Final Lecture

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

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Transportation Systems Analysis: Demand & Economics
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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.


ITS Applications (cont.)

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

Images removed due to copyright restrictions.

- 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

Images removed due to copyright restrictions.

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

- Access
  - Pre-Trip Usage
  - Travel Response
    - Travel or Not
    - Destination Choice
    - Mode Choice
    - Departure Time Choice
    - Route Choice
  - En-Route Usage
    - Travel Response
      - Return to Origin
      - Change Destination
      - Change Mode
      - Switch Routes
Travel Behavior Models in DynaMIT

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


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

  ![Habitual travel pattern diagram]

  - Do not change
  - Change

- **Descriptive**

  **Pre-trip**
  - Habitual travel pattern
  - Do not change
  - Change
  - Mode
  - Departure time
  - Path
  - Both departure time and path
  - Cancel trip
  - All intervals in DTA horizon
  - All feasible paths
  - Combinations of all intervals in DTA horizon and all feasible paths

  **En-route**
  - Prior route choice
  - Do not change
  - Change
  - All routes in choice set

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\textsuperscript{1,2}

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

\textsuperscript{1} Khattak, A., A. Polydoropoulou and M. Ben-Akiva (1996). “Modeling Revealed and Stated Preference Pre-trip Travel Response to ATIS” TRR, No. 1537.

Aggregate Calibration with DynaMIT

\begin{itemize}
  \item Benefits
    \begin{itemize}
      \item Jointly adjusts all model parameters
        \begin{itemize}
          \item Route choice, OD flows, supply
        \end{itemize}
      \item Uses general aggregate traffic data
        \begin{itemize}
          \item e.g. counts, speeds, travel times
        \end{itemize}
      \item Applies to any traffic model
      \item Updates available parameters with latest traffic data
    \end{itemize}
  \item More detail in Appendix
\end{itemize}
Case Study

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

Map of downtown Boston highways removed due to copyright restrictions.


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.

Images removed due to copyright restrictions.
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:**
  \[
  \text{Minimize } \left[ z_1(M, M) + z_2(0, 0^a) \right] \\
  \text{subject to :} \\
  M = f(0, G) \rightarrow \text{DTA model} \\
  l \leq 0 \leq u \rightarrow \text{Bounds}
  \]
  
  $M$: sensor data, $\mathcal{M}$: Model output
  
  $\theta$: Vector of variables ($\theta^a$: $a$ priori values)
  
  $G$: Exogenous inputs


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Aggregate Calibration with DynaMIT (cont’d)

- **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

![Graphs showing cumulative counts over time for different sensor numbers, comparing observed counts with reference and SD (c) approaches.]

Reference: Current state-of-the-art
SD (c): New approach, supply + demand calibrated with counts

<table>
<thead>
<tr>
<th>Estimator</th>
<th>Freeway Counts</th>
<th>Arterial Counts</th>
<th>Freeway Speeds</th>
<th>Arterial Speeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>0.218</td>
<td>0.239</td>
<td>0.181</td>
<td>0.203</td>
</tr>
<tr>
<td>SD (c)</td>
<td>0.090</td>
<td>0.113</td>
<td>0.088</td>
<td>0.093</td>
</tr>
<tr>
<td>SD (cs)</td>
<td>0.098</td>
<td>0.114</td>
<td>0.048</td>
<td>0.058</td>
</tr>
</tbody>
</table>

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

- Root Mean Square Normalized Error

\[
\text{RMSN} = \sqrt{\frac{\sum_{i=1}^{5}(y_i - \bar{y}_i)^2}{\sum_{i=1}^{5} y_i}}
\]

- 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

- 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

Low-Demand Scenario

Base case (no guidance)

<table>
<thead>
<tr>
<th></th>
<th>Total TT</th>
<th>Mean TT</th>
<th>Std. Dev. of Mean TT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Base Case (Incident)</td>
<td>430 veh-hrs</td>
<td>25.8 min</td>
<td>1.65 min</td>
</tr>
<tr>
<td>% Change</td>
<td>809 veh-hrs</td>
<td>48.7 min</td>
<td>16.5 min</td>
</tr>
<tr>
<td>% Change</td>
<td>+88%</td>
<td></td>
<td>+900%</td>
</tr>
</tbody>
</table>

Low-Demand Scenario (cont’d)

High-Demand Scenario

Base case (no guidance)

<table>
<thead>
<tr>
<th></th>
<th>Total TT</th>
<th>Mean TT</th>
<th>Std. Dev. of Mean TT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>1940 veh-hrs</td>
<td>29.1 min</td>
<td>1.52 min</td>
</tr>
<tr>
<td>Base Case (Incident)</td>
<td>3628 veh-hrs</td>
<td>54.4 min</td>
<td>19.3 min</td>
</tr>
<tr>
<td>% Change</td>
<td>+87%</td>
<td>+1170%</td>
<td></td>
</tr>
</tbody>
</table>
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

![Diagram of Vessel Traffic Management at the Panama Canal]

- GPS Signals
- GPS Receiver
- Other Vessel Data
- To Control Center
- Data Radio
- Laptop Display
- GPS Position
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

Benefits (cont.)
- 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

- User Identification Cards
- Mobile data terminals
- Radio frequency communication
- Automated scheduling and dispatching
- Improved service
- Improved customer access
- Increased productivity

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