Final Lecture

Intelligent Transportation Systems (ITS) and the Impact of Traveler Information & Emerging Themes in Transportation Economics and Policy

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1.201 / 11.545 / ESD.210
Transportation Systems Analysis: Demand & Economics

Fall 2008

Outline: ITS

- Introduction to ITS and its applications
- Dynamic traffic management
- The impact of traveler information
- Modeling and simulation for dynamic traffic management
- DynaMIT
  - Travel behavior models
  - Data and calibration
- Evaluating the impact of traveler information
- Appendices: Examples, Case Studies

Useful reference on ITS: http://www.itsoverview.its.dot.gov/

Introduction

- Intelligent Transportation Systems (ITS) combine advances in information systems, communications, sensors, and advanced modeling and algorithms to improve the performance of surface transportation.

Benefits of ITS

- Travel
  - Decreased travel time
  - Improved safety and security
  - Increased reliability
  - Decreased cost
  - Improved trip planning
  - Improved emergency response

Benefits of ITS (cont.)

- Economic
  - Increased productivity
  - On-time delivery
- Environmental
  - Decreased air pollution
  - Fuel savings

ITS Applications

- Advanced Transportation Management Systems (ATMS)
  - Network management, including incident management, traffic light control , electronic toll collection, congestion prediction, and congestion-ameliorating strategies.
- Advanced Traveler Information Systems (ATIS)
  - Information provided to travelers pre-trip and during the trip in the vehicle.
- Advanced Vehicle Control Systems (AVCS)
  - Technologies that enhance driver control and vehicle safety.

ITS Applications (cont.)

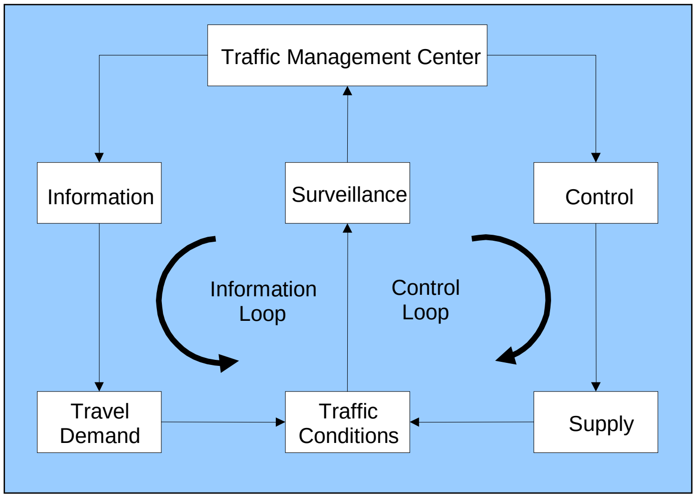
- Commercial Vehicle Operations (CVO)
  – Technologies that enhance commercial fleet productivity, including weight-in-motion (WIM), pre-clearance procedures, electronic log books, interstate coordination.
- Advanced Public Transportation Systems (APTS)
  – Passenger information and technologies to enhance system operations, including fare collection, intramodal and intermodal transfers, scheduling, and headway control.
- Advanced Rural Transportation Systems (ARTS)
  – Mostly safety and security technologies for travel in sparsely-settled areas.

Reference: Sussman, Joseph M., Introduction to Transportation Systems, Artech House, 2000.

ITS Applications (cont.)

- This lecture will focus on *dynamic traffic management*, which integrates ATMS (network management) and ATIS (traveler information) applications.

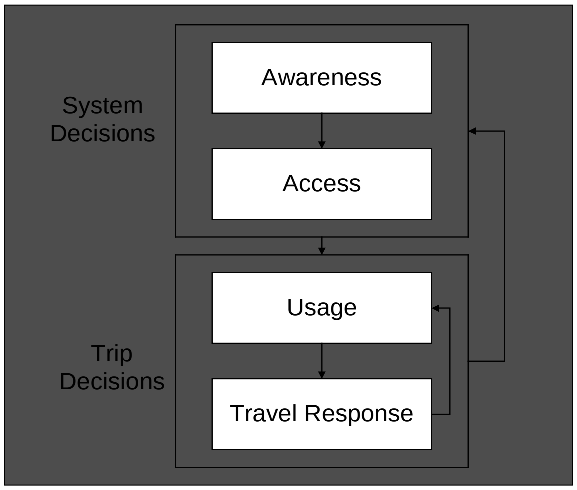
Dynamic Traffic Management



Impact of Traveler Information

- Provide information to road users before and during a trip (through in-vehicle technologies)
- Public transport users can also benefit from information provided through:
  - Vehicle location systems
  - Scheduling systems (e.g. online journey planners)
- Freight operators can use Commercial Vehicle Operations (CVO) technologies to more effectively manage their fleets
- The information not only lead to more efficient network flows but can also be used for strategic transportation planning purposes

User Response to ATIS



Example: Impact of Traveler Information

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• Critical component: user behavior models

Modeling and Simulation for Dynamic Traffic Management Systems

- Off-line evaluation of:
  - Dynamic performance (stability and robustness)
  - Effectiveness of surveillance, control system designs
  - Future system and network modifications
  - Development of new concepts and algorithms
- Real-time decision support systems
  - Route guidance
  - Adaptive traffic control
  - Incident management

DynaMIT

- DynaMIT is a…
  - simulation-based

    real-time system

    predicting traffic

    providing travel information

Broadcasting Traffic Information

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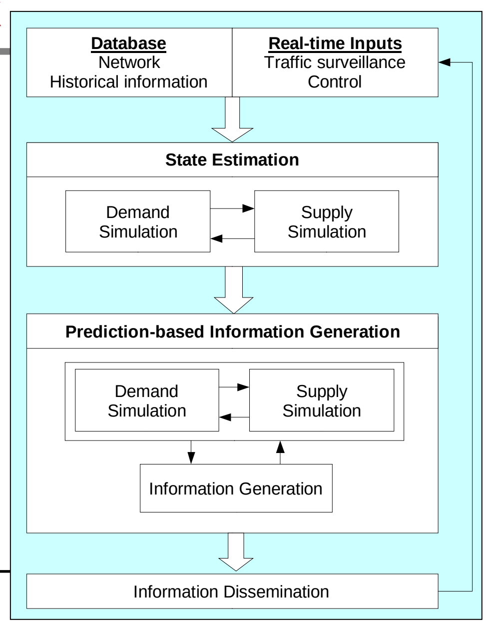
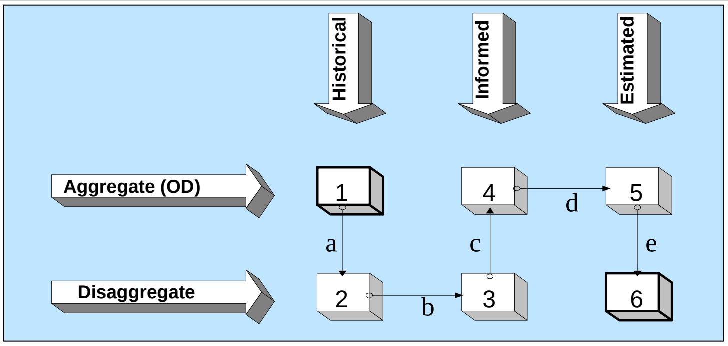
DynaMIT Framework

- Prediction-based guidance
  - Prevents over-reaction
  - Supports compliance

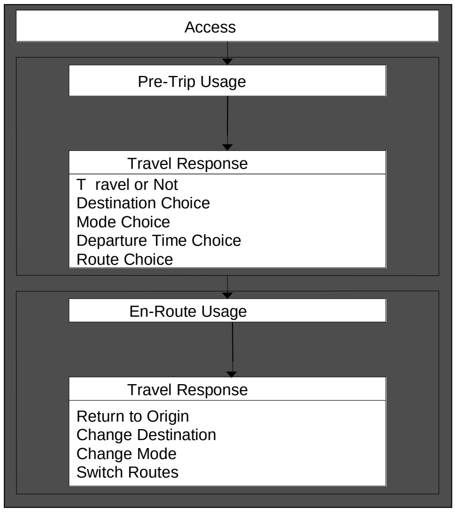


Demand Simulation in DynaMIT



a : Disaggregation of historical OD flows
b : Travel behavior update
c : Aggregation
d : OD estimation and prediction
e : Generation of driver population

Traveler Decisions



Travel Behavior Models in DynaMIT

- Route and departure time
  - Multiple driver classes
    - Value of time, access to information
  - Path-Size Logit[1]
  - Path choice set generation
    - Shortest paths
    - Link elimination
    - Random perturbation

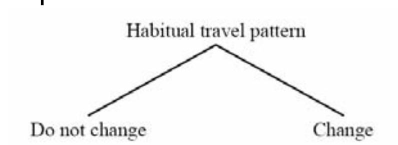
[1] *Ramming, M. S. (2002) "Network Knowledge and Route Choice", Ph. D. thesis, MIT.*

Travel Behavior Models in DynaMIT (cont'd)

- Information
  - Instantaneous, predictive
  - Descriptive, prescriptive
  - Link, sub-path, path
- Response to Information
  - Pre-trip
  - En-route
- Media
  - Variable Message Signs (VMS)
  - Television, traffic websites
  - In-vehicle (radio, cell phone, GPS navigation system)

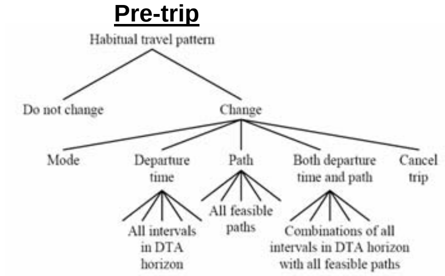
Travel Behavior Models in DynaMIT (cont'd)

- Prescriptive: Compliance

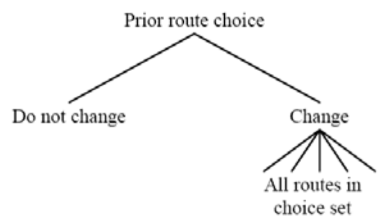


- Descriptive

Pre-trip

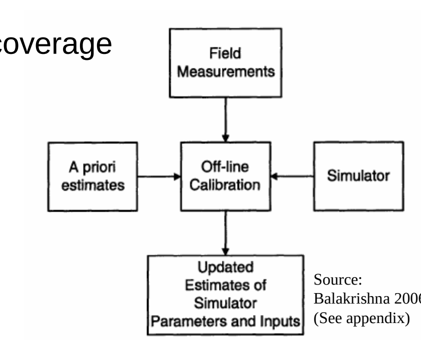


En-route



Data and Calibration

- Disaggregate (surveys, diaries)
  - Detailed individual data
  - Limited
- Aggregate (traffic sensors)
  - Easy to collect, widespread coverage
  - Special estimation methods



Source: Balakrishna 2006 (See appendix)

Disaggregate Calibration Example[1,2]

- Pre-trip response to unexpected congestion
  - Golden Gate bridge, San Francisco, CA
  - Home-to-work trips
- Conclusions
  - Travel time, expected delay, congestion level:
    - Impact willingness to change travel patterns
  - Alternative types of ATIS:
    - Trigger different travel responses, compliance rates
  - Experience-based factors very significant

[1] *Khattak, A., A. Polydoropoulou and M. Ben-Akiva (1996). "Modeling Revealed and Stated Preference Pre-trip Travel Response to ATIS" TRR, No. 1537.*

[2] *Polydoropoulou, A. (1997) "Modeling User Response to Advanced Traveler Information Systems (ATIS)" Ph. D. thesis, MIT.*

Aggregate Calibration with DynaMIT

- Benefits
  - Jointly adjusts all model parameters
    - Route choice, OD flows, supply
  - Uses general aggregate traffic data
    - e.g. counts, speeds, travel times
  - Applies to any traffic model
  - Updates available parameters with latest traffic data

- More detail in Appendix

Case Study[1]

- Boston
- 182 nodes, 211 links
- AM peak - 7:00 to 9:00

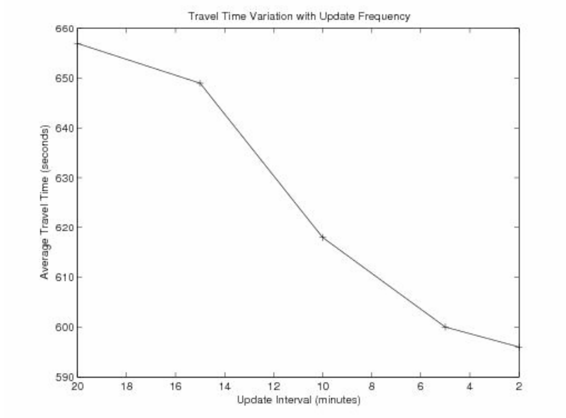
Map of downtown Boston highways removed due to copyright restrictions.

[1] *Balakrishna, R., H. N. Koutsopoulos, M. Ben-Akiva, B. M. Fernandez-Ruiz, M. Mehta (2005) "Simulation-Based Evaluation of Advanced Traveler Information Systems", TRR, No. 1910, pp. 90-98.*

Experimental Design

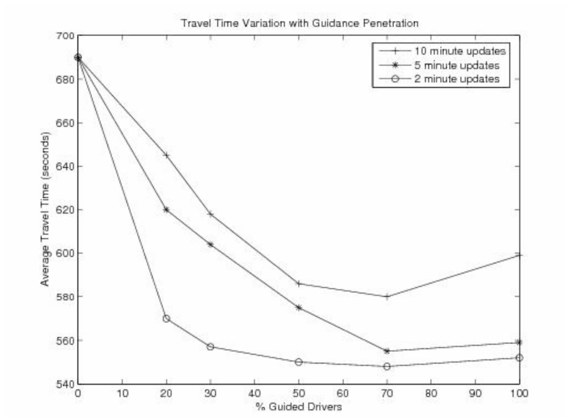
- Scenario: incident in Ted Williams tunnel
  - Capacity reduction of 65% from 7:10-7:30
- Base case
  - Avg. travel time without incident: 369 sec
  - Avg. travel time with incident (no guidance): 690 sec
- Guidance parameters
  - Information update frequency (roll interval)
  - Guidance penetration rate
  - Demand prediction error
- Guidance computation delay: 2 min

Effect of Update Frequency



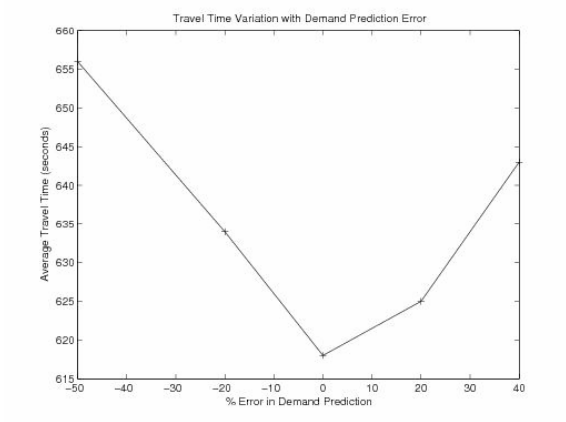
30% guided, 20-minute prediction horizon

Effect of Guidance Penetration Rate



20-minute prediction horizon

Effect of Demand Prediction Error



30% guided, 20-minute prediction horizon, 10-minute updates

ITS Summary

- ITS is applied to various surface transportation modes
- Information provided through ITS applications benefit freight operators and passengers
- DynaMIT: consistent, anticipatory route guidance
- Calibration
  - Disaggregate, aggregate data
- Predictive information
  - Eliminates over-reaction
  - Benefits guided and unguided drivers

Outline: Emerging Themes

- Public-Private Partnerships
- Controlling Mobility
- Pricing Policies and the Second-Best
- Integrated Energy & Transportation Modeling
- Other Issues

Public-Private Partnerships (PPPs)

- Increasing use of various kinds of regulation, franchising arrangements, and procurement procedures in transportation infrastructure projects and in the provision of transportation services
- There is a need to incorporate Industrial organization tools into transportation systems analysis to fully understand the strengths and weaknesses of the different institutional arrangements
- The key to good institutional design is the incentive structure:
  - To what degree are the incentives given to the different actors causing them to voluntarily act in ways that promote social goals?

Public-Private Partnerships (cont.)

- In many situations, there is a dissociation between pricing decisions and investment decisions
- This increases the burden on public finances which may sometimes lead to both arbitrary cut-backs in investments and privatization
- The problem may not be the lack of efficiency in the public sector but the failure of the decision-making process which may not necessarily change by transferring ownership

Controlling Mobility

- Individual mobility has increased substantially over the past 50 years, not only in terms of the number of trips, but also in terms of distance traveled
  – Is this good or bad? Do increased mobility and accessibility always indicate economic progress or personal freedom, or do they imply a dysfunction or imbalance, in which people have to travel further to reach certain activities?
- Studies on mobility may give different pictures, depending on the location and timescale considered:
  – Short-term models: route and mode choice
  – Long-term models: include trip generation and distribution effects (which may result in higher congestion levels)

Controlling Mobility (cont.)

- Effective transportation pricing and land use planning may not be sufficient to control mobility
  - Distortions in many other economic activities (e.g. housing subsidies)
  - Externalities (e.g. environmental effects)
- There must be a coordinated and coherent use of all possible instruments to control mobility:
  - Prices, taxes, regulation, etc
  - Broader policies (change in work hours, telecommuting, etc)
  - ITS

The Big Dig: 1994 - 2006

- Recent Boston Globe article on allegedly unintended consequences.

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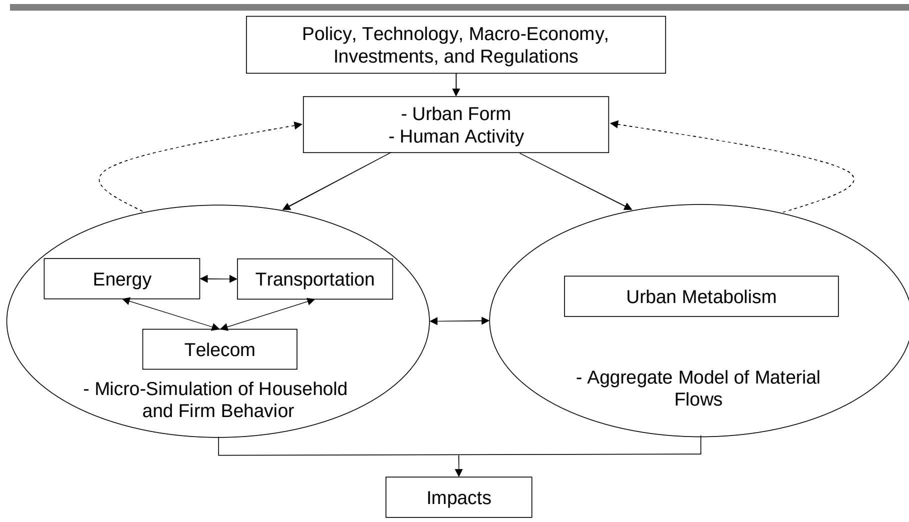
Pricing Policies and the Second-Best

- Marginal cost pricing applied to traffic congestion is not effective due to distortions in other modes and in other parts of the economy. Second-best analysis is essential in using economic models to inform transportation policy
  - Examples: Free road, 'dirty' vs. 'clean' cars
- Cost coverage usually dominates the motivation in determining pricing policies

Pricing Policies and the Second Best (cont.)

- Other issues in implementing pricing policies:
  - Valuation of time savings and environmental impacts
  - Distributional effects
  - Simplicity of pricing schemes
  - Dynamic pricing schemes
  - Creating the demand for niche products due to user heterogeneity (e.g. segmented pricing)

Integrated Energy & Transport Modeling iTEAM: General Framework



Other Issues

- Incorporating reliability into demand analysis and pricing schemes
- Importance of safety in transportation analysis
- Urban goods movement and its effect on traffic congestion and economic growth
- The roles of both technology and transportation policies in addressing environmental issues (eg Energy)

The End

- We hope you liked it
- Evaluations

Appendix

Case Study: Aggregate Calibration with DynaMIT

Aggregate Calibration with DynaMIT[1,2,3]

- Methodology:

$$\underset{\boldsymbol{\theta}}{\text{Minimize}} \left[z_1(\mathbf{M}, \mathcal{M}) + z_2(\boldsymbol{\theta}, \boldsymbol{\theta}^a) \right]$$

$$\text{subject to :}$$

$$\mathcal{M} = f(\boldsymbol{\theta}, G) \rightarrow \text{DTA model}$$

$$l \le \boldsymbol{\theta} \le u \rightarrow \text{Bounds}$$

$\mathbf{M}$: sensor data, $\mathcal{M}$: Model output

$\boldsymbol{\theta}$: Vector of variables ($\boldsymbol{\theta}^a$: *a priori* values)

G : Exogenous inputs

[1] *Balakrishna, R. (2006) "Off-line Calibration of Dynamic Traffic Assignment Models" Ph. D. thesis, MIT.*
[2] *Balakrishna, R., M. Ben-Akiva, H. N. Koutsopoulos. (2007) "Off-line Calibration of Dynamic Traffic Assignment: Simultaneous Demand-Supply Estimation", TRR (forthcoming).*
[3] *Antoniou, C. (2004) "On-line Calibration for Dynamic Traffic Assignment" Ph. D. thesis, MIT.*

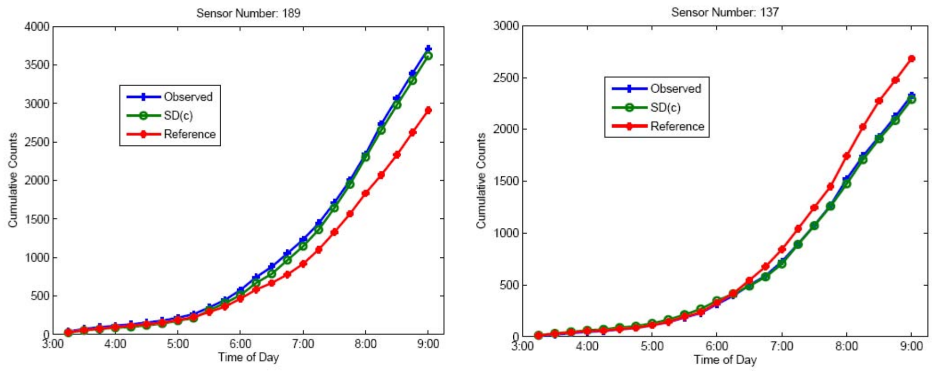
Aggregate Calibration with DynaMIT (cont'd)

Images removed due to copyright restrictions.

- Application
  - South Park, Los Angeles
  - Real-world sensor data
    - Flows, speeds
  - Route choice parameters:
    - Travel time
    - Freeway bias
    - Route hierarchy

Aggregate Calibration with DynaMIT (cont'd)

- Cumulative 15-minute counts



Reference: Current state-of-the-art

SD (c): New approach, supply + demand calibrated with counts

Aggregate Calibration with DynaMIT (cont'd)

Estimator	Fit to Counts		Fit to Speeds	
	Freeways	Arterials	Freeways	Arterials
Reference	0.218	0.239	0.181	0.203
SD (c)	0.090	0.113	0.088	0.093
SD (cs)	0.098	0.114	0.048	0.058

SD (cs): New approach, supply + demand calibrated with counts and speeds

- Root Mean Square Normalized Error

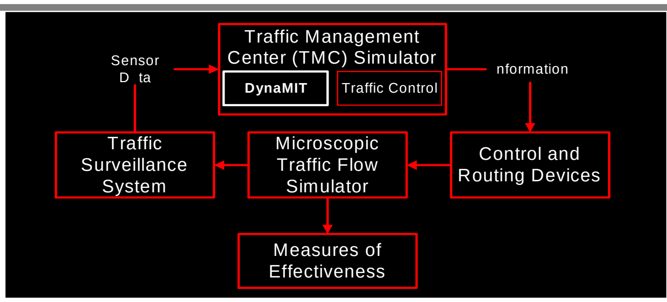
$$\text{RMSN} = \frac{\sqrt{S \sum_{i=1}^{S}(y_i - \hat{y}_i)^2}}{\sum_{i=1}^{S} y_i}$$

- Improved fit to speeds
  - Route guidance applications

Appendix

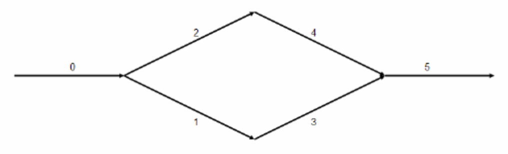
Case Study: DynaMIT and Traveler Information

Closed-Loop Evaluation



- Analysis capabilities
  - Information errors
  - Guidance generation methods
  - Guidance computation delay
  - Surveillance system design and accuracy
  - Data and information channels

Case Study[1]



- Incident on link 2
- Links 1, 3 have lower capacity than links 2, 4
- 3-hour simulation

- Impact of guidance penetration
  - Scenario 1: Low demand
  - Scenario 2: High demand

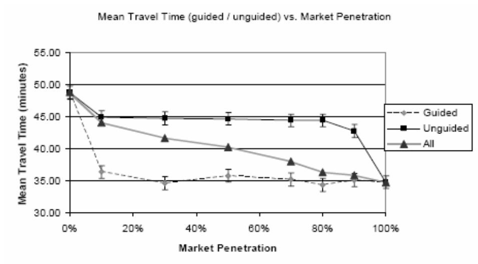
[1] Florian, D. (2004) "Simulation-Based Evaluation of Advanced Traveler Information Services (ATIS)", Masters thesis, MI

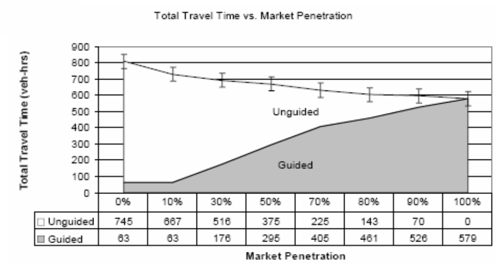
Low-Demand Scenario

Base case (no guidance)

	Total TT	Mean TT	Std. Dev. of Mean TT
Normal	430 veh-hrs	25.8 min	1.65 min
Base Case (Incident)	809 veh-hrs	48.7 min	16.5 min
% Change	+88%		+900%

Low-Demand Scenario (cont'd)



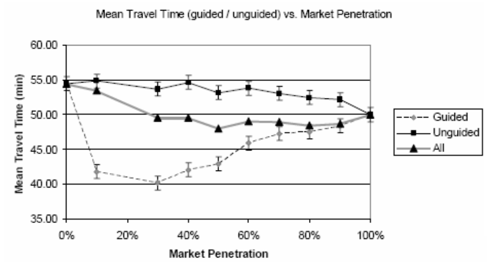


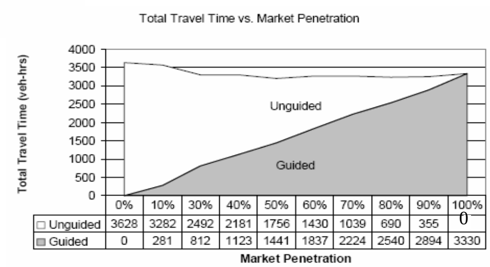
High-Demand Scenario

Base case (no guidance)

	Total TT	Mean TT	Std. Dev. of Mean TT
Normal	1940 veh-hrs	29.1 min	1.52 min
Base Case (Incident)	3628 veh-hrs	54.4 min	19.3 min
% Change	+87%		+1170%

High-Demand Scenario (cont'd)





Appendix

Examples of ITS applications

UPS

- Helps UPS in fleet management.
- Helps UPS manage its supply chain better.
- Improved customer service by on-line tracking of packages.
- Will allow on-line quick cost calculation.
- Electronic Data Interchange (EDI) using
  - Satellite and wireless technology

UPS (cont.)

- Benefits to UPS
  - Estimating the expected delay
  - Placing orders on-line
  - Re-routing of vehicles
  - Tracking and Tracing of packets on-line
- Customer benefits
  - Internet tools for package tracking available at web portals (e.g. Lycos)
  - Number of shipments tracked quadrupled
  - Approximately 360,000 packages tracked in one week

Electronic Clearance

- Used to help border officials handle the increased traffic
- Aids in faster clearing of drivers, trucks and cargo
- Helps detect contraband and illegal immigrants
- Electronic Data Interchange and Integrated Databases used with technologies like
  - Automated Vehicle Identification
  - Weigh-in-motion
  - On-board computers
  - Electronic sensors

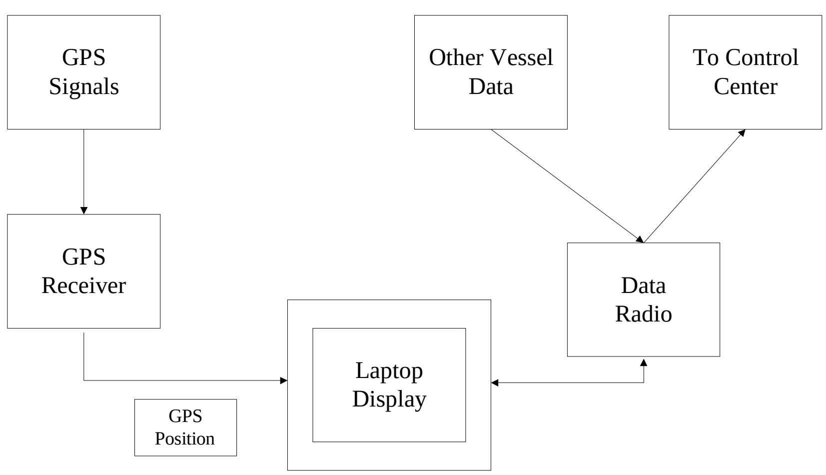
Electronic Clearance (cont.)

- Use in Traffic Management
  - Sensors determine traffic flow at the Customs facility
  - AVI determines the time spent at the Customs compound
  - This real time data allows companies to avoid peak traffic and moderate flow of traffic

Electronic Clearance (cont.)

- Immigration and Customs
  - Electronic sensors monitor the seals on shipping bags
  - Commuter traffic clearance is done using the vehicle's transponder identification number
  - GPS tracking monitors the trucks route
  - On board computers monitors the brake and steering functions and reports to the stations

Vessel Traffic Management at the Panama Canal



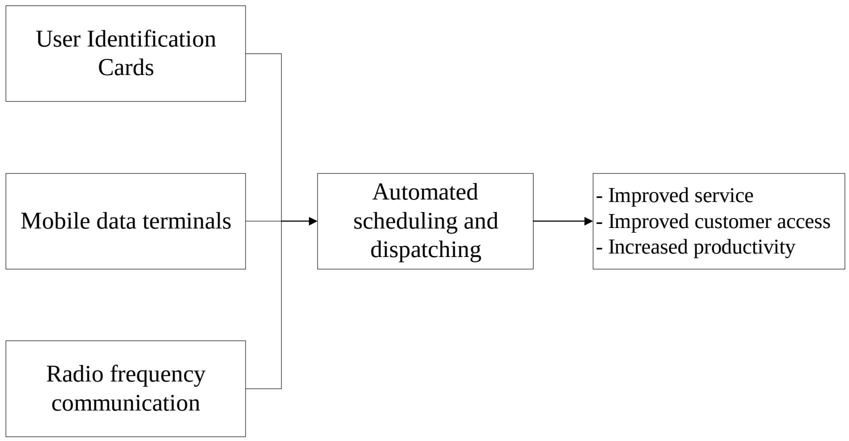
Vessel Traffic Management at the Panama Canal (cont.)

- Location system aboard vessels as navigational aid
- Data interchange among all the vessels and the control center
- Exact location of each vessel known to other vessels and the control center

Vessel Traffic Management at the Panama Canal (cont.)

- Benefits
  - Improved safety and efficiency of the transit process through the canal
  - Improved operation in case of poor visibility
  - Improved capacity
  - Better scheduling of maintenance operations to fit more efficiently with the transit operations

Personalized Transit Operations



Personalized Transit Operations (cont.)

- Dynamic Scheduling and Dispatching
  - Addresses user-specific information while registering/scheduling customers
  - Scheduling efficiency:
    - Passenger mix
    - Pick-up and drop-off locations
  - Allows scheduling flexibility

Personalized Transit Operations (cont.)

- Technologies used
  - User Identification Cards
    - Certification of passenger access
    - Accurate charging for service
    - Keeps trip records
  - Mobile Data Terminals and Radio Frequency Communication
    - Provides dispatchers with direct access to drivers
    - Allows drivers to communicate vehicle problems

Personalized Transit Operations (cont.)

- Benefits
  - Improved customer accessibility to service
  - Allows adjusting schedules to care-givers needs
  - Reduces staff involvement in scheduling and dispatching
  - Increased productivity of service

The Atlanta Olympics

- Traveler advisory interactive kiosks used
- Placed at several locations and displayed the following
  - Times of Olympic events
  - Best routes to chosen destinations
  - Traffic and congestion information
  - Available modes of transport
  - Probable travel times

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