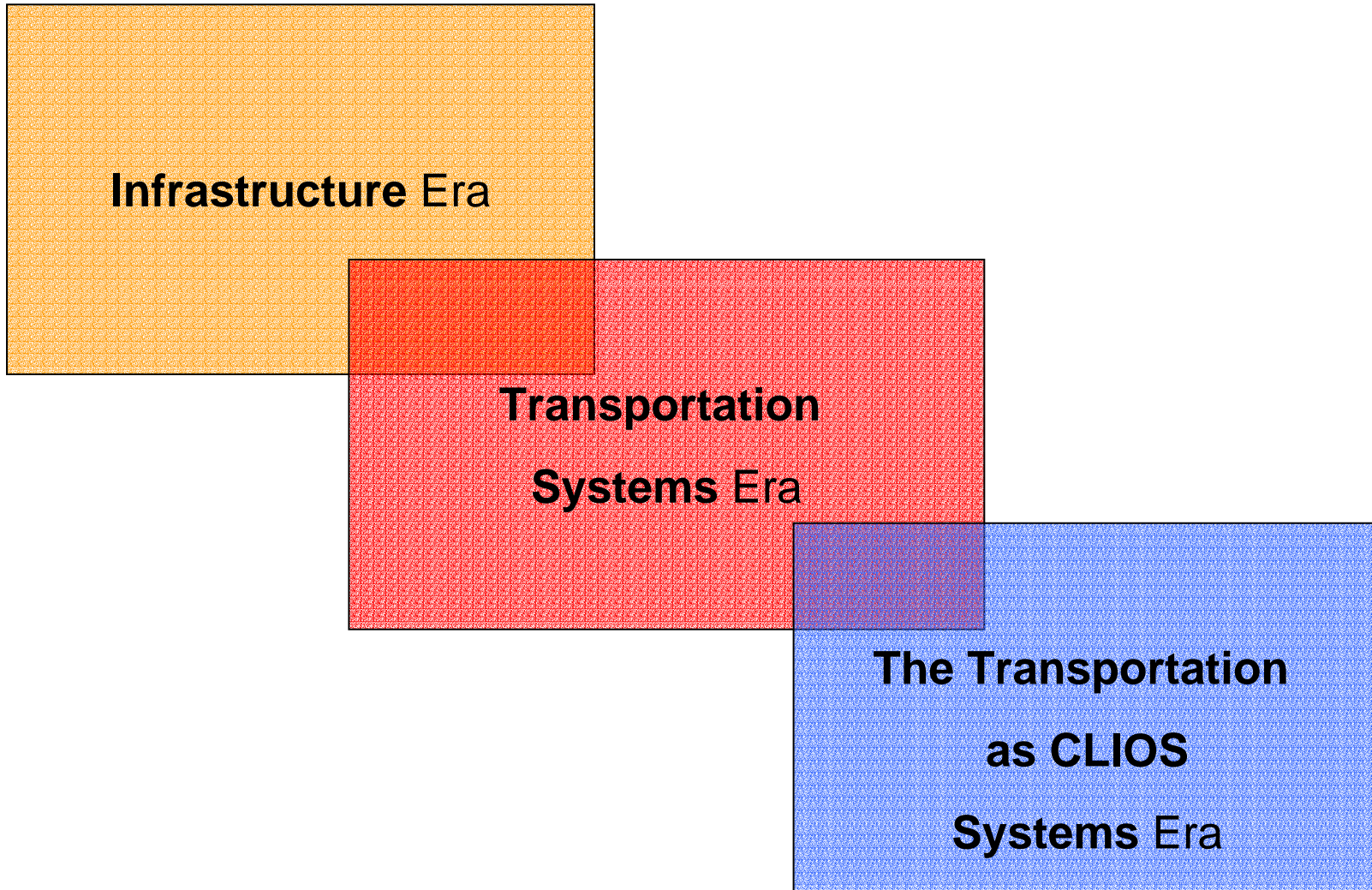


Sussman, Joseph M., "The New Transportation Faculty: The Evolution to Engineering Systems", *Transportation Quarterly*, Eno Transportation Foundation, Washington, DC, Summer 1999.





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, Large-scale, Interconnected, Open,
Socio-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”

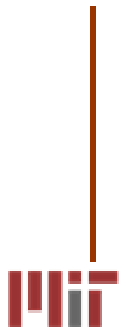
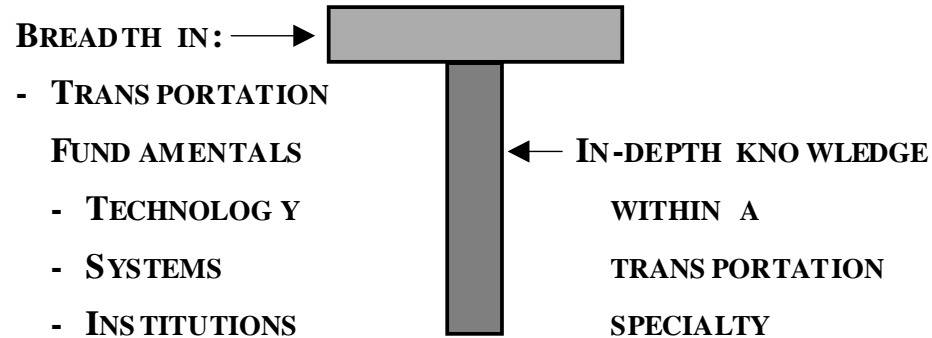
- **SUSTAINABILITY**

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





THE “T-SHAPED” NEW TRANSPORTATION PROFESSIONAL





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!

