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Attempting consistent CBA with complicated transport model systems

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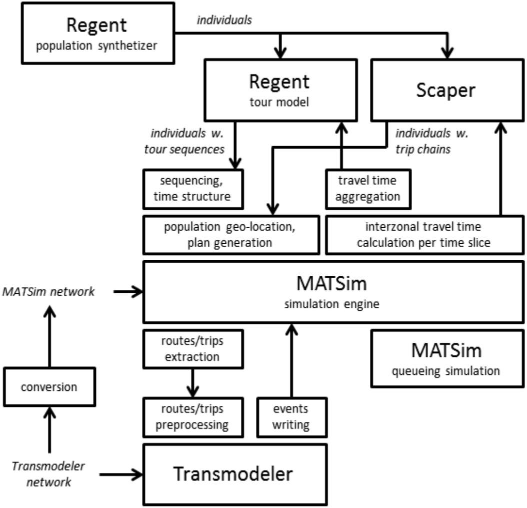
Background

- The Swedish Road Administration wants a *dynamic* strategic urban transport model.
- We convinced them them to also consider a "person-centric" approach.
- The only way to convince them was to somehow wire this into their existing models and show that it is feasible.

- One project later, they are comfortable with the idea of a dynamic microsimulation.
- But to adopt it in their practice, they need to be able to perform consistent CBA.

Overview



Regent
population synthetizer
individuals
Regent
tour model
Scaper
individuals w.
tour sequences
individuals w.
trip chains
sequencing,
time structure
travel time
aggregation
population geo-location,
plan generation
interzonal travel time
calculation per time slice
MATSim network
MATSim
simulation engine
routes/trips
extraction
MATSim
queueing simulation
conversion
routes/trips
preprocessing
events
writing
Transmodeler
network
Transmodeler

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Layered structure

- Each individual has sociodemographics and a home location.
- upper level choices:
  - activity “pattern”
  - mode
  - locations (~1000 zones)
- lower level choices:
  - time
  - route
  - (network flows, travel times, etc.)

Ideal world utility functions

- ideal upper level utility function

$$
\begin{aligned}
U_{ni} &= \left[V^{\text{upper}}(\mathbf{z}_n, \mathbf{x}_i) + \varepsilon_{ni}^{\text{upper}}\right] + S^{\text{lower}}(\mathbf{z}_n, i) \\
i \in C_n^{\text{upper}} &= \text{activities, modes, locations} \\
\mathbf{z}_n, \mathbf{x}_{ni} & \quad \text{attributes of decision maker, alternative} \\
S^{\text{lower}} & \quad \text{summary of lower-level experience}
\end{aligned}
$$

- lower level utility function

$$
\begin{aligned}
U_{nj} &= V^{\text{lower}}(\mathbf{z}_n, \mathbf{x}_j) + \varepsilon_{nj}^{\text{lower}} \\
j \in C_n^{\text{lower}} & \quad \text{route sequence incl. time structure} \\
S^{\text{lower}}(\mathbf{z}_n, i) &= \mathrm{E}\left\{ \max_{j \in C_n^{\text{lower}}} U_{nj} \right\}
\end{aligned}
$$

Layered structure

- upper level:
  - activities: “work”, “other”
  - uses an **independent** three-level nested logit per activity
    1. travel or not
    2. which mode
    3. which location
  - only **anonymous** cost (travel time, distance, monetary) feedback from lower level
  - **static**
- lower level:
  - dynamic person-centric DTA microsimulation
  - heuristic choice of trip sequence incl. timing
  - uses a utility function but cannot compute exp. max. utilities

"Utility" functions, right now

- upper level:

$$\begin{aligned} U_{ni} &= \left[V^{\text{upper}}(\mathbf{z}_n, \mathbf{x}_i) + \varepsilon_{ni}^{\text{upper}}\right] + S^{\text{lower}}(\cancel{\mathbf{z}_n}, i) \\ i \in C_n^{\text{upper}} &= \text{(to travel or not, where, what mode) per act. type} \end{aligned}$$

- lower level:

$$\begin{aligned} U_{nj} &= V^{\text{lower}}(\mathbf{z}_n, \mathbf{x}_j \mid i) + \varepsilon_{nj}^{\text{lower}} \\ j \in C_n^{\text{lower}} &= \{\text{route/activity sequence incl. time structure}\} \\ S^{\text{lower}}(\cancel{\mathbf{z}_n}, i) &= f(\text{static tour cost matrices}) \end{aligned}$$

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Tour cost matrices

- Aggregation of tour costs per OD pair and activity type:

$$
\begin{aligned}
& T_{\text{tour}}(\text{OD},\ \text{act}) \\
= & \sum_k \Pr(\text{dpt. for act at time } k) \cdot t_{\text{trip}}(\text{travel at } k) \\
+ & \sum_k \Pr(\text{dpt. for act at time } k) \\
& \cdot \sum_{\Delta k} \Pr(\text{act lasts } \Delta k) \cdot t_{\text{trip}}(\text{travel back at } k + \Delta k)
\end{aligned}
$$

- Approximates the expected tour cost of a randomly selected person per purpose.

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Any way around cost matrices?

- The problem are the non-chosen alternatives (no lower-level simulation of their performance).
- (The upper-level model system would change a lot without matrices.)
- The feasible number of matrices is limited, but perhaps something like this:

$$
\begin{aligned}
& T_{\text{tour1,tour2}}(\text{OD1}, \text{OD2}, i, n) \\
= \quad & T_{\text{tour1}}(\text{OD1}) + T_{\text{tour2}}(\text{OD2} \mid \text{tour1}) + \beta^T \begin{pmatrix} \mathbf{z}_n \\ \mathbf{x}_i \end{pmatrix}
\end{aligned}
$$

where the last term can be estimated through regression based on lower-level observations.

Exploit the lower-level of detail

- **Non-chosen upper-level alternatives**: approximate lower-level performance.
  - Computationally probably a necessity.
  - May even add realism if properly constructed.
- **Chosen upper-level alternative**: detailed lower-level performance is available.
  1. *Consistent inconsistency:* Only use approximate lower-level performance.
  2. *Inconsistent consistency:* Use detailed information at least for chosen alternative.

Possible upper-level modification

- For the chosen (upper,lower)-level alternatives (i, j):

$$U_{ni} \quad = \quad V^{\text{upper}}(\mathbf{z}_n, \mathbf{x}_i) + U^{\text{lower}}(\mathbf{z}_n, \mathbf{x}_j) + \varepsilon_{ni}^{\text{upper2}}$$

- For the non-chosen upper-level alternative i:

$$U_{ni} \quad = \quad V^{\text{upper}}(\mathbf{z}_n, \mathbf{x}_i) + S^{\text{lower}}(i) + \boldsymbol{\beta}^T \begin{pmatrix} \mathbf{z}_n \\ \mathbf{x}_i \end{pmatrix} + \varepsilon_{ni}^{\text{upper}}$$

- One would expect $\text{VAR}\{\varepsilon_{ni}^{\text{upper2}}\} < \text{VAR}\{\varepsilon_{ni}^{\text{upper}}\}$.
- Likely to require model (system!?) re-estimation. Interesting.

Alternative: Dynamic discrete choice models

- Is actually already integrated as an upper-level model.
- Requires much more parameters to be estimated.
- More difficult to communicate. No longer an incremental change.