OASIS: an integrated framework to simulate daily scheduling

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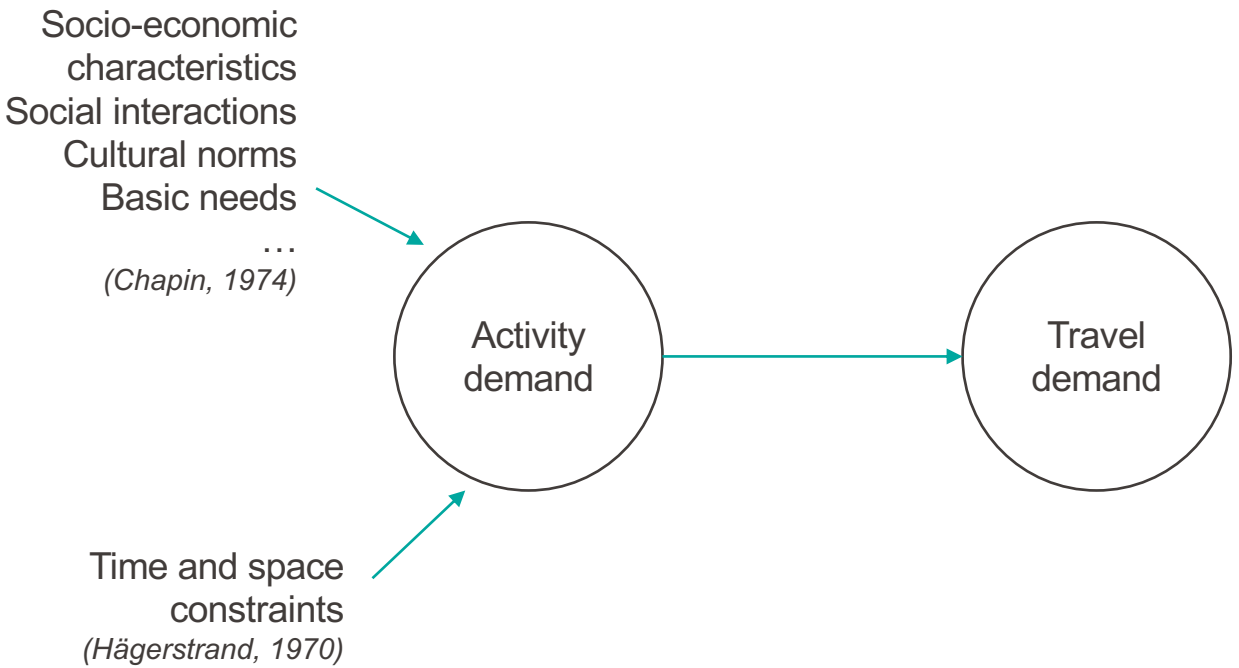
Introduction



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

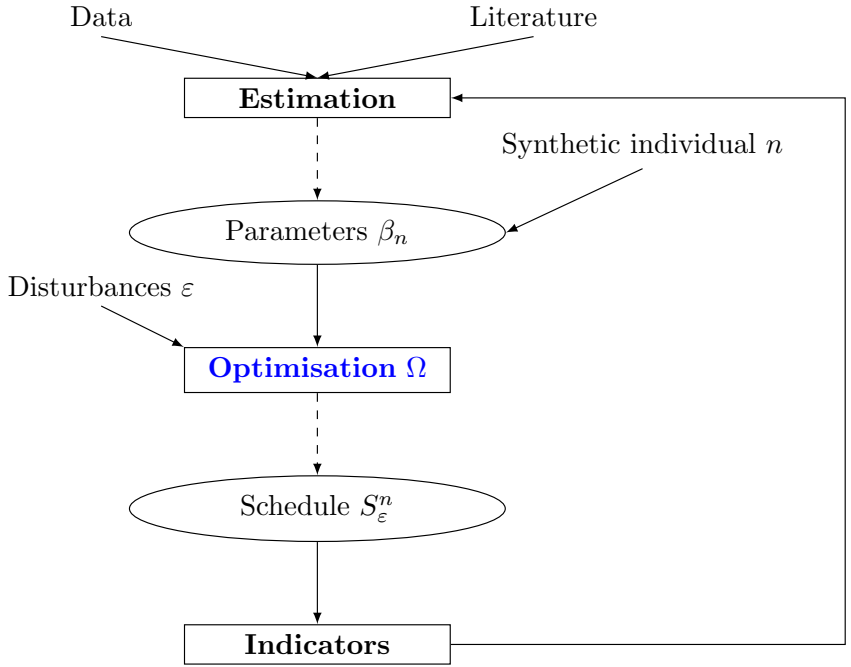
Decision is made by considering context-dependent rules

e.g.

Gollegde et al., 1994
Arentze & Timmermans 2000

OASIS framework

- Optimisation-based Activity Scheduling Integrating Simultaneous choice dimensions

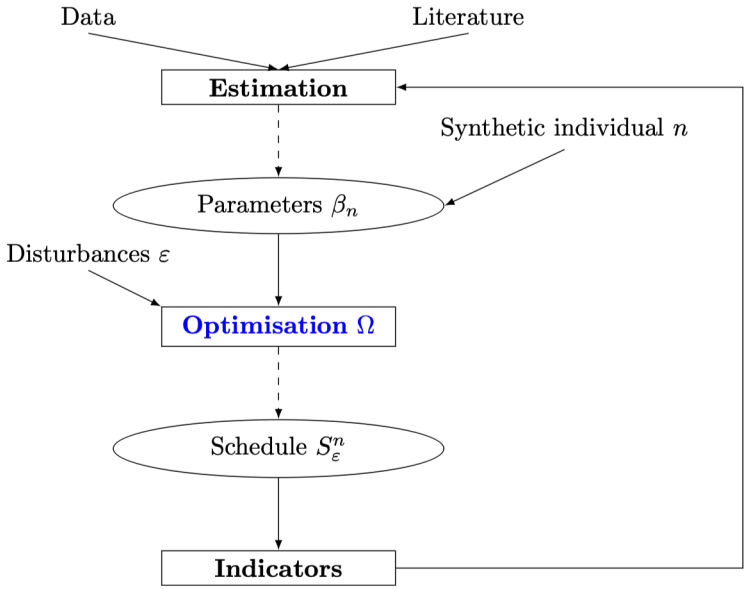


OASIS framework

- 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

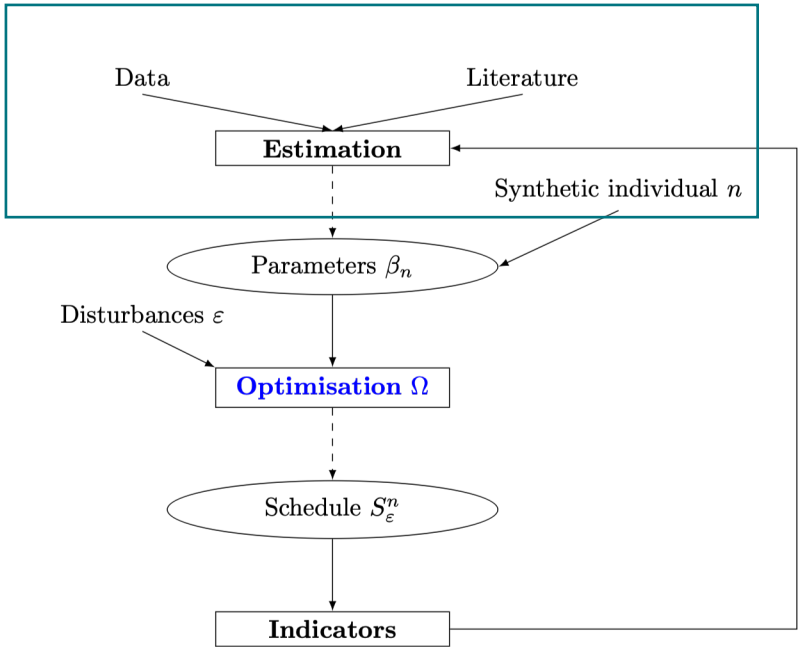
- Main components and contributions:



OASIS framework

- Main components and contributions:

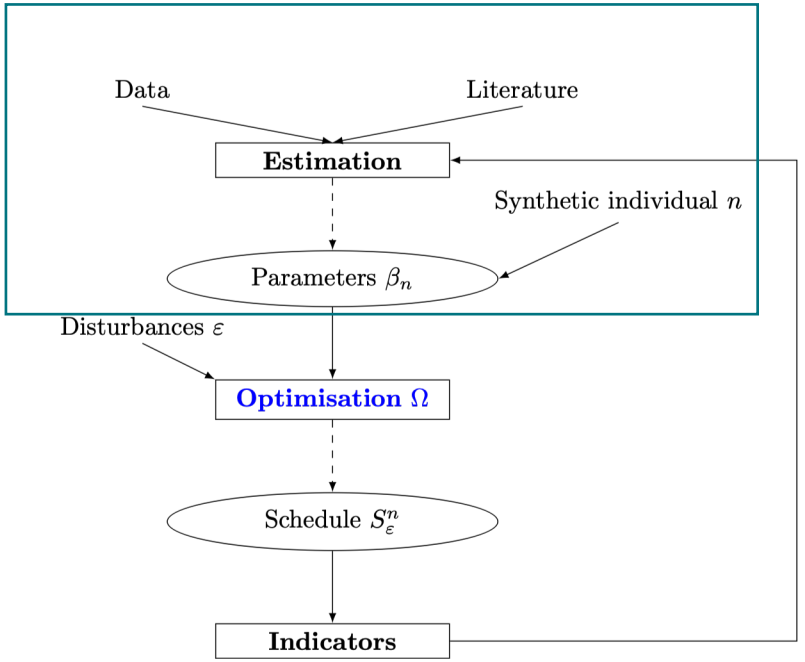
  1. Choice set generation



OASIS framework

- Main components and contributions:

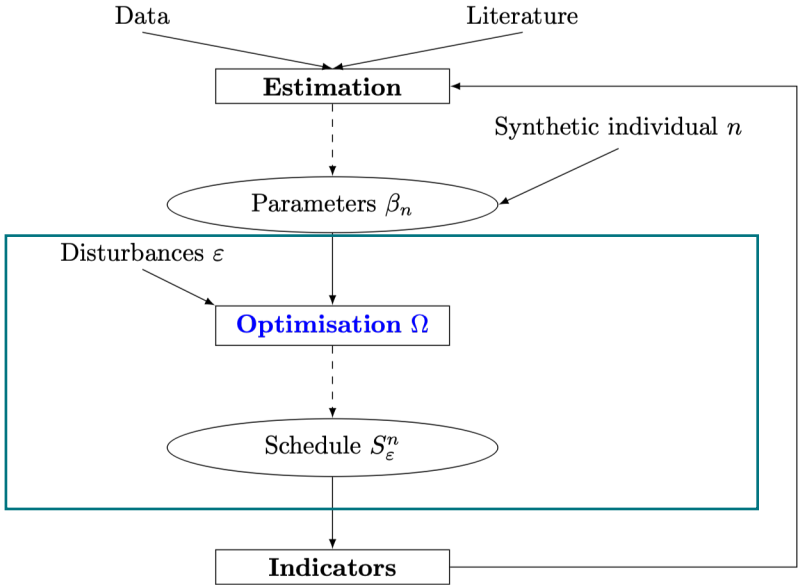
1. Choice set generation
2. Discrete choice estimation of parameters



OASIS framework

- Main components and contributions:

1. Choice set generation
2. Discrete choice estimation of parameters
3. Simultaneous estimation of scheduling choices



Choice set generation

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

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

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

Choice set generation

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

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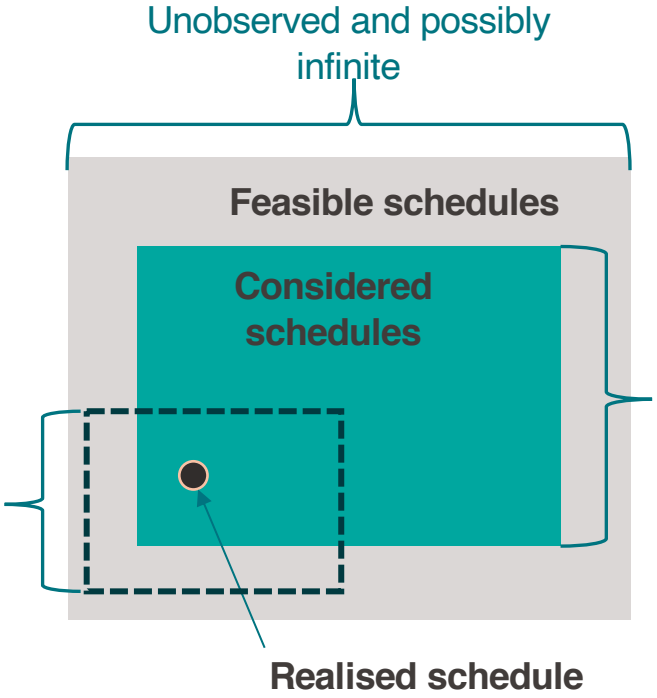
Enumeration over choice set C_n

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

Choice set generation



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

Actual choice set: Unobserved

Based on Shocker (1991)

Choice set generation

- Metropolis-Hastings sampling of feasible schedules (based on Flötterod & Bierlaire, 2013)

$t \leftarrow 0$, initialise state with random schedule $X_t \leftarrow S_0$
Initialise utility function with random parameters $\tilde{U_S}$
for $t = 1, 2, ...$ **do**
  Choose operator ω with probability P_ω
  $X^*, q(X_t, X^*) \leftarrow$ **ApplyChange**(ω, X_t)
  function APPLYCHANGE(ω, state X)
    return new state X', transition probability q(X, X')
  Compute target weight $p(X^*) = \tilde{U_S}(X^*)$
  Compute acceptance probability $\alpha(X_t, X^*) = \min\left(\frac{p(X^*)q(X_t|X^*)}{p(X_t)q(X^*|X_t)}\right)$
  With probability $\alpha(X_t, X^*)$, $X_{t+1} \leftarrow X^*$, else $X_{t+1} \leftarrow X_t$

Choice set generation

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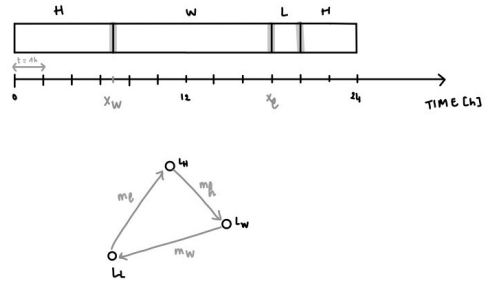
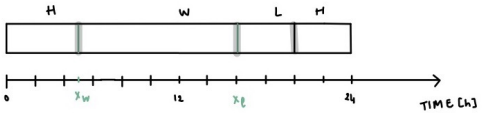
Choice set generation

- Operators (non exhaustive)

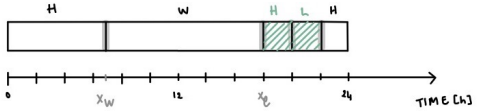
Initial state



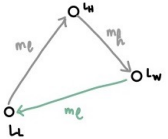
Inflate/Deflate



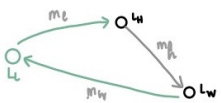
Swap



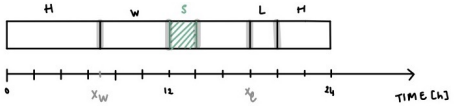
Mode



Location



Assign



Parameter estimation

- **Utility specification**

- Default OASIS utility function (Pougala et al 2022)

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

Schedule deviations

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

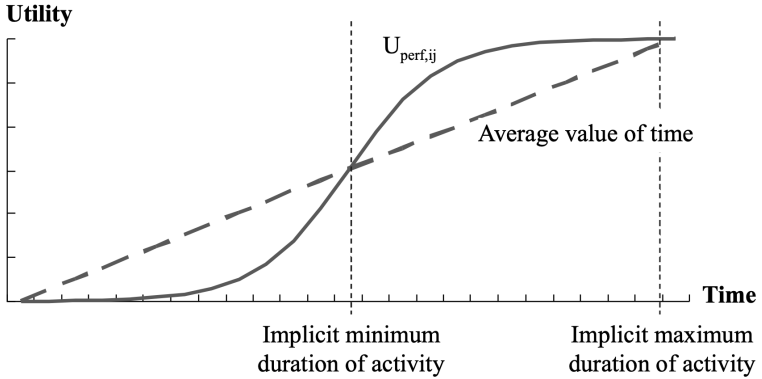
Parameter estimation

- **Utility specification**

- Utility function based on MATSIM scoring (after Feil, 2010), and PJET time of day utility (Ettema et al, 2007):

$$U_{an} = U_{perf} + U_{start\ time} + U_{duration,home}(+U_{travel}) + \varepsilon_{an}$$

$$U_{perf,i}(t_{perf,i}) = U_i^{min} + \frac{U_i^{max} - U_i^{min}}{(1 + \gamma_i \cdot exp\,[\beta_i(\alpha_i - t_{perf,i})])^{1/\gamma_i}}$$



Parameter estimation

- **Swiss Mobility and Transport Microcensus 2015** (BFS & ARE, 2017)
- **Sample**
  - Students living in Lausanne (236 individuals)
- **Choice set size**
  - N = 10 alternatives (schedules)/person
- **Considered activities:**
  - Education, Work, Leisure, Shopping, (Home)
  -

Model 1 (OASIS Generic - 12 parameters):

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

Model 2 (OASIS Specific -20 parameters):

- Activity-specific constants
- Activity specific penalties

Model 3 (S-shaped - 25 parameters):

- U_{max}, β, α estimated for duration and start time
- U_{min}, γ fixed

Parameter 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

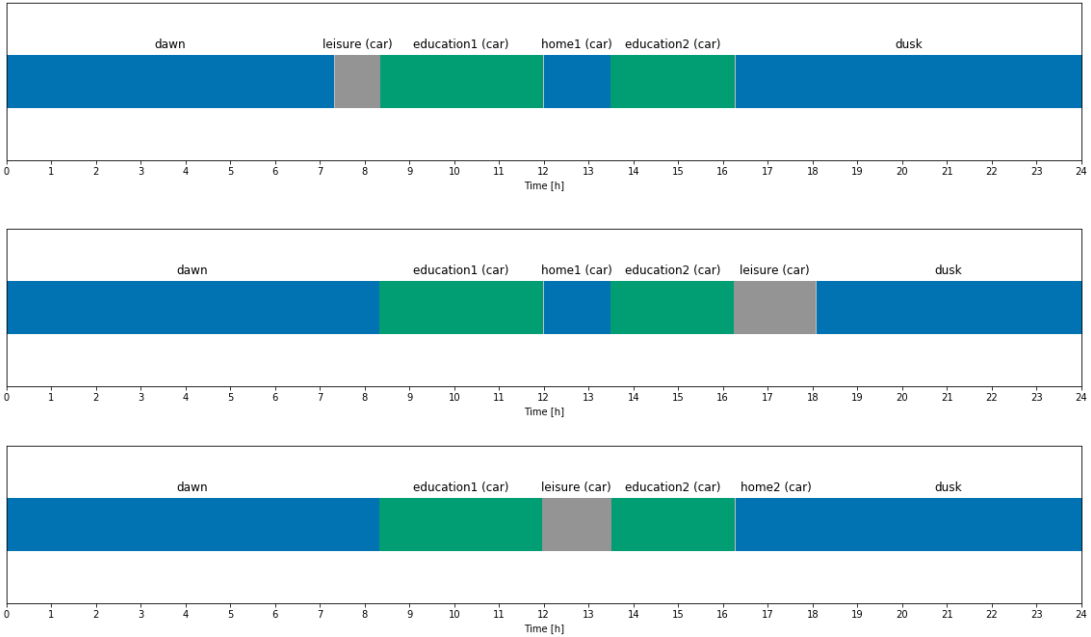
Parameter estimation

- Model 3

Name	Value	Rob. Std err	Rob. t-test	Rob. p-value
education:Umax_dur	6.07	1.38	4.4	1.11e-05
education:Umax_st	17	4.67	3.63	0.000281
education:alpha_dur	4.6	0.198	23.2	0
education:alpha_st	0.328	0.066	4.98	6.45e-07
education:beta_dur	3.77	1.37	2.75	0.00594
education:beta_st	-0.29	0.0127	-22.8	0
home:duration	0.329	0.0739	4.46	8.38e-06
leisure:Umax_dur	4.28	1.25	3.42	0.000621
leisure:Umax_st	15.3	4.6	3.33	0.000877
leisure:alpha_dur	1.12	0.0139	80.5	0
leisure:alpha_st	0.369	0.0772	4.78	1.76e-06
leisure:beta_dur	89.7	21.2	4.24	2.26e-05
leisure:beta_st	-0.169	0.0259	-6.51	7.36e-11
shopping:Umax_dur	2.16	1.34	1.62	0.106
shopping:Umax_st	12.4	4	3.09	0.00198
shopping:alpha_dur	1.98	0.000363	5.45e+03	0
shopping:alpha_st	0.35	0.101	3.46	0.000542
shopping:beta_dur	24.3	3.31	7.34	2.17e-13
shopping:beta_st	-0.192	0.0212	-9.06	0
work:Umax_dur	-14.8	8.99	-1.65	0.0993
work:Umax_st	18.5	7.78	2.37	0.0176
work:alpha_dur	1.26	1.22	1.03	0.305
work:alpha_st	0.0993	0.0905	1.1	0.273
work:beta_dur	-1.33	0.846	-1.57	0.117
work:beta_st	-0.706	0.278	-2.54	0.011

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
- Comparison of literature and OASIS estimated parameters



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Simulation

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

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

a :

Simulation

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

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

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

Simulation

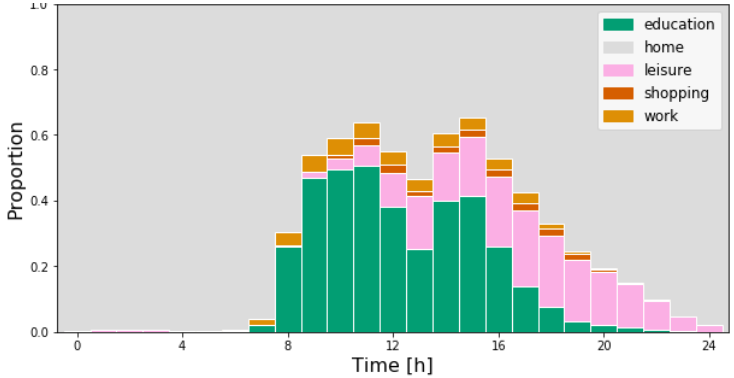
- Individuals maximise the **total utility**, subject to constraints:

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

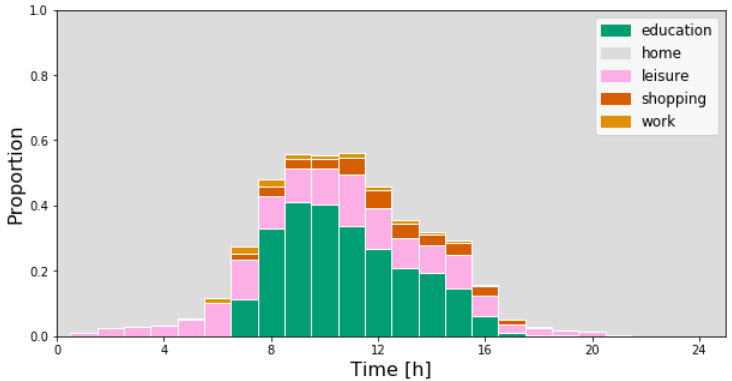
- Constraints:
  - Time budget
  - No duplicates
  - Mode consistency
  - Resource availability
  - Participation constraints
  - Sequence constraints

Simulation

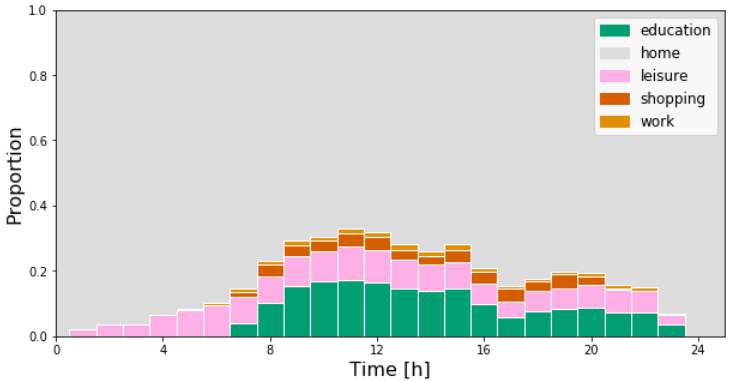
Data



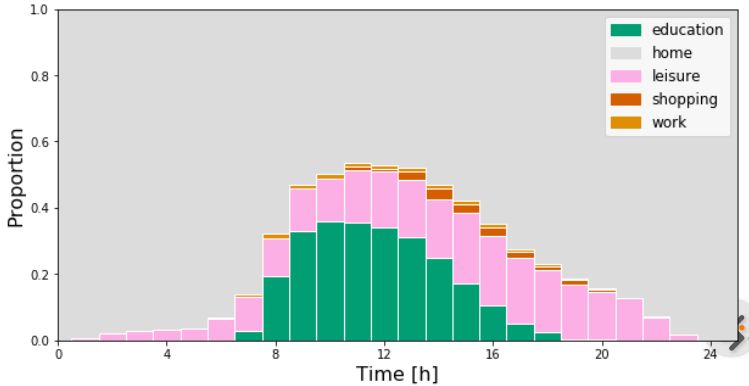
Generic



Literature

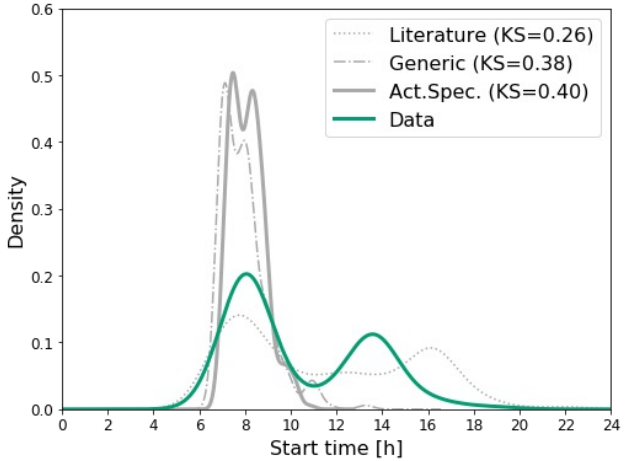


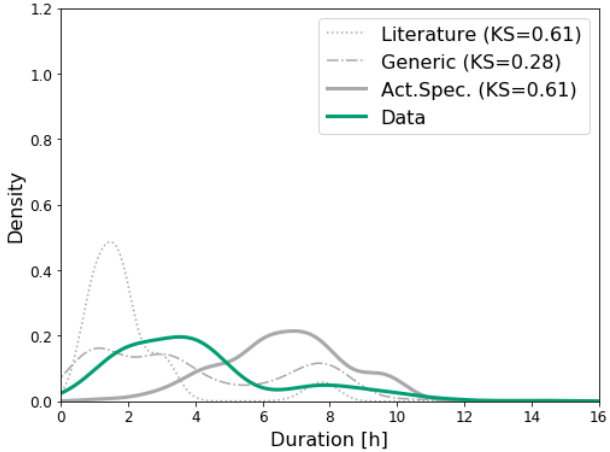
Activity-specific



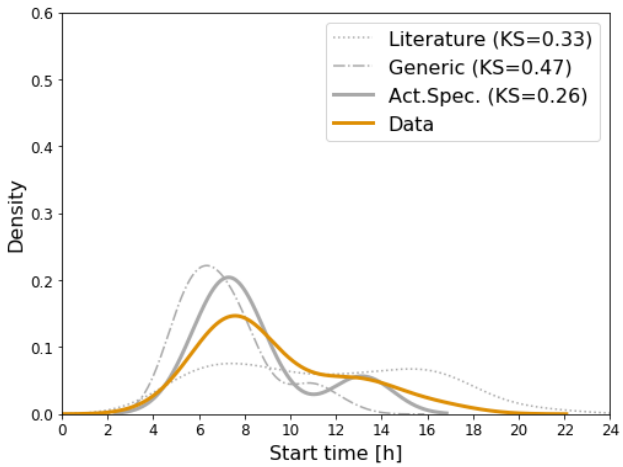
Simulation

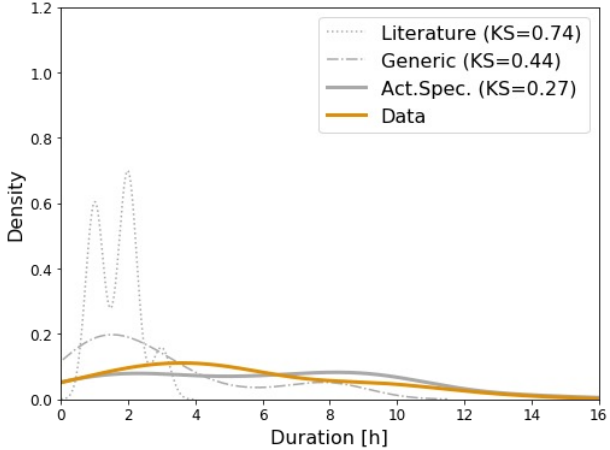
Education





Work





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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
  - Proof of concept with linear utility specification
  - Estimation of state of the art specifications

Current challenges – future work:

- Sensitivity to choice set size
- Scalability of case study
- Intra- and interpersonal interactions (N. Rezvany's PhD)

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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