OASIS: an optimisation framework for daily activity scheduling

Janody Pougala · Tim Hillel · Michel Bierlaire

Urban Systems Lab Seminar – 25/11/2022
OASIS framework

- Optimisation-based Activity Scheduling Integrating Simultaneous choice dimensions
OASIS framework

- Optimisation-based Activity Scheduling **Integrating Simultaneous choice dimensions**
  
  - Activity participation, scheduling, mode, location choice
  
  - Explicitly capture **trade-offs** between choices
  
  - Combine econometric and rule-based approaches
OASIS framework
OASIS framework

- **Data**
- **Estimation**
- **Literature**
- **Parameters** $\beta_n$
- **Synthetic individual** $n$
- **Simulation module**
  - **Disturbances** $\varepsilon$
  - **Optimisation** $\Omega$
  - **Schedule** $S^n_\varepsilon$
  - **Indicators**
Simulation

Feasible time interval

Location Mode

Location 2 Mode 2

Location n Mode m

From an activity...

…to a utility function...

\[ U_i(x_i, \tau_i, \delta_{xin}, \delta_{tin}, t_i, \omega_{in}) \]

\[ \Omega_n = \max \sum_i U_{in} \]

… to a maximisation problem
Definitions

- **Activities**

  - **Location**
  - **Mode**
  - **Start time**
  - **Duration**
  - **Travel**
  - **Feasible time interval**
Definitions

- Activities

Location 1
Mode 1
- e.g. Working from home

Location 2
Mode 2
- e.g. Working on campus, travelling by car

... 

Location n
Mode m
- e.g. Working on campus, travelling by PT
## Definitions

### Utilities

- People are time sensitive:
  - Preferences for start time, duration and/or end-time

![Diagram showing time sensitivity](image-url)
Utilities

People derive a utility (satisfaction) when they perform activities

\[ U = f(\beta, X) \]

\[ U_{an} = U_{participation} + U_{start\ time} + U_{duration} + U_{travel} + \varepsilon_{an} \]

e.g. (Pougala et al, 2022)
Individuals maximise the total utility, subject to constraints:

\[
\Omega = \max \sum_a U_{an}
\]

Decision variables:
- Activity participation
- Start time
- Duration
- Succession between activities
Individuals maximise the **total utility**, subject to constraints:

\[ \Omega = \max \sum_{a} U_{an} \]

**Constraints:**
- Time budget
- No duplicates
- Mode consistency
- Resource availability
- Participation constraints
- Sequence constraints
Simulation procedure:

- Draw $\beta^r$ from distribution of $\beta$
- Draw $\varepsilon^r$ from distribution of $\varepsilon$
- Solve $\Omega$ for $(\beta^r, \varepsilon^r)$
- Repeat $N$ times
OASIS framework

Data → Estimation → Parameters $\beta_n$ → Synthetic individual $n$

Disturbances $\varepsilon$ → Optimisation $\Omega$ → Schedule $S^n_\varepsilon$ → Indicators
OASIS framework

Parameter estimation

Data → Literature → Estimation

Parameters $\beta_n$ → Synthetic individual $n$

Disturbances $\varepsilon$ → Optimisation $\Omega$

Schedule $S^n_\varepsilon$ → Indicators
How do we estimate the parameters of the model?

\[ U = f(\beta, X) \]

\[ U_{an} = U_{participation} + U_{start\ time} + U_{duration} + U_{travel} + \varepsilon_{an} \]
Parameter estimation

- Maximum likelihood estimation (MLE) of parameters in discrete choice models:

\[
\hat{\beta} = \arg\max L_n(\beta) \\
L_n = \prod_{n=1}^{N} \prod_{i \in C_n} P_n(i)^{y_{in}}
\]
Parameter estimation

- Maximum likelihood estimation (MLE) of parameters in discrete choice models:

\[
\hat{\beta} = \arg \max L_n(\beta)
\]

\[
L_n = \prod_{n=1}^{N} \prod_{i \in C_n} P_n(i)^{y_{in}}
\]

- Common assumptions on choice set:
  - Universal across population
  - Fully observed or observable
Estimation

- **Choice set generation**

  - **Feasible schedules**
  - **Considered schedules**
  - **Actual choice set**: Unobserved
  - **Realised schedule**: Unobserved and possibly infinite

  **Estimation choice set**: sample of feasible schedules generated for estimation purposes

  Based on Shocker (1991)
Choice set generation

- Metropolis-Hastings sampling of feasible schedules
Swiss Mobility and Transport Microcensus 2015 (BFS & ARE, 2017)

Sample
- Students living in Lausanne (236 individuals)

Choice set size
- N = 10 alternatives

Model 0 (Literature):
- Deviation parameters from literature

Model 1 (Generic - 12 parameters):
- Activity-specific constants
- Aggregated penalties (flexible vs. Non flexible)

Model 2 (Specific -20 parameters):
- Activity-specific constants
- Activity specific penalties
## Estimation

### Model 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Param. estimate</th>
<th>Rob. std err</th>
<th>Rob. t-stat</th>
<th>Rob. p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F: early</td>
<td>-0.175</td>
<td>0.12</td>
<td>-1.46</td>
</tr>
<tr>
<td>2</td>
<td>F: late</td>
<td>-0.333</td>
<td>0.14</td>
<td>-2.38</td>
</tr>
<tr>
<td>3</td>
<td>F: long</td>
<td>-0.105</td>
<td>0.0722</td>
<td>-1.45</td>
</tr>
<tr>
<td>4</td>
<td>F: short</td>
<td>-0.114</td>
<td>0.194</td>
<td>-0.585</td>
</tr>
<tr>
<td>5</td>
<td>NF: early</td>
<td>-1.14</td>
<td>0.367</td>
<td>-3.10</td>
</tr>
<tr>
<td>6</td>
<td>NF: late</td>
<td>-0.829</td>
<td>0.229</td>
<td>-3.61</td>
</tr>
<tr>
<td>7</td>
<td>NF: long</td>
<td>-1.20</td>
<td>0.393</td>
<td>-3.05</td>
</tr>
<tr>
<td>8</td>
<td>NF: short</td>
<td>-1.19</td>
<td>0.468</td>
<td>-2.54</td>
</tr>
<tr>
<td>9</td>
<td>Education: ASC</td>
<td>16.0</td>
<td>2.46</td>
<td>6.49</td>
</tr>
<tr>
<td>10</td>
<td>Leisure: ASC</td>
<td>8.81</td>
<td>1.7</td>
<td>5.17</td>
</tr>
<tr>
<td>11</td>
<td>Shopping: ASC</td>
<td>6.85</td>
<td>1.80</td>
<td>3.80</td>
</tr>
<tr>
<td>12</td>
<td>Work: ASC</td>
<td>16.0</td>
<td>2.58</td>
<td>6.18</td>
</tr>
</tbody>
</table>

### Model 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Param. estimate</th>
<th>Rob. std err</th>
<th>Rob. t-stat</th>
<th>Rob. p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Education: ASC</td>
<td>18.7</td>
<td>3.17</td>
<td>5.89</td>
</tr>
<tr>
<td>2</td>
<td>Education: early</td>
<td>-1.35</td>
<td>0.449</td>
<td>-3.01</td>
</tr>
<tr>
<td>3</td>
<td>Education: late</td>
<td>-1.63</td>
<td>0.416</td>
<td>-3.91</td>
</tr>
<tr>
<td>4</td>
<td>Education: long</td>
<td>-1.14</td>
<td>0.398</td>
<td>-2.86</td>
</tr>
<tr>
<td>5</td>
<td>Education: short</td>
<td>-1.75</td>
<td>0.457</td>
<td>-3.84</td>
</tr>
<tr>
<td>6</td>
<td>Leisure: ASC</td>
<td>8.74</td>
<td>1.94</td>
<td>4.50</td>
</tr>
<tr>
<td>7</td>
<td>Leisure: early</td>
<td>-0.0996</td>
<td>0.119</td>
<td>-0.836</td>
</tr>
<tr>
<td>8</td>
<td>Leisure: late</td>
<td>-0.239</td>
<td>0.115</td>
<td>-2.07</td>
</tr>
<tr>
<td>9</td>
<td>Leisure: long</td>
<td>-0.08</td>
<td>0.0617</td>
<td>-1.30</td>
</tr>
<tr>
<td>10</td>
<td>Leisure: short</td>
<td>-0.101</td>
<td>0.149</td>
<td>-0.682</td>
</tr>
<tr>
<td>11</td>
<td>Shopping: ASC</td>
<td>10.5</td>
<td>2.20</td>
<td>4.78</td>
</tr>
<tr>
<td>12</td>
<td>Shopping: early</td>
<td>-1.01</td>
<td>0.287</td>
<td>-3.51</td>
</tr>
<tr>
<td>13</td>
<td>Shopping: late</td>
<td>-0.858</td>
<td>0.237</td>
<td>-3.63</td>
</tr>
<tr>
<td>14</td>
<td>Shopping: long</td>
<td>-0.683</td>
<td>0.387</td>
<td>-1.76</td>
</tr>
<tr>
<td>15</td>
<td>Shopping: short</td>
<td>-1.81</td>
<td>1.73</td>
<td>-1.04</td>
</tr>
<tr>
<td>16</td>
<td>Work: ASC</td>
<td>13.1</td>
<td>2.64</td>
<td>4.96</td>
</tr>
<tr>
<td>17</td>
<td>Work: early</td>
<td>-0.619</td>
<td>0.217</td>
<td>-2.85</td>
</tr>
<tr>
<td>18</td>
<td>Work: late</td>
<td>-0.338</td>
<td>0.168</td>
<td>-2.02</td>
</tr>
<tr>
<td>19</td>
<td>Work: long</td>
<td>-1.22</td>
<td>0.348</td>
<td>-3.51</td>
</tr>
<tr>
<td>20</td>
<td>Work: short</td>
<td>-0.932</td>
<td>0.213</td>
<td>-4.37</td>
</tr>
</tbody>
</table>
Estimation

Data

Generic

Literature

Activity-specific
Estimation

Education

Work
OASIS framework

Data → Estimation → Parameters $\beta_n$ → Synthetic individual $n$ → Literature

Disturbances $\varepsilon$ → Optimisation $\Omega$ → Schedule $S^n_\varepsilon$ → Indicators
OASIS framework

Data → Estimation → Parameters $\beta_n$ → Synthetic individual $n$ → Disturbances $\epsilon$ → Optimisation $\Omega$ → Schedule $S^n_\epsilon$ → Indicators

Applications
Applications

- **OPTIMS (OPTimisation of Individual Mobility Schedules)**
  - Collaboration with Swiss Federal Railways (SBB)
  - Integration of optimisation model into SBB’s forecasting framework

  - [https://github.com/optims-org/optims-sbb](https://github.com/optims-org/optims-sbb)
Conclusion

Summary
- Optimisation framework to simulate activity schedules
  - Simultaneous estimation of all scheduling dimensions
  - Combining econometric and rule-based approaches
- Methodology to estimate the parameters
- Successful practical applications

Current challenges – future work:
- Intra- and interpersonal interactions (N. Rezvany’s PhD, EPFL)
- Validation
Related publications


Thank you!

janody.pougala@epfl.ch
tim.hillel@ucl.ac.uk
michel.bierlaire@epfl.ch