An optimisation framework for activity-based models

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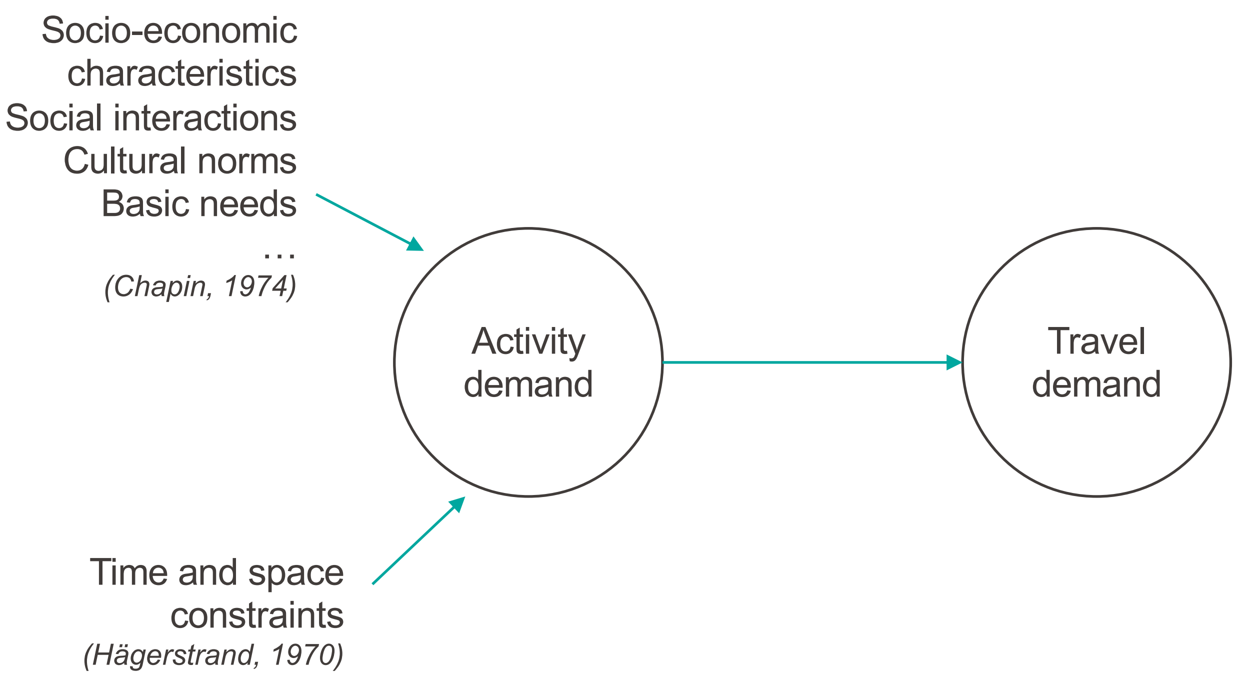
UCL ISI – 31/10/2022

About me

- 4th year PhD student
  - Transport and Mobility Lab (TRANSP-OR) @ EPFL, Switzerland
  - Supervisors: Prof. Michel Bierlaire, Dr. Tim Hillel
- Masters in Civil Engineering (2019)
- UCL Visit until December

Introduction



Introduction

Utility-based models

Decision is made by maximizing utility derived from activities

e.g.

Bowman & Ben-Akiva, 2001
Bhat et al, 2004

Rule-based models

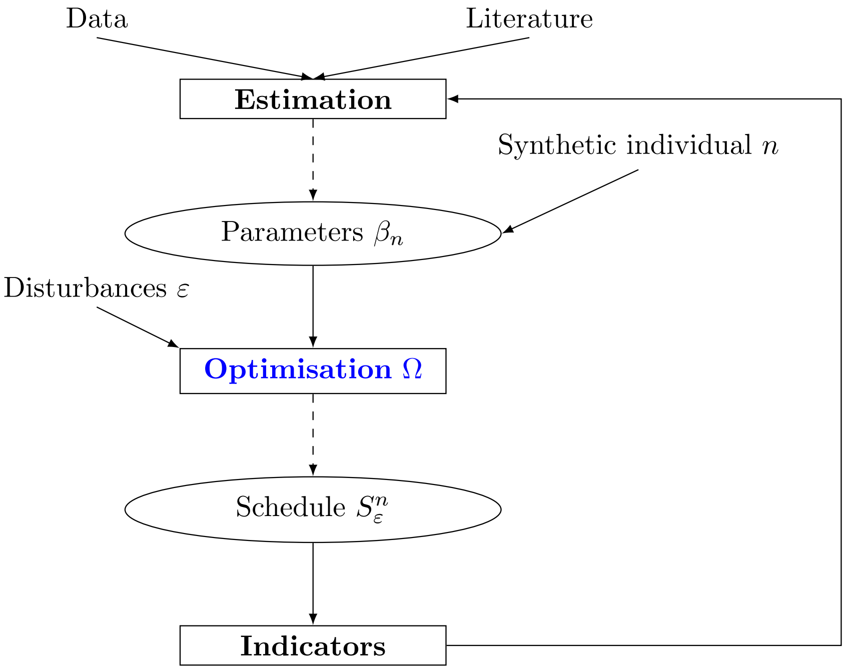
Decision is made by considering context-dependent rules

e.g.

Gollegde et al., 1994
Arentze & Timmermans 2000

OASIS framework

- Optimisation-based Activity Scheduling Integrating Simultaneous choice dimensions



OASIS framework

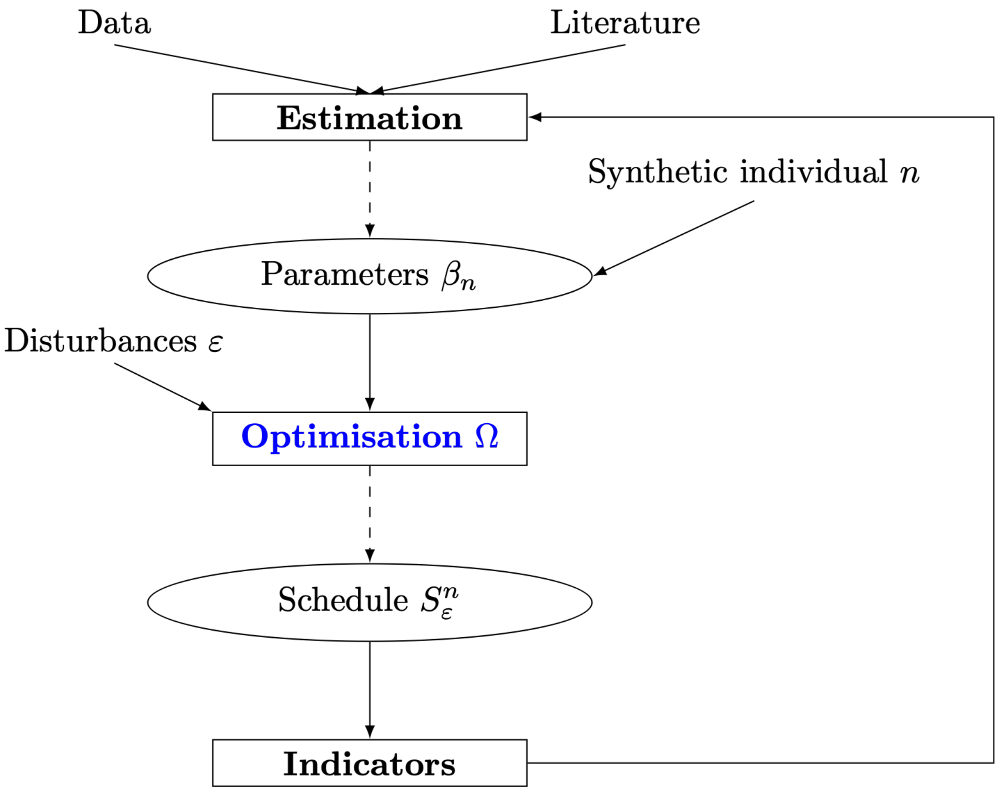
- Optimisation-based Activity Scheduling **Integrating Simultaneous choice dimensions**

    - Activity participation, scheduling, mode, location choice

    - Explicitly capture **trade-offs** between choices

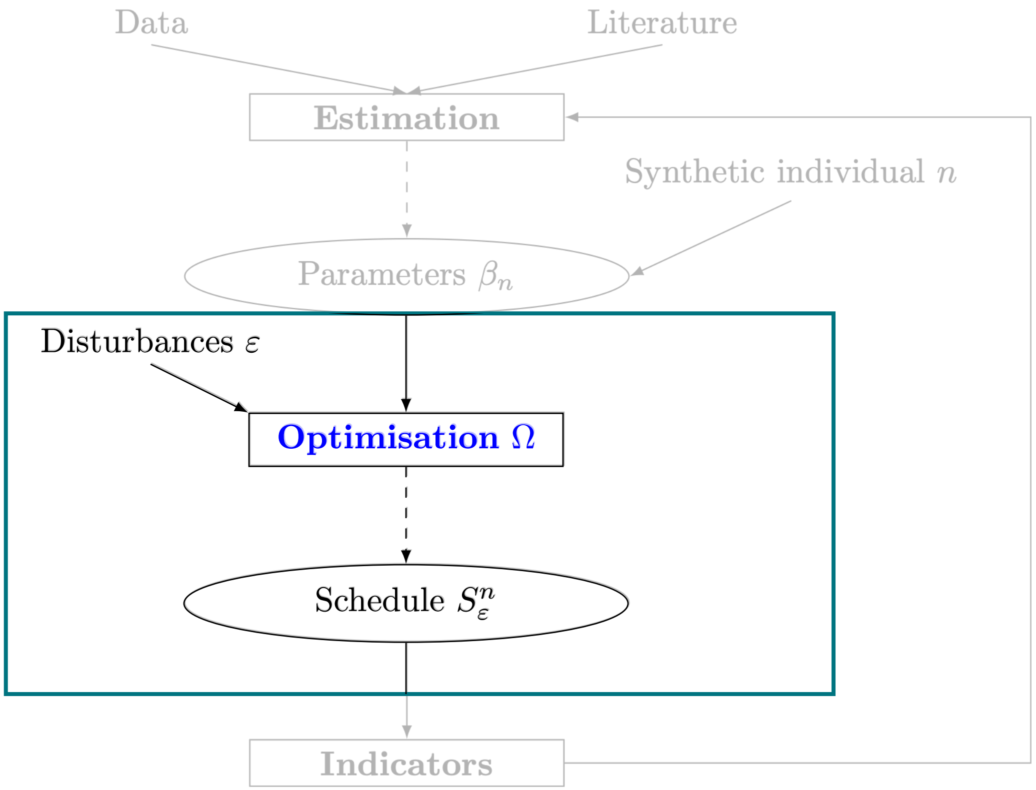
    - Combine econometric and rule-based approaches

OASIS framework

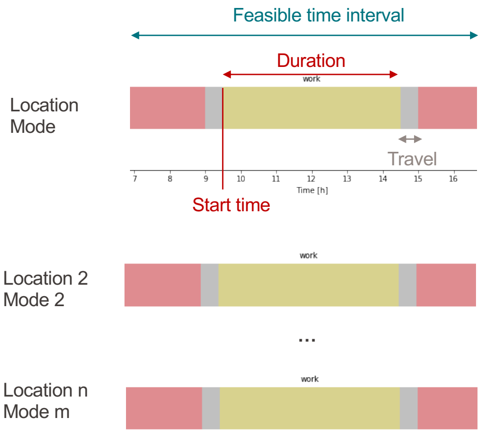


OASIS framework

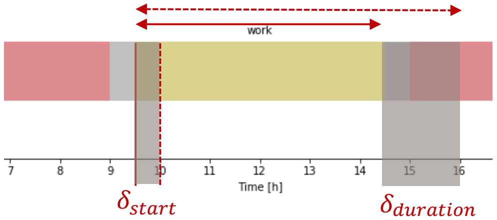
Simulation module



Simulation



From an activity...



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

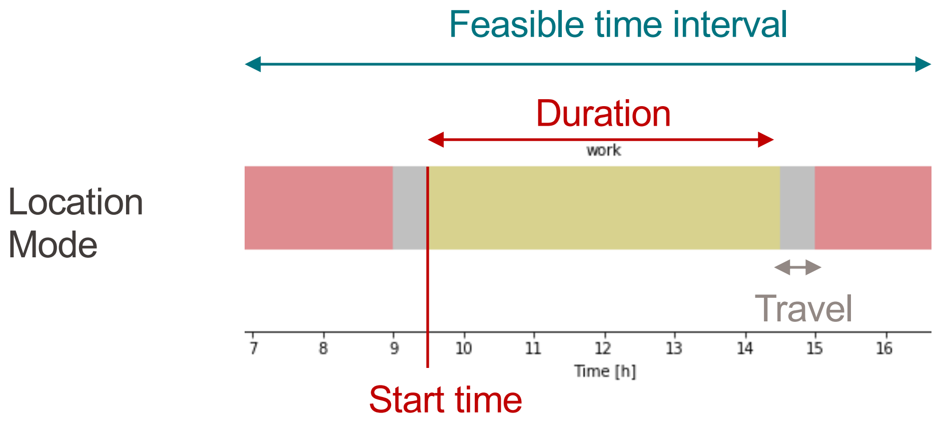
…to a utility function...

$$\Omega_n = \max \sum_i U_{in}$$

… to a maximisation problem

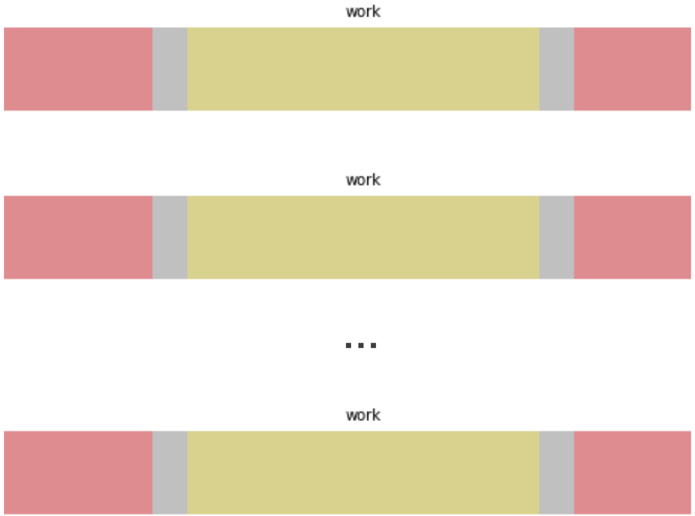
Definitions

- Activities



Definitions

- Activities



Location 1
Mode 1

e.g. Working from home

Location 2
Mode 2

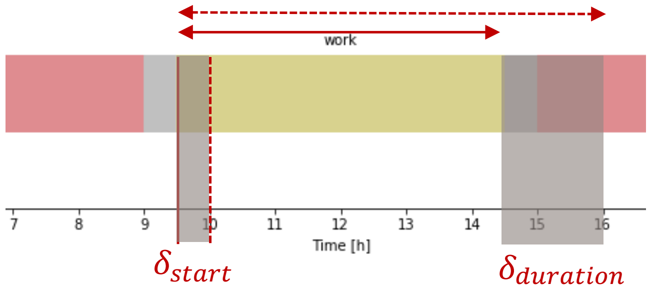
e.g. Working on campus, travelling by car

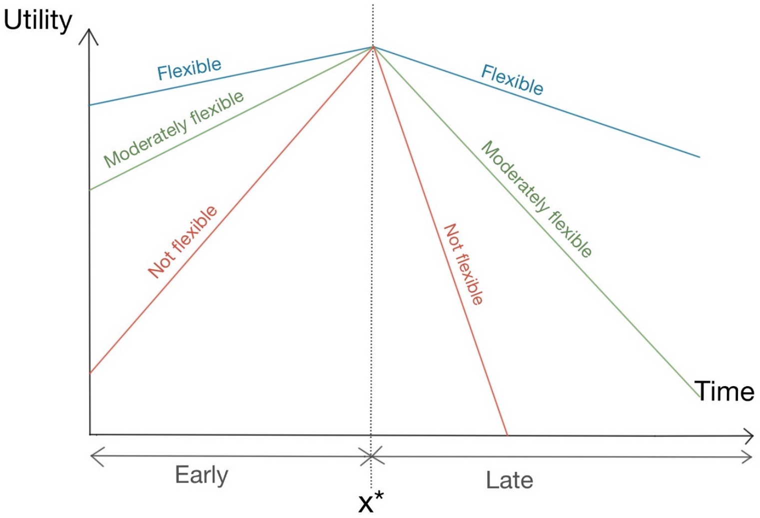
Location n
Mode m

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

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

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

Definitions

- **Utilities**

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

Utility of doing the activity itself, regardless of when/how long

e.g. $cst + \beta_{cost} c_a$

Definitions

- **Utilities**

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

Start time deviations

$$\beta_{early} \max(0, x_a^* - x_a) + \beta_{late} \max(0, x_a - x_a^*)$$

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Definitions

- **Utilities**

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

Duration deviations

$$\beta_{short} \max(0, \tau_a^* - \tau_a) + \beta_{late} \max(0, \tau_a - \tau_a^*)$$

Definitions

- **Utilities**

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

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

Travel from activity a to b
$\beta_{t,time}\rho_{ab} + \beta_{t,cost}c_{ab}$

Definitions

- **Utilities**

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

Error terms with known distribution

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

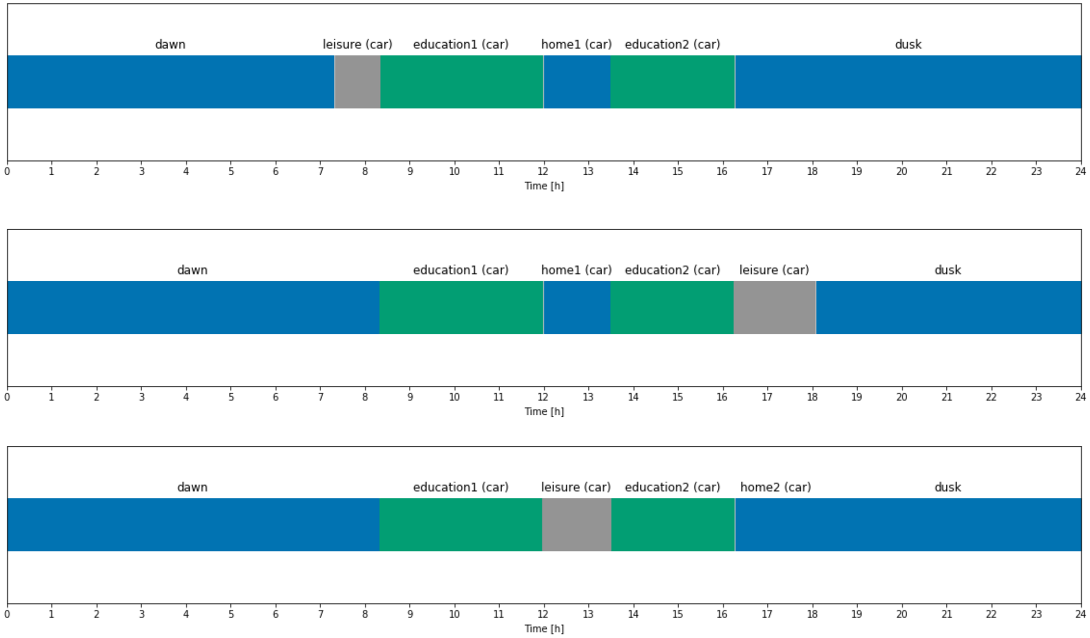
- Individuals maximise the **total utility**, subject to constraints:

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

- 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



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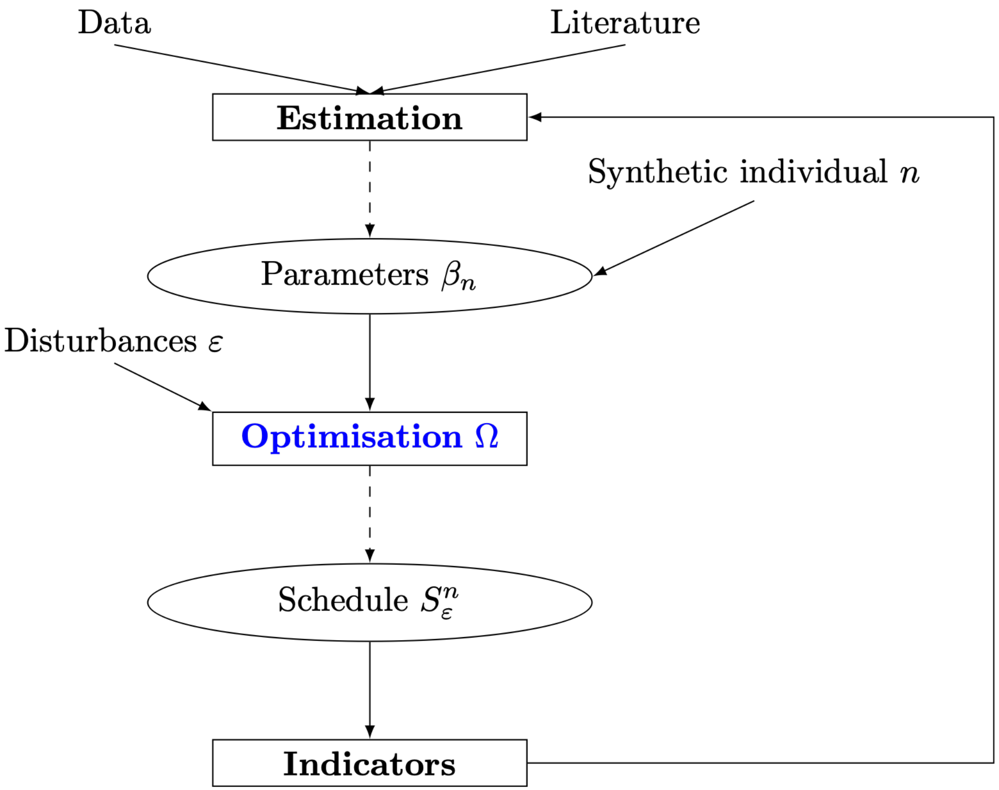
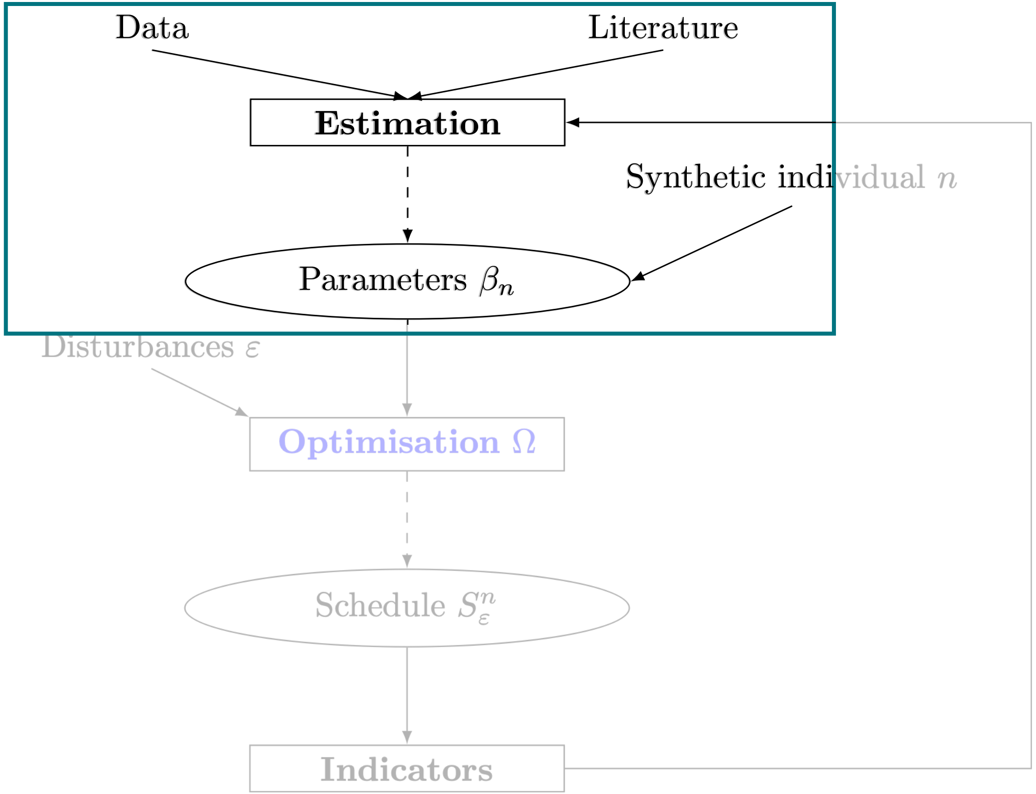
OASIS framework



OASIS framework

Parameter estimation



Estimation

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

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

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

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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:

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

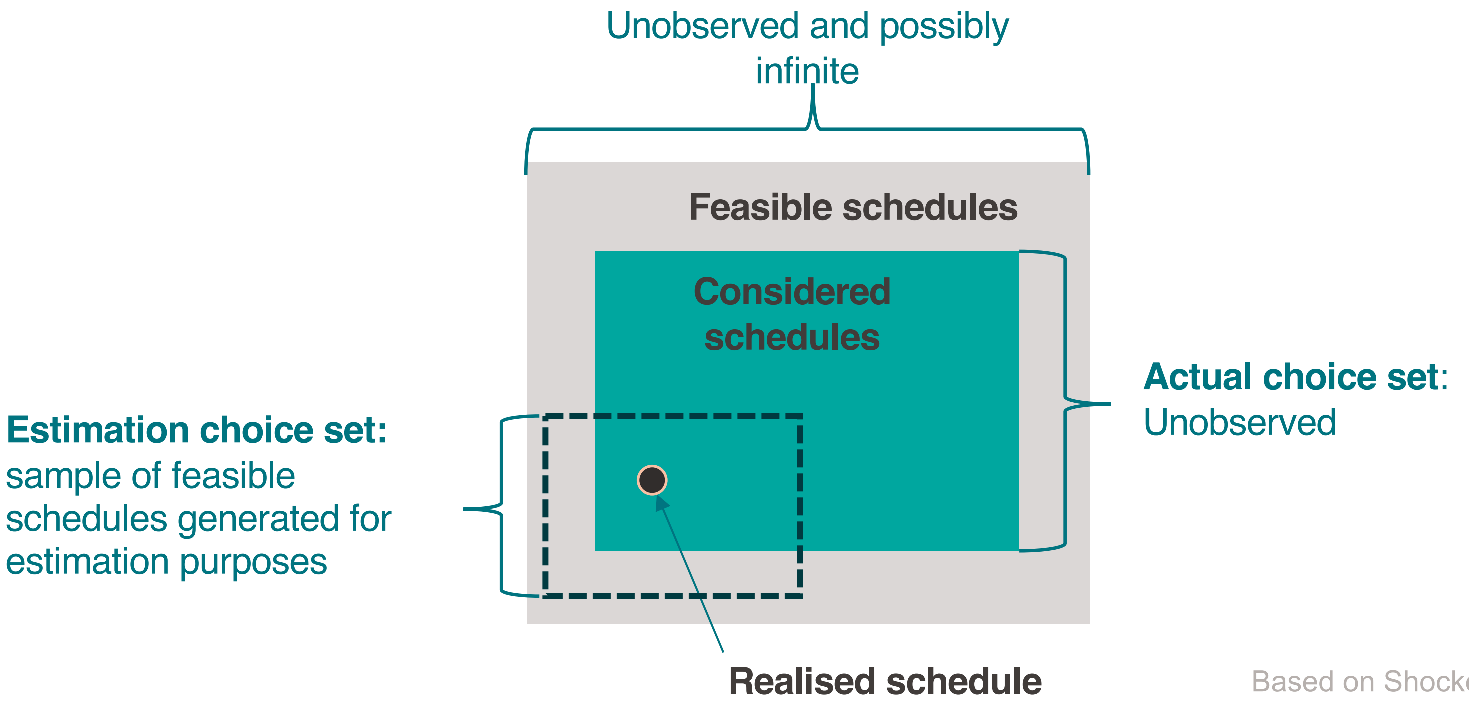
$$L_n = \prod_{n=1}^{N} \prod_{i \in C_n} P_n(i)^{y_{in}}$$

Enumeration over choice set C_n

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

Estimation

- **Choice set generation**



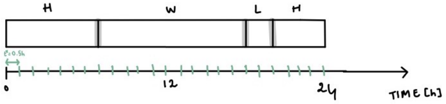
Based on Shocker (1991)

Estimation

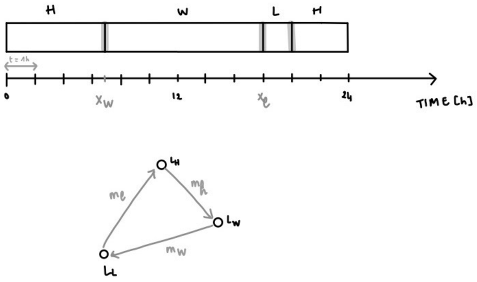
○ Choice set generation

- Metropolis-Hastings sampling of feasible schedules

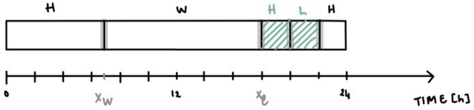
Block



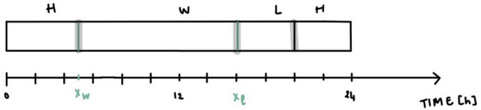
Initial state



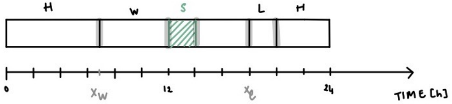
Swap



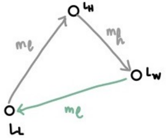
Inflate/Deflate



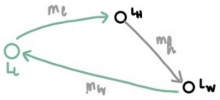
Assign



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:

- Deviation parameters from literature

Model 1 (12 parameters):

- Activity-specific constants
- Aggregated penalties (flexible vs. Non flexible)

Model 2 (20 parameters):

- Activity-specific constants
- Activity specific penalties

Estimation

Model 1

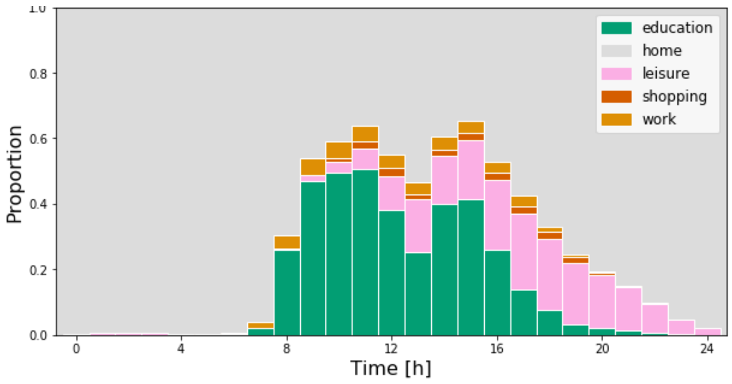
	Parameter	Param. estimate	Rob. std err	Rob. t-stat	Rob. p-value
1	F: early	-0.175	0.12	-1.46	0.145
2	F: late	-0.333	0.14	-2.38	0.0171
3	F: long	-0.105	0.0722	-1.45	0.146
4	F: short	-0.114	0.194	-0.585	0.559
5	NF: early	-1.14	0.367	-3.10	0.00191
6	NF: late	-0.829	0.229	-3.61	0.0003
7	NF: long	-1.20	0.393	-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

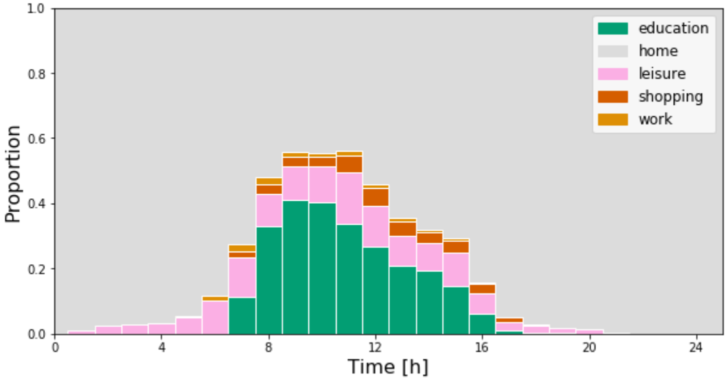
	Parameter	Param. estimate	Rob. std err	Rob. t-stat	Rob. p-value
1	Education: ASC	18.7	3.17	5.89	3.79e-09
2	Education: early	-1.35	0.449	-3.01	0.00264
3	Education: late	-1.63	0.416	-3.91	9.05e-05
4	Education: long	-1.14	0.398	-2.86	0.00428
5	Education: short	-1.75	0.457	-3.84	0.000123
6	Leisure: ASC	8.74	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

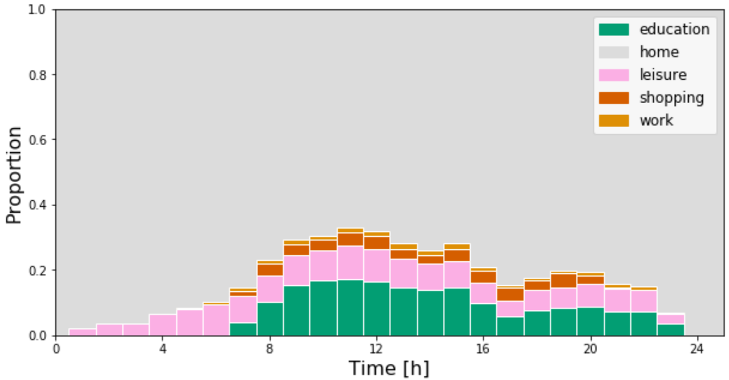
Data



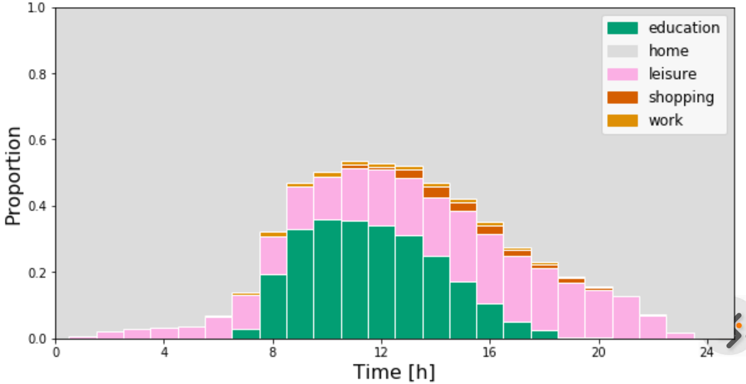
Model 1



Model 0



Model 2



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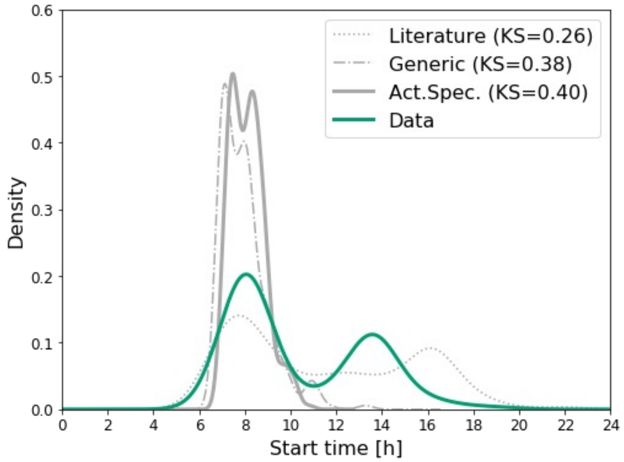
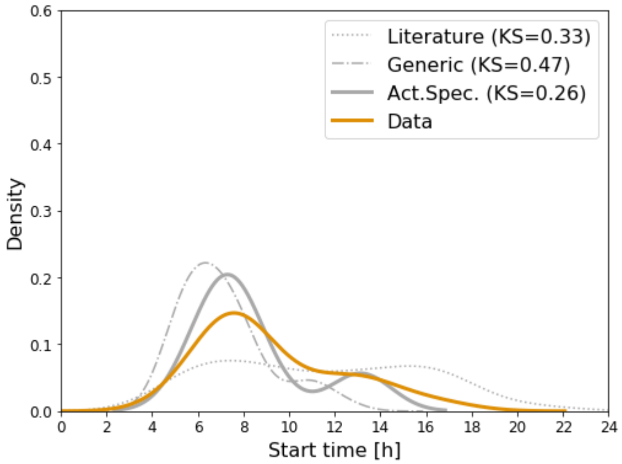
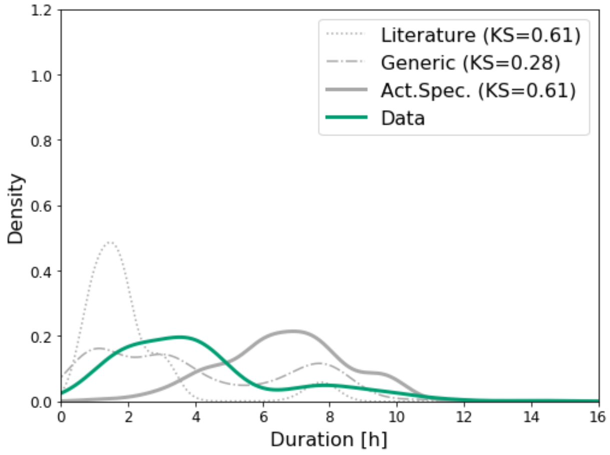
Estimation

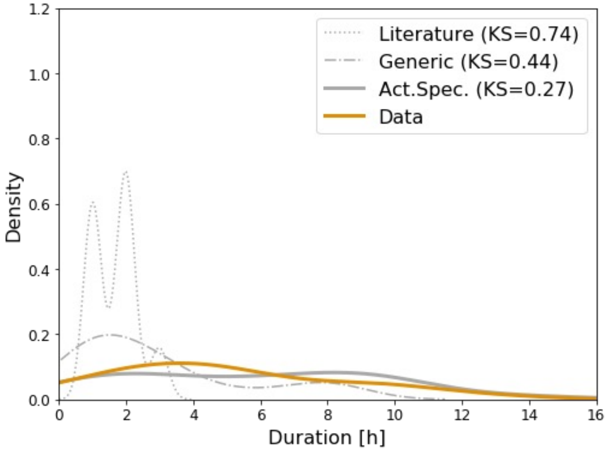




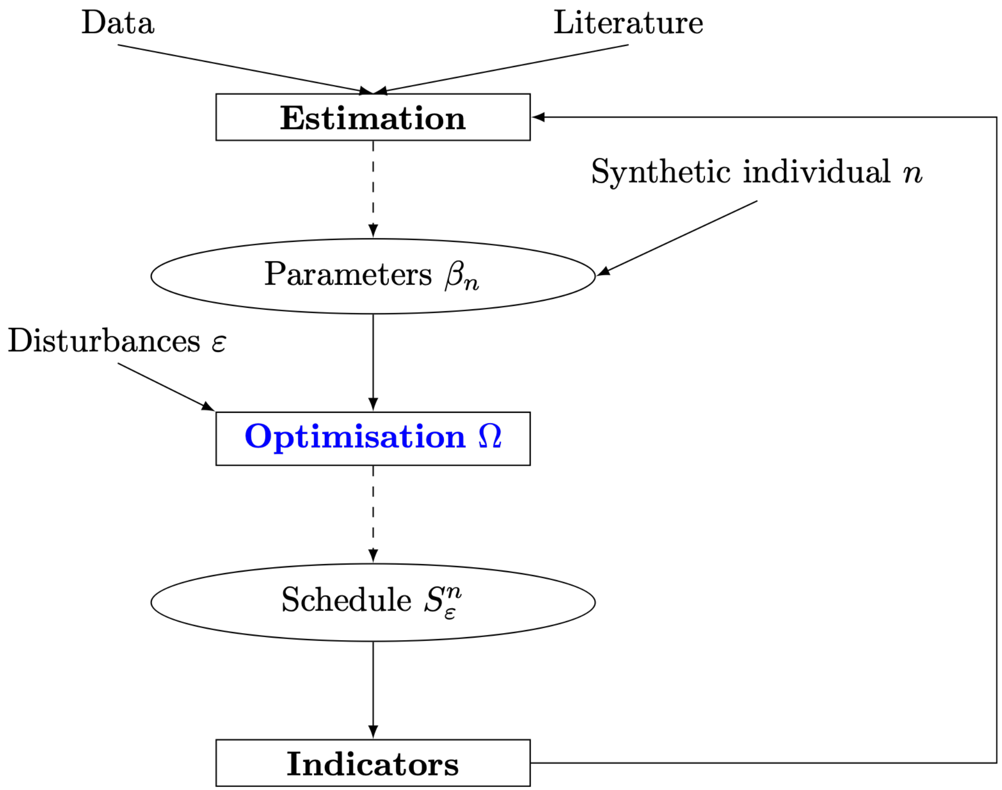
Education

Work





OASIS framework



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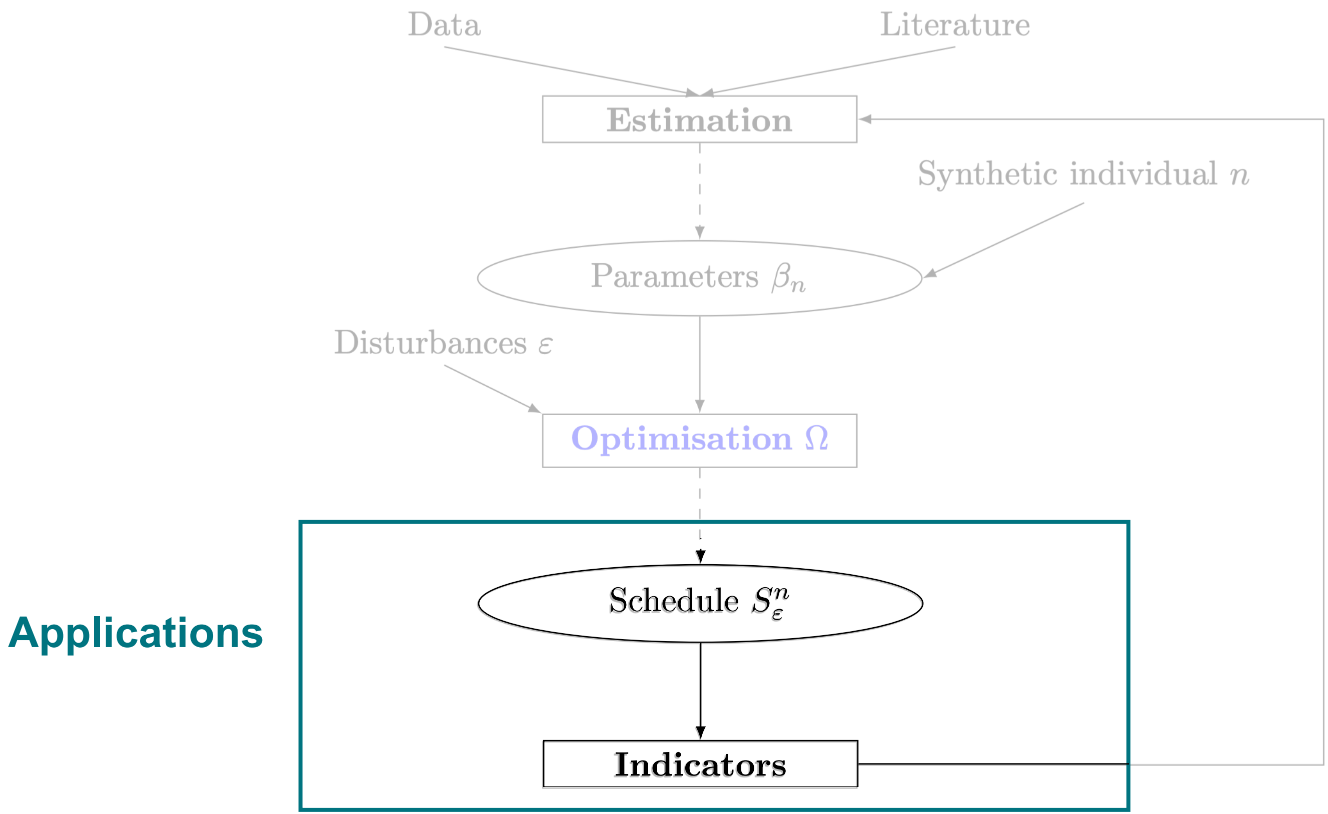


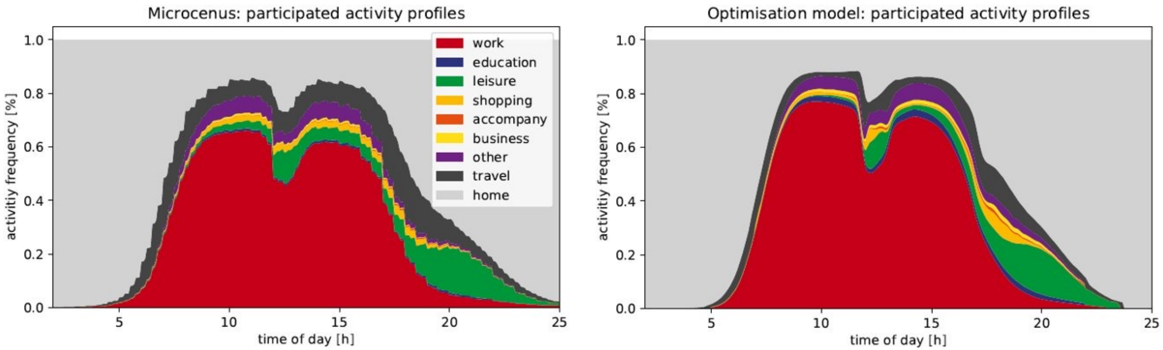
Applications

- **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)

Applications

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SBB CFF FFS

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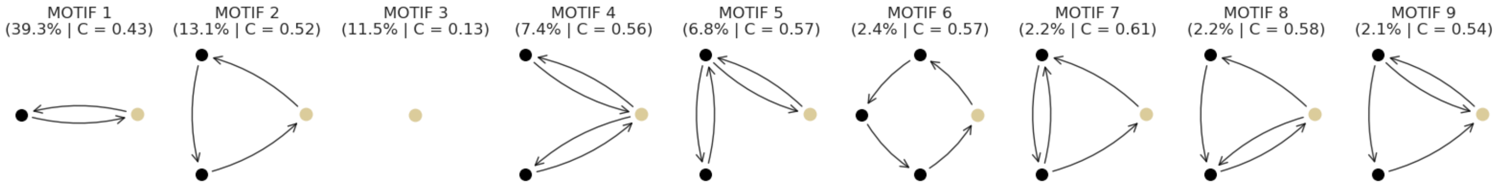
Applications

- Sociological applications (e.g. mobility motifs)
- Energy demand
- Epidemiology
- …



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:

- Validation
- Intra- and interpersonal interactions

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. (to appear). ***Estimating flexibility preferences to resolve temporal scheduling conflicts in activity-based modelling.*** Transportation (accepted for publication on Aug 22, 2022)
- 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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