Transit Travel Demand Estimation

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• **Goal**

  – To ensure that the mobility plan serves existing demand

  – Movement of People
    • Public Transport
    • Para-transit & Feeder Systems
    • Private Traffic

  – Movement of Goods
• **Short term strategies**
  
  – Minimal intervention
    • Stagger working hours
  
  – Traffic management
    • Signal timing
  
  – Route rationalization
    • Frequency optimization
• **Mid term strategies**
  – Moderate intervention
  – Enhancing Road Networks
  – Enhance Public Transport System
    • Identification of BRT routes – open system
    • Integrated route planning for buses
  – Design of route network for NMVs
• **Long term strategies**
  
  – Radical intervention
  
  – High Capacity Public Transport Systems
  
  – Identification of BRT routes - closed system
  
  – Design of full fledged feeder system including feeder buses, NMV routes
  
  – Re-densification of nodes & corridors along trunk routes
Travel Demand Estimation
Primary Surveys

• **Household**
  – Socio-economic
  – Activity
  – Opinion
  – Analysis
    • Vehicle ownership
    • Trip rates
Primary Surveys

• **Traffic**
  – Volume
  – Turning movements
  – Speed delay
Modeling Travel Demand

- Four Stage
  - Trip Generation
  - Trip Distribution
  - Modal Split
    - Transit
    - For each modes
  - Trip Assignment
Overview of TDM

By Survey

- Input: Base year data
- Trip generation
- Trip distribution
- Model split
- Trip assignment

Output: Base Year Link Flows

By projection

- Input: HORIZON YEAR data
- Trip generation
- Trip distribution
- Model split
- Trip assignment

Output: Horizon Link Flows

Verifiable

Output for design
TDM - Remarks

• **Travel Demand Model**
  – Build from first principles
  – Explains travel behavior
  – House hold travel characteristics
  – Projections possible
  – Limitation
    • Time and Cost intensive
    • Coarse zone to zone

• **Alternative way ?**
Transit OD Estimation

Boarding-Alighting Method

Case Study: Delhi/Mumbai
Transit OD Estimation

• **Importance**
  – Transit share
  – Need for its promotion
  – Challenge
    • Dynamic response to demand
    • Demand estimation
• **Benefits**
  – Route network design
  – Frequency setting
  – Crew scheduling
  – Performance evaluation
• **Benefits**
  – Service planning
  – Operational analysis
  – Impact analysis
  – Affordable
    • From Travel Demand Models
    • Boarding Alighting Surveys
Boarding Alighting Data
Case Study – 1 Delhi

- **OD from BA**
  - Data (RITE’s 1990’s)
    - 710 routes, 3149 buses, 37,000 trips
    - 1332 nodes, 4076 links
    - BA data for all 710 routes
  - Model
    - Fluid analogy model (Tsygalnitzky)
    - Assumption: equally likelihood for alighting
    - Constrain: minimum distance travelled
  - Limitation
    - Transfer not considered
• OD from TDM & BA
  – Travel Demand Model
  – Boarding Alighting data
  – Hybrid Demand Estimation
    • Combine TDM & BA
• **Boarding Alighting Data**
  – Fine grained from BA data
  – Accurate for direct
  – Limitation
    • Transfer trips are less reliable
    • Multi-mode, overlapping routes

• **Hybrid Demand Estimation**
  – Insights from TDM for transfer trips
  – BA gives direct trips accurately
Case Study – 2 Mumbai

- **Issue of TDM**
  - T12 is available from TDM
  - $t_{ad}, t_{ae}, t_{af}$?

- **Issue with BA**
  - $t_{ac}, t_{ce}, t_{ef}$ available
  - $t_{af}$?
**Hybrid Demand Estimation algorithm**

- Initializes
  - Fluid analogy model (only direct trips)
  - Accurate when no data error, direct routes

- Transfer-Trip Substitution
  - Compute excess demand
  - Add to the transfer trips
  - Subtract from the direct trips
  - How much to adjust?
Case Study – 2 Mumbai

• **Hybrid Demand Estimation algorithm**
  – Zone O-D Heuristics
    • Adjust demand for direct routes
    • Minimizes the error between the calculated and actual *zonal* error
    • Use gradient descent
  – Boarding Alighting Heuristics
    • Adjust demand for direct routes
    • Minimize the error between the calculated and actual *passenger counts*
    • Use gradient descent
Case Study – 2 Mumbai

• **Mumbai – Transit OD**
  – 80% public transport,
  – 60% rail transport
  – 317 bus routes (6,47,000 trips)
  – 56 rail lines (7,09,000 trips)

• **Results**
  – Method       BA error   OD error
  – BA alg.      0.0007%   14.5%
  – HDE alg.     0.04%     0.6%
Automated Transit OD Estimation

Use of Automatic Data Collection
• Advantages
  – Cost
  – Reliable
    • Large sample size
  – Faster
    • Automation possible
  – Frequent/ Continuous
• **Automated Fare Collection**
  – Eliminates manual paper tickets
  – Variants
    • Entry only
    • Entry and exit information
  – Limitation
    • Precise stop location
ADC systems

• **Automated Vehicle Location**
  – Technologies
    • Odometer
    • GPS
  – Access
    • Real-time
    • Uploaded at garage
ADC systems

- **Automated Passenger Counts**
  - On-off at every stop
  - Time and stop location
  - Technologies
    - IR sensors
    - Video
    - Pressure mats
    - Heat sensor
Procedure

• **Data requirement**
  – Marginal values
    • BA data for all stops (sample)
  – Seed matrix
    • Known prior estimate with lined BA
  – Transfer flow
    • Obtained from AFC
Procedure

• **Step 1**
  – Sample BA data processed from ADC

• **Step 2**
  – Combine marginal and seed matrix to get one route OD

• **Step 3**
  – Use transfer flows to link all individual OD’s to system OD

• **Note:**
  – Assumptions for missing data
### Destination

<table>
<thead>
<tr>
<th>Origins Route #1</th>
<th>Destinations on Route #1</th>
<th>Destinations on Route #2</th>
<th>Destinations on Route #n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Transfer OD Matrix Route #1</td>
<td></td>
<td>Transfer OD Matrix Route #1 To Route #2</td>
<td></td>
</tr>
<tr>
<td>Origins Route #2</td>
<td>Transfer OD Matrix Route #2 To Route #1</td>
<td>Non-Transfer OD Matrix Route #2</td>
<td></td>
</tr>
<tr>
<td>Origins Route #n</td>
<td>Transfer OD Matrix Route #n To Route #1</td>
<td></td>
<td>Non-Transfer OD Matrix Route #n</td>
</tr>
</tbody>
</table>

Note: Transfer flow matrices between any two route-dirs will have much lower values due to lower transfer volumes compared to non-transfer volumes. Transfer flow matrices are also more sparse, and transfers between many route-dirs are not possible.
ADC systems

• **Remarks**
  - Availability of electronic ticketing systems
    • BMTC/BEST
  - Provide transit OD
    • Continuous
    • Accurate
    • Economical
  - Proxy to total OD
Traffic Management

By

Adaptive signal Control
Traffic Signal Control

- Fixed Time Signal
- Vehicle Actuated
- Coordinated Signal
- Area Traffic Control
- Responsive
- Adaptive

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Traffic Signal Control

- Two Popular Network Systems
  - Centralized system
    - SCOOT
      - Split, Cycle, Offset, Optimization
  - Distributed system
    - SCAT
      - Sydney Coordinated Adaptive Traffic System
SCOOT system

- **Working philosophy**
  - Upstream detection
  - Data communicated to central controller
  - It computes the timing and send to intersections

- **Limitations**
  - Communication overheads
  - Poor progression prediction
  - Calibration issues
SCATS system

- **Working philosophy**
  - Downstream detection
  - Local controller acts akin to a VA controller
  - Communicate periodically to the central controller

- **Limitations**
  - Not an optimal system
SCOOT vs. SCAT

**SCOOT**
- Centralized System
- Upstream detection
- Fixed traffic regions
- Fallback - fixed
- Adaptive

**SCAT**
- Distributed system
- Stop line detection
- Adjustable region
- Fallback - VA
- Algorithmic
Adaptive Control
Adaptive control (Isolated)

- Detector placement
  - Stop line - No demand prediction

- Input
  - Demand from every loop from every cycle

- Output
  - Green time for each phase, Cycle length and delay
General structure:

Minimize the average control delay per vehicle \(d_p(q_p, g_p, C)\) with respect to timings and demands, subject to bound constraints on green times \(g_p\) and cycle time \(C\).
Mathematical formulation

\[
\min \sum_{p \in P} d_p(q_p, g_p, C) \quad \text{(minimize total delay)}
\]

subject to:

\[
g_p \geq g^p_{\text{min}}, \quad \forall p \in P \quad \text{(lower bounds on green times)}
\]

\[
C_{\text{min}} \leq C \leq C_{\text{max}} \quad \text{(bounds on cycle time)}
\]

\[
C = \sum_{p \in P} g_p \quad \text{(definition of cycle time)}
\]

\[
g_p \in \mathbb{Z}, \quad \forall p \in P \quad \text{(green times are integers)}
\]
Delay function (HCM 2000)

\[
d = \frac{0.5C (1 - \lambda)^2}{1 - [\min (1, x) \lambda]} + 900T \left[ (x - 1) + \sqrt{(x - 1)^2 + \frac{4x}{cT}} \right]
\]

\[
\lambda = \frac{g_p}{C}
\]

\[
x = \frac{q_p}{\lambda s_p} = \frac{q_p C}{s_p g_p}
\]

\[
c = \lambda s_p = \frac{g_p s_p}{C}
\]

\[
d_p = \frac{0.5C \left(1 - \frac{g_p}{C} \right)^2}{1 - \left[\min \left(1, \frac{q_p C}{s_p g_p} \right) \frac{g_p}{C} \right]} + 900T \left[ \left( \frac{q_p C}{s_p g_p} - 1 \right) + \sqrt{\left( \frac{q_p C}{s_p g_p} - 1 \right)^2 + \frac{4q_p C^2}{s_p^2 g_p^2 T}} \right]
\]

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Evaluation

Traffic Simulator (VISSIM)

- Traffic Simulation with actuated controller settings ($g_{p_{\min}}, g_{p_{\max}}$, unit extension time)
- for each phase, delay, queue length, cycle time
- VA data, detector data
- $g_{p_{\max}}$

Database

- Information Storage
- vehicle discharge and utilized green time in each phase

Com Interface

Data Processing

- $sp$, $qp$
- $gp$

Optimization Solver (Bonmin)

Parameter Optimization

Initial input

flow profile, road network, phase plan, simulation period
Evaluation
Evaluation

- Input demand

![Graph showing demands over time with different phases and moving averages.](chart.png)
Evaluation

- Output - Cycle

![Total Demand and Cycle Time](chart.png)
Evaluation

- Output – Green times
### Evaluation

- **Output – Delays**

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Avg. Control Delay (s/veh)</th>
<th>Avg. Queue Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ph-1</td>
<td>Ph-2</td>
</tr>
<tr>
<td>VA ( g_{max} = 45 ) s)</td>
<td>84.5</td>
<td>82.8</td>
</tr>
<tr>
<td>VA ( g_{max} = \infty )</td>
<td>131.8</td>
<td>99.4</td>
</tr>
<tr>
<td>RLM</td>
<td>65.2</td>
<td>63.3</td>
</tr>
<tr>
<td>OPT</td>
<td>51.7</td>
<td>53.6</td>
</tr>
<tr>
<td>% red. w.r.t VA ( g_{max} = 45 ) s)</td>
<td>38.8</td>
<td>35.3</td>
</tr>
<tr>
<td>% red. w.r.t VA ( g_{max} = \infty )</td>
<td>60.8</td>
<td>46.1</td>
</tr>
<tr>
<td>% red. w.r.t RLM</td>
<td>20.7</td>
<td>15.3</td>
</tr>
</tbody>
</table>
Evaluation (Smoothening)

(a) No smoothening (OPT)
(b) 3-cycle smoothening
(c) 5-cycle smoothening
(d) 7-cycle smoothening
Adaptive Control

Summary

- Sensitive to fluctuating traffic demand
- Evaluation by traffic simulators
- Optimal use of infrastructure
- Enhances service quality
Adaptive Control

Advanced topics

- Developing for large systems
- Better delay equations
- Traffic management capabilities
Thank You, Questions?

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