OASIS: an optimisation framework for activity-based models

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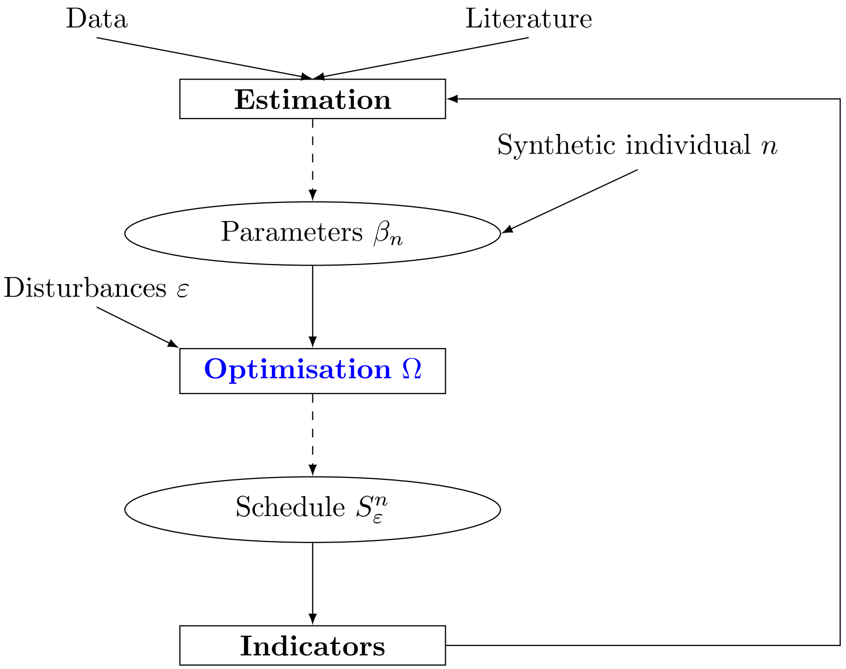
Arup CML Demo – 24/11/2022

OASIS framework

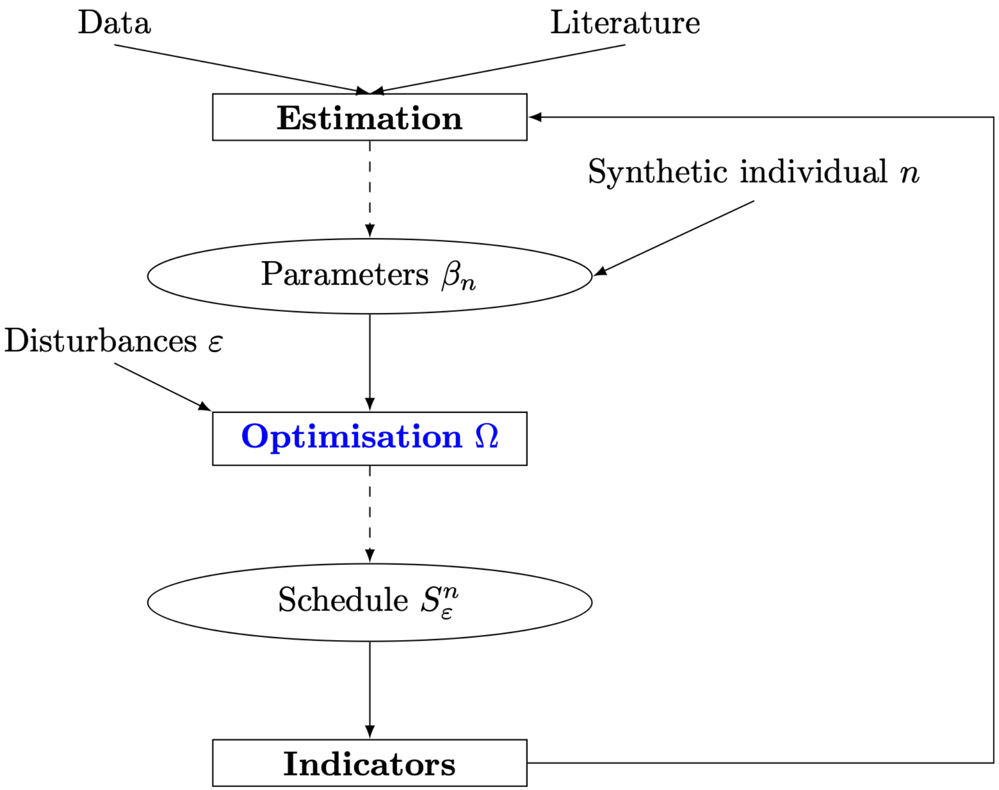
- Optimisation-based Activity Scheduling Integrating Simultaneous choice dimensions



OASIS framework

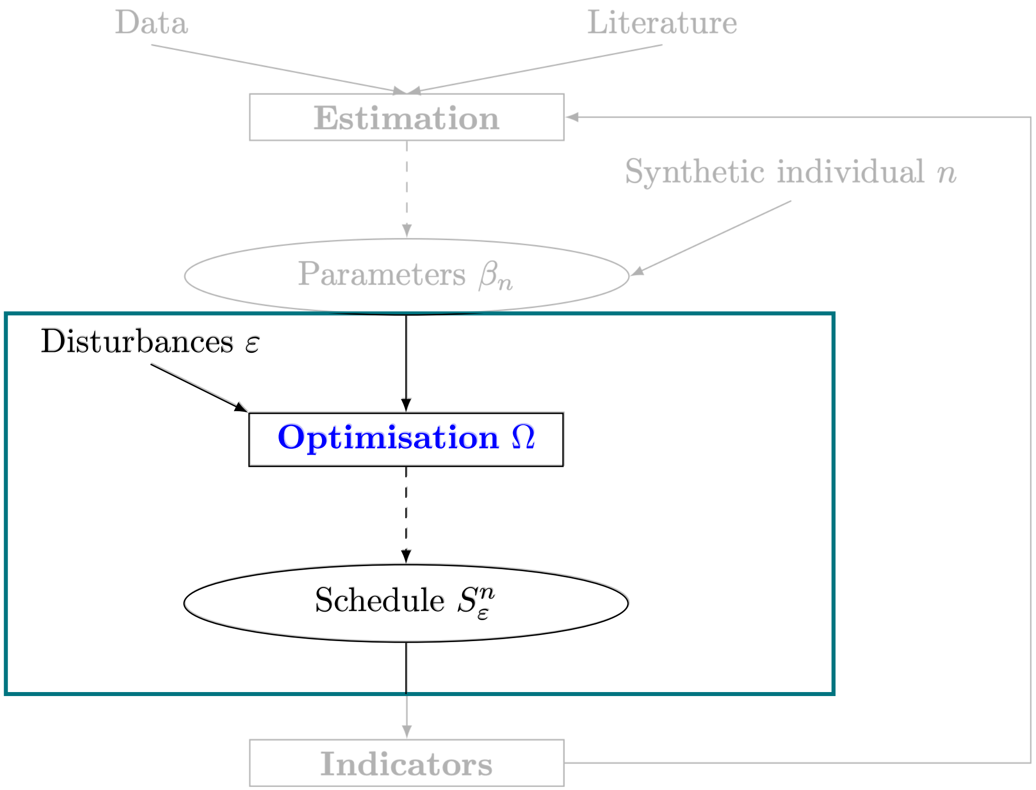
- Optimisation-based Activity Scheduling **Integrating Simultaneous choice dimensions**
  - Activity participation, scheduling, mode, location choice
  - Explicitly capture **trade-offs** between choices
  - Combine econometric and rule-based approaches

OASIS framework

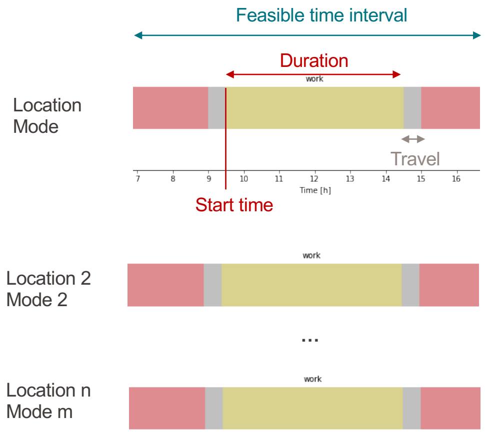


OASIS framework

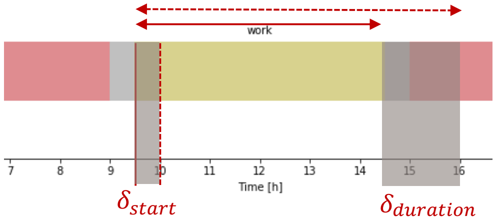
Simulation module



Simulation



From an activity...



$$U_i(x_i, \tau_i, \delta_{xin}, \delta_{\tau in}, t_i, \omega_{in})$$

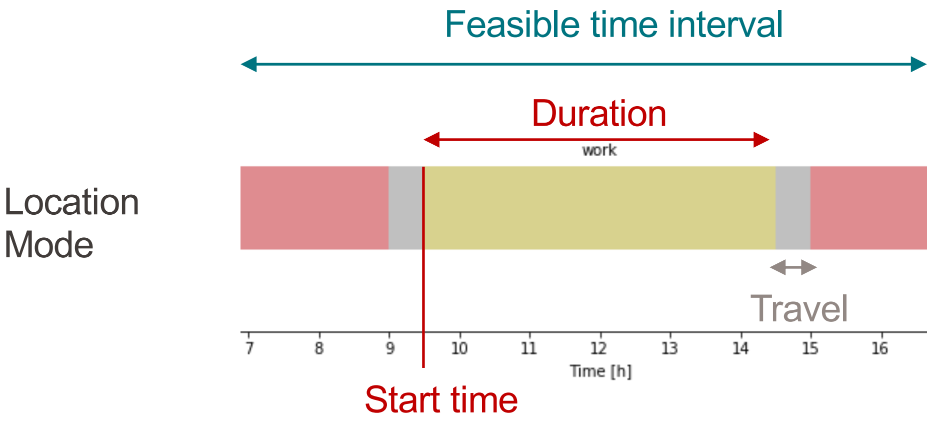
...to a utility function...

$$\Omega_{\mathrm{n}} = \max \sum_i U_{in}$$

... to a maximisation problem

Definitions

- Activities



Definitions

- Activities

Location 1
Mode 1

e.g. Working from home

Location 2
Mode 2

e.g. Working on campus, travelling by car

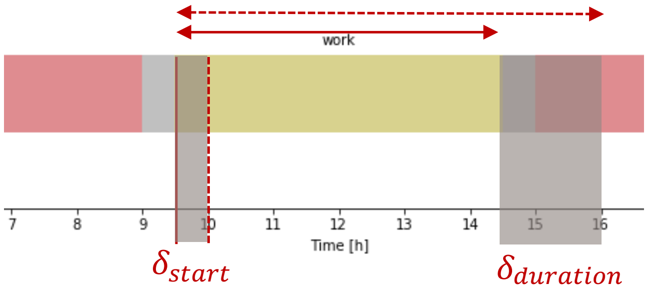
...

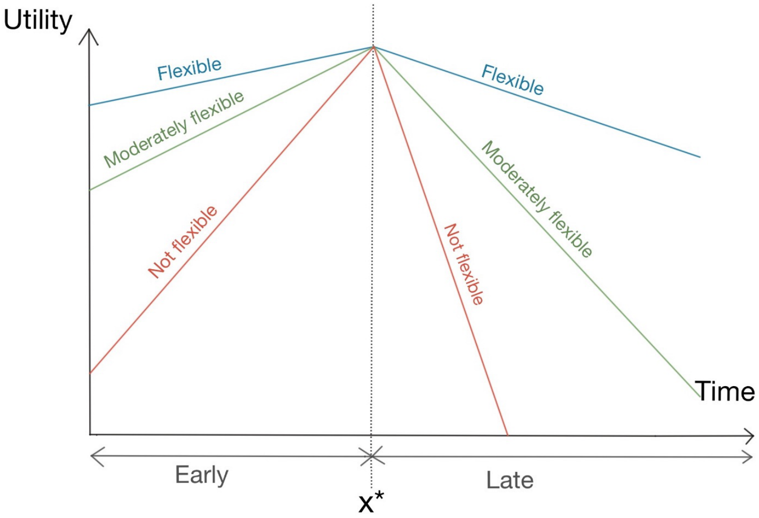
Location n
Mode m

e.g. Working on campus, travelling by PT

Definitions

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





Definitions

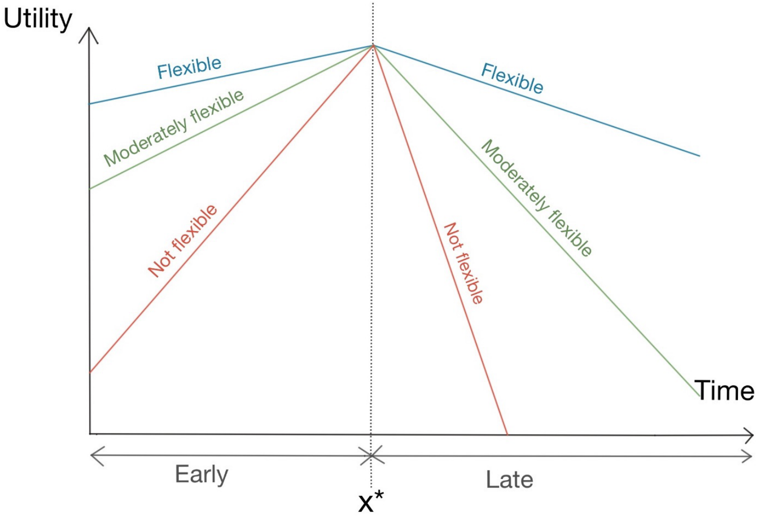
- **Utilities**

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

$$U \quad = f(\beta, X)$$

e.g. (Pougala et al, 2022)

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



Definitions

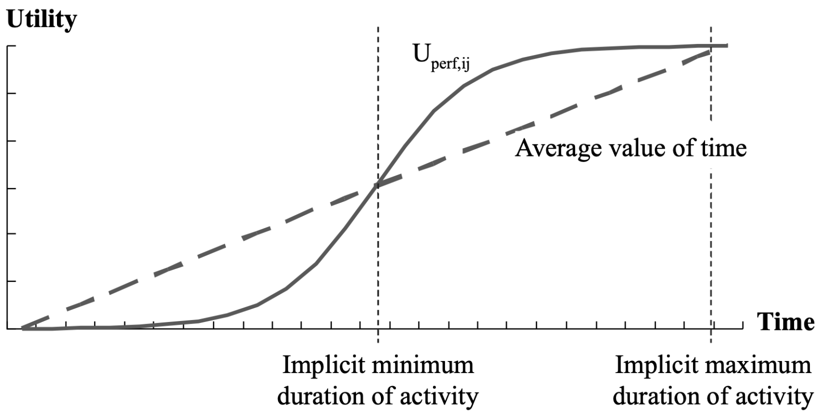
- **Utilities**

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

$$U \quad = f(\beta, X)$$

e.g. (Feil, 2010)

$$U_{an} = U_{perf} + U_{late} + U_{travel} + \varepsilon_{an}$$



Optimisation model

- Individuals maximise the **total utility**, subject to constraints:

$$\Omega = \max \sum_{a} U_{an}$$

- Decision variables:
  - Activity participation
  - Start time
  - Duration
  - Succession between activities

Optimisation model

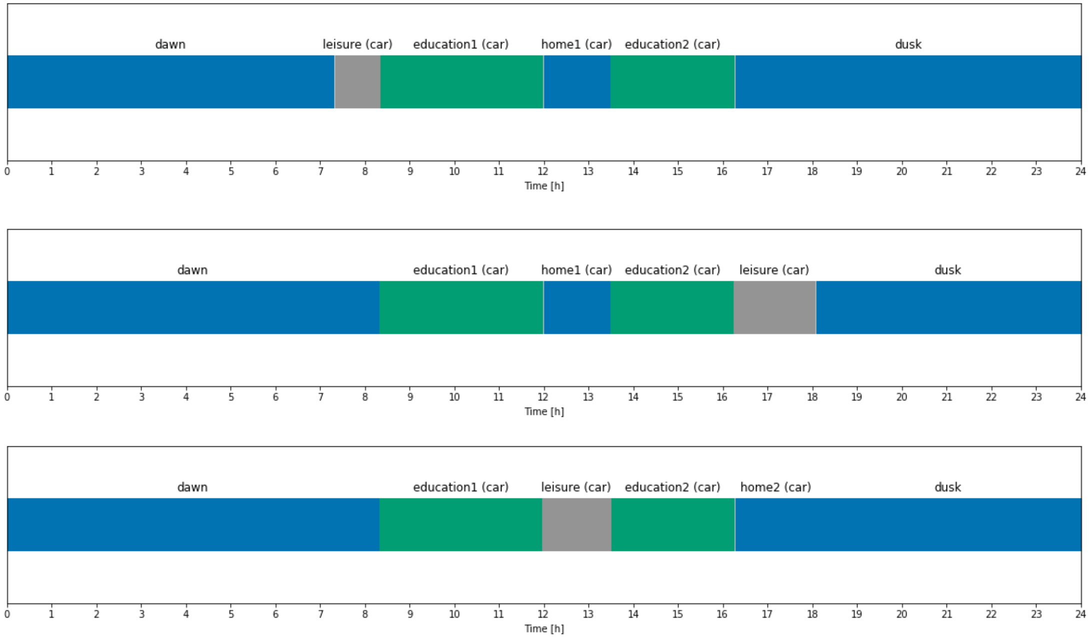
- Individuals maximise the **total utility**, subject to constraints:

$$\Omega = \max \sum_a U_{an}$$

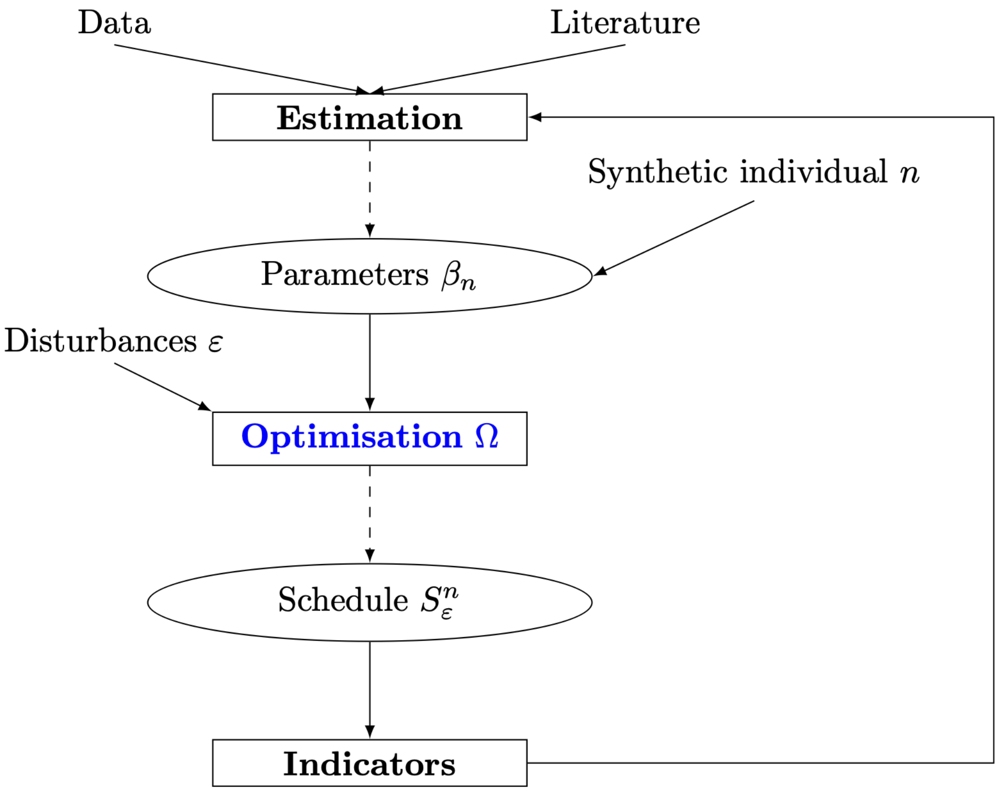
- Constraints:
  - Time budget
  - No duplicates
  - Mode consistency
  - Resource availability
  - Participation constraints
  - Sequence constraints

Simulation

- Simulation procedure:
  - Draw β^r from distribution of β
  - Draw ε^r from distribution of ε
  - Solve Ω for (β^r, ε^r)
  - Repeat N times

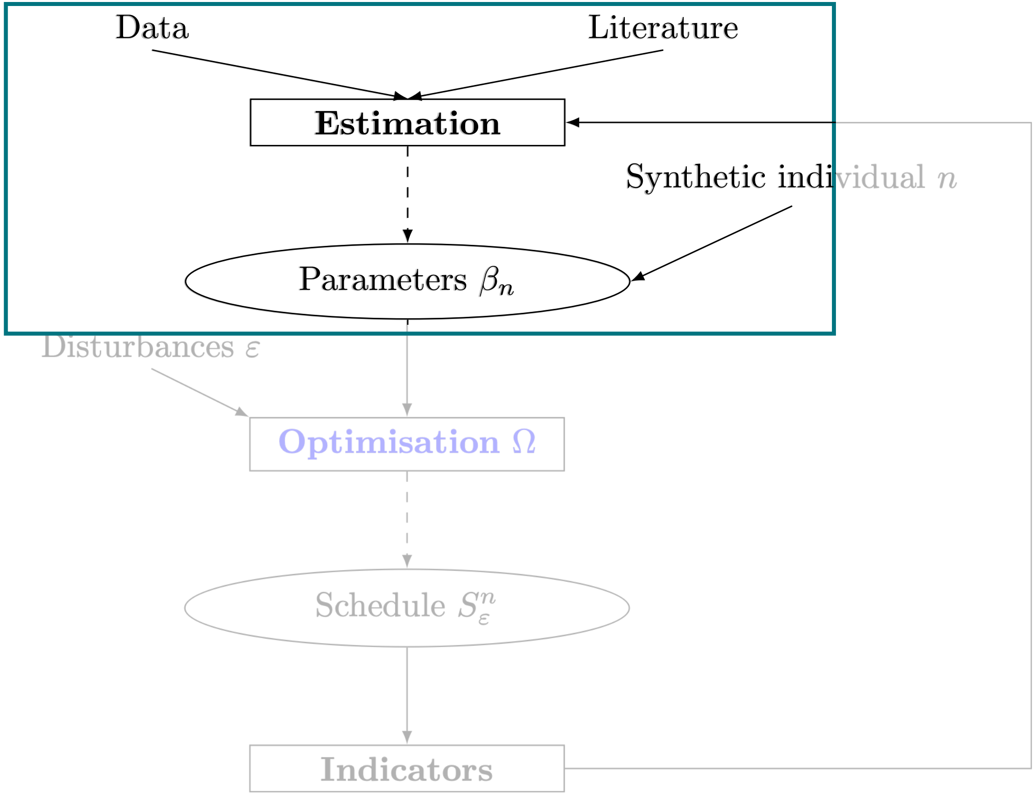


OASIS framework



OASIS framework

Parameter estimation



Estimation

How do we estimate the **parameters** of the model ?

$$U \quad = f(\boldsymbol{\beta}, X)$$

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

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:

$$\hat{\beta} = \arg\max L_n(\beta)$$

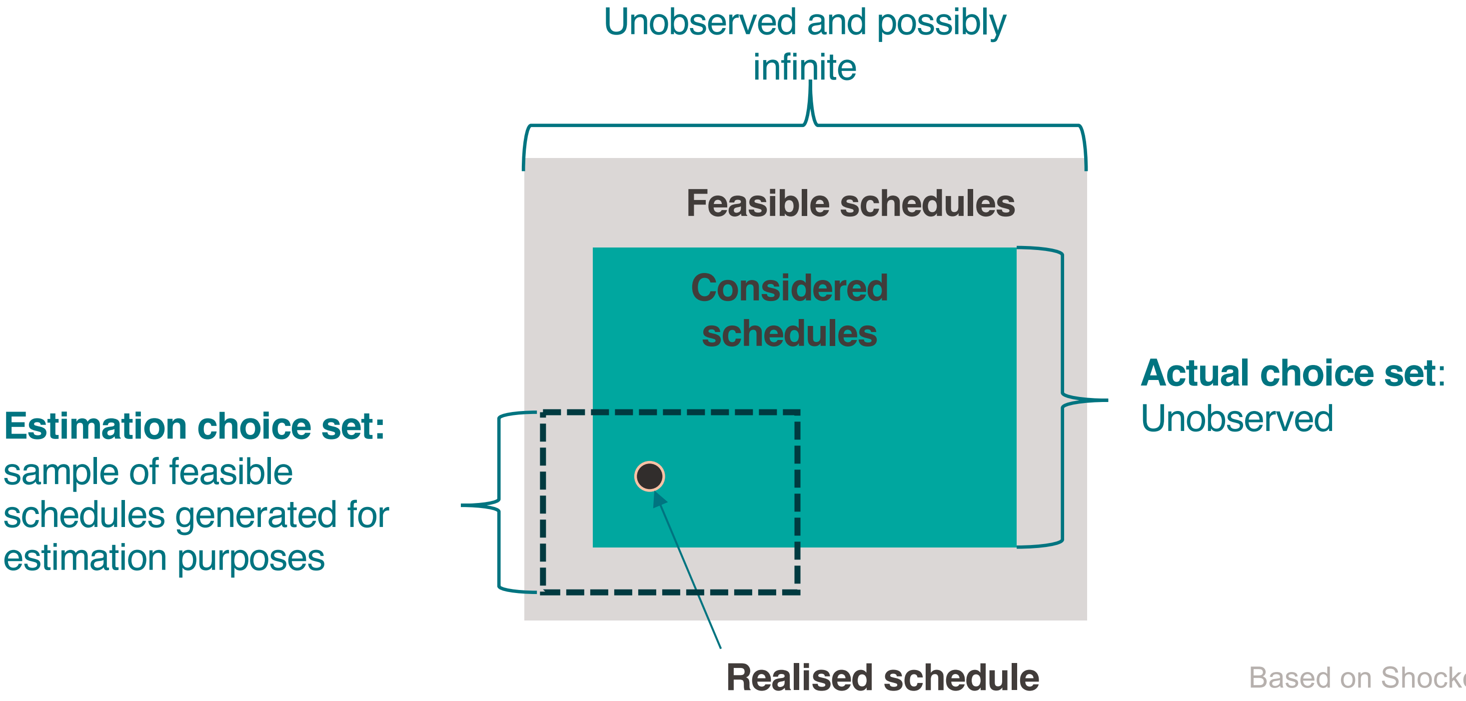
$$L_n = \prod_{n=1}^{N} \prod_{i \in C_n} P_n(i)^{y_{in}}$$

Enumeration over choice set C_n

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

Estimation

- Choice set generation

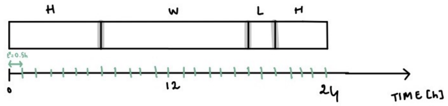


Based on Shocker (1991)

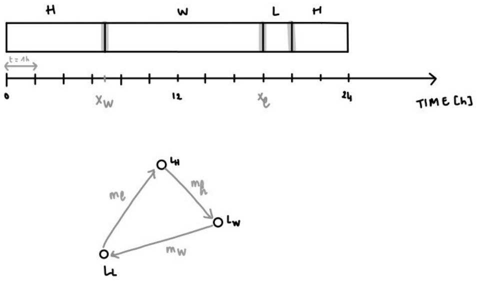
Estimation

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

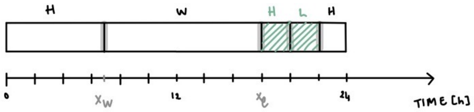
Block



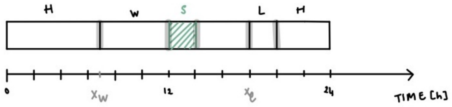
Initial state



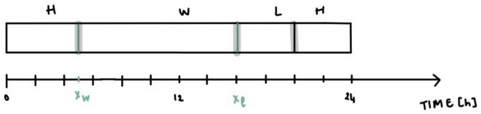
Swap



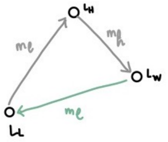
Assign



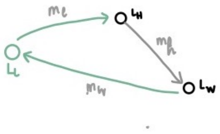
Inflate/Deflate



Mode

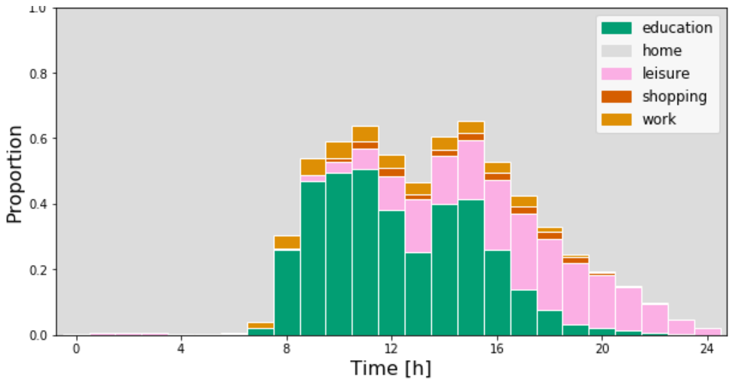


Location

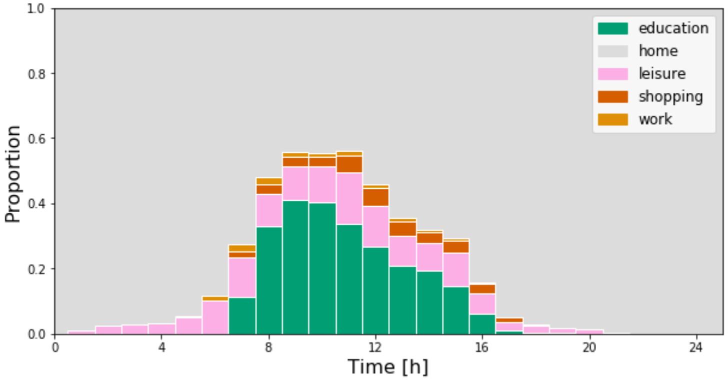


Estimation

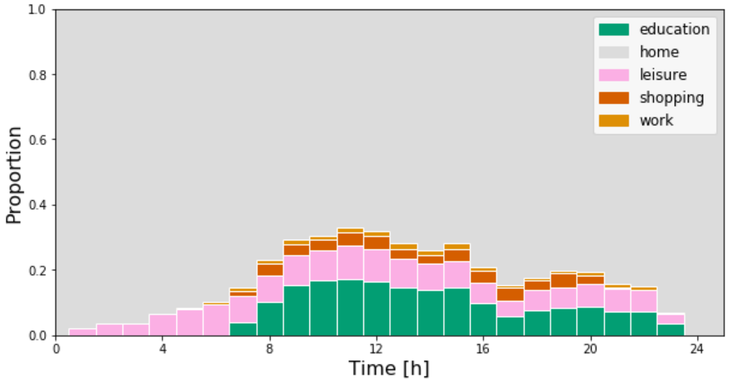
Data



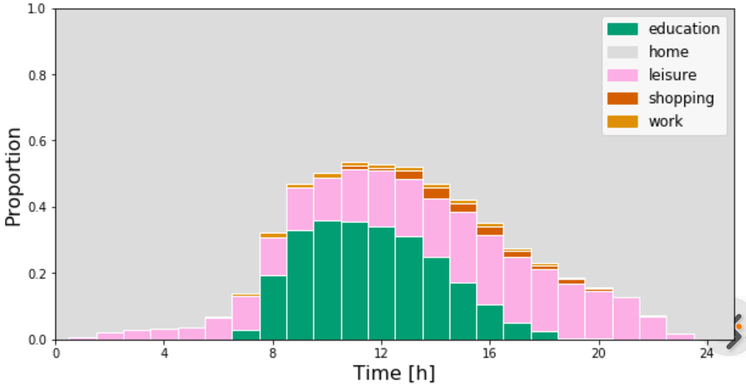
Generic



Literature

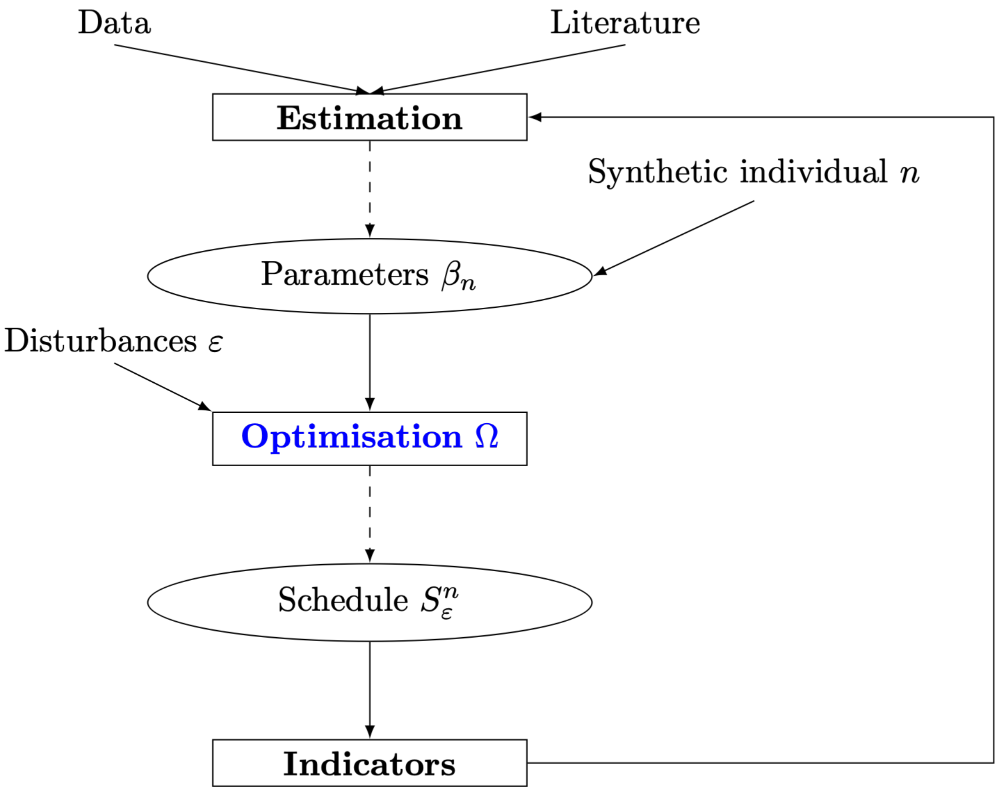


Activity-specific



TRANSP-OR

OASIS framework



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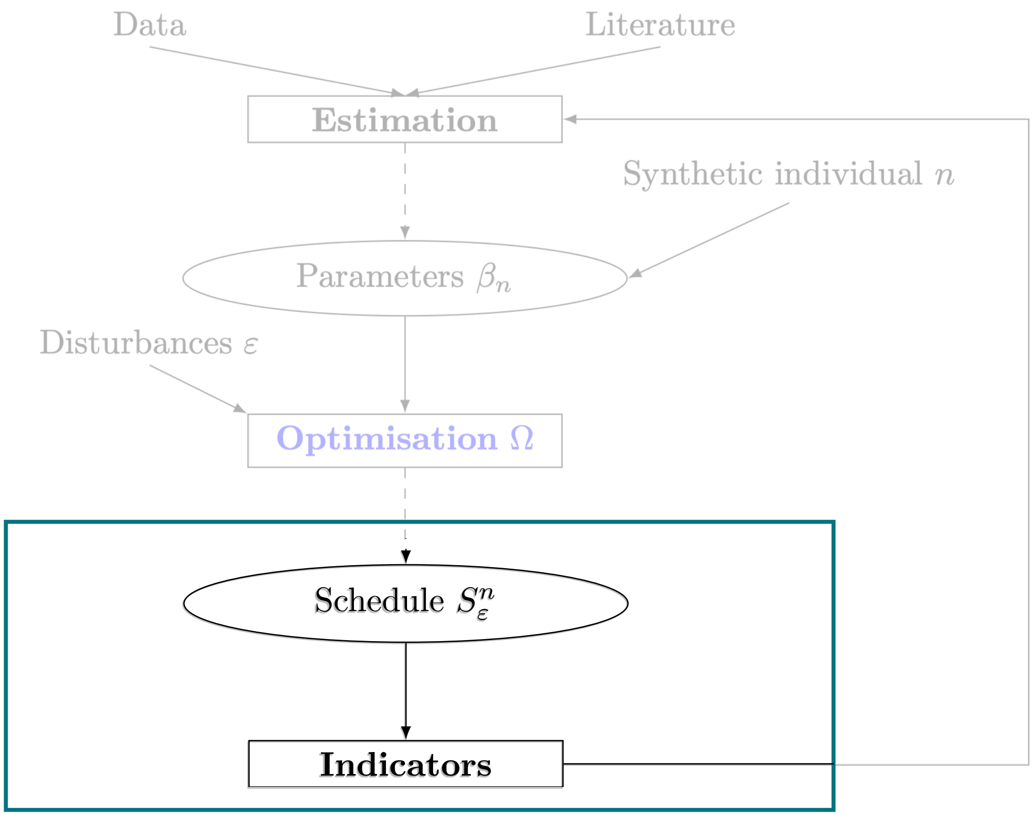
OASIS framework



Applications

Applications

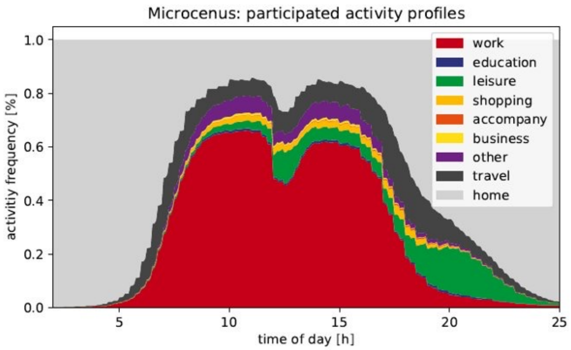
- **OPTIMS (OPT**imisation of **I**ndividual **M**obility **S**chedules**)**
  - Collaboration with Swiss Federal Railways (SBB)
  - Integration of optimisation model into SBB's forecasting framework

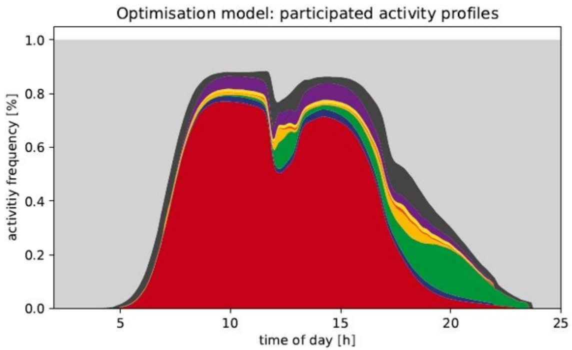
  - https://github.com/optims-org/optims-sbb

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Innosuisse – Schweizerische Agentur für Innovationsförderung

SBB CFF FFS

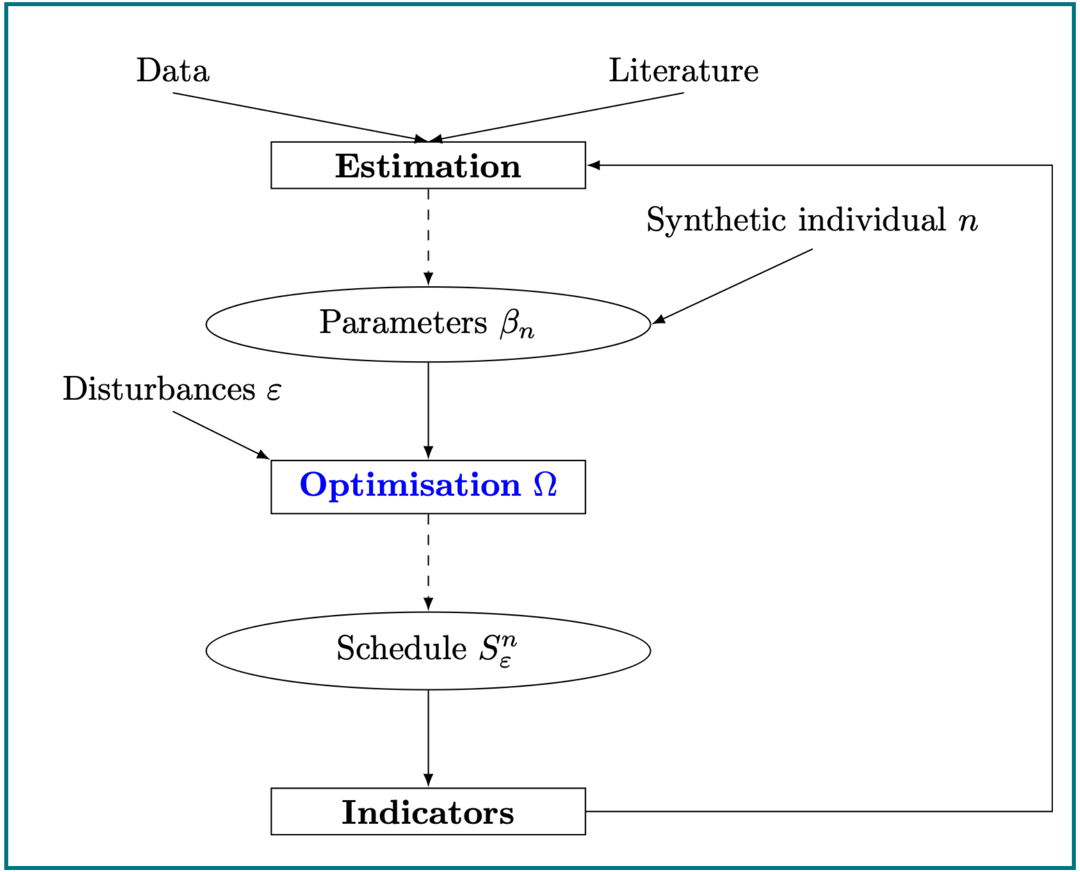




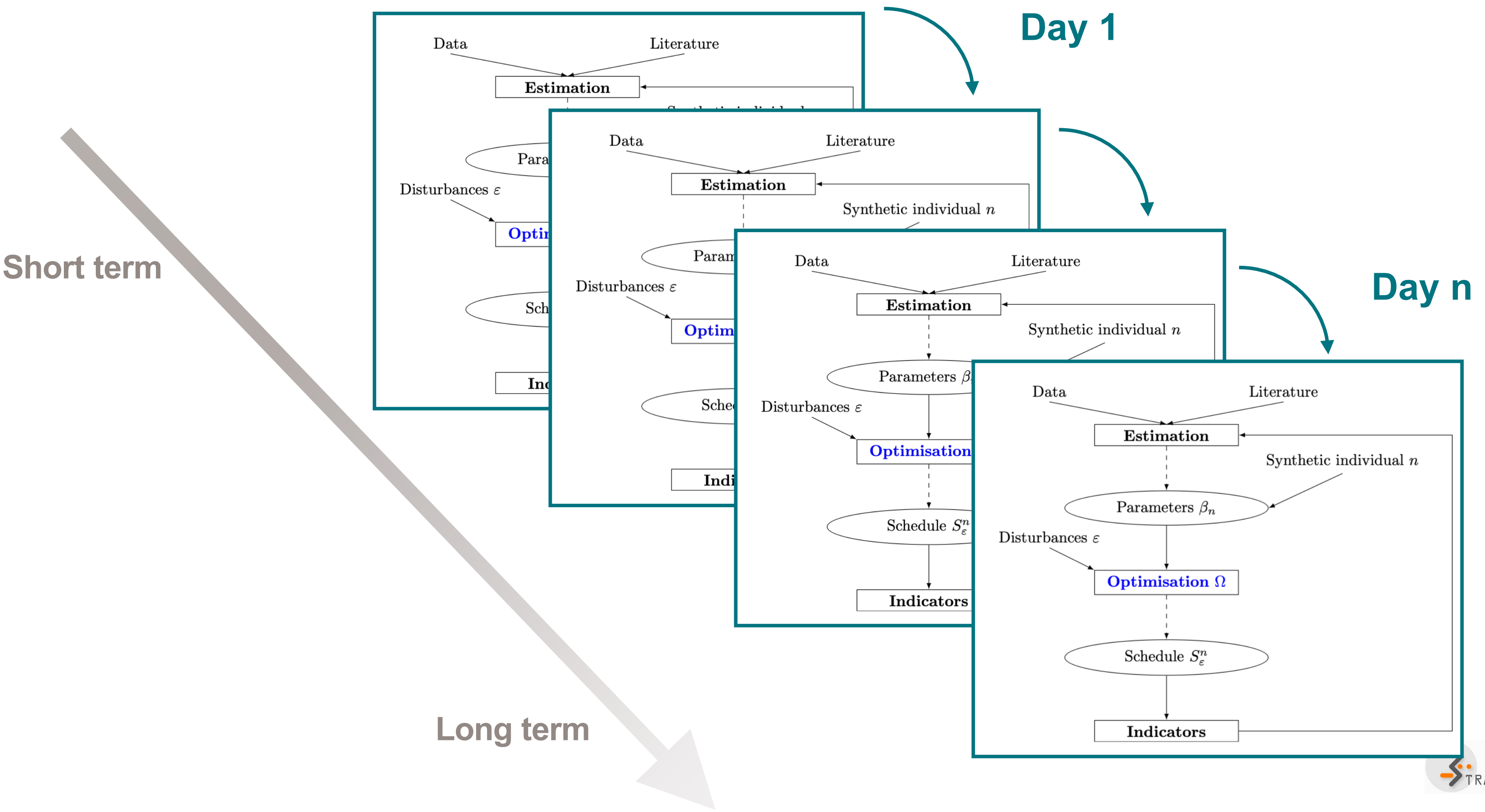
Manser et al (2022)

Multiday extension

Single day



Multiday extension



Multiday extension

- We solve a **multiobjective** optimisation problem

$$\Omega = \max \sum_{d} w_d \sum_{a} U_{ad}$$

- Decision variables for **each day $\boldsymbol{d}$** :
  - Activity participation
  - Start time
  - Duration
  - Succession between activities

Multiday extension

- We solve a **multiobjective** optimisation problem

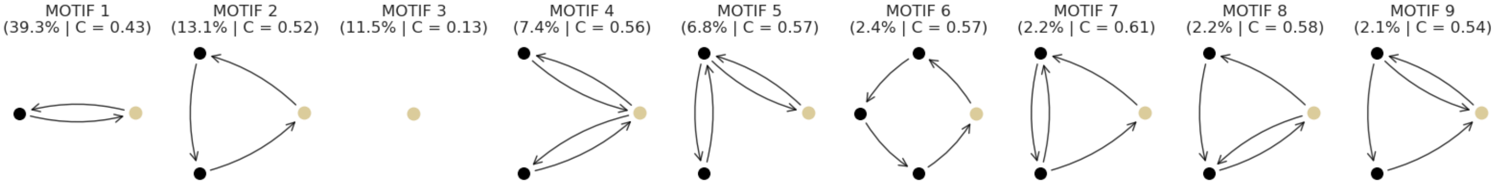
$$\Omega = \max \sum_{d} w_d \sum_{a} U_{ad}$$

- Constraints for **each day** $\boldsymbol{d}$:
  - Daily time budget
  - No duplicates
  - Mode consistency
  - Resource availability
  - Participation constraints
  - Sequence constraints

- Consistency across days
- Time budget over time horizon
- …

Multiday extension

- 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

- Pougala J., Hillel T., Bierlaire M. (2022). ***Capturing trade-offs between daily scheduling choices.*** Journal of Choice Modelling 43 (100354)
- Manser P., Haering T., Hillel T., Pougala J., Krueger R., Bierlaire M. (2022). ***Estimating flexibility preferences to resolve temporal scheduling conflicts in activity-based modelling.*** Transportation
- Pougala J., Hillel T., Bierlaire M. (2021) ***Choice set generation for activity-based models*.** Proceedings of the 21st Swiss Transport Research Conference (STRC), 12-14 September, Ascona, Switzerland
- Pougala J., Hillel T., Bierlaire M. (2022) ***Parameter estimation for activity-based models*.** Proceedings of the 22nd Swiss Transport Research Conference (STRC), 18-20 May, Ascona, Switzerland.

Thank you!

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