OASIS: an optimisation framework for daily activity scheduling

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EPFL

Urban Systems Lab Seminar – 25/11/2022

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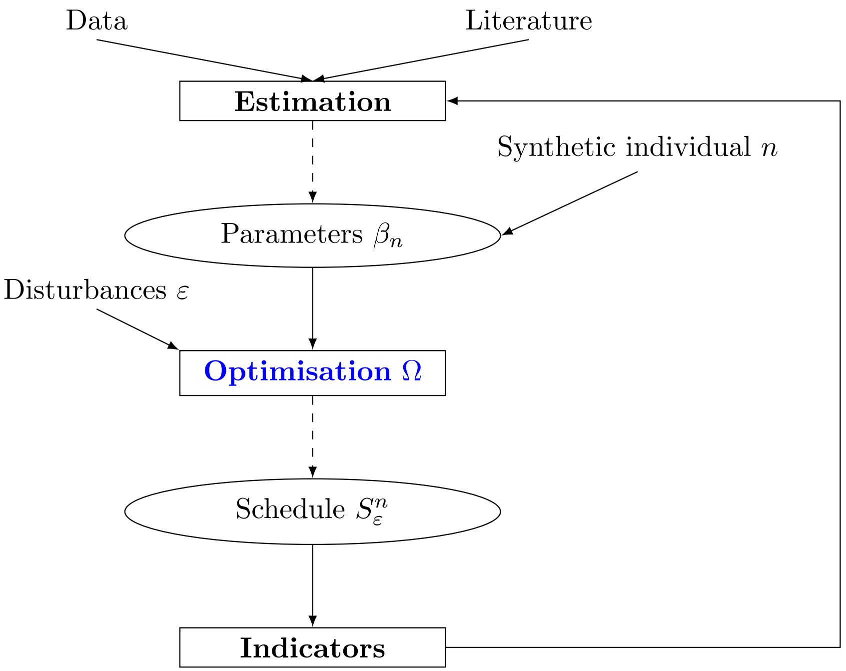
OASIS framework

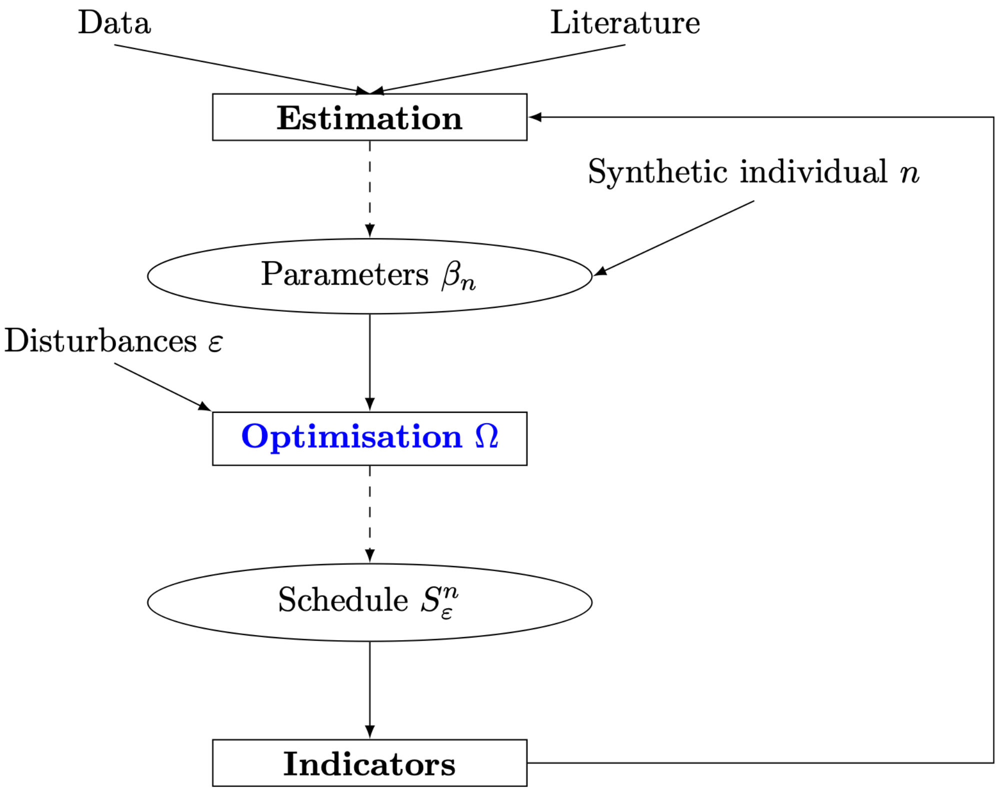
- Optimisation-based Activity Scheduling Integrating Simultaneous choice dimensions



OASIS framework

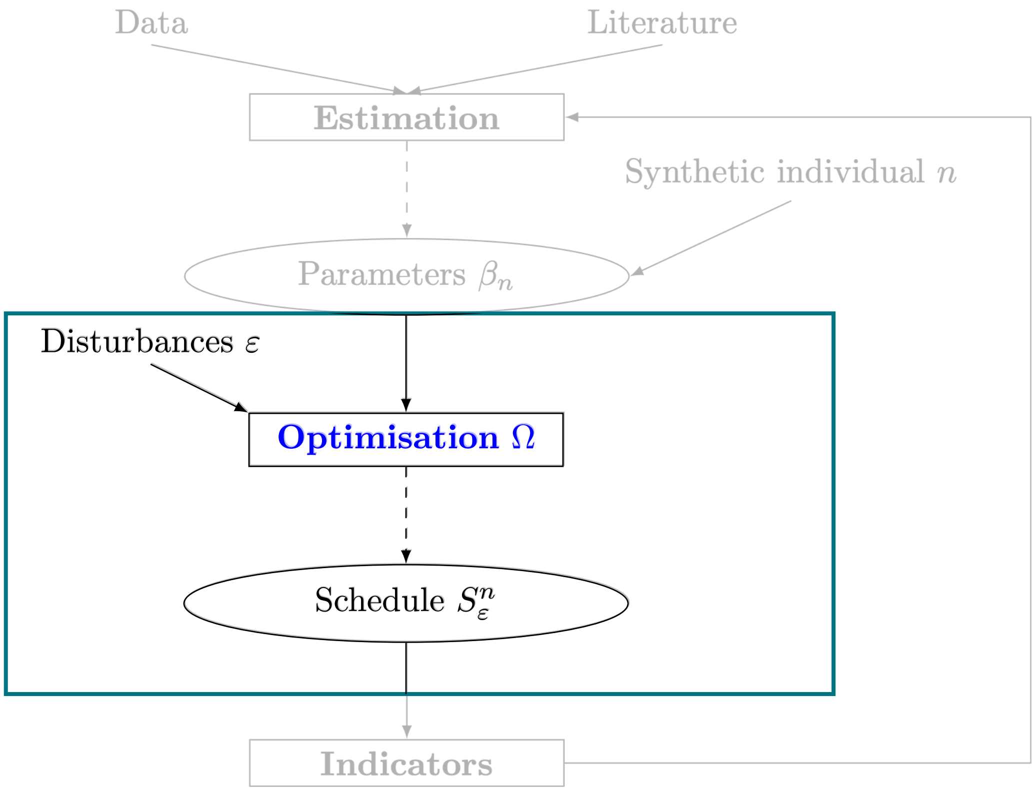
- Optimisation-based Activity Scheduling **Integrating Simultaneous choice dimensions**
    - Activity participation, scheduling, mode, location choice
    - Explicitly capture **trade-offs** between choices
    - Combine econometric and rule-based approaches

OASIS framework

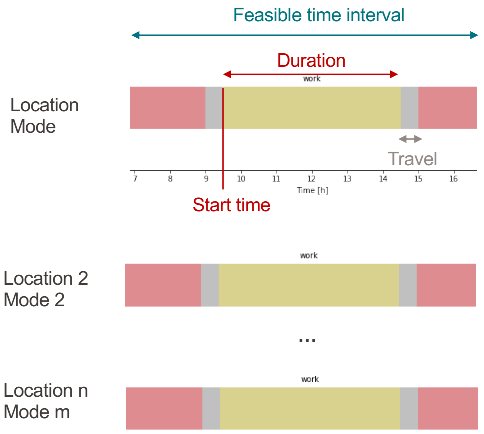


OASIS framework

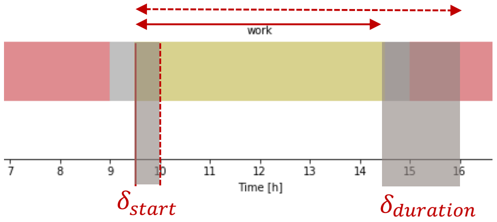
Simulation module



Simulation



From an activity...



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

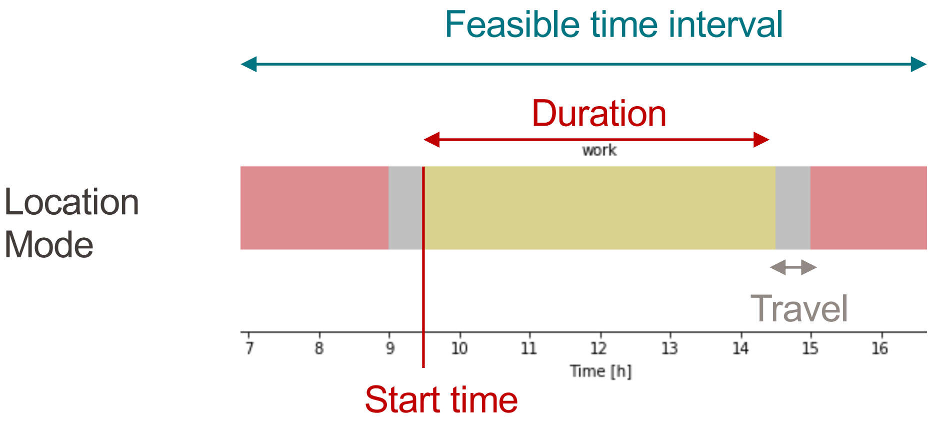
…to a utility function...

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

… 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

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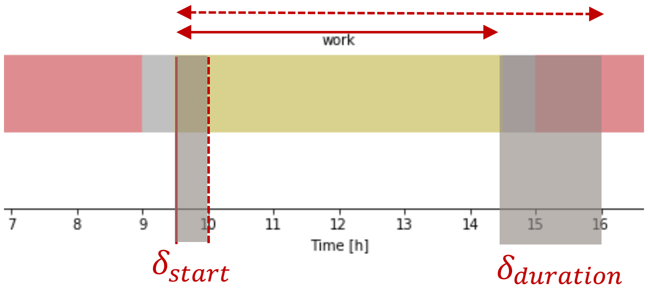
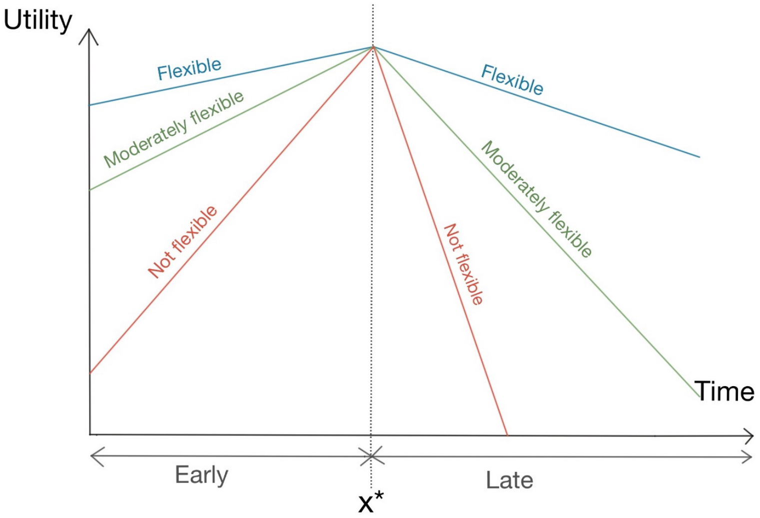
Definitions

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





Definitions

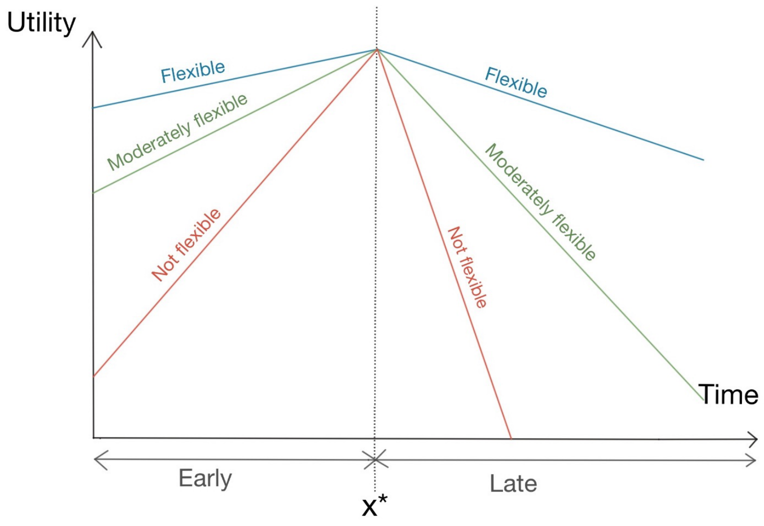
- **Utilities**

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

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

e.g. (Pougala et al, 2022)

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



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

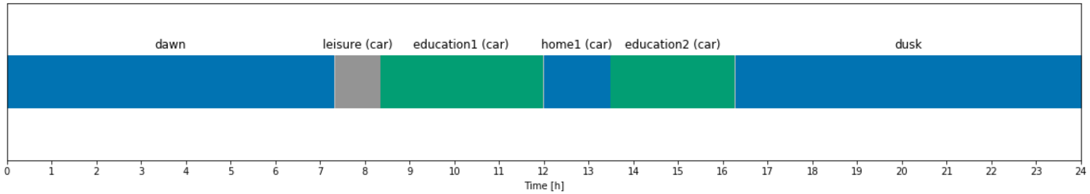
- Individuals maximise the **total utility**, subject to constraints:

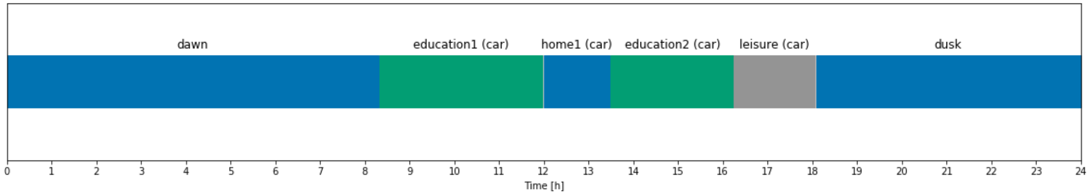
$$\Omega = \max \sum_a U_{an}$$

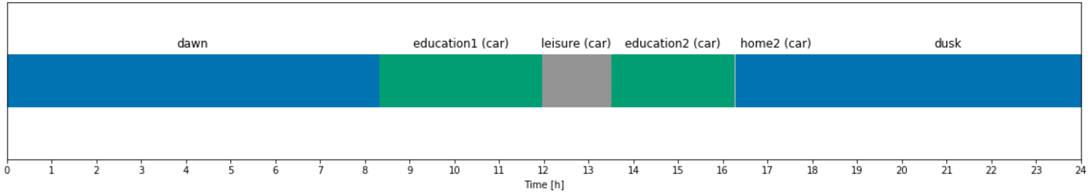
- Constraints:
  - Time budget
  - No duplicates
  - Mode consistency
  - Resource availability
  - Participation constraints
  - Sequence constraints

Simulation

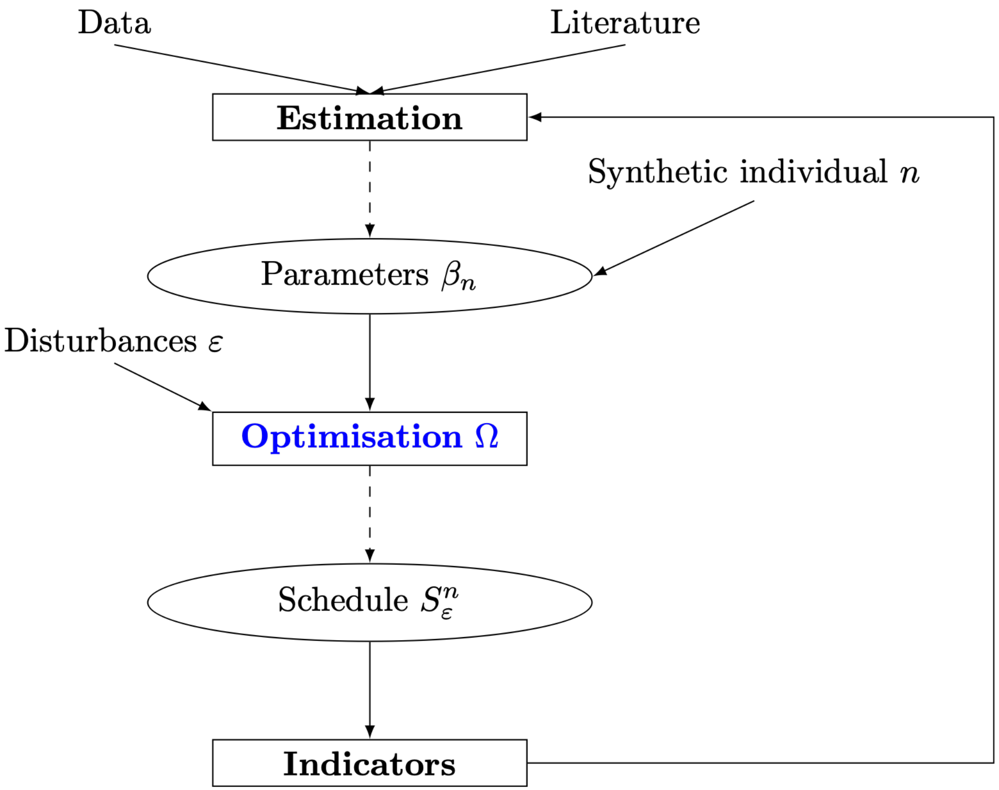
- Simulation procedure:
  - Draw β^r from distribution of β
  - Draw ε^r from distribution of ε
  - Solve Ω for (β^r, ε^r)
  - Repeat N times





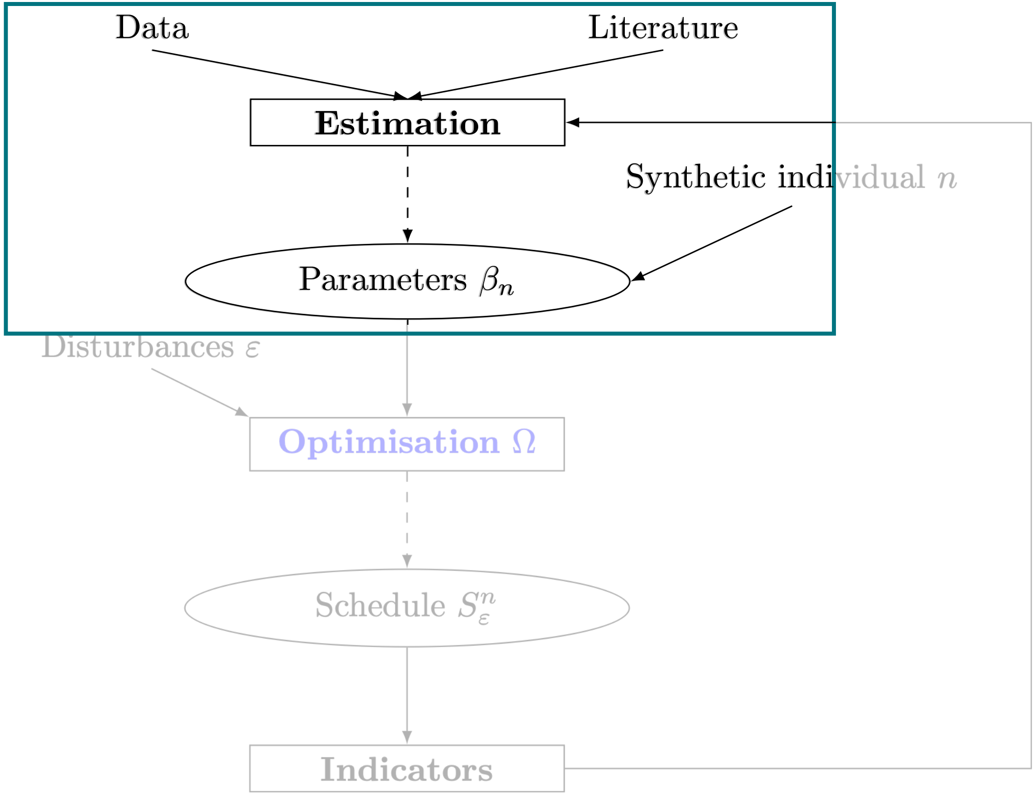


OASIS framework



OASIS framework

Parameter estimation



Estimation

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

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

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

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:

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

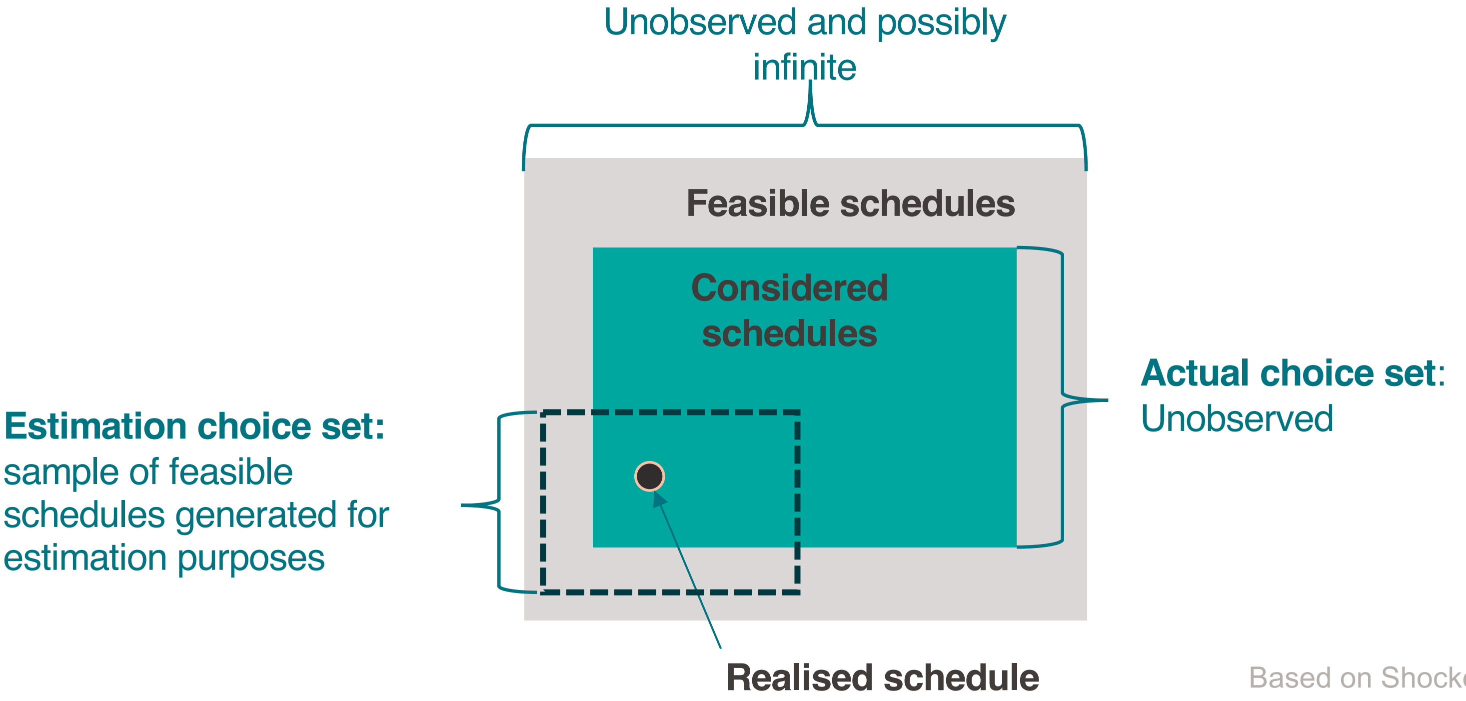
$$L_n = \prod_{n=1}^{N} \prod_{i \in C_n} P_n(i)^{y_{in}}$$

Enumeration over choice set C_n

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

Estimation

○ Choice set generation

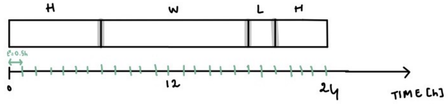


Based on Shocker (1991)

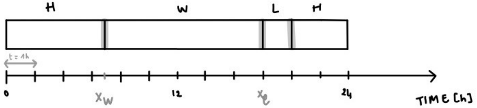
Estimation

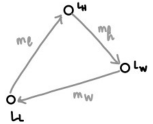
- ○ **Choice set generation**
  - Metropolis-Hastings sampling of feasible schedules

Block

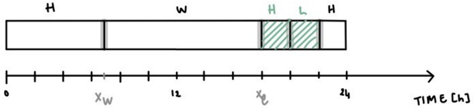


Initial state

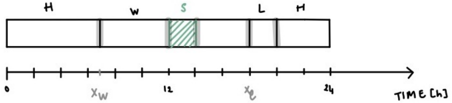




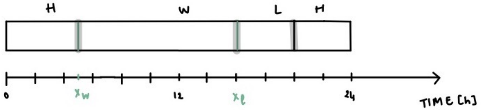
Swap



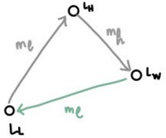
Assign



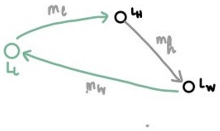
Inflate/Deflate



Mode



Location



Estimation

- **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

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Estimation

Model 1

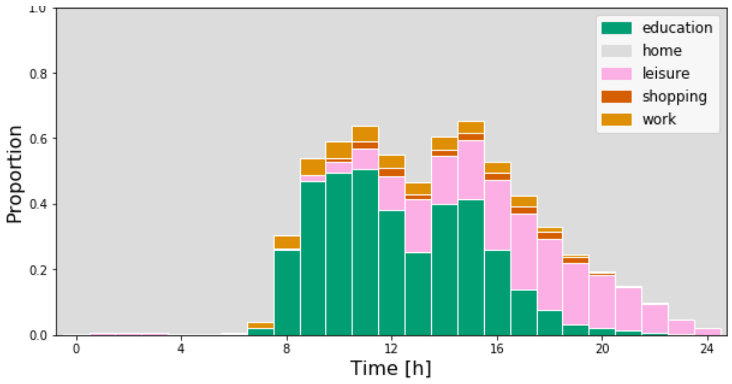
	Parameter	Param. estimate	Rob. std err	Rob. t-stat	Rob. p-value
1	F: early	-0.175	0.12	-1.46	0.145
2	F: late	-0.333	0.14	-2.38	0.0171
3	F: long	-0.105	0.0722	-1.45	0.146
4	F: short	-0.114	0.194	-0.585	0.559
5	NF: early	-1.14	0.367	-3.10	0.00191
6	NF: late	-0.829	0.229	-3.61	0.0003
7	NF: long	-1.20	0.393	-3.05	0.00231
8	NF: short	-1.19	0.468	-2.54	0.0011
9	Education: ASC	16.0	2.46	6.49	8.63e-11
10	Leisure: ASC	8.81	1.7	5.17	2.28e-07
11	Shopping: ASC	6.85	1.80	3.80	0.000146
12	Work: ASC	16.0	2.58	6.18	6.57e-10

Model 2

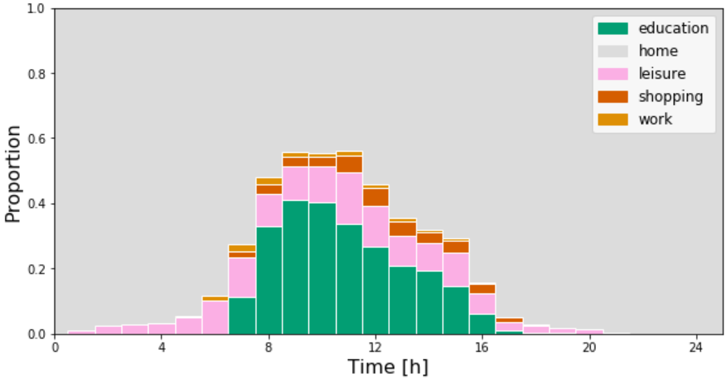
	Parameter	Param. estimate	Rob. std err	Rob. t-stat	Rob. p-value
1	Education: ASC	18.7	3.17	5.89	3.79e-09
2	Education: early	-1.35	0.449	-3.01	0.00264
3	Education: late	-1.63	0.416	-3.91	9.05e-05
4	Education: long	-1.14	0.398	-2.86	0.00428
5	Education: short	-1.75	0.457	-3.84	0.000123
6	Leisure: ASC	8.74	1.94	4.50	6.79e-06
7	Leisure: early	-0.0996	0.119	-0.836	0.403
8	Leisure: late	-0.239	0.115	-2.07	0.0385
9	Leisure: long	-0.08	0.0617	-1.30	0.195
10	Leisure: short	-0.101	0.149	-0.682	0.495
11	Shopping: ASC	10.5	2.20	4.78	1.74e-06
12	Shopping: early	-1.01	0.287	-3.51	0.000443
13	Shopping: late	-0.858	0.237	-3.63	0.000284
14	Shopping: long	-0.683	0.387	-1.76	0.0779
15	Shopping: short	-1.81	1.73	-1.04	0.297
16	Work: ASC	13.1	2.64	4.96	7.16e-07
17	Work: early	-0.619	0.217	-2.85	0.00438
18	Work: late	-0.338	0.168	-2.02	0.0438
19	Work: long	-1.22	0.348	-3.51	0.000441
20	Work: short	-0.932	0.213	-4.37	1.23e-05

Estimation

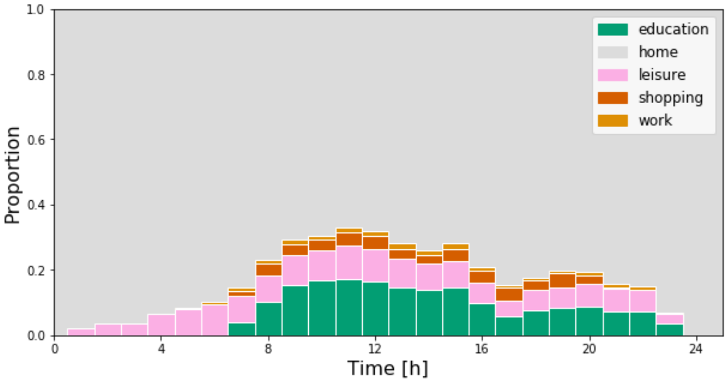
Data



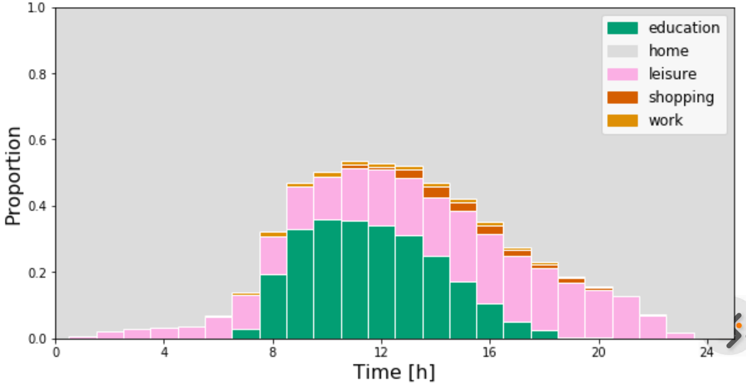
Generic



Literature



Activity-specific



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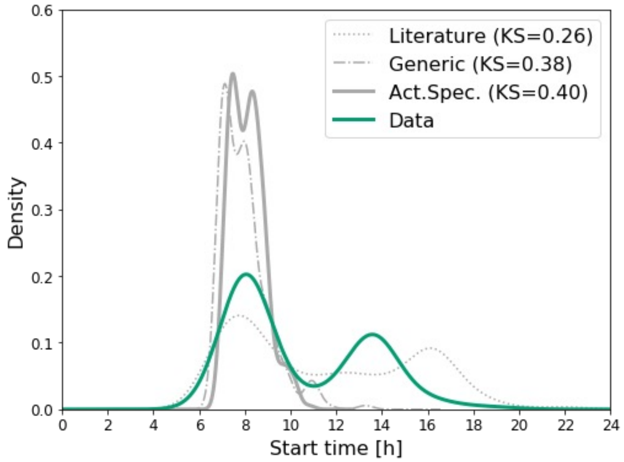
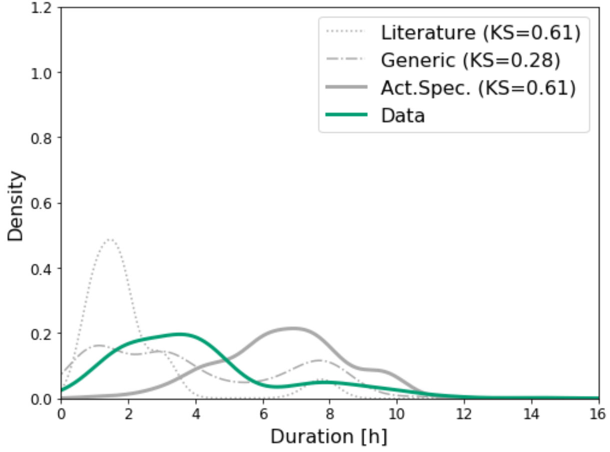
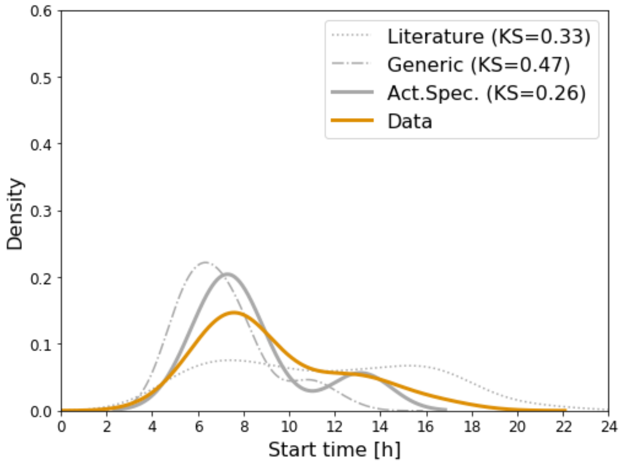
Estimation

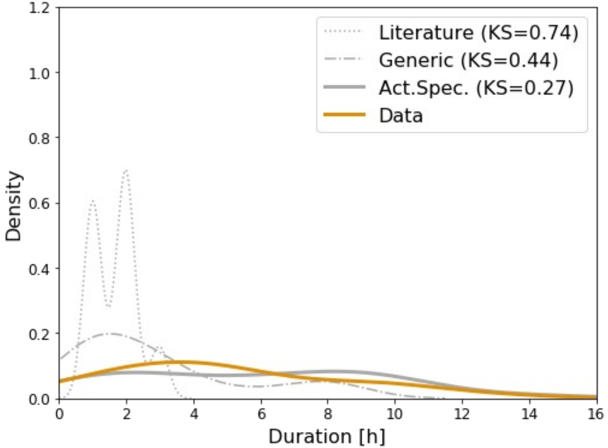
Education



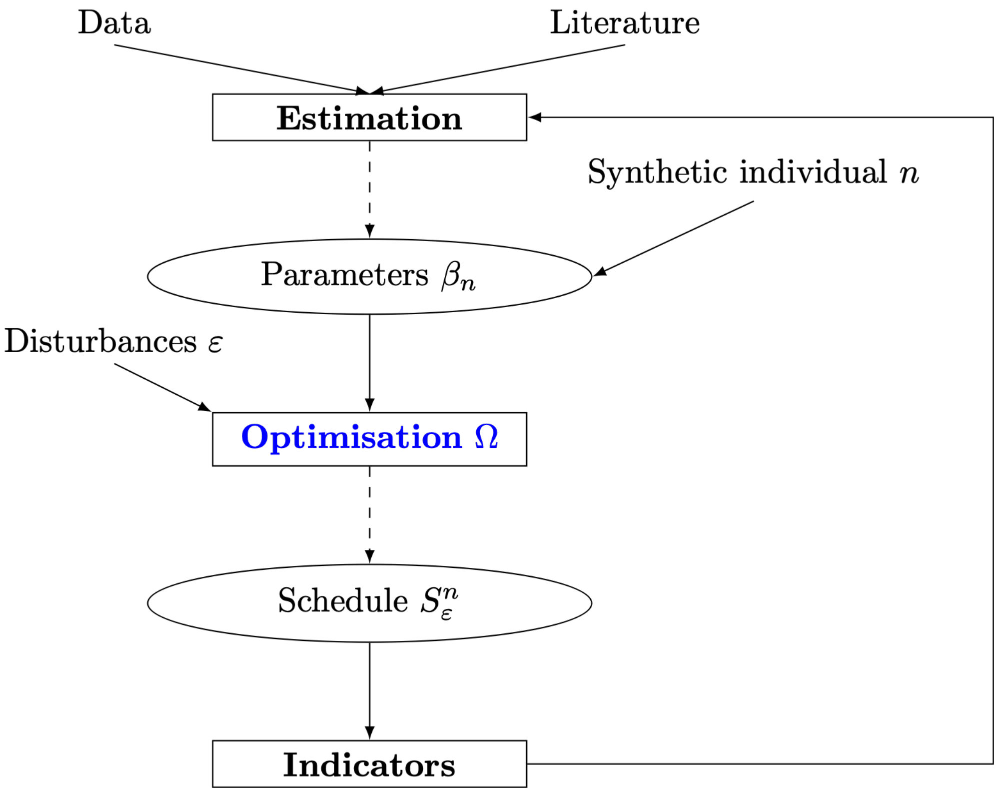


Work

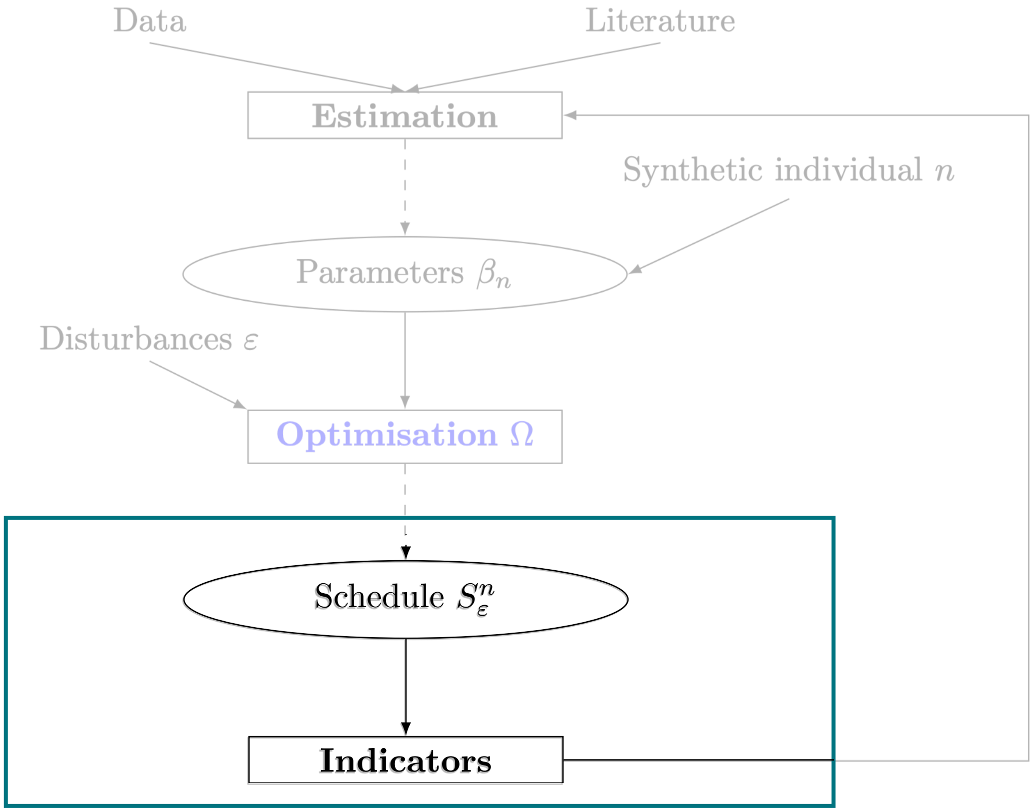




OASIS framework



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
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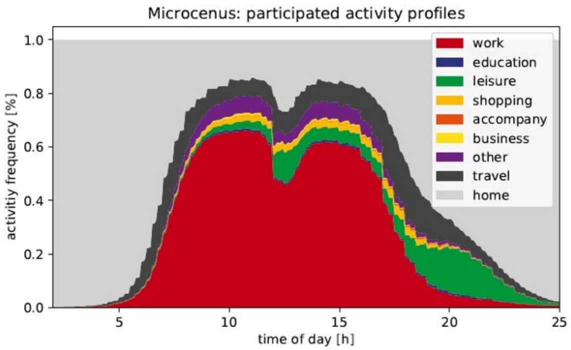
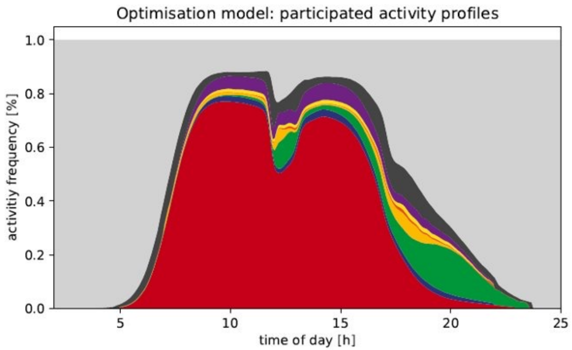
Innosuisse – Schweizerische Agentur für Innovationsförderung

SBB CFF FFS





Manser et al (2022)

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). ***OASIS: Optimisation-based Activity Scheduling with Integrated Simultaneous choice dimensions.*** Report TRANSP-OR 221124
- 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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