

Managing cyber-physical systems in the real world

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Introduction

- ❑ The promise of CPS
- ❑ Necessary conditions
- ❑ The case of CPS applied to transport

The promise of CPS

□ Efficiency

- Better use of inputs
- Better management of demand
- Better monitoring and management of infrastructure

Necessary conditions

- ❑ Reliable information available and shared
- ❑ Means for system management
- ❑ Feasible options for efficiency improvements
- ❑ Responsiveness of decision-makers

Consider in context of transportation CPS

The transportation CPS

❑ Infrastructure

- Highways, railroads, public transit, ports, airports, intermodal terminals, local streets and roads

❑ Operators and owners

- Governments, private firms

❑ Users

- Individual travelers, shippers, cargo owners

❑ Regulators

- All levels of government

Complexity

- ❑ Modal “stovepipes”
 - Different operators, managers, funding sources
- ❑ Agency jurisdictions
 - Public transit agencies
 - Highway operations vs vehicle enforcement
- ❑ Technology does not assure cooperation, coordination, and lack of coordination can reduce effectiveness of technology

General issues

- ❑ Public infrastructure is costly and long-lived
 - Retrofitting may be costly and constrained
 - Costs of transition to new technologies
 - How to phase in new technologies
 - Linkages and compatibility with existing systems
- ❑ Mismatch in timing
 - The public decision-making process vs technology change
 - Long-term investments vs high turnover technology
 - With constantly changing technology, how do you decide when to invest?

Reliable information available and shared

- ❑ Many different owners of information
 - Information is power
- ❑ Some proprietary
 - Limited willingness to share
- ❑ Questions
 - Beyond the technical fixes.....
 - Under what conditions are owners willing to share?
 - How can information sharing be better incentivized?

Means for system management

- ❑ Optimization implies a system manager, but management of the transport system is fragmented among many managers
- ❑ Multiple stakeholders and multiple objectives
 - Centralized control systems are incompatible
 - Who has authority?
 - All stakeholders have veto power

Multiple stakeholders, con't

- ❑ Fragmented authority weakens decision-making
 - Affects technology design and implementation
 - May affect project leadership and management
 - Difficult decisions deferred
 - Lack of authority, accountability
- ❑ Benefits must exceed costs for each participant
 - Without net benefits, no incentive to participate
 - Because of veto power, participants can hold out for more, raising project costs and/or reducing project effectiveness

Questions

- ❑ Are there forms of collaboration that can lead to near optimal solutions?
- ❑ What motivates collaboration among managers?

Feasible options

- ❑ Technical feasibility \neq implementation feasibility
- ❑ Options may assume shifts in behavior that are not practical from user perspective
- ❑ Options may assume technical capacity that does not exist

On technical capacity

- ❑ Technology has changed faster than the public workforce
- ❑ Those who will use the technology may not have adequate skills
- ❑ Communication problems between the tech experts and managers, decision-makers
 - Managers, decision-makers may have unrealistic expectations
 - Managers, decision-makers vulnerable to the “hard sell” of vendors, technology developers

Questions

□ Questions

- How do we incorporate practical considerations in complex modeling?
- Should we be thinking about phased implementation?
- Do we adequately understand the technology implementation process?

Decision maker response

- ❑ To move research to implementation, need support of decision-makers (public sector representatives and private sector users)
- ❑ Interests of agency officials, elected officials, public
 - Elected officials make funding, project decisions
 - Public agencies are responsible
- ❑ The high cost of failure
 - One failure may delay adoption of worthy technology for a long time
 - Makes public sector highly risk adverse, hence unwilling to experiment
 - A disincentive for specific goals, performance measurement

Questions

- ❑ What is the acceptable technology failure rate?
- ❑ How do we better understand the institutional impacts of CPS?
- ❑ Should we incorporate institutional constraints in our models?