Integrated models of transport and energy demand

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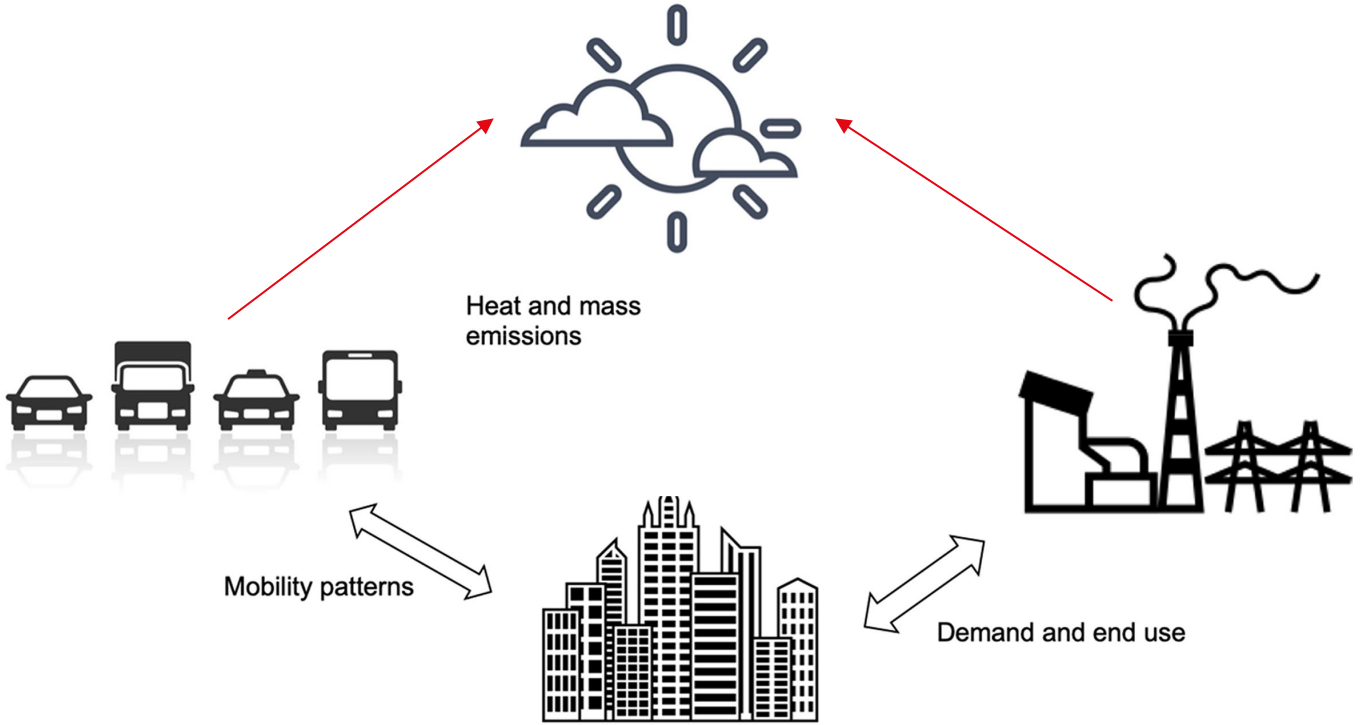
Outline

- Motivation and Introduction
- Research questions
- Literature review and limitations
- General framework
- State of research
- Results
- Further research

Motivation

- Common element: behavior



Introduction

- **Question:**
  - How can we jointly model **energy** and **transportation** demand from **behavioral first principles**?
- **Proposed solution:**
  - **Activity-based** approach to model complex **individual** behaviors
    - Capture relationships between **participations in various activities**.
    - Model high-level demand as the result of the **interactions** of multiple agents.
    - Can represent **complex behaviors** within a city or region to test more flexible scenarios and policies.

Research questions

1. What are the essential **components** to integrate **transport** and **energy** demand models?
   - General framework
2. How to incorporate **in-home** and **out-of-home** activity scheduling in a **single model**?
   - Scheduling (in/out-of-home activities) model based on first-principles
3. How to **operationalize** integrated simulation of transportation and energy demand?
   - Incorporating the proposed scheduling model for simulation of agent-based energy model
4. How to account for wider **interactions and correlations** that affect individuals' activity scheduling?
   - Extending the daily scheduling model to account for interactions and correlations; inter-household interactions/ day-to-day scheduling correlations.

Research Plan

- **WP1**: Problem definition
- **WP2**: Daily scheduling model (joint in- and out-of-home activities)
- **WP3**: Model application and scenario-testing
- **WP4**: Extended scheduling model with interactions

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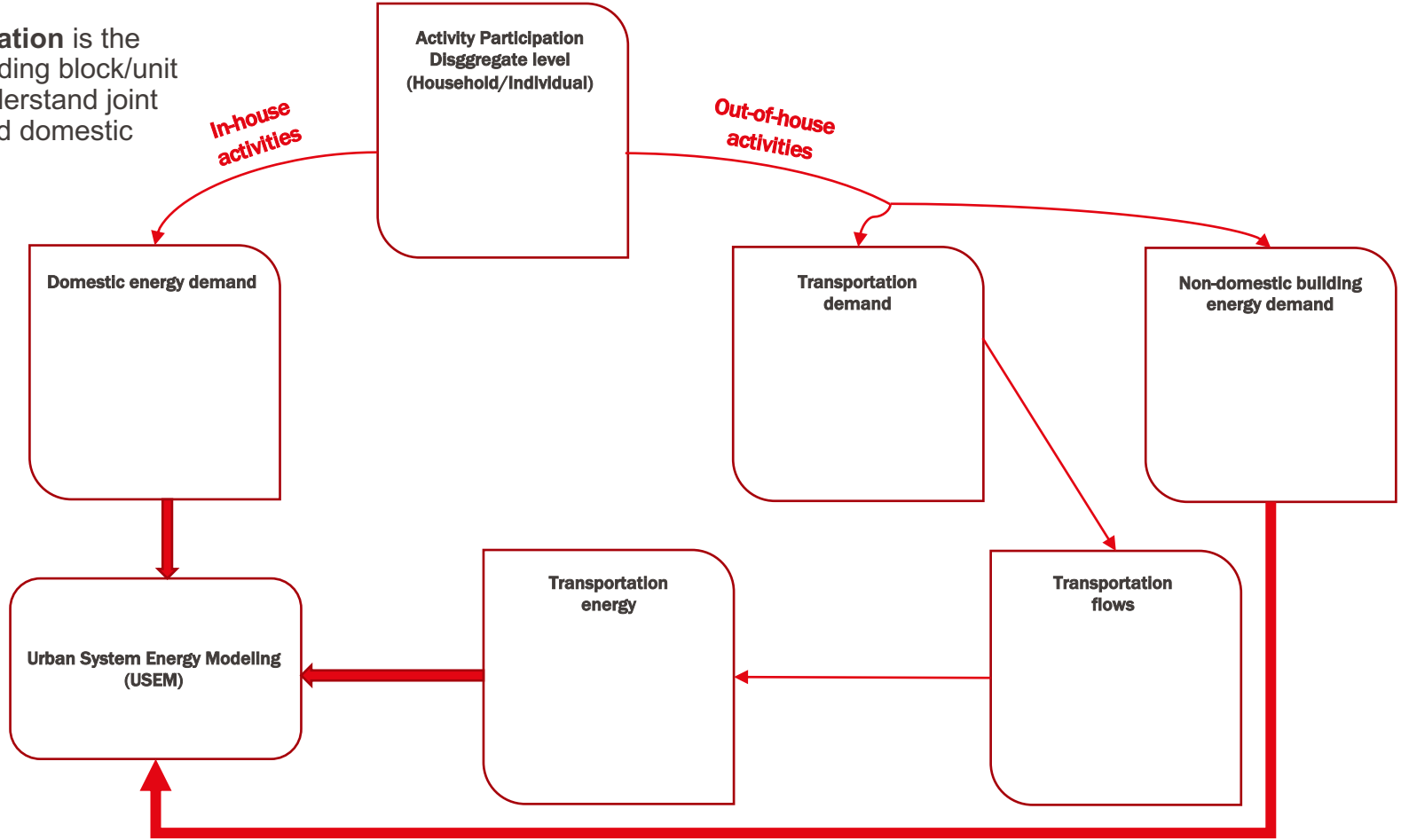
Research plan
WP1: Problem definition

This workpackage aims to answer research question 1, i.e. “What are the essential **components** to integrate **transport** and **energy** demand models?”.

- Literature review on transportation and energy demand modelling
- Establish the state-of-research in transport and energy demand modelling
- Identify suitable approach for joining the two domains
- General framework

Framework

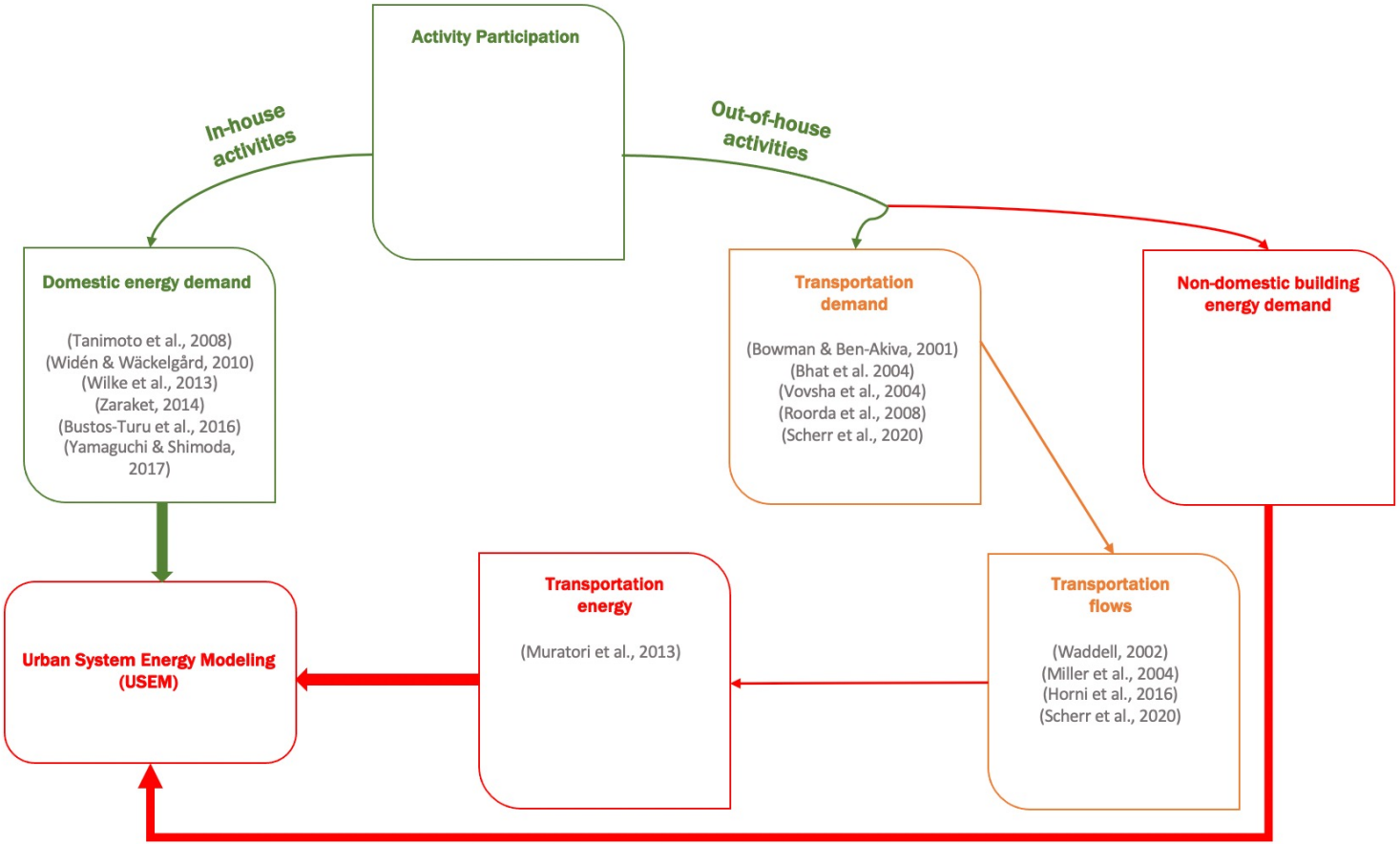
- **Activity participation** is the fundamental ‘building block/unit of analysis to understand joint transportation and domestic energy



Literature review

- What approaches have been used to (independently) model transportation and building energy demand?
- How have the links between in-house and transportation energy demand been analyzed in the literature?
- To what extent has activity-based modeling been applied to analyze urban-scale energy demand?

Current state of research



Limitations of the current models

- **Contextual:**
  - Transportation and energy demand has not been considered in a single framework together
  - The human behavior element is frequently neglected in the energy demand literature
  - 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
- **Methodological:**
  - Empirical rule-based or randomized sequential 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

Key advantages of the proposed framework

1. Integrates the **human behavior** to the models by including **activity scheduling** in the core → Can be generalized to **complex** scheduling and mobility situations
2. Captures the **trade-offs** between in-home and out-of-home activities → Captures their corresponding **energy demand**
3. Provides a **detailed** activity scheduling as an **input** to building energy demand simulators rather than using building occupancy profiles → **Address** the limitations of occupancy-based models in which **behavior of individuals is lost**
4. Based on the **activity-based modeling paradigm** → A significant **new opportunity** for the development of **bottom-up urban energy demand models** (Sola et al. 2020)
5. Based on **a bottom-up** approach → Suitable for **future scenario** testing

Research Plan

- **WP1**: Problem definition
- **WP2**: Daily scheduling model (joint in- and out-of-home activities)
- **WP3**: Model application and scenario-testing
- **WP4**: Extended scheduling model with interactions

A day in life of Americans (source: FlowingData)

4:02am

SLOW | MEDIUM | FAST

The simulation kicks in, based on data from the American Time Use Survey.

This is a simulation of 1,000 people's average day. It's based on 2014 data from the American Time Use Survey, made way more accessible by the ATUS Extract Builder.

Scheduling framework

ω_{in}: activity participation (1/0)

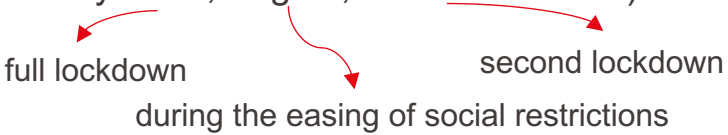
$$\Omega_n = max \sum_i \omega_{in} U_{in}$$

- Build on the scheduling model developed by Pougala et al. (2021):
  - Utility-based optimisation model
  - Generate distribution of schedules from which likely schedules can be stochastically drawn
  - Incorporates simultaneous estimation of multiple scheduling decisions such as activity participation, and activity scheduling (start time, duration, sequence)
  - Output: a feasible schedule
- Extend the framework to:
  - Incorporate joint modelling of time-use in the home alongside activities outside the home
  - Incorporates estimation of activity location as well as other scheduling decisions

Dataset

CaDDI* survey: 2016-2020 UK TUS Pre- and During Covid-19 Social Restrictions (Gershuny & Sullivan, 2021)

- A sequence of **online** time-use diary surveys designed to capture daily behavior throughout the various stages of the pandemic 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**, **device use**, **enjoyment**, and **co-presence**

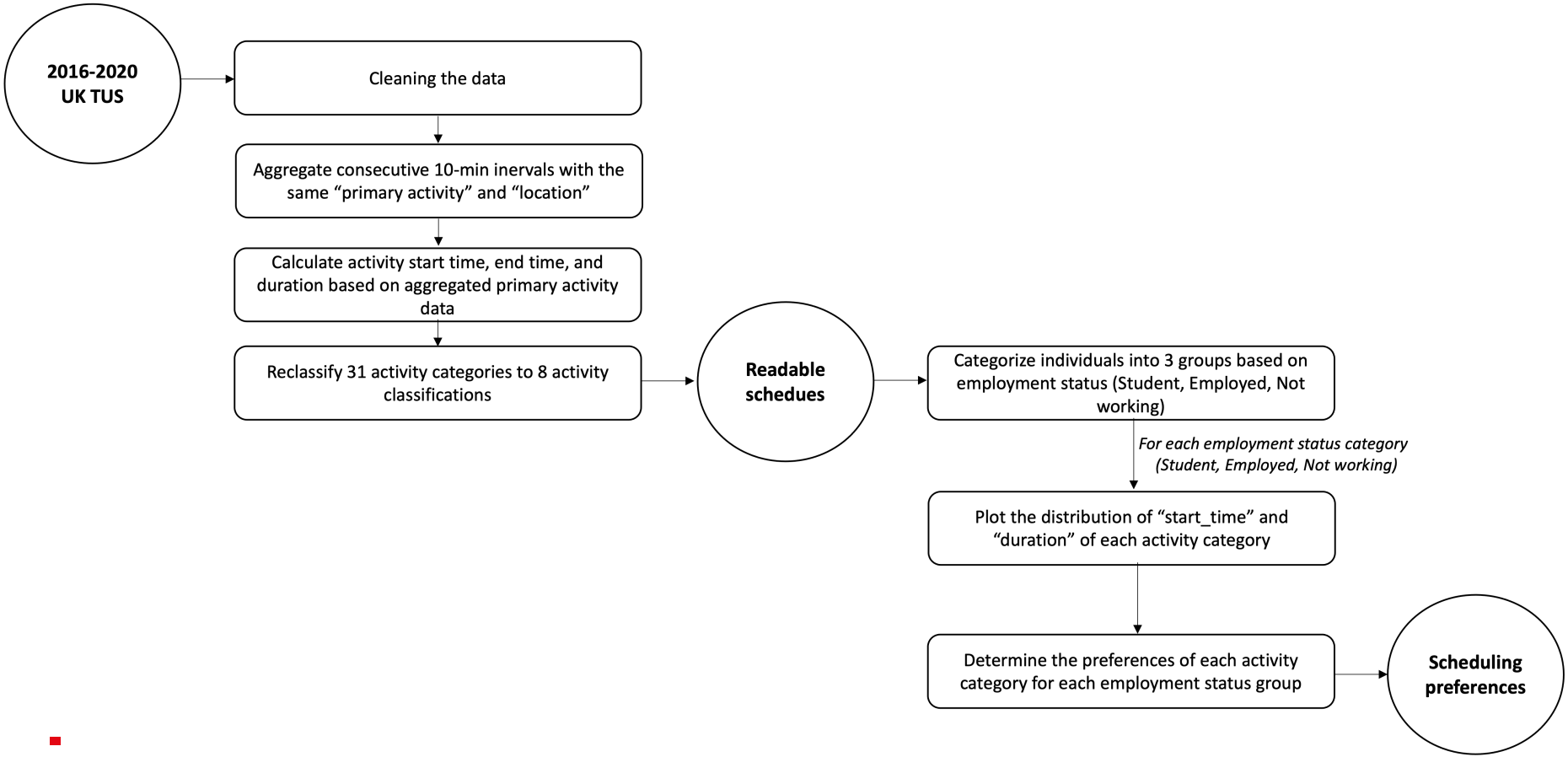
* Click and drag diary

Data pre-process

	mainid	survey	dday	econstat	pri1	pri2	pri3	pri4	pri5	pri6	...	pri135	pri136	pri137	pri138	pri139	pri140	pri141	pri142	pri143	pri144	loc1	loc2	loc3	loc4	loc5	loc6	...	loc135	loc136	loc137	loc138	loc139	loc140	loc141	loc142	loc143	loc144
0	47	1.0	3	3	101	101	101	101	101	101	...	101	101	101	101	101	101	101	101	101	101	201	201	201	201	201	201	...	201	201	201	201	201	201	201	201	201	201
1	47	1.0	6	3	101	101	101	101	101	101	...	101	101	101	101	101	101	101	101	101	101	201	201	201	201	201	201	...	203	203	203	203	203	203	203	203	203	203
2	62	1.0	1	3	101	101	101	101	101	101	...	101	101	101	101	101	101	101	101	101	101	201	201	201	201	201	201	...	201	201	201	201	201	201	201	201	201	201
3	62	1.0	7	3	101	101	101	101	101	101	...	101	101	101	101	101	101	101	101	101	101	201	201	201	201	201	201	...	201	201	201	201	201	201	201	201	201	201
4	69	1.0	1	10	101	101	101	101	101	101	...	101	101	101	101	101	101	101	101	101	101	201	201	201	201	201	201	...	201	201	201	201	201	201	201	201	201	201
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4355	41766	4.0	3	3	101	101	101	101	101	101	...	101	101	101	101	101	101	101	101	101	101	201	201	201	201	201	201	...	201	201	201	201	201	201	201	201	201	201
4356	41766	4.0	4	3	101	101	101	101	101	101	...	101	101	101	101	101	101	101	101	101	101	201	201	201	201	201	201	...	201	201	201	201	201	201	201	201	201	201
4357	41769	4.0	7	3	101	101	101	101	101	101	...	101	101	101	101	101	101	101	101	101	101	201	201	201	201	201	201	...	201	201	201	201	201	201	201	201	201	201
4358	41771	4.0	1	3	101	101	101	101	101	101	...	101	101	101	101	101	101	101	101	101	101	201	201	201	201	201	201	...	201	201	201	201	201	201	201	201	201	201
4359	41772	4.0	5	5	101	101	101	101	101	101	...	101	101	101	101	101	101	101	101	101	101	201	201	201	201	201	201	...	201	201	201	201	201	201	201	201	201	201

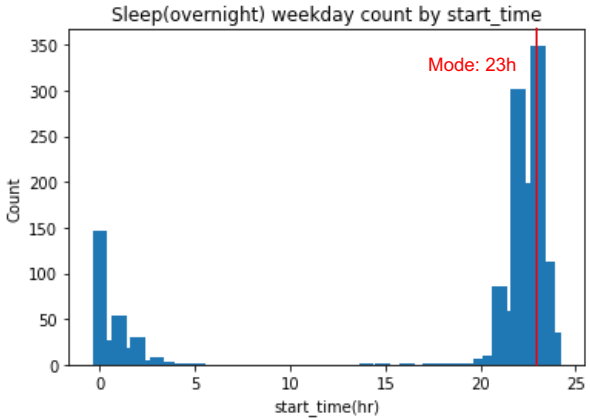
	mainid	dday	act_id	loc_id	location	act_label	label	start_time	end_time	duration
0	47	3	101	201	Home	Sleeping	Sleep	4.000000	6.333333	2.333333
1	47	3	103	201	Home	Washing, dressing	Personal care	6.333333	7.000000	0.666667
2	47	3	121	201	Home	Caring for own child	Home care	7.000000	8.500000	1.500000
3	47	3	111	203	Other	Walking, Jogging	Trips	8.500000	10.000000	1.500000
4	47	3	117	202	Work	Paid work	Work	10.000000	13.000000	3.000000
...	...	...	...	...	...	...	...	...	...	...
50345	41772	5	118	201	Home	Formal education	Study	14.000000	15.000000	1.000000
50346	41772	5	125	201	Home	Work,study break	Leisure	15.000000	17.000000	2.000000
50347	41772	5	105	201	Home	Preparing food, cooking etc	Home care	17.000000	21.000000	4.000000
50348	41772	5	127	201	Home	Watching tv,video,dvd,music	Leisure	22.000000	23.500000	1.500000
50349	41772	5	101	201	Home	Sleeping	Sleep	23.500000	4.000000	4.500000

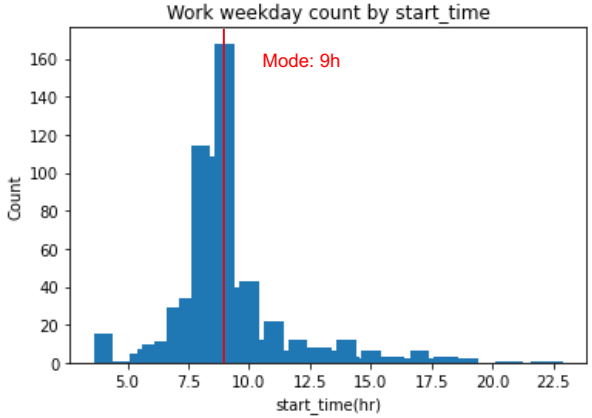
Data pre-process

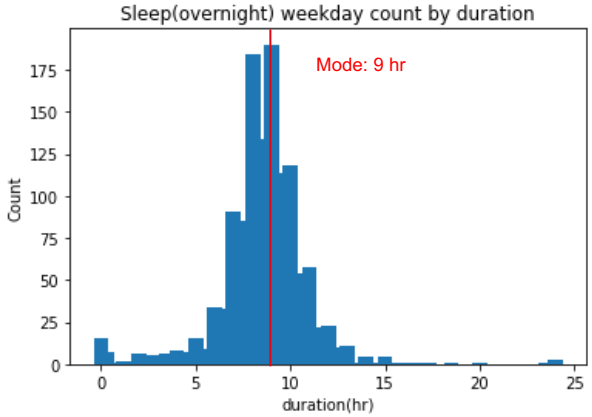


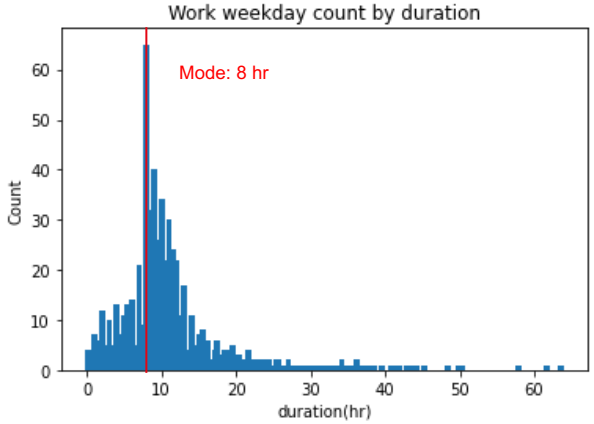
Data pre-process

- *Examples of activity schedule distributions for "**Employed**" individuals:*

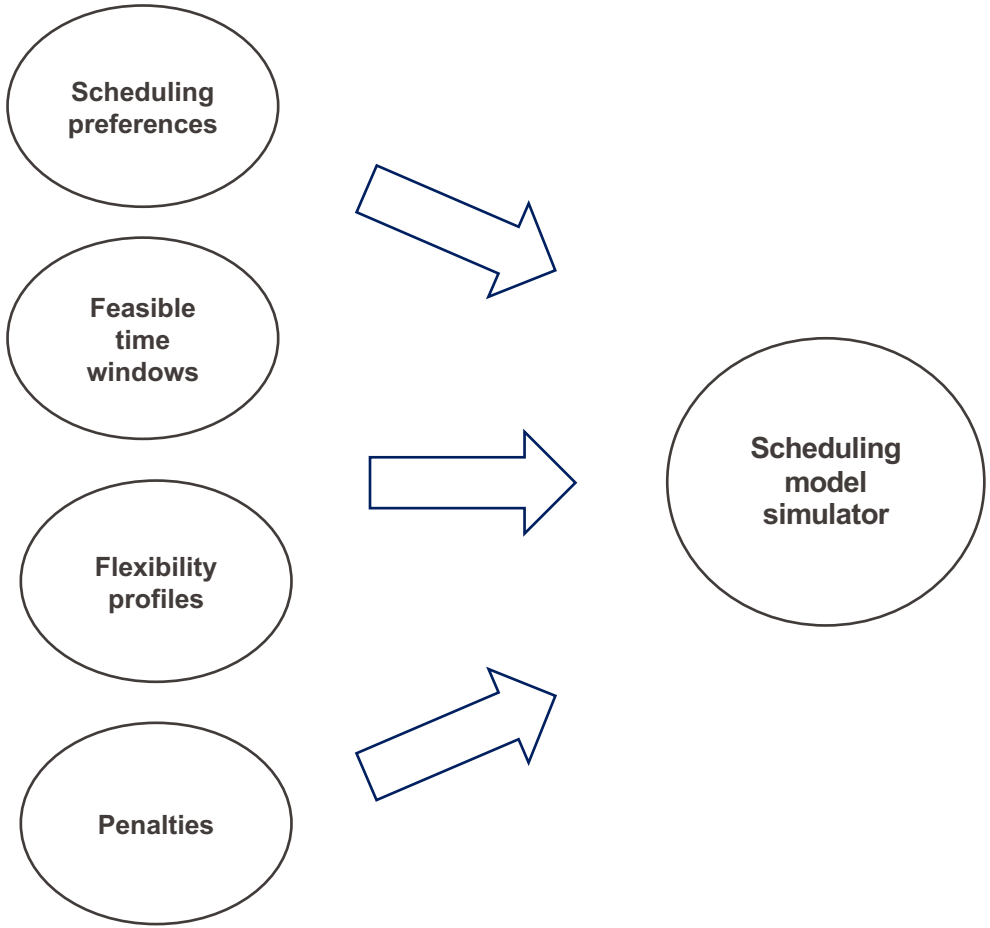




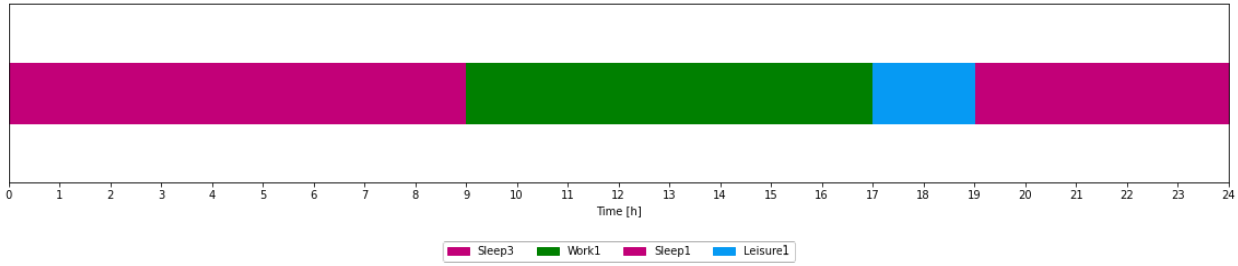


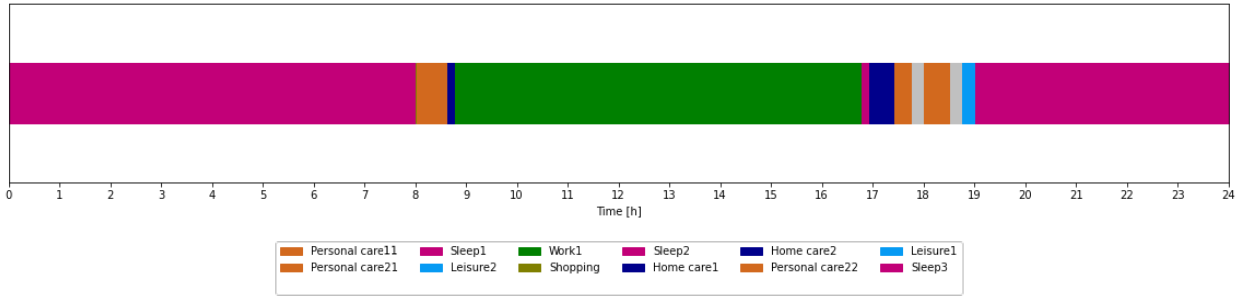


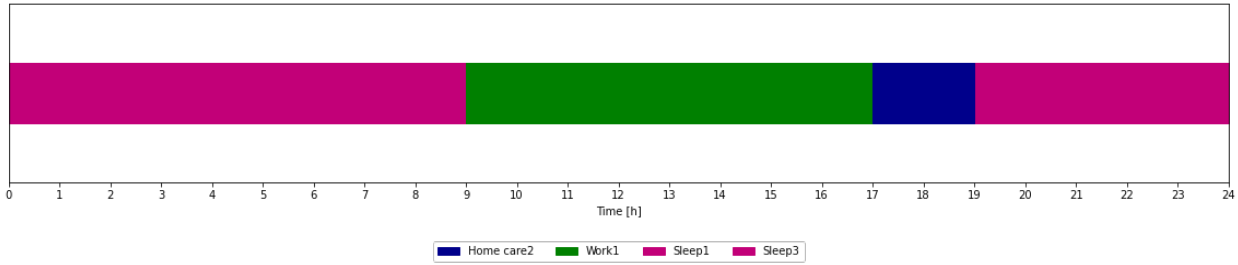
Scheduling model



Some results:
Employed (weekday)



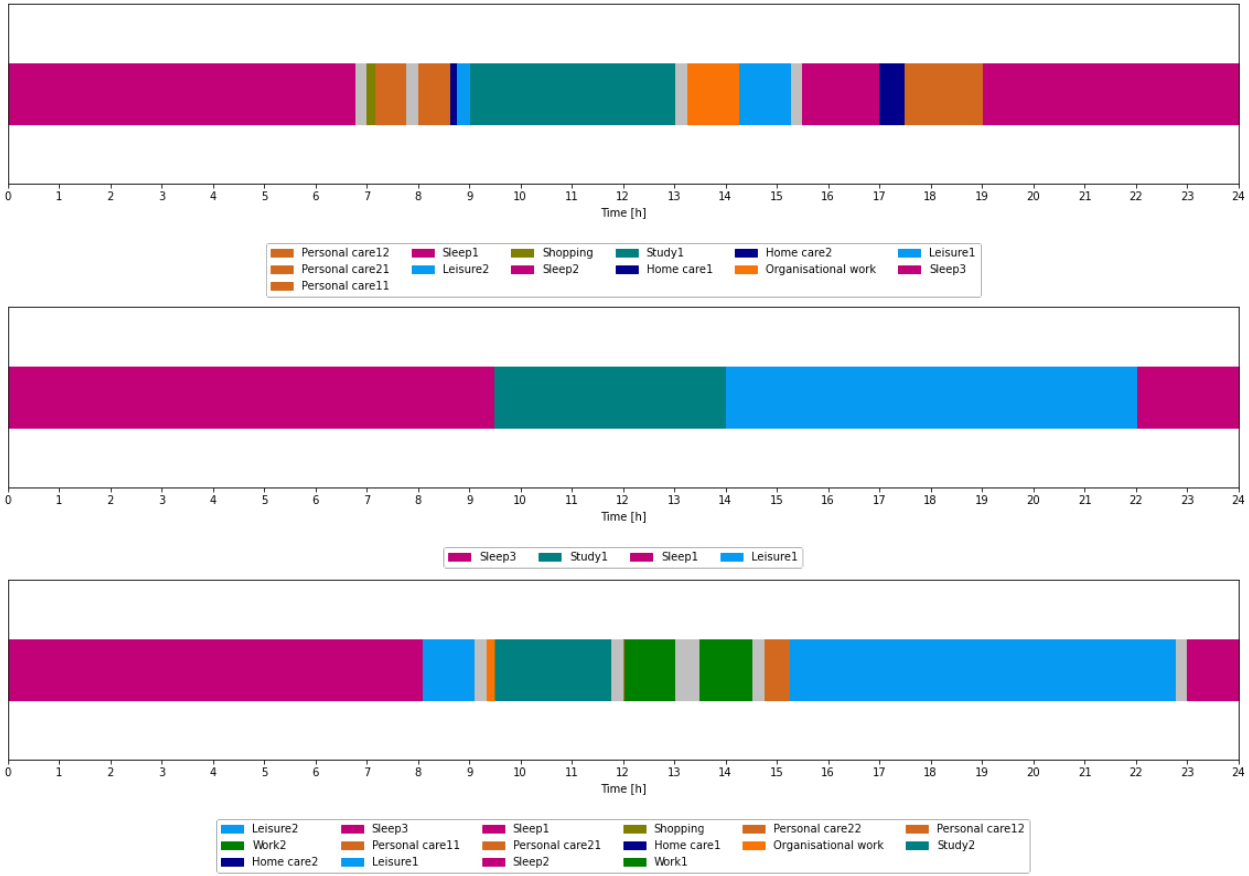




x1: location ‘Home’
x2: location ‘Work/Other’

* The grey bars between activities show ‘trips’

Some results: Student (weekday)



x1: location ‘Home’
x2: location ‘Work/Other’

* The grey bars between activities show ‘trips’

Current challenges

- Limitations of the data:
  - No data on the location coordinates →
    - Limitations estimating travel times
    - Limitations modeling mode choice behavior

Further research

- **WP1**: Problem definition
- **WP2**: Daily scheduling model (joint in- and out-of-home activities) →
  - Improve utility specifications
  - Parameter estimation
  - Find solution to travel times estimation
- **WP3**: Model application and scenario-testing
- **WP4**: Extended scheduling model with interactions

Thank you!

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