Transportation Education Series: Travel Demand Modeling

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Presentation overview

- What are travel demand models?
- Why use them?
- How do they work?
- What goes into building them?
- What are their limitations?
- Some further issues
- Questions/discussion
Some of our past experience

- Plus other areas of country
  - Champaign/Urbana
  - Boise
  - Florida
  - Puget Sound
Where does travel demand modeling fit in?

Monitor:
- How is the system performing?
- Where are the problems?

Alternatives:
- How can we fix the problems?
- What alternatives are available?

Analyze:
- What will each alternative do? (traffic levels, costs, air pollution)

Evaluate:
- How well does each alternative perform?
- How do the alternatives rank?

Implement:
The problem

• Given a future projection:
  – Land use (population, employment distribution)
  – Highway and transit networks

• What will happen?
  – Traffic volumes on individual roads
  – Congested road segments, intersections
  – Transit patronage by route
  – Air pollution emissions
History: Ancient times (postwar pre-1950)

Planning issues
- New highway investment
- Where to locate new highways

Studies
- Local, regional studies

Travel forecasts
- Trend projection on individual roadways
### History: 1950s – early 1960s

<table>
<thead>
<tr>
<th>Planning issues</th>
<th>Studies</th>
<th>Travel forecasts</th>
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<tbody>
<tr>
<td>• Regional growth</td>
<td>• Large-scale regional studies (Chicago, Detroit)</td>
<td>• Development of 4-step modeling process</td>
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<td>• New highway investment</td>
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History: Late 1960s – 1980s

Planning issues
• Regional growth
• New highway investment
• Environmental Protection Act (1969)
• Air quality stds
• New transit starts

Studies
• Regional transportation plans
• Air quality inventories
• Transit alternatives analyses

Travel forecasts
• Refinement of 4-step modeling process (UTPS, Tranplan, MINUTP)
• Introduction of disaggregate models into process
## History: 1990s - now

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<td>• Regional transportation plans</td>
<td>• Continued refinement of 4-step modeling process</td>
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<td>• Maintaining existing system</td>
<td>• Air quality inventories</td>
<td>• Increasing development of local models</td>
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<td>• Transit starts</td>
<td>• New transit starts</td>
<td>• Land use models</td>
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<td>• Congestion management, traffic mitigation at local level</td>
<td>• Local general plans</td>
<td>• Activity-based models</td>
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<td>• Traffic impact</td>
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Types of transportation models

• Planning
  – Provide information on transportation activity
  – “Travel demand model”
  – “Traffic forecast model”
  – Software: Cube, TransCAD, EMME, Visum

• Operations
  – Provide information on operation of transportation system
  – Static capacity analysis
  – Simulation of vehicles or groups of vehicles
  – Software: Synchro, VISSIM, Paramics, Transmodeler
Integrated modeling

• Level of modeling appropriate for analysis required

• Macroscopic
  – Evaluate large groupings of people/vehicles
  – All activity occurs during a single time period (day, peak hour)
  – Can cover large geographic area
  – *Example: Most travel demand forecast models*

• Mesoscopic
  – Evaluate smaller groups, time slices
  – Useful when conditions change during time period
  – *Example: Freeway operations analysis for 4-hr peak*

• Microscopic or Microsimulation
  – Evaluate individual people/vehicles
  – Useful when individual behavior affects system
  – *Example: Difficult freeway ramp weaving section*
What is a Travel Demand Forecast Model?

A systematic process for translating demand

*(people moving from one land use to another to do activities)*

and

supply

*(available transportation systems)*

into projections of future travel demand
What is a model?

• A “bookkeeping” device
• Incorporates current knowledge of travel behavior
• Projects travel behavior into the future using
  – Supply-demand relationships derived from knowledge of travel behavior
  – Future land use and transportation system configurations
• Examples of “models”
  – Past experience
  – Trend projection
  – Computer simulation
“Travel” “Demand” “Forecast”

- **Travel**
  - We have often called them “traffic models”
  - Now need to account for other modes such as walking, bicycling

- **Demand**
  - Models estimate how many people want to make the trips
  - Not necessarily how many can make the trips when they want to

- **Forecast**
  - Models do not replicate every nuance of existing travel
  - Most important is reasonable response to future changes
How do we set up a travel model?

- Divide the region into smaller subareas (TAZs)
- Build a model of highway and transit networks (supply)
- Develop demand models using available data
  - Household travel surveys
  - Borrow models from other regions
  - NCHRP 365
A Presentable Version of the Madera Model
What the Model Really Looks Like
Madera Model with “Zones” (Land Use Groupings)
Transportation Analysis Zones (TAZs)

All land uses in TAZ (grey boundary) represented by a single point (red dot)
The “4-step” process

• Trip-based model
• Forecasts trips by type:
  – Home-work
  – Home-school
  – Home-shop
  – Home-other
  – Other-other
• Produces forecasts of:
  – Vehicle trips on highway links
  – Person trips on transit routes
  – Trips on other modes (bike, walk)
4-step process

**Inputs:**
- Socioeconomic data by zone (households, employment, …)
- Network description (road capacity, connectivity, transit lines, …)

**Outputs:**
- Travel volumes and speeds on each road link
- Network description (road capacity, connectivity, transit lines, …)

**Diagram:**
- Trip generation: How many trips?
- Trip distribution: Where do the trips go?
- Mode choice: Which travel modes do they use?
- Assignment: By which route?
4-step process

- **Trip generation**
  - Productions $P_i$
  - Attractions $A_j$

- **Trip distribution**
  - $T_{ij}$

- **Mode choice**
  - Auto
  - Transit

- **Assignment**

*Michael Meyer, Urban Transportation Planning*
Trip generation

• Trip production model approaches
  – Trip rates: fixed rate per household type
    • HH size
    • Number of workers
    • Number of autos
  – Regression models based on TAZ population, income, etc.

• Trip attraction models
  – Trips attracted to TAZ based on employment
Types of trips: depends on region, locality

- Home – work
- Home – school
  - K-12
  - University
- Home – shop
- Home – social & recreational
- Home – other
- Other – other ("non-home based")
Trip generation

• Different trip types
  – Home-work
  – Home-school
  – Home-shop
  – Home-other
  – Other-other

• Why?
  – Different trip rates by type for different HH types
  – Different trip length, mode choice characteristics
Trip distribution

- How many trips between zone \( i \) and \( j \)
- Function of
  - \# trips produced at production zone
  - \# trips attracted at attraction zone
  - Impedance between zones

- Approaches
  - Gravity model
  - Destination choice model
Trip distribution – gravity model

\[ T_{ij} = P_i A_j f(t_{ij}) \]
Friction factors
Trip distribution – destination choice model

\[ p_{ij} = f(\text{employment}_j, \text{composite access time}_{ij}) \]
Mode choice

• Which travel mode will be used?
  – Auto (drive alone, shared ride)
  – Transit (bus, rail)
  – Non-motorized (bike, walk)

• Modern approach: probability choice model

\[ p_{ij} = \frac{\exp(U_{ij})}{\sum_k \exp(U_{ik})} \]

\[ U_{ij} = f(\text{cost, time, inherent attractiveness of mode } j) \]
Mode choice

- Not always included in travel models
- Some rural areas, cities do not have mode choice component
The “fifth step” of the four-step process

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<tr>
<th>P/A tables by purpose</th>
<th>O/D tables by time period</th>
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<td><strong>Home-work</strong></td>
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<td>Attraction zone</td>
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**AM peak**

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**Off peak**

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**Home-work**

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**Other-other**

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Trip assignment

- Highway, transit assignments
- Types: All-or-nothing (AON), equilibrium, capacity constrained, stochastic
- Highway assigns vehicle trips to road network (after factoring using auto occupancies)
- Transit assigns passengers to buses or trains – uses AON
- Time of day (AM Peak 1 hour, 2 hour, etc, PM peak, Midday or Off-Peak) after splitting daily trips into desired peak period
Trip assignment

- Route chosen based on shortest time/distance path, capacity constrained or equilibrium
- Factors affecting choice include road speed, length, capacity, level of congestion
- Uses speed-flow relationship (curve) to do this (also called volume/delay function)
Volume-delay function on a link: BPR curve

\[ T = T_0 \left[ 1 + \alpha \left( \frac{V}{C} \right)^\beta \right] \]
Trip assignments - outputs

• Highway links
  – Number of vehicles by type (drive alone, shared ride, truck)
  – Travel time on link

• Transit links
  – Number of passengers by transit line
Assignment output (example)
The *Real* Process

- Define Model Area – What happens at gateways?
- Code Transportation Networks
- Define Zone System – Aggregate land uses
- **Inventory Land Uses**
- Calibration – Formulas based on survey data
- Validation – Compare model results to counts
- Forecast Inputs – Land uses, networks
- **Policy Framework** – Which assumptions should remain constant?
- Adjust Model Results
More recent approach: Activity-based models
Activity-based models

• Sometimes called “microsimulation demand” or “tour-based” models
• Travel is a “derived” demand
  – Demand for travel arises from demand for other activities (work, shopping, social, etc.)
• Captures idea of “trip chaining”: models all legs of a tour
Tours vs trips

- Home
- Grocery shopping
- Pick up child at school
- Work
- Eat lunch
- Drop off child at school

- Home based work tour
- Work based subtour
Differences from traditional 4-step models

- Model works on a set of individuals rather than population aggregates
- Models tours first, individual trips second
- Outputs consist of set of trip patterns for a sample of individuals
Activity model steps

1. Generate a synthetic population
2. Apply travel models to each person in population to generate a set of tours
3. Aggregate tours into trip tables by time of day and mode
4. Assign trip tables to highway and transit networks
Types of tours

• **Home-based**
  – Mandatory (work, school)
  – Maintenance (personal business, medical, shopping)
  – Discretionary (social, recreational)

• **Subtours**
  – Work based (e.g., visit a client, return to work)
  – School based (e.g., go to job, return to school)
Advantages of activity based models

- Estimated on disaggregate data
- Therefore, more accurate representation of travel behavior
- Captures interdependency between trips on a tour
- Ability to disaggregate outputs by population groups
  - Income
  - Ethnicity
  - Other special populations: seniors, handicapped, etc.
Concerns with activity-based models

- Very data intensive
- Some needed data sources may not be around in the future: Census long form, PUMS/ACS data
- Very complex, usually with hundreds of parameters
- Danger of overfitting, poor predictive capability
- How much better do they actually perform?
  - Hint: nobody really knows yet!
The bottom line:

What is all this effort in aid of?
Uses of travel models

• **Fulfill Requirements**
  – Air quality conformity
  – Transit project funding applications
  – State highway project requirements
  – Now, Sustainable Community Strategies, etc...

• **Long Range Transportation Planning**
  – Regional transportation plans
  – Design of new roads
  – Passengers on new transit services
  – Evaluate land use alternatives
Why Make it Complicated?

• Can’t we just count cars?
  – Okay for existing or short-term only
• How about growth trends?
  – No relation to future land uses
• Count cars and add known development on top?
  – Okay for specific development studies (EIS)
  – Can’t easily account for interactions between future land uses (new housing + new jobs)
Travel Model Capabilities

- Can evaluate changes in travel by people who are already on the road
  - Diversion to new road connection or transit service
  - Diversions due to increased congestion
  - New land use that will divert existing travel
    - WalMart may divert from existing stores
- Evaluate several new developments that will interact with each other
  - New housing plus new jobs
- Agencies use as database for consistency
Limitations of Travel Models
The basic limitation

It's tough to make predictions, especially about the future.

- Yogi Berra
Travel Model Limitations

- Assume that past relationships will hold in future
- We still don’t understand human behavior
- Grouping of people and land uses
- Travel models do not predict land use
- Sensitivity to non-auto travel
- Sensitivity to urban form
- Difficult to get real world data
Planning objectives can change

The future ain't what it used to be.

- Yogi Berra
Planning objectives

• Originally: where to build more roads
• Later on:
  – Transit investments
  – Air quality
  – Local congestion mitigation
• Now:
  – Environmental issues
  – Safety
  – Quality of life
  – Sustainability
• Future: who knows?
Putting it all together:

Evaluation
Where does travel demand modeling fit in?

- Monitor: How is the system performing? Where are the problems?
- Alternatives: How can we fix the problems? What alternatives are available?
- Analyze: What will each alternative do? (traffic levels, costs, air pollution)
- Evaluate: How well does each alternative perform? How do the alternatives rank?
- Implement:
Evaluation: the forgotten step

- Often spend too much time in forecasting, not enough time in evaluation
- Need to go into process with clear purpose:
  - Goals
  - Objectives
  - Performance measures (these set information requirements from travel forecasting process)
Evaluation

• Need to have clear idea on how to make tradeoffs
  – Capacity expansion vs. environmental goals
  – Reduce delay vs. improving reliability
  – Distributional effects (who gains, who pays)

• Benefit-cost analysis
  – Uses market values to help make tradeoffs
  – Increasing use by MPOs (MTC, PSRC)
  – Called for in MAP-21
  – David Quarmby: If you don’t put values on things, someone else will do it for you
Our basis for understanding travel behavior:

Household travel surveys
Household travel surveys

- Provide basic information for travel modeling
- Household characteristics
- Persons in household
- Trips made by each person
- Vehicles in household
Household travel survey steps

- Questionnaire
- Sample definition
- Pilot survey
- Refine questionnaire, sampling method
- Conduct interviews
- Process data: clean, edit, code
- Build database for further use
Sample development

- Typically: random sample of phone numbers
- May have different sample size for different sub-regions
- Special sampling to adequately represent some groups
  - Elderly
  - Minorities
Initial interview

- Contact household
- Secure agreement to participate
- Collect information on household & persons
  - # persons
  - # vehicles
  - Age, sex, relation, occupation of each person in HH
  - Information on each vehicle: make, model, year, fuel type, fuel efficiency
- Set travel day(s)
- Send diaries to household
Follow-up interview(s)

• Collect trip information
  – Formerly: limit to persons over 5 yrs old
  – Now: all persons in household

• Go through diary:
  – Origin, destination type (home, work, shop, etc.)
  – Origin, destination location
  – Begin, end trip time
  – Travel mode (# persons in vehicle if rideshare)
  – Amount paid (transit fare, toll, parking)
Data processing

- CATI almost universally used, so no need to code
- Still need to check data for consistency
- Setting up database with appropriate structure
  - Household file
  - Person file
  - Trip file
  - Vehicle file
  - Location file (Caltrans)
  - Codebook
Household survey travel “gotchas”

- “Foreign” area codes
- Wireless households
- Response rate, nonresponse bias
- Underreporting of trips
  - Intermediate stops (e.g., between home and work)
  - Nonwork trips
  - Bike, walk trips
  - Short trips
Some personal reflections

• We’ll never be able to model travel behavior completely
• Accept limitations of models and supplement with other actions
  – Past experience (post-project evaluation)
  – Negative feedback: monitoring
    • Yogi Berra: You can observe a lot just by watching
Follow-up questions

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