OASIS: an optimisation framework for activity-based models

Janody Pougala · Tim Hillel · Michel Bierlaire

Arup CML Demo – 24/11/2022
OASIS framework

- Optimisation-based Activity Scheduling Integrating Simultaneous choice dimensions

Diagram:
- Data
- Literature
- Estimation
- Parameters $\beta_n$
- Disturbances $\varepsilon$
- Optimisation $\Omega$
- Schedule $S^m_\varepsilon$
- Indicators
- Synthetic individual $n$
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

Data → Estimation

Parameters $\beta_n$ → Synthetic individual $n$

Disturbances $\epsilon$ → Optimisation $\Omega$

Schedule $S^n_\epsilon$ → Indicators
OASIS framework

Simulation module

Data

Estimation

Parameters $\beta_n$

Synthetic individual $n$

Literature

Disturbances $\varepsilon$

Optimisation $\Omega$

Schedule $S^n_\varepsilon$

Indicators
Simulation

From an activity... 

...to a utility function...

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

... to a maximisation problem

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

- Activities

![Diagram showing time intervals for activities, travel, and duration.](image-url)
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 and utility](image)
Definitions

- **Utilities**

- People derive a utility (satisfaction) when they perform activities

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

E.g. (Pougala et al, 2022)

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

People derive a utility (satisfaction) when they perform activities

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

e.g. (Feil, 2010)

\[ U_{an} = U_{perf} + U_{late} + U_{travel} + \varepsilon_{an} \]
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

Literature → Estimation

Estimation → Parameters $\beta_n$

Parameters $\beta_n$ → Synthetic individual $n$

Disturbances $\varepsilon$ → Optimisation $\Omega$

Optimisation $\Omega$ → Schedule $S^n_\varepsilon$

Schedule $S^n_\varepsilon$ → Indicators
OASIS framework

Parameter estimation

Data → Literature → Estimation

Synthetic individual $n$

Parameters $\beta_n$

Disturbances $\varepsilon$ → Optimisation $\Omega$

Schedule $S^n_{\varepsilon}$ → Indicators
Estimation

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:

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

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

Enumeration over choice set \(C_n\)

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

- Choice set generation

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

Feasible schedules

Considered schedules

Unobserved and possibly infinite

Actual choice set: Unobserved

Realised schedule

Based on Shocker (1991)
Estimation

- **Choice set generation**
  - Metropolis-Hastings sampling of feasible schedules

![Diagram](image)

- **Block**
- **Inflate/Deflate**
- **Swap**
- **Assign**
- **Mode**
- **Location**
Estimation

Data

Literature

Generic

Activity-specific
OASIS framework

Data → Estimation → Parameters $\beta_n$ → Optimisation $\Omega$ → Schedule $S^n_\varepsilon$ → Indicators

Literature → Synthetic individual $n$ → Disturbances $\varepsilon$
OASIS framework

Data

Estimation

Parameters $\beta_n$

Synthetic individual $n$

Disturbances $\varepsilon$

Optimisation $\Omega$

Schedule $S^n_{\varepsilon}$

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)

---

Manser et al (2022)
Multiday extension

Single day

Data

Estimation

Parameters $\beta_n$

Disturbances $\varepsilon$

Optimisation $\Omega$

Schedule $S^n_\varepsilon$

Indicators

Literature

Synthetic individual $n$
Multiday extension

Day 1

Short term

Long term
Multiday extension

- We solve a multiobjective optimisation problem

\[ \Omega = \max \sum_d w_d \sum_a U_{ad} \]

- Decision variables for **each day** \( d \):
  - Activity participation
  - Start time
  - Duration
  - Succession between activities
We solve a multiobjective optimisation problem

$$\Omega = \max \sum_d w_d \sum_a U_{ad}$$

Constraints for each day $d$:
- Daily time budget
- No duplicates
- Mode consistency
- Resource availability
- Participation constraints
- Consistency across days
- Time budget over time horizon
- ...
The simulation results must reflect **typical patterns (habits)**

Additional parameters in utility function accounting for:

- Specific daily preferences (e.g., leisure activities on week-ends)
- Similarity across days (e.g., Weekdays vs. Week-ends)

Schultheiss (2021)
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