EPFL

hEART 2022

10th Symposium of the European Association for Research in Transportation

1-3 JUNE 2022
LEUVEN, BELGIUM

A utility optimization-based framework for joint in- and out-of-home scheduling

Negar Rezvany

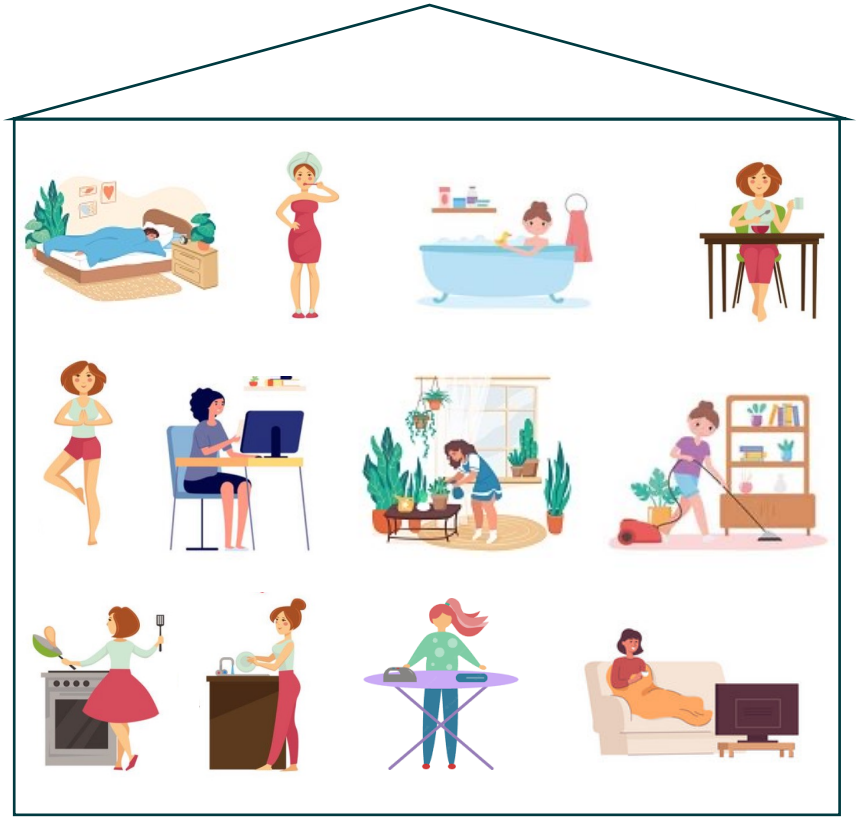
Tim Hillel

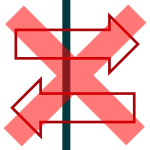
Michel Bierlaire

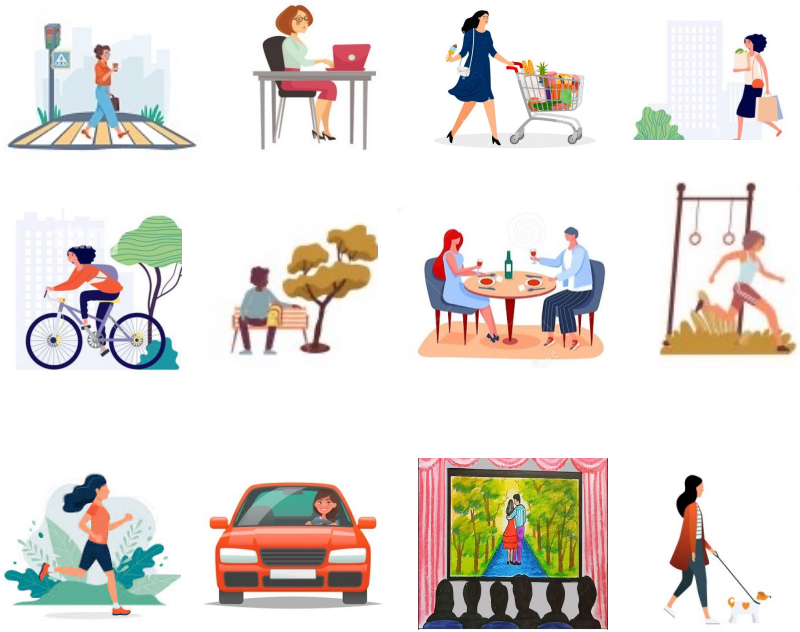
Outline

- **Introduction and motivation**
  - Why is studying activity scheduling throughout the day important?
- **Current literature and limitations**
  - What are the current research streams in activity-based modeling?
- **Model framework**
  - What are the differences between scheduling activities in-home and out-of-home?
- **Empirical investigation**
- **Results**
- **Further research**

Introduction







Introduction

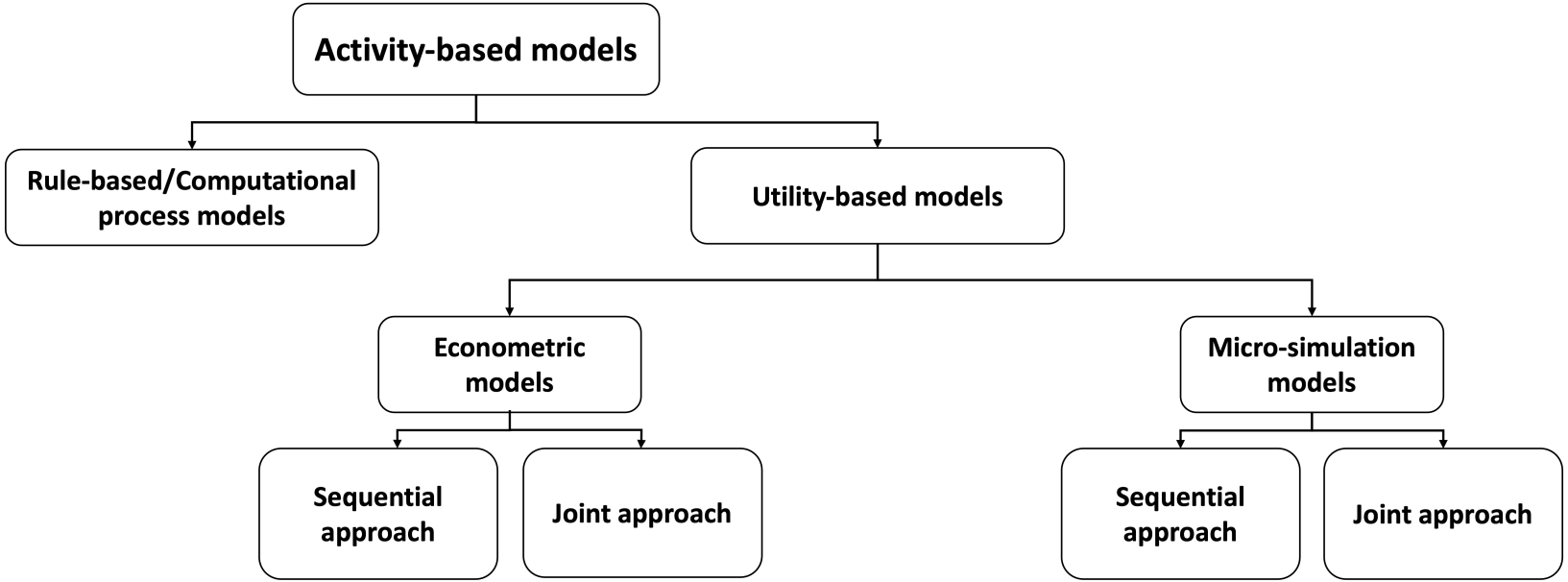
Motivation and possible applications
Why is studying activity scheduling throughout the day important?

1. It allows modellers to capture the **trade-offs and interactions** between in-home and out-of-home activities
   - Squeezing in-home activities when spending more time on out-of-home activities
   - Deciding where to do different activities; at home or at an out-of-home location; based on the schedule of the whole day

2. This modeling approach can contribute to **demand side management**
   - Energy and transport demand can both be considered as being derived from an individual's activity participation
   - Activity scheduling is the connecting element between transportation and energy simulation
   - Time-use pattern inside home can be used to predict building energy demand at high temporal resolution

Major research streams in Activity-based models

What are the current research streams in activity-based modeling?



Limitations of the current models

- **Methodological:**
  - Empirical rule-based or randomized process to determine individuals' activity scheduling
    - Hard-coded and cannot be generalised to situations not seen in the data
    - Do not represent the nature of scheduling process and cannot capture complex trade-offs and household interaction

- **Contextual:**
  - The current approaches to simulate the activity patterns focus on either time-use in home or out-of-home activities and **not both**
    - Thus, the interactions between in- and out-of-home activities (e.g., squeezing in-home activities when spending more time on out-of-home activities) are not considered

Utility-based optimisation model (*Pougala et al., 2022)*

ω_{in}: indicate activity participation (0/1)

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

Activity *i*

Individual *n*

- In order to address these shortcomings, *Pougala et al. (2021)* proposes a new scheduling framework:
  - Utility-based approach based on first behavioral principles
  - Mixed-integer optimization model to generate a distribution of likely schedules *for each individual*
  - Treats *individuals* as *utility maximizers,* maximising the sum of the utilities of completed activities in a schedule over a fixed time budget
  - Incorporates *simultaneous estimation* of multiple scheduling decisions such as activity participation, and activity scheduling (start time, duration, sequence)
  - **Output:** a feasible schedule
  - **Major advantages:** high level of flexibility, explicit constraints, simultaneous estimation of scheduling decisions
  - **Possible gaps for extension:**
    - the framework has been investigated only for studying the out-of-home activity scheduling (developed for transportation models) → the resulting schedules do not contain any information on activities performed at home

Formulation (*Pougala et al., 2022*)

- Utility of a schedule: $\mathrm{U_n} = \sum_i \omega_{in} U_{in}$
  - For an individual n considering an activity i with a flexibility k:

$$U_{in} = U_{const} + \boxed{U_{early} + U_{late}} + \boxed{U_{long} + U_{short}} + \boxed{U_{travel}} + \varepsilon_{in}$$

Start time deviations:

$$U_{early} = \boldsymbol{\theta_{ek}} \max(0, \boldsymbol{x_i^*} - x_i)$$
$$U_{late} = \boldsymbol{\theta_{lk}} \max(0, x_i - \boldsymbol{x_i^*})$$

Duration deviations:

$$U_{short} = \boldsymbol{\theta_{dsk}} \max(0, \boldsymbol{\tau_i^*} - \tau_i)$$
$$U_{long} = \boldsymbol{\theta_{dlk}} \max(0, \tau_i - \boldsymbol{\tau_i^*})$$

Disutility of travelling:

$$U_{travel} = \boldsymbol{\theta_t}\, \boldsymbol{t_i}$$

Model framework

ω_{in}: indicate activity participation (0/1)

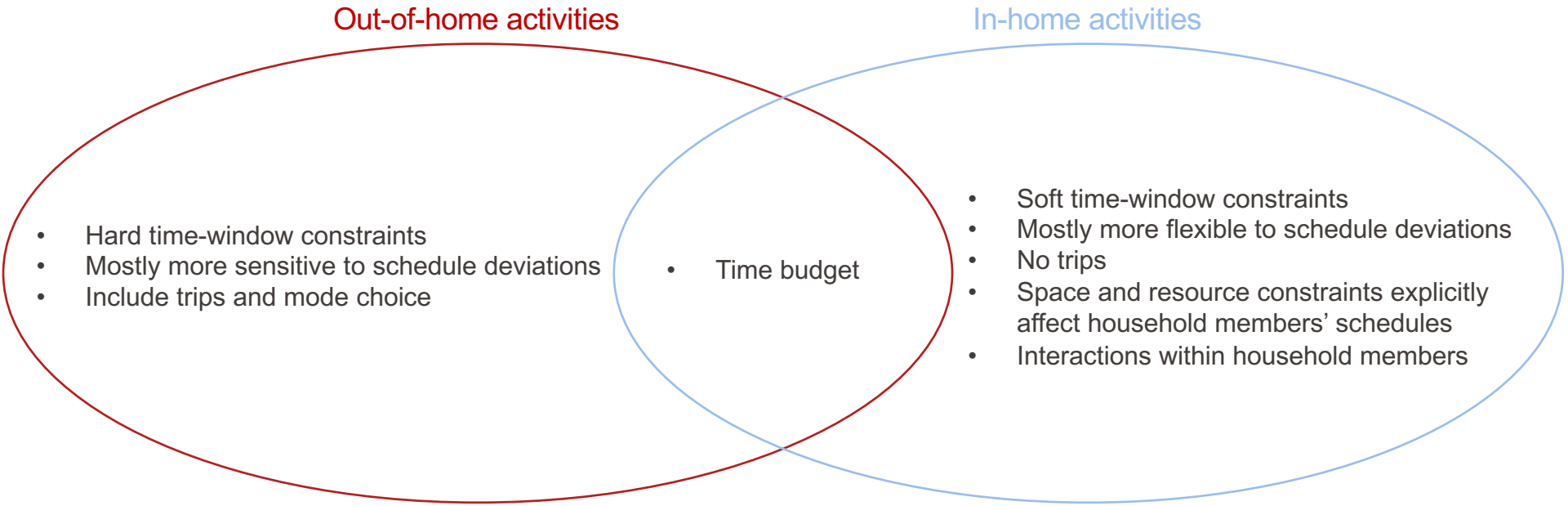
$$\Omega_n = max \sum_i \omega_{in} U_{in}$$

Activity *i*

Individual *n*

- Build on the scheduling model developed by *Pougala et al. (2021)*
- Extend the framework to:
  - Incorporate joint modelling of time-use in the home alongside activities outside the home
  - Incorporates simultaneous estimation of choice of activity location as well as other scheduling decisions

What are the differences between scheduling activities in-home and out-of-home?



Empirical investigation

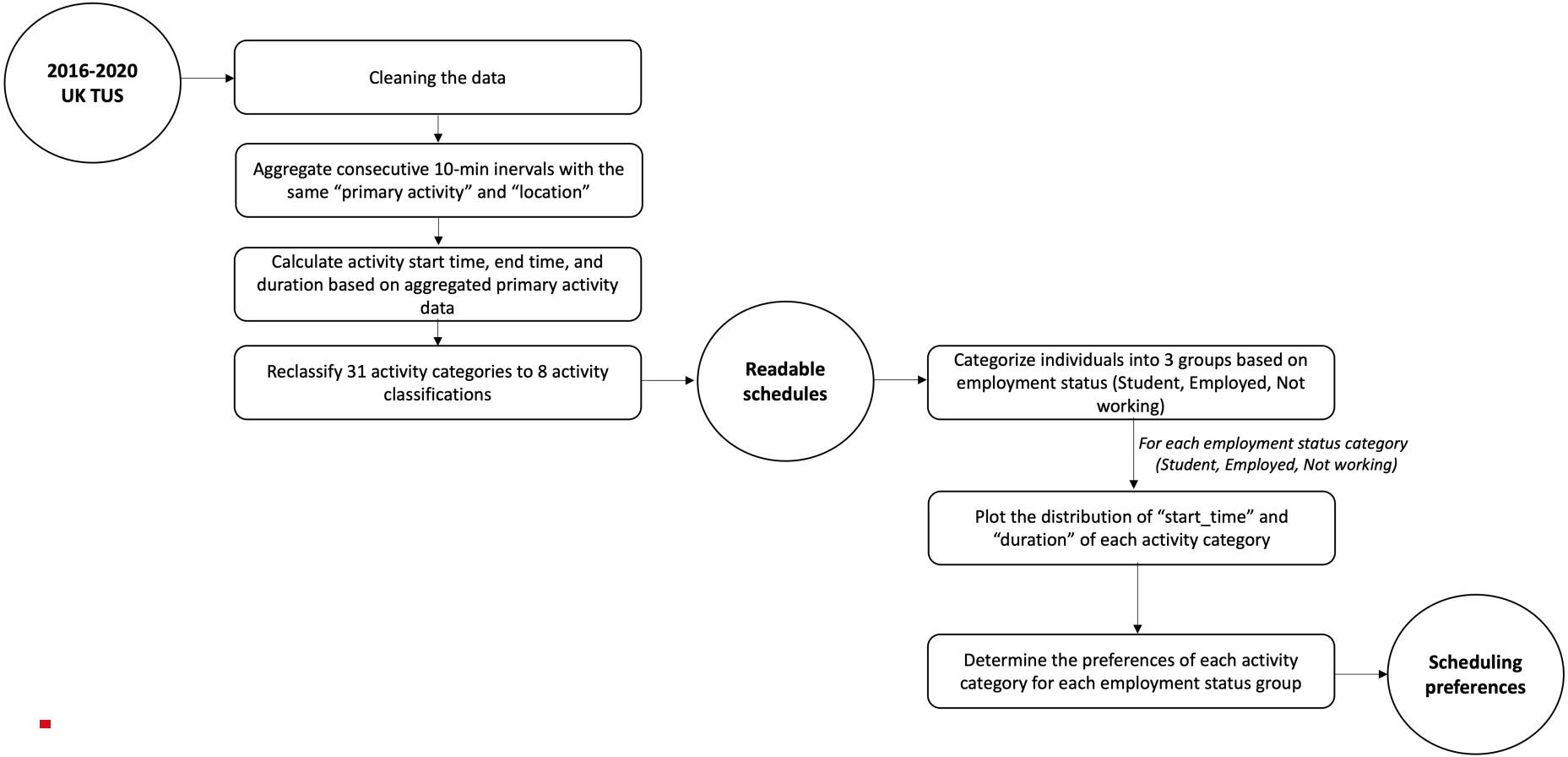
Dataset

CaDDI* survey: 2016-2020 UK TUS (Gershuny & Sullivan, 2021)

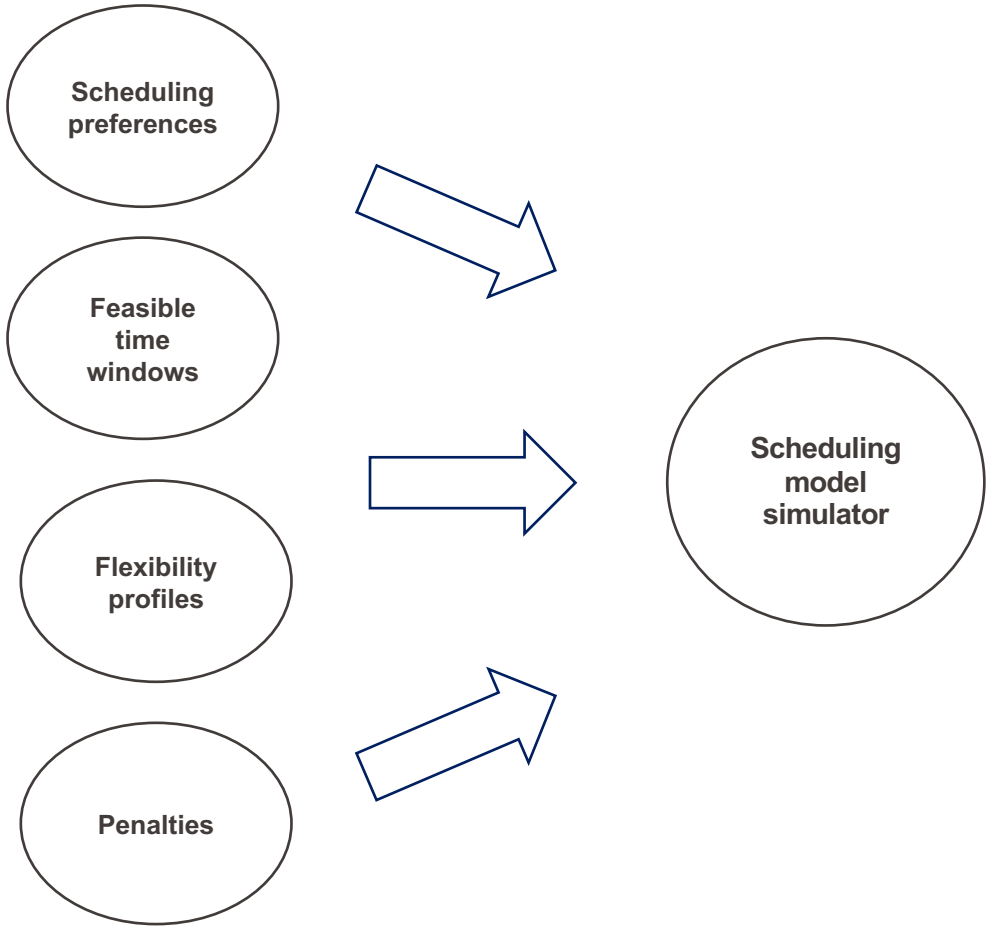
- A sequence of **online** time-use diary surveys in the UK
- **4'360** diaries from **2'202** individuals across 4 waves
- ***4 waves*** (2016 & late May-June, August, November 2020)
- Contains **1 to 3** time-use diaries per respondent (include 1 weekday and 1 weekend day)
- Includes information on **socio-demographic** variables, **activities**, **location**, **enjoyment**, and **co-presence**

* Click and drag diary

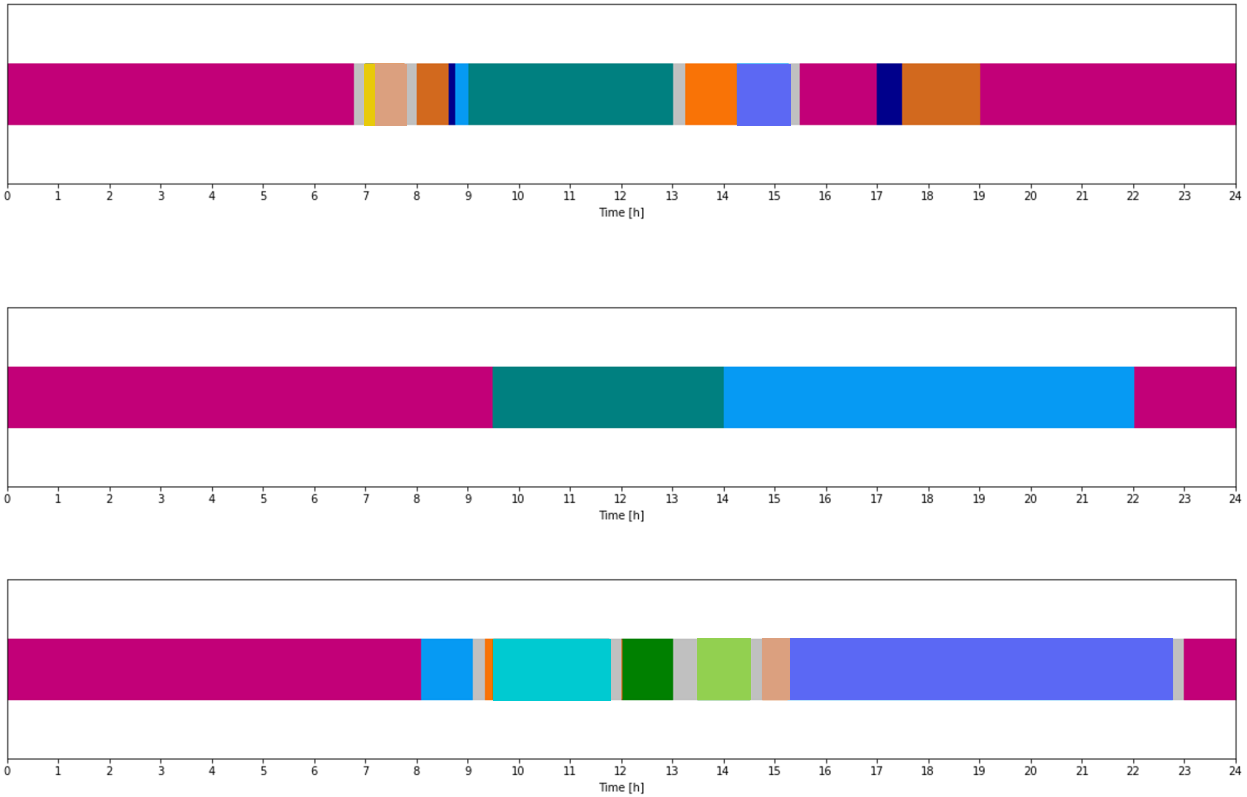
Data pre-process



Scheduling model



Some results:
Student (weekday)



Further model extensions

- One major opportunity to extend the current scheduling approach is to investigate the **household interaction effects** and **interpersonal dependencies.**

- **What are the inter-household interactions?**

Further model extensions

- One major opportunity to extend the current scheduling approach is to investigate the **household interaction effects** and **interpersonal dependencies.**

- **What are the inter-household interactions?**
  - Car availability limitation
  - Resource constraints
  - Sharing household maintenance responsibilities by family members
  - Joint participation of household members in maintenance and leisure activities
  - Sharing common household vehicles
  - Facilitation of activity participation of household members with restricted mobility by undertaking pick-up and drop-off trips (escorting)
  - Coordination of daily rhythms between partners

Further model extensions

- How can we capture the inter-household interactions?

Further model extensions

- **How can we capture the inter-household interactions?**

1. Considers the activity scheduling at the level of **household** (group decision model); rather than at the level of isolated individuals (individual model)

$$\Omega = \max \sum_{n} \sum_{i} \omega_{i_n} U_{i_n}$$

Individual n Activity i

2. Capture **interactions**
   - Terms in utility (altruism, companionship, efficiency, coordination costs)
   - constraints

3. Capture **resource constraints**

$$\sum_{n} \omega(t)_{in} r_m \leq C_m \qquad \forall t \in [0, period], \forall m$$

Activity participation (0/1) at time t

Resource m

Conclusions

- Motivation for joint in- and out-of-home activities scheduling
- How to incorporate time-use for activities in-home
- Adapted the utility-optimization based model to jointly model in-home activities as well as the out-of-home activities wthin the same framework
- The results show that the model is able to generate generic individuals' activity schedules
- Further extensions within the concept of the framework

References

- Gershuny, J. and O. Sullivan (2021) United Kingdom Time Use Survey Sequence Pre and During COVID-19 Social Restrictions.
- Pougala J., Hillel T., Bierlaire M. (2022). Capturing trade-offs between daily scheduling choices. Journal of Choice Modelling 43 (100354).

Thank you!

negar.rezvany@epfl.ch

École
polytechnique
fédérale
de Lausanne