Introduction to Transportation Behavioral Modelling

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Why are we interested in Travel Demand Modelling?

Forecast - Transportation Demand

Changes in the Attributes

Transportation system

People

User

Vehicle/ Carrier

Roadway/ Facility

Environment
Contents

• Introduction to four step model
• Choice Models
• Activity Based Modelling Approach
Introduction

• Demand for Travel is a derived Demand

• Components of Transportation System
  1. User
  2. Vehicle/ Carrier
  3. Roadway/ Facility
  4. Environment

• Transportation systems problems
  1. Congestion
  2. Pollution
  3. Safety
  4. Parking
Four step model
Four step model

Inputs
- Transportation system
- Characteristics
- Land use – activity system characteristics

Urban Transportation model system
1. Trip Generation (How many trips)
2. Trip Distribution (Where do they go?)
3. Mode Choice (By what mode?)
4. Traffic Assignment (By what route?)

Outputs
- Traffic flow on network
- Quantity (Volume)
- Quality (Speed)
Four step model

1. Trip generation

2. Trip distribution

3. Modal split

4. Assignment

Route taken by flow $T_{ijM1}$
### Example

#### Production

<table>
<thead>
<tr>
<th>Zone</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>47</td>
</tr>
<tr>
<td>2</td>
<td><strong>66</strong></td>
</tr>
<tr>
<td>3</td>
<td>110</td>
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</table>

#### Attraction

<table>
<thead>
<tr>
<th>Zone</th>
<th>Attraction</th>
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<tbody>
<tr>
<td>1</td>
<td>45</td>
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<tr>
<td>2</td>
<td><strong>90</strong></td>
</tr>
<tr>
<td>3</td>
<td>88</td>
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</table>

#### Trip Purpose

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Count</th>
</tr>
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<tbody>
<tr>
<td>Education</td>
<td>2</td>
</tr>
<tr>
<td>Work</td>
<td>6</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
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</table>

#### Income

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
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<tbody>
<tr>
<td>Low</td>
<td>9</td>
</tr>
<tr>
<td>Medium</td>
<td>5</td>
</tr>
<tr>
<td>High</td>
<td>3</td>
</tr>
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</table>

#### Mode I

<table>
<thead>
<tr>
<th>Route</th>
<th>Tijm</th>
<th>Tijmrs (Income)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
<td>Low</td>
</tr>
<tr>
<td>B</td>
<td>17</td>
<td>Low</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>Low</td>
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</table>

#### Mode II

<table>
<thead>
<tr>
<th>Route</th>
<th>Tijm</th>
<th>Tijmrs (Income)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>25</td>
<td>Low</td>
</tr>
<tr>
<td>B</td>
<td>15</td>
<td>Low</td>
</tr>
<tr>
<td>C</td>
<td>40</td>
<td>Low</td>
</tr>
</tbody>
</table>

#### Tijmrs

<table>
<thead>
<tr>
<th>Trip Purpose</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>3</td>
</tr>
<tr>
<td>Work</td>
<td>12</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
</tr>
</tbody>
</table>

#### Tijmr

<table>
<thead>
<tr>
<th>Trip Purpose</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>3</td>
</tr>
<tr>
<td>Work</td>
<td>12</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
</tr>
</tbody>
</table>
Trip Generation

• Aims at predicting the total number of trips generated by \((Oi)\) and attracted to \((Dj)\) each zone of the study area

• **Trip or Journey:** This is a one-way movement from a point of origin to a point of destination

• **Home-based (HB) Trip** This is one where the home of the trip maker is either the origin or the destination of the journey

• **Non-home-based (NHB) Trip** This, conversely, is one where neither end of the trip is the home of the traveler
Classification of Trips

- travel to work
- travel to school or college (education trips)
- shopping trips
- social and recreational journeys
- escort trips (to accompany or collect somebody else)
- other journeys
Trip Distribution

- The purpose of the trip distribution is to estimate ‘zone to zone’ movements, i.e., trip interchanges

Gravity Model

- Probability that a trip of a particular purpose k produced at zone i will be attracted to zone j, is proportional to the attractiveness or ‘pull’ of zone j, which depends on two factors.
- One factor is the magnitude of activities related to the trip purpose k in zone j, and the other is the spatial separation of the zones i and j.
Trip Distribution: Gravity Model

- The gravity model assumes that the trips produced at an origin and attracted to a destination are directly proportional to the total trip productions at the origin and the total attractions at the destination.

- The calibrating term or "friction factor" (F) represents the reluctance or impedance of persons to make trips of various duration or distances.

- The general friction factor indicates that as travel times increase, travelers are increasingly less likely to make trips of such lengths.

Standard form of gravity model

\[ T_{ij} = \frac{A_j F_{ij} K_{ij}}{\sum_{k=1}^{m} A_k F_{kj} K_{kj}} x P_i \]

Where:
- \( T_{ij} \) = trips produced at \( I \) and attracted at \( j \)
- \( P_i \) = total trip production at \( I \)
- \( A_j \) = total trip attraction at \( j \)
- \( F_{ij} \) = a calibration term for interchange \( ij \), (friction factor) or travel time factor ( \( F_{ij} = C/t_{ij}^n \) )
- \( C \) = calibration factor for the friction factor
- \( K_{ij} \) = a socioeconomic adjustment factor for interchange \( ij \)
- \( i \) = origin zone
- \( n \) = number of zones
Mode Choice

- Relates the probability of transit usage to explanatory variables in mathematical form
- **Factors Affecting Mode Choice**

Factors that may explain a trip maker’s choosing a specific mode of transportation for a trip are grouped commonly as follows:

- **Trip Makers Characteristics:**
  - Income
  - Car-Ownership
  - Car Availability
  - Age

- **Trip Characteristics:**
  - Trip Purpose - work, shop, recreation, etc.
  - Destination Orientation - CBD vs. non-CBD
  - Trip Length

- **Transportation Systems Characteristics**
  - Waiting time
  - Speed
  - Cost
  - Comfort and Convenience
  - Access to terminal or transfer location
Mode Choice

Bus - 40 minutes

Car - 35 minutes

Actual Behavior – Revealed Preference (RP) Data

I chose CAR
Mode Choice

- Bus: 40 minutes
- Car: 35 minutes
- Metro: 15 minutes

A new service introduced

If new service is introduced, I will chose Metro

Hypothetical Behavior – Stated Preference (SP) Data
Mode Choice

\[ P_{\text{Metro}} = \exp(v_{\text{Metro}}) / \exp(v_{\text{Metro}}) + \exp(v_{\text{EM}}) \]

\[
V_{\text{Metro}} = \alpha WT_{\text{Metro}} + \beta TT_{\text{Metro}} + \gamma TC_{\text{Metro}} + \phi DC_{\text{Metro}} + \text{CONST}
\]
\[
V_{\text{EM}} = \alpha WT_{\text{EM}} + \beta TT_{\text{EM}} + \gamma TC_{\text{EM}} + \phi DC_{\text{EM}}
\]

\( Pr (\text{Metro/EM}) \) = probability of shifting to Metro

\( V_{\text{Metro}} \) = deterministic component of utility of Metro mode

\( V_{\text{EM}} \) = Utility of Existing Mode

\( WT \) = waiting time

\( TT \) = travel time

\( TC \) = travel cost

\( DC \) = discomfort

\( \alpha, \beta, \gamma, \phi \) = parameters to be estimated using SP data

\( \text{CONST} \) = constant that explains the unobserved effects
4 Traffic Assignment

- Allocates the trips between each zone pair to the links comprising the most likely travel routes.
- The trips on each link are accumulated and the total trips on each link are reported at the end of the assignment process
  - All or Nothing Assignment
  - User Equilibrium
Traffic Assignment

All or nothing

• Trips from any origin to any destination is loaded into a single, minimum cost path between them.

Limitations:

• Unrealistic as only one path is utilized.
• No consideration for capacity or congestion – travel time is a fixed input.

User Equilibrium (UE)

• The user equilibrium assignment is based on Wardrop’s first principle, which states that no driver can unilaterally reduce his/her travel costs by shifting to another route.
• UE conditions can be written for a given O-D pair as:

\[ f_k (c_k - u) = 0 : \forall k \]
\[ c_k - u >= 0 : \forall k \]

where \( f_k \) is the flow on path \( k \), \( c_k \) is the travel cost on path \( k \), and \( u \) is the minimum cost.

Equation label (eq)2 can have two states.

1. If \( c_k - u = 0 \), from equation 10.1 \( f_k \geq 0 \). This means that all used paths will have same travel time.
2. If \( c_k - u \geq 0 \), then from equation 10.1 \( f_k = 0 \).

This means that all unused paths will have travel time greater than the minimum cost path, where \( f_k \) is the flow on path \( k \), \( c_k \) is the travel cost on path \( k \), and \( u \) is the minimum cost.

Two Link Problem with constant travel time function

and total flows from 1 to 2 is given by. \( q_{12} = 12 \)

Since the shortest path is Link 1 all flows are assigned to it making \( x_1 = 12 \) and \( x_2 = 0 \).
Choice models
Choice Models

• Choice modelling is based primarily on the utility theory.
• Characteristics of the alternatives defines its attractiveness for a particular user
• Utility is a subjective concept but it can be useful for comparison between given alternatives.
Utility Theory

- Each alternative has attractiveness or utility associated with it
- Decision maker is assumed to chose that alternative which yields the highest utility
- Utilities are expressed as sum of measured attractiveness and a random term
- Measured attractiveness is a function of the attributes of the alternative as well as the decision maker’s characteristics

\[ U_{ji} = V_{ji} + \varepsilon_{ji} \]

\[ V_{ji} = \beta^T Z_{ji} \]

\[ Z_{ji} = (X_{ji}, S_i) \]

Where,

- \( U_{ji} \) = utility of alternative \( j \) for individual \( i \)
- \( V_{ji} \) = measured attractiveness of alternative \( j \) for individual \( i \)
- \( \varepsilon_{ji} \) = random part
- \( Z_{ji} \) = column vector of characteristics of the individual \( i \) and attributes of the alternative \( j \)
- \( \beta \) = column vector of parameters
Utility Theory

• The alternative $j$ is chosen by $i$ when

\[ U_{ji} > U_{li} \quad \text{for all } l \neq j \]

• The probability $P_{ji}$ for the $j^{th}$ alternative to be chosen is

\[
P_{ji} = \Pr[V_{ji} + \epsilon_{ji} > V_{li} + \epsilon_{li}] \quad \text{for all } l \neq j
\]

\[
= \Pr[(\epsilon_{li} - \epsilon_{ji}) < (V_{ji} - V_{li})]
\]
Utility Theory

\[ V_{\text{Car}} = -0.023*TIME -0.021*COST +0.003*INCOME -0.001 \]

\[ V_{\text{Bus}} = -0.023*TIME -0.021*COST-0.001*INCOME \]

\[ V_{\text{Train}} = -0.023*TIME -0.021*COST+0.003 \]

*TIME* and *COST* are *generic variables*

*INCOME* is *alternative specific variable*
Variables ...

• Generic Variable - Variable that appears in the utility functions of all alternatives in a generic sense and has same coefficient estimate for all the alternatives

• Alternative Specific Variable - Variable that appears only in the utility function of those alternatives to which it is specific and has different coefficient estimate for each of the alternatives

• Alternative Specific Constant - Takes care of unexplained effects
Some Limitations of 4-step TDM

- Traditional travel demand models ignore travel as a demand derived from activity participation decisions
- Does not incorporate the reason for traveling – the activity at the end of the trip
- Trips treated as independent and ignores their spatial, temporal, and social interactions
- Heavy emphasis on commuting trips and Home-based trips
- Limited policy sensitivity (TAZs are hard to use in policy analysis)
Activity Based Modelling
Necessity of Activity Based Travel Demand Modelling

• Development of ABM due to poor forecasting results achieved in the trip based aggregate demand models

• Introduce - road pricing

• new technologies - (Internet and mobile phones)

• For solving urbanization problems, understanding behavioural changes of people in developing countries is necessary
Activity Based Modelling – Historical

• ABM belongs to the 3rd generation of travel demand models
  • Trip based 4-step models
  • Disaggregate trip based models (1980’s & 1990’s)
  • Activity based models
• In ABM the basic unit of analysis is the activities of individuals/households
• Activity Based Models (ABM) predict travel behavior as a derivative of activities (i.e., derived demand)
• Travel decisions are part of a broader process based on modeling the demand for activities rather than merely modeling trips
• ABM are based on the theories of Hägerstrand (1970) and Chapin (1974)
  • Hägerstrand focused on personal and social constraints
  • Chapin focused on opportunities and choices
• Theory is that activity demand is motivated by basic human desires for: survival, ego gratification, and social encounters
ABM Approach

• Travel demand is derived from activities that individuals need/wish to perform

• Sequence/patterns of behavior, not individual trips, are the unit of analysis

• Household and other social structures influence travel and activity behavior

• Spatial, temporal, transportation, and interpersonal interdependencies constrain activity/travel behavior

• Activity based approaches aim at predicting which activities are conducted where, when, for how long, with whom, by mode, and ideally also the implied route decision
ABM Paradigms

• ABM rely on the following 5 paradigms:
  • Travel derived demand from activity participation
  • Focus is on the sequence of activities
  • Activities are planned within the context of the household
  • Activities are spread over a 24-hour
  • Travel choices are limited in time, space, and by personal constraints
Modelling Trips

- Trip-based model
- Tour-based model
- ABM

Hypothetical Travel Day

Trip-based model would model all 7 trips independent of the other trips.

Tour-based model would model Tour 1 and Tour 2 independent of each other, while the Work Tour would be modeled as two independent trips.

ABM would model the 4 activities and associated trips (work, meeting, shopping, and movie) as part of the same decision process.
Activities in Time and Space

Activities:
H ... Home  W ... Work  L ... Leisure  S ... Shopping
Activities in Time and Space

- Home
- Work - Mandatory
- Social connection - Leisure
- Cinema - Leisure
- Shopping - Maintenance
- Travel - Mandatory
- Travel - Leisure
- Activity time - Maintenance
- Activity time - Leisure
- Activity time - Mandatory

Source: Varun Varghese
Criticism of Trip and Tour Based Models

Modelled as independent and isolated trips

- No-connection between the different trips
- No-time component
- No-sequential information
- No-behavioural foundation
- No-data efficient

Modelled as independent and isolated tours

- No-temporal dimension
- Independent tours, model is not capable of making the integration
Advantages of ABM

• Theoretically based on human behavior
• Better understanding and prediction of traveler behavior
• Based on decision-making choices present in the “real-world”
• Use of disaggregate data
• Inclusion of time-of-day travel choices
Activity Patterns (Schedule)

A sequence of activities, or a schedule, defines a path in space and time

**What defines a person’s activity pattern?**

- Total amount of time outside home
- Number of trips per day and their type
- Allocation of trips to tours
- Allocation of tours to particular HH members
- Departure time from home
- Arrival time at home in the evening

- Activity duration
- Activity location
- Mode of transportation
- Travel party
A Person’s Daily Travel Pattern (conventional model)

TRIPS:
-2 HBW
-1 HBS
-1 HBO
-1 NHB
A Person’s Daily Travel Pattern (activity based model)

- 2 HBW
- 1 HBS
- 1 HBO
- 1 NHB

### TRIPS:
- 2 Home based tours (chains)
- Timing of all trips
- Duration of activity at each location

<table>
<thead>
<tr>
<th>Time</th>
<th>Location</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:30 PM</td>
<td>Home</td>
<td>by car</td>
</tr>
<tr>
<td>7:00 PM</td>
<td>Shop</td>
<td>by car</td>
</tr>
<tr>
<td>7:30 PM</td>
<td>Dinner</td>
<td>by car</td>
</tr>
<tr>
<td>7:30 AM</td>
<td>Work</td>
<td>by bus</td>
</tr>
<tr>
<td>9:30 PM</td>
<td>Shop</td>
<td>by car</td>
</tr>
<tr>
<td>5:15 PM</td>
<td>Work</td>
<td>by bus</td>
</tr>
<tr>
<td>8:15 PM</td>
<td>Home</td>
<td>by bus</td>
</tr>
<tr>
<td>9:00 PM</td>
<td>Dinner</td>
<td>by car</td>
</tr>
<tr>
<td>4:30 PM</td>
<td>Work</td>
<td>by bus</td>
</tr>
</tbody>
</table>
All Household Members’ Travel Pattern (activity based model)
Some Key Aspects of Activity Based Models

• Trips are linked for each person in a day

• Timing and durations are included

• Entire daily travel patterns are linked

• Car use is associated to needs (take child to school, drive together to shop & dine and back )
Survey Instrument

• Household Information
• Person Information
• Activity Information

Activity Diary

Activities classified:
• Work related activities
• Maintenance activities
• Leisure activities
Modelling approaches

• Econometric modelling
• Rule based modelling
• Markov models
• Microsimulation modelling
Case Study (PORTLAND MODEL)

• First large-scale operational activity based travel demand model in the world
• Given by John Bowman
• The Portland model belongs to the group of discrete choice models
  • Based on a 1994 household survey with some 5000 households
  • Two-day activity diaries
• 6475 observed activity patterns
• 1244 zones.
PORTLAND MODEL cont...

• The model operates with the following terms:
  • A primary activity
  • A secondary activity
  • A sub-tour
  • Intermediate stop

• Data input
  • 1) Household data, 2) zonal data and 3) network data

• Model structure
  Day activity schedule model
  • Day activity pattern model on the higher level,
  • and Tour model on the lower level
PORTLAND MODEL cont...

• primary day activities in the Portland model
  • Subsistence (work/school) at home
  • Maintenance (personal business) at home
  • Discretionary at home
  • Subsistence (work/school) on tour
  • Maintenance (shopping, personal business) on tour
  • Discretionary (social, recreational) on tour

• There are four types of tour patterns in the model
  • A simple pattern, i.e. that is without stops between home and the destination
  • One or more intermediate activities on the way from home to the primary destination
  • One or more intermediate activities on the way from the primary destination to home
  • One or more intermediate activities in both directions
PORTLAND MODEL  cont...

- **The model defines six types of secondary tours based on the number and purpose**
  - No secondary tour.
  - One secondary tour for work or maintenance.
  - Two or more secondary tours for work or maintenance.
  - One secondary tour for work or discretionary.
  - Two or more secondary tours for work or discretionary.
  - Two or more secondary tours when at least one tour is for work or maintenance and at least one tour is for discretionary.
PORTLAND MODEL cont...

• **Tour model** consists of

1) The home-based tour time-of-day model,
2) The home-based tour mode and destination model,
3) The work-based sub-tour mode and destination model, and
4) Intermediate stop location model for car-driver tours.
Portland Activity Schedule Model System

INPUT: households, zonal data, network data

Activity Pattern

Pattern (and associated tour) probabilities

home-based tours: times of day

Tour time-of-day probabilities

home-based tours: mode and destination

Expected tour time-of-day utilities

Expected tour mode and destination utilities

Expected subtour and intermediate stop utilities (not in current implementation)

Tour mode and destination probabilities

work-based subtours

Intermediate stop locations for car driver tours

OUTPUT: OD trip matrices by mode, purpose, time of day and income class
CONCLUSION

• Conventional four stage-planning models for travel demand forecasting includes the lack of behavioral foundation, over dependence on trips, and insensitivity to policy changes.

• There is a need to develop the models which will take into account above criteria's to improve the travel demand.

• The new modeling approach i.e. activity based travel demand modeling has good scope in developing countries due to its more focus on behavioral aspect of people.
Thank you & Best Wishes

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