High-Speed Rail Research: Activities of MIT’s Regional Transportation Planning and High-Speed Rail Research Group

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MIT Regional Strategies/ High-Speed Rail Group I

- Measuring productivity of HSR under various institutional structures
  - Public vs. Private Ownership
  - Vertical Separation vs. Vertical Integration
- HSR in Portugal
  - Regional development: The concept of mega-regions
  - The relationship of urban transportation/planning to intercity HSR
• HSR in the Northeast Corridor of the U.S.
  • Incremental- vs. International-quality HSR
  • Various organizational options
  • Opportunities for further economic development in an already very developed region
  • Environmental and energy implications
Critical Contemporary Issues (CCI)

- Global Climate Change
- Energy/Environment
- Developing Country Megacities
- Global Economy
- National Security
- Productivity
- Mobility and so forth
Two Linked Concepts

CRITICAL CONTEMPORARY ISSUES

AND

COMPLEX SOCIOTECHNICAL SYSTEMS
Complex Sociotechnical Systems

- Technologically enabled networks which transform, transport, exchange and regulate Mass, Energy and Information
- Large-scale
  - large number of interconnections and components
- Sociotechnical aspects
  - social, political and economic aspects
- Exhibit Nested complexity
  - technical complexity nested within institutional complexity
- Exhibit Evaluative complexity
  - Recognize different views of various stakeholders
- Dynamic
  - involving multiple time scales, uncertainty & lifecycle issues
- They require deeply rigorous quantitative and qualitative approaches
An Approach to the Study of Complex Sociotechnical Systems

*Systems-Oriented Methods

**Social Sciences, Management & Planning

Integrative Domain Knowledge

Deep

Quantitative

Engineering

Science
Beyond “Study” to “Design”

• We are not simply observers
• Our Complex Sociotechnical Systems are purposeful
• We have a normative view – what does good performance mean?
• We have a prescriptive view – how do we make our system perform better?
An Approach to the *Design of Complex Sociotechnical Systems*

**Integrative Domain Knowledge**

- **Deep**
- **Quantitative**
- **Engineering**
- **Science**

*Systems-Oriented Methods*

**Social Sciences, Management & Planning**
“Work, however, cannot be defined in terms of the disciplines. End results are interdisciplinary of necessity.” Drucker
TRANSPORTATION IN THE NORTHEAST CORRIDOR OF THE U.S.: A MULTIMODAL AND INTERMODAL CONCEPTUAL FRAMEWORK

Research Performed for the Institution for Transportation Policy Studies, Japan International Transport Institute (JITI)
Northeast Corridor of the U.S. – What more can possibly be learned?

- MIT’s approach– treat the NEC as a complex sociotechnical system (CSS)
Methodology

1. **CLIOS Process**: Conceptual Framework -- Physical Domain embedded in an Institutional Sphere

2. **Scenario Planning**: Scenarios are “stories about the way the world might turn out”, but not predictions of the future nor extrapolations of the past

3. **Flexibility – ‘Real Options’**: Flexibility allows decision-makers to respond dynamically to different realizations of the future
Motivation
- The Obama administration is the first U.S. administration that has made HSR a national priority.
- The nascent field of engineering systems as studied in the ESD of MIT presents the possibility of looking at the NEC with new methods that could possibly lead to further insights about how one might go about improving mobility.

Objective
- Apply new and innovative methods in the engineering systems field to seek new insights.
- Platform for further study.

Source: Sussman
The Northeast Corridor (NEC) is the most densely settled and richest region in the US – congested transportation system.

Challenges in upgrading to high-speed rail a multi-state, multi-use and multi-operator corridor.

Source: NEC Infrastructure Master Plan Working Group 2010
Context II

- 457 mile-long corridor
  - 4 owners
  - 9 states
- 13 million intercity rail passengers per year
  - Amtrak
- 250 million commuter rail passengers per year
  - 8 agencies
- Freight rail traffic
  - 7 companies

Source: NEC Infra. MP 2010
Approach

- New and innovative methods in the engineering systems field to seek new insights about how one might go about improving mobility

- Planning and implementation under uncertainty related to inputs, requirements, and outcomes of the system
Complex, Large-Scale, Interconnected, Open, Sociotechnical (CLIOS) Systems

A CLIOS (Complex, Large-Scale, Interconnected, Open, Socio-Technical) System is characterized as follows:

A CLIOS system has technology as an important element – but, by definition, is socio-technical in nature, and therefore will almost always exhibit nested and evaluative complexity.
The CLIOS Process

Complex
Large
Interconnected
Open
Sociotechnical

1. Describe CLIOS System: Checklists & Preliminary Goal Identification
2. Identify Subsystems in Physical Domain & Groups on Institutional Sphere
3. Populate the Physical Domain & Institutional Sphere
4A. Describe Components
4B. Describe Links
5. Transition from Descriptive to Prescriptive Treatment of System
6. Refine CLIOS System Goals & Identify Performance Measures
7. Identify & Design Strategic Alternatives for System Improvements
8. Identify Important Areas of Uncertainty
9. Evaluate Strategic Alternatives & Select "Bundles"
10. Physical Domain / Subsystems
11. Institutional Sphere
12. Evaluate, Monitor & Adapt Strategic Alternatives for CLIOS System

Design and Implement Plan for:

First order understanding of CLIOS System
Mental mapping of physical & institutional systems
General insights regarding CLIOS System structure & behavior
More detailed & quantitative understanding of system behavior
Deeper understanding of and appreciation for system possibilities, limits, uncertainties, and sensitivities
Updating of prior beliefs/models regarding system goals, structure, & behavior

Stages of the CLIOS Process

• Representation

• Design, Evaluation and Selection: Create **bundles of strategic alternatives**

• Implementation

Distinction between CLIOS Process and specific methods (models and frameworks)
1. Representation

“Defining the problem may be the most important element in making effective decisions ... The right answer to the wrong problem is very difficult to fix ... once the problem has been correctly defined, the decision itself is usually pretty easy.” Drucker.
2. **Design, Evaluation and Selection:** develop bundles of strategic alternatives and select among them

3. **Implentation:** develop bundles of strategic alternatives and select among them

Implicitly, there is iterative behavior throughout
“The characteristic of the innovator is the ability to envisage as a system what to others are unrelated, separate elements.” Drucker
Transportation

- Transport Funding & Investment
- Transport Operations Subsidy
- Fuel Tax
- Transportation Infrastructure
- Transportation Service
- Energy Output
- Fuel Cost & Availability
- Global Fuel Prices
- Trip Attributes
  - Fare/Cost
  - Comfort
  - Reliability
  - Travel Time
  - Waiting Time
  - Safety
- Congestion
- Weather
- Air Emissions
- Modal Split
- Network Usage
- Transportation Demand
- Transport Revenues
Complexity

**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

Institutional “sphere”
- More qualitative in nature and often more participatory
- Stakeholder evaluation and organizational analysis

Different methodologies are required
- within the physical system
- between the institutional sphere and the physical system
- within the institutional sphere
CLIOS System/Process Ideas I

• Sustainability as an overarching design principle for CLIOS Systems
• Separate “organizations” from other components -- CLIOS System world view
• Distinguish between representation and modeling
  Representation related to visualization
  Think carefully about when to quantify – when to “model”
• Recognize different kinds of complexity
• Emphasis on dealing with uncertainty
Emphasis on stakeholder roles
Strategic alternatives
Robust bundles of strategic alternatives
Strategic alternatives are needed for implementation as well
  • In the physical domain
  • On the institutional sphere -- change management
Monitoring the outcomes is central to the CLIOS Process
The CLIOS Process as iterative among all the stages
Bundles of Strategic Alternatives

Initial State

Technology
- International-quality HSR
- Incremental HSR

Infrastructure organization structure
- Amtrak
- Alternative public owner
- Amtrak
- Alternative public owner

Vertical integration/separation
- Vertical integration
- Vertical separation
- Vertical integration
- Vertical separation

Competitive structure of intercity train operations
- One operator (Amtrak)
- Multiple operators
- One operator (Amtrak)
- Multiple operators
One overarching conclusion: **Uncertainty dominates**

- Demand for high-speed rail is uncertain
- There may be changes in the fuel tax in structure and magnitude
- What will be the pricing mechanism for high-speed rail? (does the gov’t intend to recoup infrastructure costs?)
- Is there sufficient patience in the political process?
- Will there be intermodal cooperation between aviation industry and high-speed rail… etc. etc.
We identified three categories of desired flexibility:

- Institutional flexibility
- Technological flexibility
- Intermodal-connectivity flexibility
Three Scenarios

Driving forces

- economic growth
- political support
- congestion
- technological change
- public perception
- environmental changes
- energy
- funding sources
- multimodal cooperation

Scenarios:

- “No-Growth—Support”
  Slow economic growth and strong political support

- “Growth—No-Support”
  Rapid economic growth and little political support

- “Growth—Modest Support”
  Medium economic growth and modest political support
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Thanks for your attention!

Questions or Comments?