AN INTRODUCTION TO
INTELLIGENT TRANSPORTATION SYSTEMS
1.212

SPRING 2005

Professor Joseph M. Sussman

Mon/Wed 2:30-4

Part 1
Introduction to Commercial Vehicle Operations
(Sussman)

Part 2
Regional ITS Planning and Architecture Group Project Support Lecture I
(McConnell)

LECTURE 11

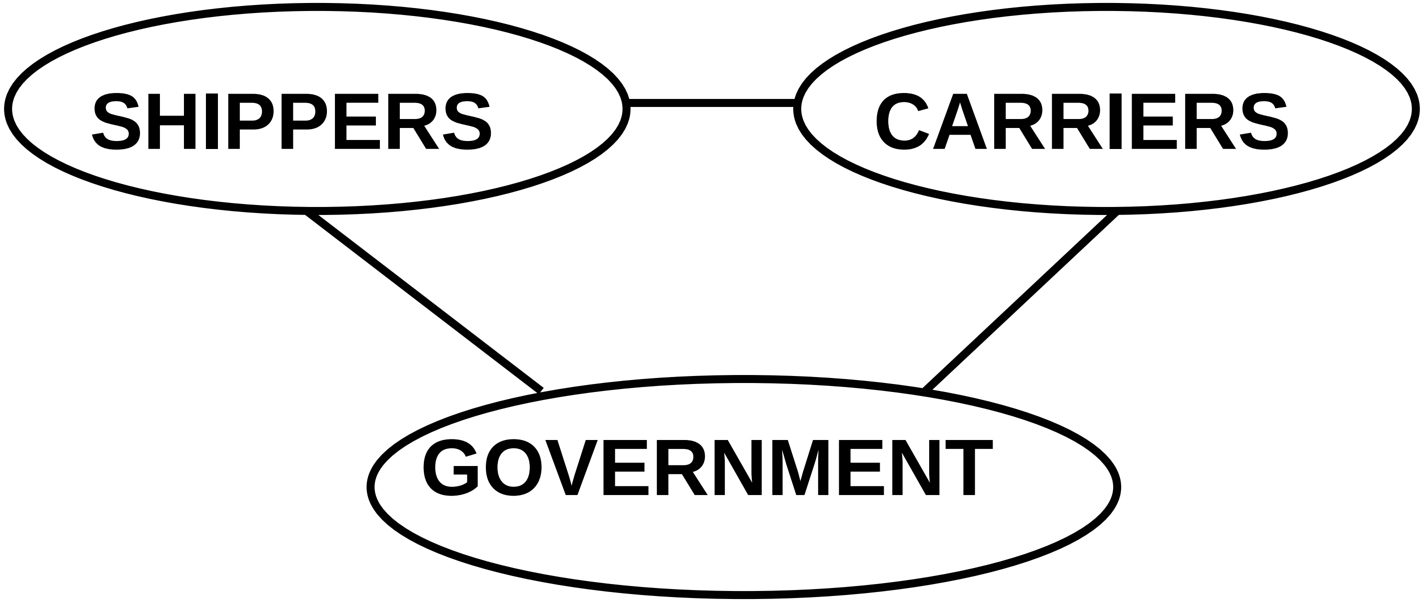
COMMERCIAL VEHICLE OPERATIONS (CVO)

SPEAKER: Joseph M. Sussman
MIT

Difference between trucking trips and auto trips

What can a trucking company do with real-time information about location of its vehicles and network state?

CLASS DISCUSSION


SHIPPERS
CARRIERS
GOVERNMENT

"Commercial Vehicle Operations and Freight Movement", Kim Richeson and Valerie B. Barnes (Applied Physics Labs, Johns Hopkins University), Chapter 9 in *Intelligent Transportation Primer*, Institute of Transportation Engineers, Washington, DC, 2000.

CVO FUNCTIONS

- Freight Movement
- Carrier Operations
- Vehicle Operations
- Safety Assurance
- Credentials Administration
- Electronic Screening

-- Richeson & Barnes

KEY ITS/CVO OPERATIONAL CHANGES

- Integrated logistics management
- Just-in-time manufacturing
- Enterprise resource planning

-- Richeson & Barnes

KEY ITS/CVO OPERATIONAL CONCEPTS FOR CARRIER OPERATIONS

- Total asset visibility
- Automated identification and tracking
- Automated routing and dispatch
- Maximizing equipment readiness and utilization
- Automated finding and bidding on loads
- Interoperability with customer systems
- Specialized load handling and logistics services

-- Richeson & Barnes

KEY ITS/CVO OPERATIONAL CONCEPTS FOR VEHICLE OPERATIONS

- On-board location and navigation
- Real-time monitoring of equipment, load and driver
- Communication between vehicle and dispatch
- Communication between vehicle and roadside

-- Richeson & Barnes

KEY ITS/CVO OPERATIONAL CONCEPTS FOR ELECTRONIC SCREENING

- Interoperability among screening systems
- Widespread participation encouraged
- Up-to-date electronic information at the roadside
- Credential and safety checks at the roadside
- ...

-- Richeson & Barnes

CVO VISION

- Interoperable system
- Smooth regulatory compliance
- Improved productivity through fleet management
- Integration with shippers -- supply-chain management
- International scale

1.212 Lecture 11
March 14, 2005

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Regional ITS Planning and Group Project Support Lecture I

ITS and Flexibility: A New Way of Thinking about ITS

Joshua McConnell

Presentation Overview

- Uncertainty and Flexibility
- Flexibility and ITS
- Quantifying the Benefits and Costs Associated with Flexibility
- Case study
- Additional Considerations
- References

Key Concepts

- Concepts from 1.212 to date
  - ITS technologies have inherent benefits
  - Consideration of ITS during planning phase introduces alternatives in addition to traditional infrastructure investment
  - ITS investments may cost less than traditional infrastructure investments
- Additional concepts to be introduced today
  - ITS technologies and integration into the planning process can create operational flexibility in transportation system
  - Flexibility may have some value in transportation system, if uncertainty is high
  - Operation flexibility is benefit of ITS, ***in addition to*** inherent value of ITS
  - ITS technologies can be designed for dual use, applicable in other industries and create new capabilities and stakeholder coalitions

Types of Uncertainty in Transportation Systems: Some Examples

To make decisions even more difficult, there are many types of uncertainty…

- **Technical:** demand/congestion, mode share, technology availability/development
- **Economic:** costs and benefits, economic activity, funding availability
- **Political:** political support or resistance, political objectives and priorities
- **External:** security

Strategies for Addressing Uncertainty

Luckily, some strategies exist!

- Reduce or control uncertainty
  - Increase information and knowledge of system
  - Reduce system complexity
  - Manage demand
- Increase robustness
  - Increased capacity / less sensitivity to uncertainty
- Design in flexibility
  - Ability to alter system configuration, based on future circumstances

Overview of Flexibility

- What is flexibility?
  - Ability to change the future configuration of a system, i.e. postpone final configuration of system until a future date when additional information is available
- Why flexibility?
  - Flexibility adds value to the system, allowing the system to adapt to future circumstances
- Flexibility is not for free! General costs include
  - Money to buy flexibility
  - Increased complexity in design and management
  - Time and effort to create flexibility in designs and plans

Real Options

- "Option" is the formal name given to define flexibility
- "Real option" is the formal name given to define flexibility in a "real" system (as opposed to financial options on financial assets)
- A real option gives the owner the
  - Right, but not an obligation,
  - To take some action,
  - Now or in the future,
  - At a pre-determined price
- Option terminology
  - Option purchase or implementation – fielding the option at t=0
  - Option exercise – "triggering" the option at t>0
  - Option price or purchase price – cost of option paid at t=0
  - Exercise price – additional price paid to exercise the option at t>0

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Flexibility in Transportation Systems

- Need for flexibility due to:
  - Presence of many types of uncertainty
  - Possible expense of building robust system
  - Possible inability to control or reduce uncertainty
- Different methods available for creating flexibility in transportation systems – some examples…
  - Modularity in infrastructure construction or rolling stock allows parts of system to be modified in future or introduced in phases
  - Decentralized operations allows changes in operations across geographic areas over time
  - Use of ITS during planning phase to create flexibility in operations
  - Legal authority to change toll rates or fare box rates in future to meet operating objectives

ITS as a Real Option: Examples

Option Types	ITS Example
Wait	The use of ITS capabilities to defer infrastructure investments until additional information is gathered on future transportation system conditions.
Abandon	End of service for most types of ITS capabilities is possible and is easier to accomplish than with fixed infrastructure. For example, ending service to customers is simple, compared with removing infrastructure.
Expand / Contract	Variable Message Signs can be used to expand the types of information available to travelers or Electronic Toll Collection technologies can have their use expanded upon, first as dedicated ETC and then to help monitor congestion.
Growth	ITS infrastructure, such as fiber optic cable or embedded roadside sensors, can be invested in during routine construction, before there is an identified need for full ITS capabilities. This can result in new capabilities being added at a later date.
Switch	ITS capabilities, such as cameras, can be switched between functions. In a normal state they can be used to observe traffic flows and identify traffic accidents, though their functionality could be switched to incorporate the cameras into a security system in the event of terrorist threats, similar to the use of cameras deployed in London.
Compound	ITS capabilities that enhance user operations can be deployed sequentially – GPS onto trucks first, then tracking equipment, then two way communications, then real time scheduling capabilities, etc.

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To be flexible or not to be flexible, that is the question…

- Flexibility seems like a good idea, but since flexibility costs something, we need to know if the benefits are worth the costs
- Value of flexibility driven by:
  - Specific design or management attributes
  - Nature and amount of uncertainty
- Costs of flexibility driven by:
  - Specific design or management attributes
- Therefore, to understand the benefits and costs associated with flexibility, we need to quantify
  - Uncertainty
  - System attributes

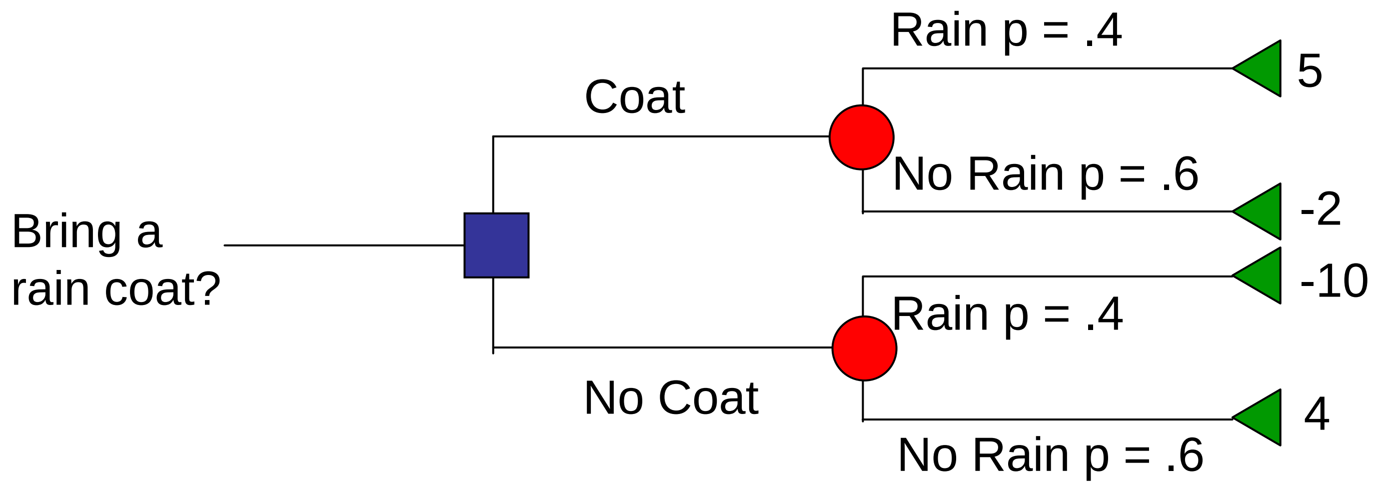
Tools for Addressing Uncertainty

- Tools for understanding uncertainty
  - Monte Carlo analysis
  - Sensitivity analysis
  - Parametric analysis
  - Forecasting
- Tools for coping with uncertainty and/or evaluating performance of system under uncertainty
  - Factor of safety
  - Scenario analysis
  - Decision trees
  - Real options

Decision Trees Overview

- Decision trees – organized and structured way to present information about future events and decisions
- Useful for calculating expected value of future choices under uncertainty
- Composed of:
  – Nodes: decision and chance
  – Data: Probabilities and values

Decision Trees Overview



EV (rain coat) = 0.4 * 5 + 0.6 * -2 = **0.8**

EV (no coat) = 0.4 * -10 + 0.6 * 4 = -1.6

Example from Richard de Neufville, ESD.71 class notes on ardent.mit.edu

Case Study: Traditional Infrastructure Build vs ITS

- Demonstrate an example of flexibility for physical system
- Illustrate quantitative benefits of flexibility
- Identify potential challenges associated with ITS as a real option

Description of Current Situation

- System of interest: intersection in surface infrastructure
- Current status: heavy congestion
- Goals
  - Reduce congestion and increase utility of intersection
  - Avoid unnecessary costs
- Typical alternatives
  - Expand traditional infrastructure
  - Deploy ITS capabilities, such as ATIS or ATMS
  - Maintain the status quo

Analysis of Alternatives

	EX NPV	Benefit to Cost Ratio	EX Benefits	EX Costs	Prob.	Values
Trad. Infra.	$6M	1.25	$30M	$24M	High cong = .6 Low cong = .4	High cong = $50 M Low cong = $0 M
ITS	$0.5	1.33	$2M	$1.5M	High cong = .6 Low cong = .4	High cong = $3.3 M Low cong = $0 M
Status Quo	-$10M	n/a	-$10M	0	High cong = .6 Low cong = .4	High cong = -$17 M Low cong = $0 M

Alternatives: No Flexibility

EX NPV = $6 M
B/C = 1.25

Current State

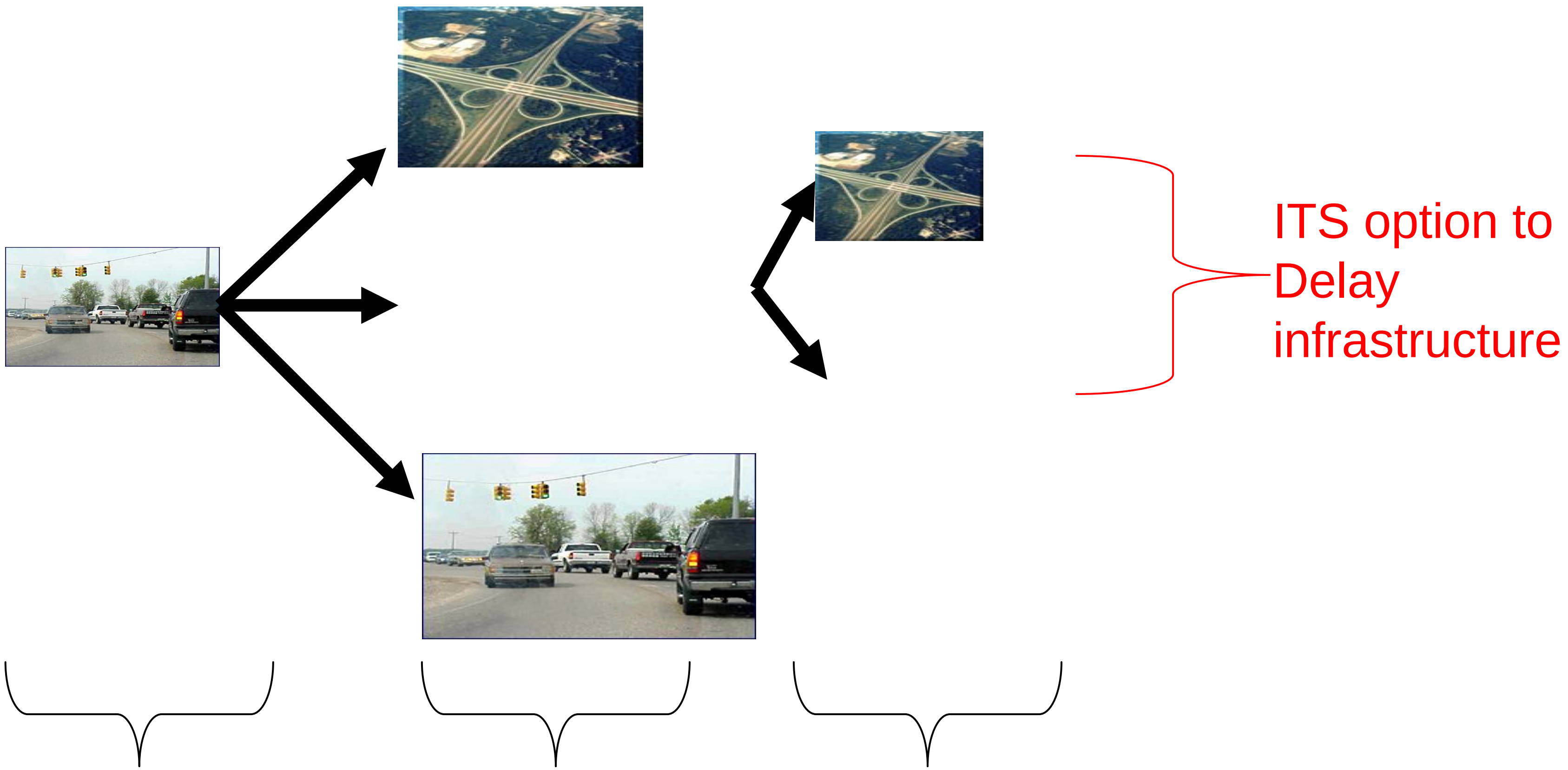
EX NPV = $0.5 M
B/C = 1.3

EX NPV = -$10 M
B/C = NA

Possible Future States

- What to do? Infrastructure highest NPV, ITS highest B/C
- NPV and B/C only show Expected Value –
  significant probability of loss if no future congestion → 40%

Adding in Flexibility to Delay Infrastructure



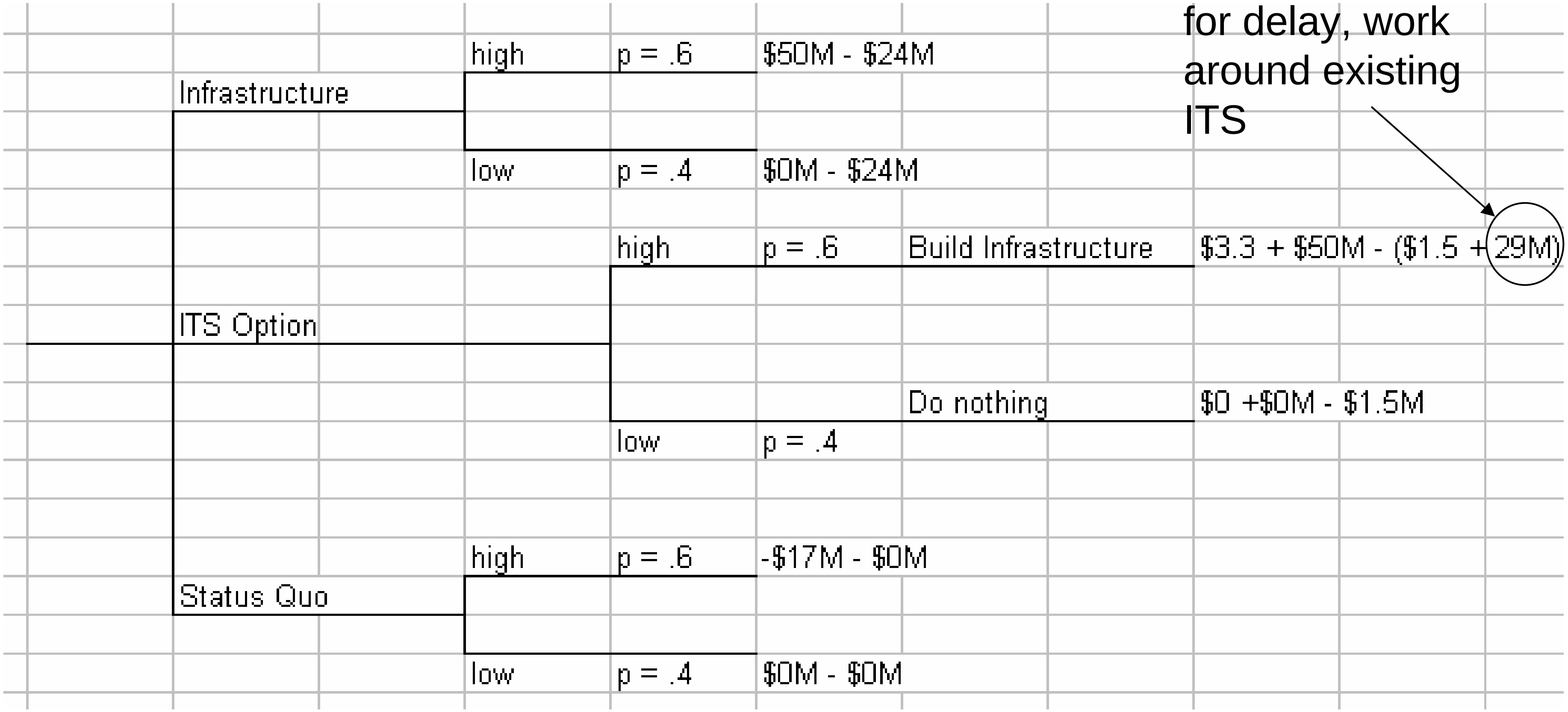
Current situation, t<0

Implement alternative, t=0

Exercise option, t>0

- ITS has lower costs, reducing capital at risk at t=0.
- Decision for larger investment postponed when additional information or funding is available

New Decision Tree
(perfect information assumed)



- New expected NPV of ITS = $13M, value of ITS + infra = $2.7M
- Flexibility = $13M - $2.7M = $10.3M
- $10.3M flexibility value > $5M cost, so flexibility economically feasible
- Value from ITS: EX inherent value = $2M, Value of flexibility = $10.3M

Advantages and Shortcomings of ITS as a Real Option

- Advantages
  - Potential costs savings over traditional infrastructure
  - Flexibility to respond to changing environment by changing operations or postponing traditional infrastructure lock-in
  - New possibilities in and out of transportation field – IT technology applicable to wide range of industries
- Shortcomings
  - Often more expensive to build a flexible system than a non-flexible system
  - Institutional and intellectual barriers towards thinking about including flexibility in systems
  - Questionable ability to actually use flexibility – do decision makers have the will to exercise an option, creating change in a system?
  - Some foresight of the future and understanding of uncertainty is needed during the design phase at t<0

Additional Considerations

- Additional Uses for ITS
  - Non-transportation usage – dual use
    - New revenue streams to transportation agencies
    - Example – Smart Cards also useful as
      - Insurance cards
      - Identification cards
      - Banking / ATM cards
      - Parking payment
      - Retail shopping
  - Inclusion of new stakeholders through dual use technology
    - can be good or bad – more stakeholders brings more views and allows new coalitions to be formed, but also can make decision making harder
- Other sources of uncertainty
  - Political: exercising an option means creating a change in the system – will stakeholders with an investment in the status quo resist this change? Will decision makers have the will to resist this pressure?
- Other types of uncertainty
  - Options require some anticipation of future events and uncertainty – what about uncertainties we are unable to anticipate?

For more on…

- Additional discussion of ITS as a real option and more advanced analysis
  - Email me and I will give you a copy of my latest research summary. joshua11@mit.edu or soon to be available on the class Stellar website
- Concept of flexibility and addressing uncertainty
  - de Neufville, Richard. (2004) *Uncertainty Management for Engineering Systems Planning and Design,* Monograph draft for Engineering Systems Division.
- Decision analysis/trees theory
  - Raiffa, Howard. (1968) *Decision Analysis: Introductory Lectures on Choices Under Uncertainty*, Addition-Wesley Publishing.
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  - Copeland, Tom and Vladimir Antikarov. (2003) Real Options: A Practitioners Guide, Thompson.
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  - Federal Highway Administration (FHWA). (2004) Getting More by Working Together: Opportunities for Linking Planning and Operations.
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  - Ankner, William. (2003) *Financing Intermodal Transportation*, Reconnecting America Report, Sept. 2003.
- Overview of real options, decision analysis, flexibility
  - de Neufville, Richard. (2004) Notes from ESD.71, Engineering System Analysis for Design, Fall 2004. ardent.mit.edu