Multi-Modal Inter-Regional Travel Demand Estimation

A Review of National-Level Passenger Travel Analysis Methodologies and Their Implications on the Development of National and Statewide Travel Demand Models in the U.S.

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Introduction

Needs for a U.S. National Multimodal Passenger Transportation Analysis System:

- Lacking inter-regional passenger OD data
- Evaluating national and regional transportation investment and operational improvements
- Major corridor analyses that cross state borders
- Other national/regional-level planning and policy analysis needs

Benefits to statewide transportation modeling

- National model provides long-distance passenger travel OD for statewide models
- National database helps meet statewide modeling data needs
Research Objectives

1. Synthesize national travel demand models focusing on methodology, data, and applications
2. Compare alternative modeling approaches and data collection methods
3. Identify existing data sources for national passenger travel demand modeling in the U.S. and additional data needs
4. Recommend future research directions
Background

Previous Studies in the U.S.:

- Virginia Tech (2007), TSAM analysis model
- Cambridge Systematics (2008), NatMod model framework
- Epstein et al. (2008), agent-based micro-simulation model
- Regional/major corridor models, e.g. I-95 corridor model
- Statewide models in more than 30 states

Modeling Practices in Other Countries:

- National models are available in many nations in Europe
- Several Pan-European models have also been developed
- Limited development in other continents
Overview of the Reviewed Models

60 studies/projects in and out of the U.S.
## Summary of National Model Properties

**Design Period/Data/Modes/Purposes/Zone/Modeling Methods**

<table>
<thead>
<tr>
<th>Model name</th>
<th>Year (Period)</th>
<th>Data sources</th>
<th>Modes considered</th>
<th>Purposes considered</th>
<th>Zone structure</th>
<th>O-D model description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Danish National Transport Model (PETRA)</td>
<td>1998-1995</td>
<td>National Travel Survey (TU), Panel data (The Rijkswaterstaat survey)</td>
<td>Walk, cycle, car, car passenger, bus, and train</td>
<td>Home, work, errand, and leisure</td>
<td>3,010 zones</td>
<td>Using activity-based nested logit model with a chain choice sub-model for trip generation</td>
</tr>
<tr>
<td>Dutch National Model System (LMS)</td>
<td>1985-1990</td>
<td>National Travel Survey (OVG), Panel data (The Rijkswaterstaat survey)</td>
<td>Car driver, car passenger, train, BTM (Bus, Tram, and Metro), and slow modes</td>
<td>Commuting, other work-related, education, shopping and private business, and social recreational and other</td>
<td>1,308 zones</td>
<td>Using tour frequency sub-model, using nested logit sub-model in mode and destination choice</td>
</tr>
<tr>
<td>Great Britain (NTM)</td>
<td>2006-2006</td>
<td>National Travel Survey (NTS), Panel data (The Rijkswaterstaat survey)</td>
<td>Car (driver and passenger), bus, train, and slow modes (walk and cycle)</td>
<td>-HB: work, employer’s business, education, personal business, recreation, holidays trips &lt;br&gt; -NHB: employer’s business, and other</td>
<td>17 zone types for PASS1 sub-model, 9,988 zones for PASS3 sub-model</td>
<td>Traditional four step method following a top-down structure</td>
</tr>
<tr>
<td>Strategic European Multimodal Modeling (STEMM)</td>
<td>1990-1998</td>
<td>National passenger travel surveys, Some border crossing survey data</td>
<td>Air, rail, and car</td>
<td>Business, private, and vacation</td>
<td>NUTS-3 (1,209 zones)</td>
<td>Quasi-direct demand method with combined aggregate generation-distribution model and disaggregate mode choice model</td>
</tr>
<tr>
<td>TOOLS for Transport forecasting AND Scenario testing (TRANS-TOOLS)</td>
<td>2004-2006</td>
<td>Pan-European Household Long-Distance Trip Survey, and ETIS-Base matrix</td>
<td>Air, rail, and car</td>
<td>Business/home-work, holiday, and other</td>
<td>NUTS-2 (294 zones) for economic model, NUTS-3 (1,286 zones) for travel demand model</td>
<td>Using four-step method, using hybrid approach for different steps</td>
</tr>
</tbody>
</table>
Categorization of Modeling Methods

Are behavioral responses modeled?
How are they modeled?

1. Direct Demand and Elasticity Analysis
   - Consider Behavior Responses aggregated
   - Trips are the basic units of behavioral analysis

2. Trip-Based Four-Step Model
   - Consider Various Individual Responses
   - Tours, activity-chains, interdependencies, and constraints are considered

3. Tour-/Activity-Based Model and Microsimulation
   - Do not consider Behavior Responses

4. Multimodal OD Estimation without Behavior Theory
   - Consider Various Individual Responses
Direct Demand Models

Econometric models wherein demand between each OD pair by mode is a function of zone-level socio-economic and demographical variables, mode-specific travel costs, and other factors.

Example: Traffic Growth Forecasting, British National Road Traffic Forecast (NRTF) (Source: DfT UK, 1997)
Trip-Based Four Step Method

The Most Dominant Method

- Pre-processing (e.g. socio-economic, demographic, and auto ownership modules);
- Trip generation;
- Trip distribution;
- Modal split;
- Assignment;
- Post-processing (e.g. policy impact analysis, and emission estimation modules).
Trip-Based Four Step Method: Example

Example: TOOLS for TRansport forecasting ANd Scenario testing (TRANS-TOOLS) (Source: Bergess et al. 2008)
Tour/Activity-Based Micro-Simulation

Example: Netherlands Modeling System (LMS) Structure
OD Estimation without Behavior Theory

Building OD matrices directly from traffic count and other data sources with statistical methods

Example: DATELINE OD Estimation Procedure
(Source: Davidson and Clarke 2004)
## Qualitative Model Comparison

<table>
<thead>
<tr>
<th>Model Properties</th>
<th>Direct Demand</th>
<th>Trip-Based Four-Step</th>
<th>Tour/Activity-based &amp; microsimulation</th>
<th>Direct OD Estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behavioral Foundation</td>
<td>Good</td>
<td>Good</td>
<td>Great</td>
<td>None</td>
</tr>
<tr>
<td>Transparency of the Model</td>
<td>Good</td>
<td>Average</td>
<td>Low</td>
<td>Good</td>
</tr>
<tr>
<td>Data Requirement</td>
<td>Average</td>
<td>Average</td>
<td>High</td>
<td>Low-Average</td>
</tr>
<tr>
<td>Development Cost</td>
<td>Low-Average</td>
<td>Average</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Development Risk</td>
<td>Low</td>
<td>Low-Average</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Maintenance/Application Cost</td>
<td>Low</td>
<td>Average</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Policy Sensitivity</td>
<td>Average</td>
<td>Good</td>
<td>Great</td>
<td>None</td>
</tr>
<tr>
<td>Short-term operational analysis?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Long-range planning analysis?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Produce base-year matrix</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
# Review of Data Sources

## Data Source/Period/Type/Data Coverage/Collecting Methods

<table>
<thead>
<tr>
<th>The Models</th>
<th>Primary Data Sources</th>
<th>Survey Period</th>
<th>Data Type</th>
<th>Data Coverage Range</th>
<th>Collecting Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dutch National Model System</td>
<td>Netherlands National Travel Survey (OVG), Special SP surveys</td>
<td>1985-present</td>
<td>Repeated cross-sectional</td>
<td>10,000-68,000 households, supplemented by several hundred SP surveys</td>
<td>Computer Assisted Telephone Interview (CATI), and a one-day travel diary</td>
</tr>
<tr>
<td>(LMS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great Britain (NTM)</td>
<td>National Travel Survey (NTS)</td>
<td>1988-present</td>
<td>Repeated cross-sectional</td>
<td>5,000-15,000 households</td>
<td>Home interview, and a 7-day travel diary</td>
</tr>
</tbody>
</table>
| Italian Decision Support System (SISD) | 1. Household-based survey  
2. Border-crossing interviews  
3. Manual traffic counts | 1. 7/94 and 4/95  
2. 7/94 and 3/95  
3. 7/94 and 3/95 | 1. Twice in 1 year  
1. Twice in 1 year  
1. Twice in 1 year | 1. 8,500 households in summer, 10,000 in winter  
2. 16,000 interviews in summer, 12,000 in winter  
3. 138 traffic counts | 1. Household telephone interview,  
2. Border face-to-face interview,  
3. Bidirectional traffic counts |
| Swedish National Model System (SAMPLES) | National Swedish Travel Survey (RiksRVU) | 1994-1998 | Repeated cross-sectional | 30,000 personal interviews                                                | CATI, and a one-day travel diary                                               |
| Danish National Transport Model (PETRA) | National Travel Survey (TU) | 1995 | One year cross-sectional | 13,793 personal interviews                                                 | CATI, and a one-day travel diary                                               |
| German National Travel Demand Model (Validate) | 1. Mobility in Germany (MiG) 
2. Mobility in Cities (SrV) | 1. 2002  
2. 2003 | 1. One year cross-sectional 
2. One year cross-sectional | 1. 49,000 households  
2. 34,000 persons | 1. CATI, and a one-day travel diary  
2. N/A |
| Swiss National Travel Demand Model | Swiss National Travel Survey (Mikrozensus) | 2000 | Cross-sectional, collected every five years | 27,918 households | CATI |
| STREAMS                       | National travel surveys, Border crossing, roadside, tourism | Mostly 1994 | Cross-sectional | 7 EU countries: Denmark, Finland, France, Germany, Netherlands, Sweden, and UK |                                                                                 |
Typical Data Sources

- Household and personal travel surveys
- User interception surveys
- Stated preference surveys
- Tourism data
- Dedicated long-distance travel surveys
- Traffic counts, other supply-side network and cost data

Available U.S. Data Sources Summarized in Paper

- Most surveys (except 1995 ATS) are not designed specifically for long-distance travel analysis
- Almost all survey data are (repeated) cross-sectional
- The data quality in different years is often inconsistent
Data Limitations

- Lack of data (longer long-distance trips, and network and other supply-side data)
  - Dedicated long-distance surveys/oversampling/synthetic methods
  - Use synthetic methods for estimating costs between OD pairs

- Data from different sources with different levels of accuracy
  - Use statistical methods weighing data items from multiple sources based on accuracy

- Lack of longitudinal observations of behavioral dynamics in standard surveys
  - Conduct SP or joint SP-RP surveys on a smaller sample size

- Available data sources not suitable for standard modeling procedures
  - Use modified/hybrid modeling procedures
# Innovative Travel Data Collection Methods

<table>
<thead>
<tr>
<th>Information Needs</th>
<th>GPS</th>
<th>Smartphone</th>
<th>License Plate</th>
<th>Bluetooth</th>
<th>Cell Phone</th>
<th>Web-Based</th>
<th>Social Media/Networking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin-Destination</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Mode: Main/access/egress</td>
<td>M</td>
<td>Y</td>
<td>Y-auto</td>
<td>Y-auto</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Trip Purpose</td>
<td>M</td>
<td>Y</td>
<td>M</td>
<td>N</td>
<td>M</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Routes</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Trip Frequency</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Travel Season</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Trip Duration</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Itinerary and Side Tours</td>
<td>Y</td>
<td>Y</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Trip Cost and LOS</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Travel Party Size</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Traveler Characteristics</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>N</td>
<td>M</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Domestic or International</td>
<td>M</td>
<td>M</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td><strong>Other Considerations</strong></td>
<td>GPS</td>
<td>Smartphone</td>
<td>License Plate</td>
<td>Bluetooth</td>
<td>Cell Phone</td>
<td>Web-Based</td>
<td>Social Media/Networking</td>
</tr>
<tr>
<td>Passive Data Collection</td>
<td>Y</td>
<td>M</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>M</td>
</tr>
<tr>
<td>Major Privacy Concern</td>
<td>M</td>
<td>M</td>
<td>N</td>
<td>N</td>
<td>M</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>High Respondent Burden</td>
<td>M</td>
<td>M</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Sampling Bias</td>
<td>N</td>
<td>M</td>
<td>N</td>
<td>N</td>
<td>M</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Sufficient Sample Size</td>
<td>M</td>
<td>Y</td>
<td>Y</td>
<td>M</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>
Alternative Routes toward a National Travel Demand Model

Available Data Sources

A. Base-Year Multimodal OD Matrix

B. Aggregate Direct Demand Model

C. Disaggregate Models of Travel Behavior

D. Extensive New Data Collection for Analyzing Behavioral Dynamics

E. Hybrid Aggregate-Disaggregate Demand Model

F. Trip-Based Four-Step Travel Demand Model

G. Tour/Activity-Based and Microsimulation

Travel Demand Model

<table>
<thead>
<tr>
<th>Low Needs</th>
<th>Medium Needs</th>
<th>High Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Resource</td>
<td>AB</td>
<td>ABE</td>
</tr>
<tr>
<td>Medium Resource</td>
<td>ACE</td>
<td>ACF</td>
</tr>
<tr>
<td>High Resource</td>
<td>Unlikely</td>
<td>ADCF</td>
</tr>
</tbody>
</table>
Conclusions and Recommendations

The development of a base-year OD matrix is almost always a good initial investment:

- Provides immediate results for system evaluation and monitoring
- Provides the basis for various types of aggregate/disaggregate models
- Can be used to calibrate more advanced models
- Can be the starting point of policy scenario analysis in a pivot-point model implementation
- Does not rely on new data sources
- Relatively low development cost and no maintenance
Conclusions and Recommendations (cont.)

Dedicated passenger long-distance travel survey

- Innovative survey tools should be explored and compared
- Sampling methods that address the low frequency of long-distance travel for most individuals

Choice of modeling methods for the U.S.

- Applications and needs are abundant, but their priorities could be more clearly defined
- Selection of modeling methods is also intertwined with the design of long-distance data collection tools
- The choice between trip-based, tour-based, and microsimulation approaches is debatable
- Agent-based microsimulation has great potentials
Thank You!

Questions and Comments

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