Modelling the impact of activity duration on utility-based scheduling decisions

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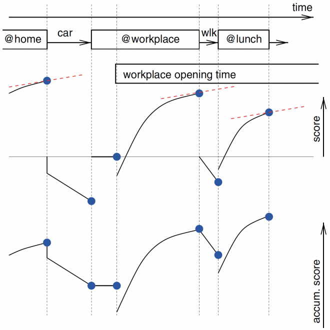
Introduction

MATSim scoring function (Nagel et al., 2016)

- Iterative process for each agent: **mobsim→scoring→replanning**
- Plans with a low score are removed from agent's choice set
- Econometric utility functions can be used to score plans



MATSim scoring function

Schedule utility (Charypar and Nagel, 2005)

$$U_S = \sum_{a=0}^{A-1} \left(U_a^{\text{act}} + U_a^{\text{travel}} \right)$$

Utility components

- Activity duration
- Start time: schedule deviations (early, late)
- Waiting time
- Travel time

MATSim scoring function

Research questions

- Estimation of (agent- and activity-specific) parameters
- Specification of utility function

```
<module name="planCalcScore" >
   <param name="performing" value="6.0" />
   <param name="waiting" value="-0.0" />
   <param name="lateArrival" value="-18.0" />
   <param name="earlyDeparture" value="-0.0" />
   <parameterset type="activityParams" >
      <param name="activityType" value="work" />
      <param name="typicalDuration" value="08:00:00" />
```

(Nagel et al., 2016)

MATSim scoring function

Research questions

- Estimation of (agent- and activity-specific) parameters
- Specification of utility function
- **Focusing on activity duration**

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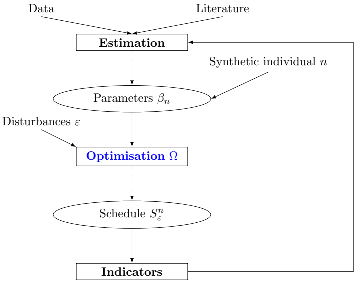
(Nagel et al., 2016)

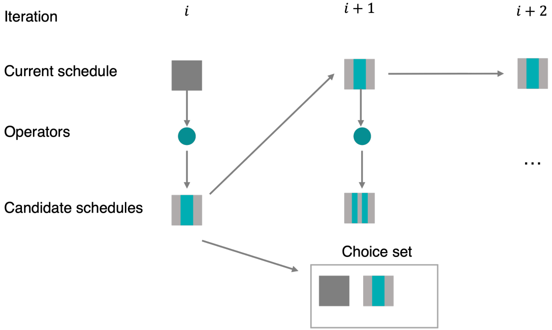
OASIS framework



- **O**ptimisation-based **A**ctivity **S**cheduling **I**ntegrating **S**imultaneous choice dimensions (Pougala et al., 2023)
    - Activity participation, scheduling, mode, location choice
    - Explicitly capture **trade-offs** between choices
    - Combine econometric and rule-based approaches: utility maximisation + constraints

Parameter estimation

1. Generate a **choice set** of feasible schedules with MH algorithm (based on Flötteröd and Bierlaire, 2013)
2. Discrete choice estimation on generated sample, with correction of likelihood function (Ben-Akiva and Lerman, 1985)



MATSim scoring function

Schedule utility (Charypar and Nagel, 2005)

$$U_S = \sum_{a=0}^{A-1} \left(U_a^{\text{duration}} + U_a^{\text{start time}} + U_a^{\text{travel}} \right)$$

Duration

$$U_a^{\text{duration}} = \max \left[0, \beta_{\text{act}} \tau_a^* \ln \left(\frac{\tau_a}{\tau_a^* \exp(-A/(\rho \tau_a^*))} \right) \right] + \beta_a^{\text{short}} \delta_a^{\text{short}}$$

Assumptions

- Log of duration
- Start time: schedule deviations (early, late)
- τ_a^*: typical duration
- ρ: activity priority term

OASIS utility function

Schedule utility

$$U_S = U + \sum_{a=0}^{A-1} \left(U_a^{\text{participation}} + U_a^{\text{start time}} + U_a^{\text{duration}} + \sum_{b=0}^{A-1} U_{a,b}^{\text{travel}} \right)$$

Duration (resp. start time)

$$U_a^{\text{duration}} = \theta_a^{\text{short}} \max(0, \tau_a^* - \tau_a) + \theta_a^{\text{long}} \max(0, \tau_a - \tau_a^*) + \varepsilon_{\text{duration}}$$

Assumptions

- τ_a^*: desired duration (point or interval)
- Linear-in-parameters influence of duration
- Asymmetric penalty parameters

MATSim scoring - modified (PlanomatX)

Schedule utility (Feil, 2010)

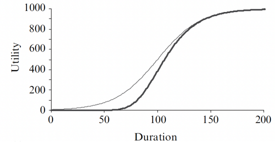
$$U_S = \sum_{a=0}^{A-1} \left(U_a^{\text{duration}} + U^{\text{travel}} \right)$$

Duration

$$U_a^{\text{duration}} = U_a^{\text{min}} + \frac{U_a^{\text{max}} - U_a^{\text{min}}}{\left(1 + \gamma_a \exp \beta_a \left[\alpha_a - \tau_a\right]\right)^{1/\gamma_a}}$$

Assumptions

- S-shape (Joh et al., 2005)
- No start time!



Empirical investigation

1. Estimate the parameters on a given sample
2. Compare simulation outputs for each specification

Case study

- MTMC 2015 (BFS and ARE, 2017): Swiss nationwide travel survey
- Sample of Lausanne **students** (236 individuals)
- 5 activities: education, work, leisure, shopping, (home)

Parameters

MATSim

Parameter	Param. estimate	Rob. std err	Rob. t-stat	Rob. p-value
β_{act}	0.0514	0.00974	5.27	1.34e-07
Education: early	-1.6	0.449	-3.57	0.00036
Education: late	-1.01	0.291	-3.48	0.00051
Leisure: late	-0.467	0.122	-3.84	0.00012
Shopping: early	-0.476	0.119	-4.01	6.04e-05
Shopping: late	-0.293	0.0842	-3.48	0.00049
Work: early	-2.75	0.712	-3.87	0.000111
Work: short	-1.59	0.493	-3.22	0.00126

Summary statistics

$L(0) = -593.8925$

$L(\hat{\beta}) = -248.568$

$\bar{\rho}^2 = 0.56$

- Significant parameters (reference = home)
- Priority across activities (education, work > leisure, shopping)

Parameters

OASIS

Parameter	Param. estimate	Rob. std err	Rob. t-stat	Rob. p-value
Education: ASC	7.62	1.26	6.04	1.55e-09
Education: early	-1.15	0.282	-4.07	4.62e-09
Education: late	-0.89	0.214	-4.15	3.28e-05
Education: short	-0.452	0.23	-1.97	0.0493
Leisure: ASC	5.02	0.679	7.38	1.57e-13
Leisure: late	-0.747	0.135	-5.54	3.1e-08
Leisure: long	-0.137	0.0497	-2.75	0.00593
Shopping: ASC	5.04	0.807	6.25	4.07e-10
Shopping: early	-0.652	0.144	-4.53	5.88e-06
Shopping: late	-0.534	0.0944	-5.65	1.57e-08
Shopping: long	-0.17	0.06	-2.84	0.00456
Work: ASC	4.34	1.53	2.84	0.00448
Work: early	-0.71	0.223	-3.19	0.00145
Work: short	-1.37	0.481	-2.86	0.00423

Summary statistics
$L(0) = -454.1869$
$L(\hat{\beta}) = -152.0466$
$\bar{\rho}^2 = 0.621$

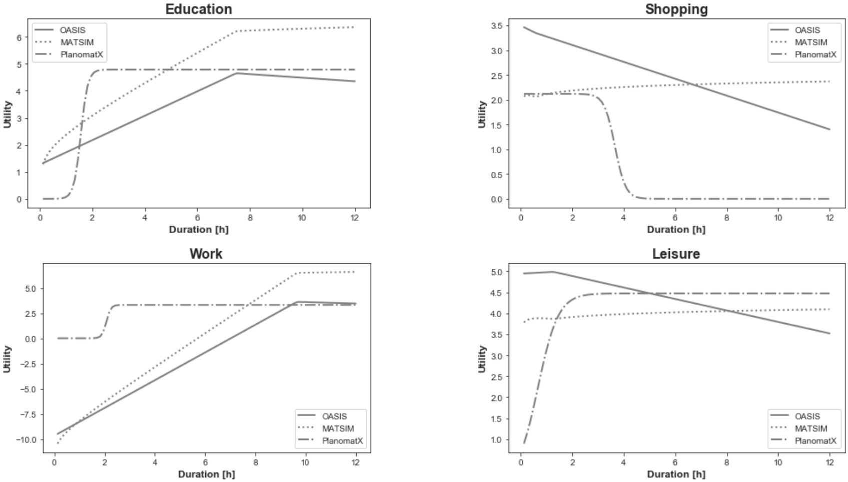
PlanotmatX

Parameter	Param. estimate	Rob. std err	Rob. t-stat	Rob. p-value
Education: $U^{\max}$	4.79	0.443	10.8	0.00
Education: α	1.57	0.202	7.75	9.1e-15
Education: β	7.56	4.84	1.56	0.119
Leisure: $U^{\max}$	4.47	0.379	4.50	9.1e-15
Leisure: α	0.668	0.213	3.13	0.00172
Leisure: β	2.53	0.686	3.69	0.000225
Shopping: $U^{\max}$	2.12	0.333	6.36	2.04e-10
Shopping: α	3.66	0.975	3.75	0.000175
Shopping: β	-4.85	2.3	-2.1	0.0353
Work: $U^{\max}$	3.31	0.637	5.19	2.08e-07
Work: α	2.07	0.0459	45.	0.00
Work: β	11.5	0.792	14.5	0.00

Summary statistics
$L(0) = -454.1869$
$L(\hat{\beta}) = -187.871$
$\bar{\rho}^2 = 0.56$

- Significant parameters

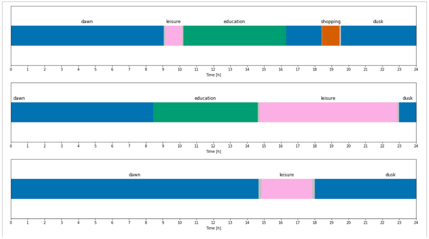
Utility of duration per activity



Schedule simulation

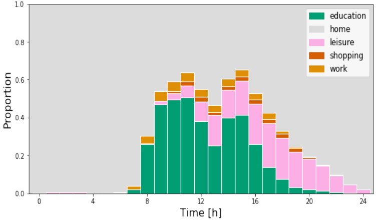
Algorithm

1. Initialise n, β_n, A_n, M_n, L_n
2. For $r = 1, 2, ..., R$
    1. Draw ε^r_S from distribution of error terms.
    2. Draw schedule S^r_n by solving $\Omega = \max U_S(X_n, \beta_n, \varepsilon^r_S)$ s.t. constraints

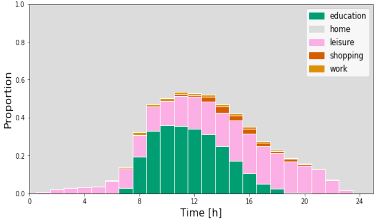


Simulation outputs (100 schedules / individual)

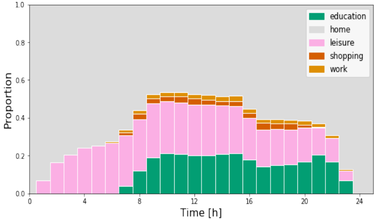
Data



OASIS



PlanotmatX



Conclusion

Summary

- Estimated parameters of activity-based utility functions
- Tested different specifications of duration component

Further work

- New case study (e-bike city project)
  - Estimating travel parameters: PostCarWorld (Schmid et al., 2019)
  - Simulations with MATSim
- Specification:
  - Including socio-demographic characteristics, latent behaviour
  - Other influences?

Thank you!

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OASIS

Code

Paper

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