Integrating Demand and Network Models: New AB Aspects

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Informs, Pittsburgh, Nov 5, 2006

Turning Point?

- Conventional trip-based fractional-probability models can be combined with SUE assignment by means of Beckman-type congestion link terms and entropy-type demand terms
- With the advent of AB models this world has been ruined:
  – Complicated choices with structural changes in the list of agents
  – Microsimulation of crisp choices instead of fractional probabilities

Practice Cannot Wait

- Heuristics & Tricks:
  – MSA always works for link volumes travel times and fractional trip tables
  – Predetermined strategy of freezing choices (portions of households) to enforce convergence
- Experience with the existing regional AB models (New York and Columbus):
  – Most problematic dimensions (spatial and temporal) because of horrendous dimensionality
  – Most problematic choice chains with variable structure (list of agents)

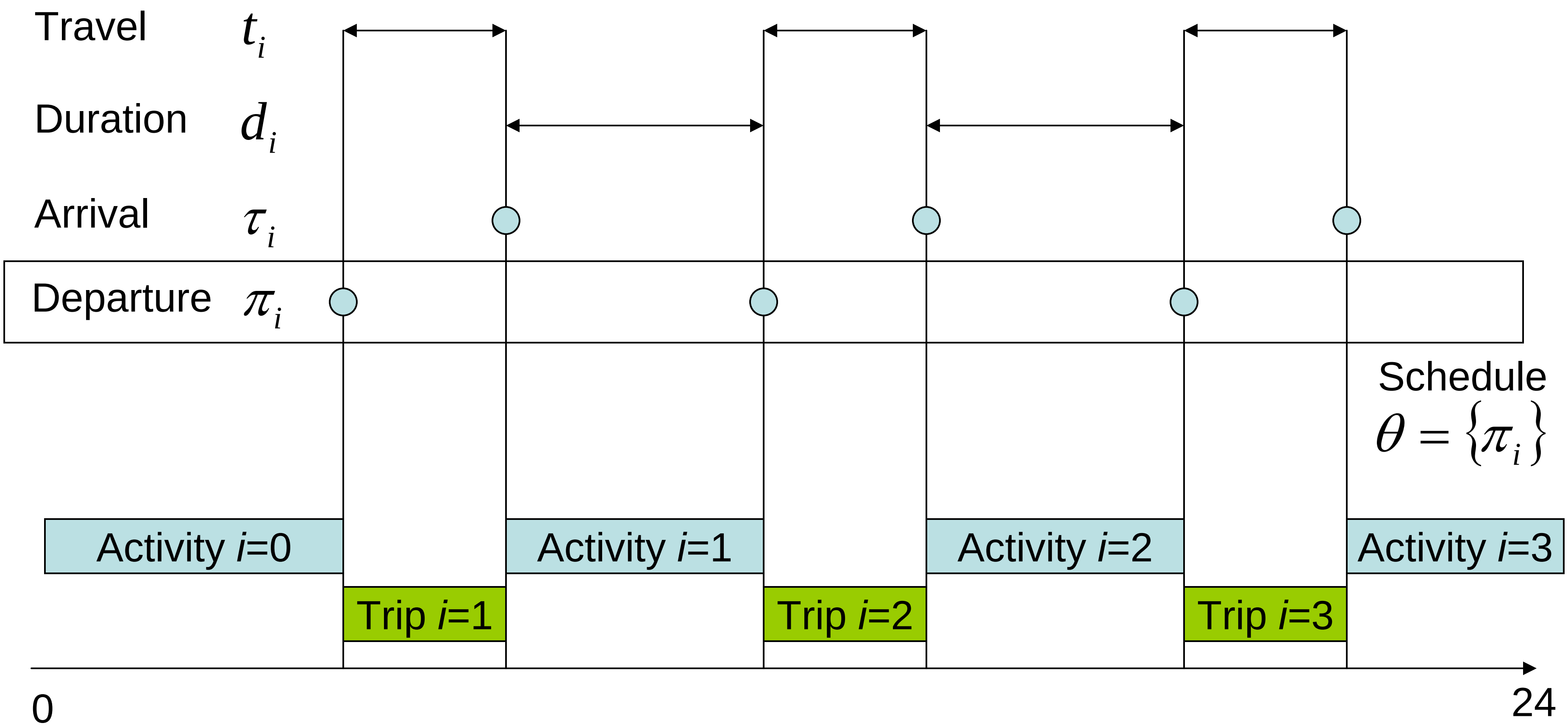
Some New Approaches

- Partial Equilibration:
  - Single out certain travel dimension (while fixing everything else):
    - Spatial
    - Temporal
    - Mode / route choice
  - Useful tool for comparison of alternatives in practice
- Analytical “discretizing” instead of Monte-Carlo

Single Out Temporal Dimension

- Each individual has a fixed ordered set of activities at fixed locations connected by trips
- Equilibrium formulation:
  - Each individual maximizes utility:
    - Additive by activity/trip
    - Includes components:
      - Activity start
      - Activity end
      - Activity duration
      - Travel cost
  - Each individual has a consistent schedule
  - Trips are assigned to period-specific networks

Schedule Consistency



Theoretical Formulation

$$\min\left\{\sum_{p}\sum_{a}\int_{0}^{v_{pa}} c_a(v)dv + \mu\sum_{n}\sum_{\theta} p_{n\theta}\ln\frac{p_{n\theta}}{U_{n\theta}}\right\}$$

Link volumes

Route flows

$$v_{pa} = \vartheta\left(f_{pr}^{od}\right)$$

Trip table

Individual schedules

$$M_p^{od} = \sum_r f_{pr}^{od} = \psi\left(\{p_{n\theta}\}\right)$$

Initial Algorithm

1. Initialize travel time / cost
2. Model individual schedules:
   - Set of choice models
   - Microsimulation
3. Calculate period specific trip matrices
4. Run network simulation to update travel time / cost
5. Go to 2

- No (or very slow) convergence
- Cannot freeze schedules with fluctuating travel time (unrealistic or infeasible activity durations)

Schedule Adjustment Trick

Find new schedule close to previous durations and departures

$$\min\left\{\sum_i \left(x_i \ln \frac{x_i}{d_i} + y_i \ln \frac{y_i}{\pi_i} \right)\right\}$$

New durations

New departures

Previous durations

Previous departures

Daily consistency

$$\sum_i \left(x_i + t_i\right) = 24$$

Departure time

$$y_i = \sum_{j \le i} \left(x_j + t_j\right)$$

Solution

$$x_i = k \times d_i \times \prod_{j \ge 1} \frac{\pi_j}{y_j}$$

Improved Algorithm

1. Initialize travel time / cost
2. Model individual schedules:
   - Households to fully rerun:
     - Set of choice models
     - Microsimulation
   - Households to adjust schedules:
     - Schedule adjustment
     - Utility drop (fully rerun if significant)
3. Calculate period specific trip matrices
4. Run network simulation to update travel time / cost
5. Go to 2

“Discretizing” vs. Monte-Carlo

Record (r)	Probability of alternatives (*i*)			“Crisp” choice of alternative (*i*)		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
1	0.6	0.2	0.2	1	0	0
2	0.3	0.6	0.1	0	1	0
…	…	…	…	…	…	…
Total	120.1	110.1	50.8	120	110	51

Matrix Disretizing Problem

$$\sum_i x_r^i = 1$$ One choice per record

$$\sum_r x_r^i = A^i$$ Target total by alternative

$$x_r^i = 0{,}1$$ Discretize as close as possible to the original matrix

$$\min \sum_{r\,i} x_r^i \ln\left(\frac{x_r^i}{p_r^i}\right) = -\sum_{r\,i} x_r^i \ln p_r^i$$

Matrix Discretizing

- LP problem:
  - Guaranties discrete solution
  - Effective solution algorithms / heuristics
- Replicates observed choices significantly better than Monte-Carlo
- Stable to small or local variations in probabilities, improve convergence to equilibrium tremendously
- Likelihood in application is always better than in estimation
  - Interesting bias eliminating low-probability choices that are observed in reality
  - Can be constrained to replicate estimation likelihood

Thank you for your attention!