CE-780 Behavioral Travel Modeling

Instructor: Prof. K. V. Krishna Rao
Course Contents

• Introduction to behavioral travel modeling
• Individual choice theory: binary choice models, multinomial and multi-dimensional choice models, issues in model specification, methods and statistics of model estimation with emphasis on maximum-likelihood estimation, aggregation and forecasting with discrete choice models, validation and transferability aspects, ordered multinomial models, nested logit models
• Survey design and analysis: travel surveys and their role in transport planning, survey methods, precision and accuracy in travel surveys, sample design, sampling procedures, survey format, pilot surveys, survey administration, collection of stated and revealed preference data, survey data processing.
• Advanced concepts: accommodating unobserved population heterogeneity in choice behavior, mixed logit models, joint stated preference and revealed preference modeling, and longitudinal choice analysis
• Discrete choice models for integrated land use and transport modeling, review of state-of-the-art and future directions.
Texts/References

• Selected papers from journals such as Transportation Research, Transportation Science, and Transportation Research Record.
• Class Notes
Categories of Demand Models
Sequential Versus Simultaneous Models

- **Sequential model**
  - The travel demand is modeled in sequential steps of trip generation, trip distribution, modal split and assignment

- **Simultaneous model**
  - If two or more steps in the sequential approach are combined then it results in a simultaneous model.
  - Simultaneous demand models are also called as direct demand models
  - Examples
    - Combined modal split and distribution model
    - Intercity travel demand model
THE URBAN TRANSPORTATION MODEL SYSTEM

INPUTS
• TRANSPORTATION SYSTEM CHARACTERISTICS
• LAND USE – ACTIVITY SYSTEM CHARACTERISTICS

URBAN TRANSPORTATION MODEL SYSTEM (UTMS)

TRIP GENERATION
(How many trips?)

TRIP DISTRIBUTION
(Where do they go?)

MODE CHOICE
(By what mode?)

TRAFFIC ASSIGNMENT
(By what route?)

OUTPUTS
TRAFFIC FLOWS ON NETWORK LINKS
• Quantity (Volume)
• Quality (Speed)
Cross-section model versus Temporal model

• Cross-section model
  – model that uses data on dependent and independent variables collected at one point in time for several spatial units (e.g., TAZs)
  – The traditional four stage urban travel demand model is a cross-sectional model

• Temporal model
  – Model that uses panel data (collected at different points of time) on dependent and independent variables for a single spatial unit (e.g., airport, city, etc)
Trend model versus Econometric Model

• Trend Model
  – Causal variable is only time
  – All growth factor models are trend models
  – e.g., linear, exponential, logistic trend models

• Econometric Models
  – The econometric variables (e.g., GDP, employment, car ownership, etc.,) that cause the changes in demand are used as independent variables
  – Traditional four stage model is an econometric model
Aggregate versus Disaggregate Models

• Aggregate Models
  – The demand model that uses summaries of data is an aggregate model
  – The traditional four stage urban travel demand model is an aggregate travel demand model as it uses zonal summaries or aggregate data

• Disaggregate Model
  – The demand model that uses the data on individual decision making unit as it is and explains the behaviour of the decision making unit when confronted with alternatives is a disaggregate model
Top-down model versus Bottom-up Model

• Top-down model
  – Top down models are also known as market share models. A single modal is developed for a larger spatial unit (state) and the demand for the smaller units (regions, individual airports, etc.) with in the larger unit is worked out by market share methods

• Bottom-up model
  – Separate models are developed for each smaller unit, and when aggregated across all smaller units the demand for the bigger unit comes out
Overview of UTMS
• Metropolitan Planning Organisation (MPO) divides the urban region into 100 - 2000 Traffic Analysis zones (TAZs)
• MPO develops networks that represent all major roads and public transport lines, generally termed as strategic network
• Performs household travel survey, cordon line and screen line surveys, speed surveys, etc.
• Collects data relating to demography, land use and activity system
• Establishes travel pattern in terms of trips made by purpose, time, mode, route and destination.
• This data is then used to estimate several submodels, viz., trip generation, distribution, modal split and assignment representing the travel pattern.
UTMS

- The models would include explanatory variables relevant to all major policy issues, such as transit fares, road tolls, land use policies, etc.
- The model set is then validated by comparing the base year volumes obtained by the calibrated model with actual traffic volume counts in certain parts of the region.
- This validation is done also for public transport ridership, regional modal shares and number of trips.
- After the model is validated, it is run for those future years of interest, based on the amount and location of projected population and employment.
- Generally, models are run on a 20-year horizon for facility planning and are also run on intermediate years for the requirement of transit ridership estimation or emission deadlines, etc.
PREANALYSIS PHASE
• Problem/Issue Identification
• Formulation of Goals and Objectives
• Data Collection
• Generation of Alternatives

TECHNICAL ANALYSIS PHASE
• Land Use –Activity System Model
• UTMS
• Impact Prediction Models

POSTANALYSIS PHASE
• Evaluation of Alternatives
• Decision Making
• Implementation
• Monitoring
Pre-analysis Phase

• Define problem broadly
  – Examples
    • Maximise public transport accessibility
    • Achieve reasonable level of service on roads

• Identify broad objectives
  – Examples
    • Public transport area coverage >95%
    • Congestion inside transit vehicles < 5 standees/m²
    • LoS of Arterial Road network ≥ D
Overcrowding in Suburban Trains
Generation of Alternatives

• Generate alternatives by judgment
• Narrow them down to manageable number by DELPHI technique
• “No Action Alternative” needs to be considered for comparative evaluation
• Generate enough number of
  – transit investment schemes
  – road network investment schemes
  – land use options
PROJECTS IN YEAR: 2011

- Passenger Water Transport
- Metro – Phase I: Andheri – Ghatkopar - Versova
- Bandra – Worli Sea Link
- Western Freeway Sea Link
- Eastern Freeway
- SC Link Road
- JVLR
- Sewri – Worli Fast Corridor
- MTHL
PROJEC TS IN YEAR: 2021

- Metro Phase II: **Colaba – Mahim - Charkop / Mankhurd**
- Metro – Phase I: Andheri – Ghatkopar - Versova
- Bandra – Worli Sea Link
- Western Freeway Sea Link
- Sewri – Worli Fast Corridor
- MTHL
- MTHL-RAIL
- JVLR
- SC Link Road
- Passenger Water Transport
- Eastern Freeway
- Western Freeway Sea Link
- Eastern Freeway
PROJECTS IN YEAR: 2031

- Metro – Phase II: Ghatkopar – Mulund & Charkop - Dahisar
- Metro – Phase I: Andheri – Ghatkopar - Versova
- Metro Phase II: Colaba – Mahim - Charkop / Mankhurd
- Bandra – Worli Sea Link
- Sewri – Worli Fast Corridor
- Western Freeway Sea Link
- JVLR
- SC Link Road
- MTHL/RAIL
- Eastern Freeway
- Passenger Water Transport
Metro Phase II: Colaba – Mahim - Charkop / Mankhurd

Metro – Phase I: Andheri – Ghatkopar - Versova

Metro Phase II: Colaba – Mahim - Charkop / Mankhurd

Bandra – Worli Sea Link

Western Freeway Sea Link

Passenger Water Transport

Metro – Phase II: Ghatkopar – Mulund & Charkop - Dahisar

Metro Phase III

JVLR

SC Link Road

Sewri – Worli Fast Corridor

MTHL/RAIL

Eastern Freeway

PROJECTS IN YEAR: 2041
Plan Evaluation Criteria

• Measures of congestion
  – LoS (A-F) on each network link

• Travel Delay
  – Person hours

• Measures of pollution
  – Number of tons of each pollutant produced per day

• Economic welfare (equity measure)
  – Net benefit to travelers in terms of reduction in generalised cost of travel
  – Net benefits to travelers by income class
Data Collection

• Data gathering and data cleaning is part of an ongoing process
• This exercise is fundamental to accurate travel modeling
• Household travel survey need to be performed every decade, coordinated with the national census
• Usual traffic surveys such as cordon line and screen line counts and O-D surveys need to be performed more frequently (three times in a decade)
• Panel surveys on the same household can be used to model household and firm location behaviour
• Survey of employment is needed to supplement national economic census
• Demographic data need to be collected from census.
• Land use data need to be collected from development plan sheets supplemented with satellite imagery
• Survey firms to determine goods movement by commodity type
Procedure for Generating Base Year O-D Matrices

1. Eliminate bias in HH data and compute expansion factors
2. Expanded partial O-D matrices
3. O-D matrices with all trips
4. Comparison of trips from O-D matrices with screen line counts
   - Adjustment of matrices
5. Load matrices on to the network and compare the assigned and observed link flows. Validate matrices. Select appropriate assignment technique
6. Validated O-D matrices for base year

Inputs:
- Outer cordon O-D
- O-D surveys at terminals
- Workplace based surveys

Network data
- Screen line data
- Cordon line data
- Bus route network
Technical Analysis Phase

• Activity Forecasts
  – Population and employment forecasts are taken from the planning body (for example MMRDA projects population using ratio method)
  – Other important variables in travel models like household income and size need to be forecast
  – Allocate the households and employment to the traffic analysis zones
  – A land use model would be more appropriate in allocating the future activities to zones
Technical Analysis Phase

• Car ownership model
• UTMS
  – Trip generation
  – Trip distribution
  – Modal split
  – Assignment/ route choice
• Impact Prediction Models
  – Travel impacts
  – Air pollution impacts
  – Noise pollution impacts
  – Ecological impacts
  – Social impacts
### TRIP PRODUCTION

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### TRIP DISTRIBUTION

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<td>2</td>
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### MODE SPLIT

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### TRIP ATTRACTION

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<td>ROUTE B</td>
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<tr>
<td>ROUTE C</td>
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### TRIP ASSIGNMENT

- **MODE I**
- **MODE II**
Post-analysis Phase

• Plan Evaluation
  – Done using economic, equity and environmental measures
  – Reduction in generalized cost categorized by at least three income groups represents social equity
  – Environmental measures consider pollution impacts, noise impacts, ecological impacts, social impacts
Good Modeling Practice

• Time Representation
  – Peak and off-peak periods

• Data Gathering
  – Household travel survey every decade with tours
  – Vehicle speed surveys
  – Data for urban model

• Activity Forecasts
  – GIS land use model or economic urban model
Good Modeling Practice

• Car Ownership
  – Discrete choice model, dependent on land use, parking costs, and accessibility by mode

• Trip Generation
  – Walk and bicycle modes
  – More trip purposes
  – Dependent on car ownership
  – Three or more time periods

• Trip Distribution
  – Full Model Equilibration
  – Composite costs used (all modes, all costs)
  – All-day trip tours represented
Good Modeling Practice

• Mode Choice
  – Discrete choice models used
  – Land use variables in transit, walk, and bike models

• Goods Movement
  – Fixed trip tables

• Assignment
  – Capacity-restrained
  – Cleaned-up link capacities
  – Speeds calibrated
  – Three or more time periods
BASE YEAR TRAVEL DEMAND PROCESS

Validated base year O-D matrices

Trip productions
Trip attractions

Trip Generation Modelling for internal trips
  • Trip production equations
  • Trip attraction equations

Planning Variables
  • Population
  • Residential workers
  • Vehicle ownership
  • Employment

Assignment of PT trips on to the public transport network
Assignment of highway trips on to the road network taking PT flows as preloads

PT time/cost skims
Highway time/cost skims

Road network data
PT network data

Calibration of Gravity trip distribution model for internal trips

Calibration of a disaggregate mode choice model
ASSIGNMENT OF PUBLIC TRANSPORT TRIPS

- Assignment based on Generalized Time
  - In-vehicle travel time
  - Waiting time
  - Transfer time
  - Walk time
  - Fare
  - Discomfort

- \( GT = IVTT + WTFAC \times WT + TRFAC \times TR +
  \quad WKFAC \times WKT + FARE / VOT + DCFAC \times DC \)
- Path building based on GT
- Assignment by Logistic choice function based on GT
FORECASTING

Projection of Planning Variables using Land-use / demographic models for the future year

Apply trip-end equations and obtain future year trip-ends of internal trips

Apply calibrated gravity model and obtain O-D matrix for internal trips

Previous cost/time skims for initial run

Apply mode choice model and obtain PT, car and two-wheeler O-D matrices of passenger internal trips
• Matrix of daily PT (bus+rail+ taxi+walk) passenger trips
• AM peak and PM peak matrices of car, two-wheeler and truck trips in PCU

• Assignment of PT passenger trips on to the public transport network
• Assignment of peak-hour PCU trips on road network taking peak-hour PT & truck PCU flows as preloads

Link costs stable?

No

Obtain truck matrix and mode-wise external O-D matrices by Furness method using growth factors

Regional peak hour to daily flow ratios
Passenger - PCU conversion factors

Yes

Road network data and PT network data for the scenario under consideration

Final Link flows
PT Loadings (Bus, MRTS, Rail, Taxi, walk)
MRTS Boardings and Alightings
Final PT and Highway Cost/Time skims
Definition of a Behavioural Model

A behavioural model is one that explains the decisions of an individual when confronted with several alternatives.
Travel as a Choice Process

- Actual choice
  - Trip
    - Mode 1
      - Peak
        - Destination 1
        - Destination 2
        - Destination 3
      - Off Peak
        - Destination 1
        - Destination 2
        - Destination 3
  - Mode 2
    - Peak
      - Destination 1
      - Destination 2
      - Destination 3
    - Off Peak
      - Destination 1
      - Destination 2
      - Destination 3
- No Trip
Factors Influencing the Choice of Mode

- **Socioeconomic Characteristics of Trip Maker**
  - Car Availability and/or ownership
  - Possession of driving license
  - Household Structure
  - Income
  - Residential Density

- **Characteristics of Journey**
  - Trip purpose
  - Time of day of travel

- **Characteristics of Transport System**
  - Travel time
  - Waiting Time
  - Travel cost
  - Comfort & Convenience
  - Reliability & regularity
  - Protection & Security
Revealed Preference (RP) Data

I CHOSE CAR.

ACTUAL BEHAVIOUR

CAR - 20 min.

RAIL - 30 min.
If new service was introduced...

RAIL - 30 min.

METRO - 15 min.

CAR - 20 min.

If new service was introduced, I WOULD CHOOSE METRO.

HYPOTHETICAL BEHAVIOUR

Stated Preference (SP) Data