Revealing Preferred Departure Times for Large-Scale Transport Modelling

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Congestion is time dependent

- Extra travel time and uncertainty
- Emissions
- Incidents
- Noise
- Similar working/school times
- Trip chains
- Shopping times
Time of day variation

![Graph showing time of day variation]

Source: Stockholm County Planning and Transportation Office

Capacity extension

- Would it be possible to build roads that bear peak hour travel demand?
- Economically unacceptable (The capacity would not be used most of the day)
- Environmentally unacceptable (intrusion)
- Induced demand
- Cf parking large enough for Xmass shopping
Alternative measure: time dependent congestion charges

Cordon location in Stockholm

Photo: Mikael Ullén

TDM Symposium, Semmering, 16-18 July 2008
Leonid Engelson
Traffic flows before and during the Stockholm Trial

Veh/h over the cordon (directions combined)
Mean for April 2005 (blue) and April 2006 (black)

Source: Summary of Stockholm Trial analysis

Analysis

- The peaks lowered but did not spread
- Is it possible to modify the charges in order to spread the peaks?
- What charge levels and timetables are suitable?
- Inappropriate to test in practice → use models and simulation
What should be in the model?

- The travel demand is influenced by changes in charges, travel time and uncertainty
- Impact on
  - Route
  - Mode
  - Departure time
- Development of model including the choice of departure time

Basic idea for choice of departure time

The traveller weights departure time against travel cost (time, uncertainty, charge)

Utility maximisation, discrete choice model (Small 1982)

$$\min_{DT} \alpha (DT - PDT)_+ + \beta (PDT - DT)_+ + \gamma DT + \delta DT + \epsilon$$
SILVESTER – SImuLation of choice betWEen Starting TimEs and Routes

- Model for Stockholm with suburbs (ca 1.5 mln)
- Drivers in the baseline scenario
- Extended peak (06:30-09:30)
- Travellers choose DT between 15 minutes intervals based on deviation from their PDT, travel time, travel time uncertainty and charge for that DT
- Even possible to depart before 06:30, after 09:30 or switch to public transport

The model of departure time choice (1)

- Estimation based on SP and RP data trips in Stockholm County
- Same respondents in SP and RP surveys
- Takes into account higher correlation of the error term between closer time periods
- Takes into account heterogeneity of drivers’ preferences
The model of departure time choice (2)

- Purpose segments:
  Trips to work with fixed office hours and trips to school
  Business trips
  Trips to work with flexible office hours and other trips
- Result: For each trip purpose $k$ and OD-pair $w$, the probability to choose a departure time period given a preferred departure time period

$$P_{kw}^{t \tau} = \text{Prob}(DT = t | PDT = \tau)$$

Application of the model (1)

The number of trips starting at time $t$

$$q_t^{kw} = \sum_{\tau} P_{kw}^{t \tau} \nu_{kw}^{\tau}$$

where $\nu_{kw}^{\tau}$ is the number of trips with PDT = $\tau$

$$q^{kw} = P^{kw} \nu^{kw}$$

for each trip purpose $k$ and OD-pair $w$
Application of the model (2)

Preferred travel demand $v^{kw}_\tau$

Departure time choice model $P^{kw}_{t\tau}$

Realised travel demand $q^{kw}_t$

CONTRAM
Mesoscopic model
Queuing dynamics
Iterations until steady state

Travel times

Road network, Charges

Traffic flows

Calibration of the model (1)

Preferred travel demand $v$

Departure time choice model $P$

Realised travel demand $q$

CONTRAM
Mesoscopic model
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Iterations until steady state

Baseline situation

Travel times

Road network, Charges

Traffic flows
Calibration of the model (2)

Stage 1: Time-dependent OD matrix estimation
COMEST, performed before the model estimation

Stage 2: OD matrix subdivision by trip purposes \( k \)

Stage 3: Revealing the preferred departure times for each trip purpose \( k \) and OD-pair \( w \)

\[
q^{kw} = P^{kw} v^{kw} \quad v^{kw} = \left(P^{kw}\right)^{-1} q^{kw}
\]

(Reversal Engineering)

Reversal engineering

• Good: \( P \) is usually nice
• Bad: \( P^{-1} \) is never positive

Feasibility of the solution depends on \( q \)
Some \( v^{kw}_\tau < 0 \) although all \( q^{kw}_t > 0 \)

• Two methods proposed:
  Aggregation of OD pairs
  Bounded variation
Aggregation of OD pairs

- OD’s are grouped by geographical or socio-economical properties (origin zone, destination zone, distance, income, …)
- An optimal PDT profile is sought for each group by the least square method
- If the profiles are similar on infeasible, the groups are united

Fixed time work trips and school trips

- 3 OD groups by origin zone
Business trips

- 3 OD groups by origin zone

Bounded variation

- Find a best common PDT profile for all OD pairs (the least square method)
- For each OD pair, find a best PDT profile within a certain strip around the common profile
Flexible trips to work and other trips

- Solution for 4% wide strip around the common

PDT and DT for the three trip purposes

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Conclusion

• The **Reversal engineering** approach for estimation of preferred departure times is applicable for a large urban network.
• The result is consistent with skimmed travel times and the departure time choice model.
• The least square method for groups of OD pairs relieves the problem of negative solutions and delivers reasonable PDT profiles.