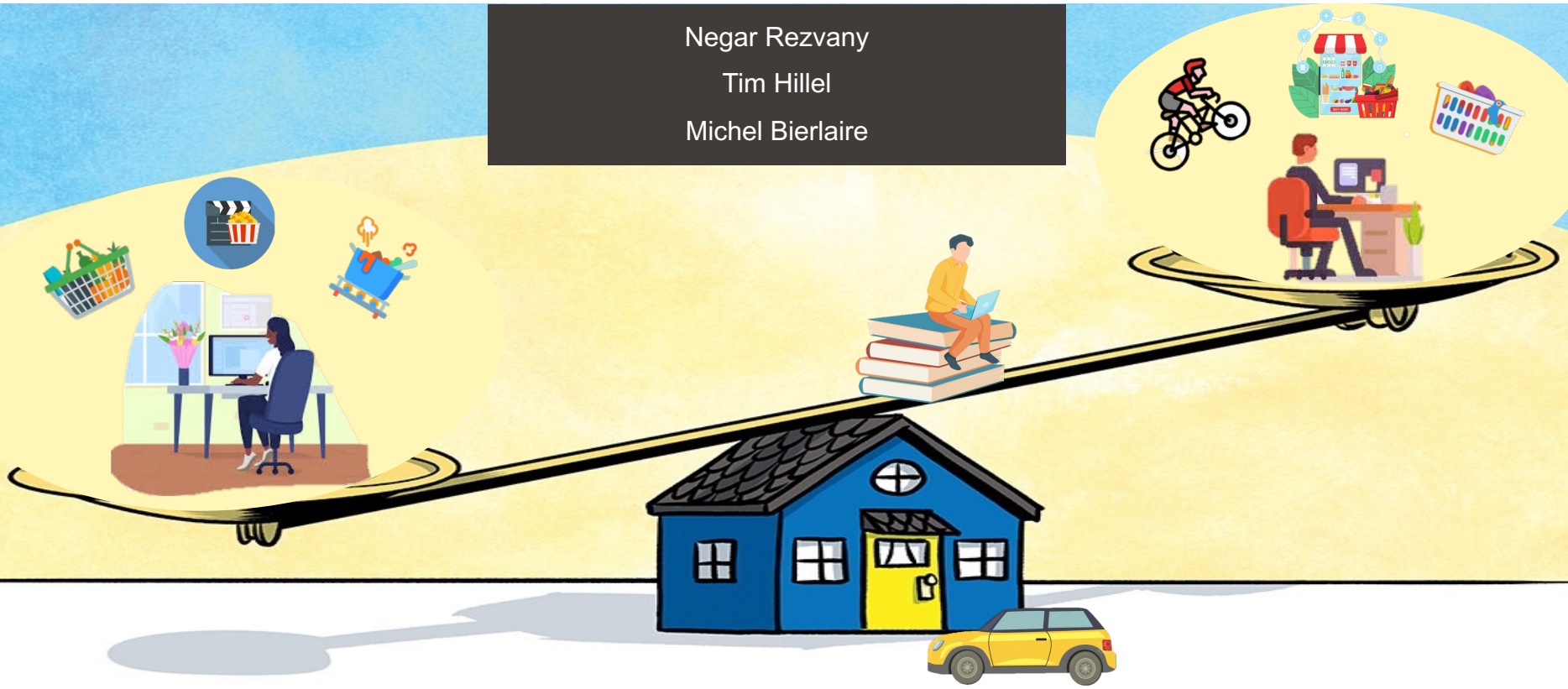


# Simulating multiple intra-household interactions in ABMs

Negar Rezvany

Tim Hillel

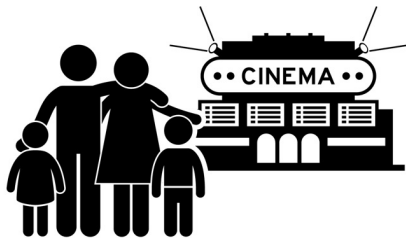
Michel Bierlaire



- **Introduction and motivation**
  - What are intra-household interactions?
  - Why is it important to capture intra-household interactions in activity-based models?
- **Current literature and opportunities to contribute**
  - What is the current state of research in activity-based modelling?
- **Contributions and scope**
- **Model framework**
- **Simulation results**
- **Conclusion**

- **Activity-based models (ABMs): Activity-based models** portray how people plan their activities and travels over a period of time such as a day.
- Individuals do **not** plan their day in **isolation** from other members of the household.
- Various **interactions**, **time arrangements**, and **constraints** affect the **in-home** as well as **out-of-home** activity schedules of individuals.

- **What are some examples of intra-household interactions?**
  - Individuals in a household synchronize their schedules to create time window overlaps for **joint activities**.



Joint participation in a recreational activity



A family dinner at home

- What are some examples of intra-household interactions?
  - Household members **coordinate their travels** as well.



Escorting children



Sharing a ride


- What are some examples of intra-household interactions?
  - The members of a household also **share responsibilities and resources** with each other to satisfy household needs.



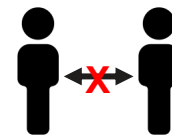
Sharing household maintenance responsibilities



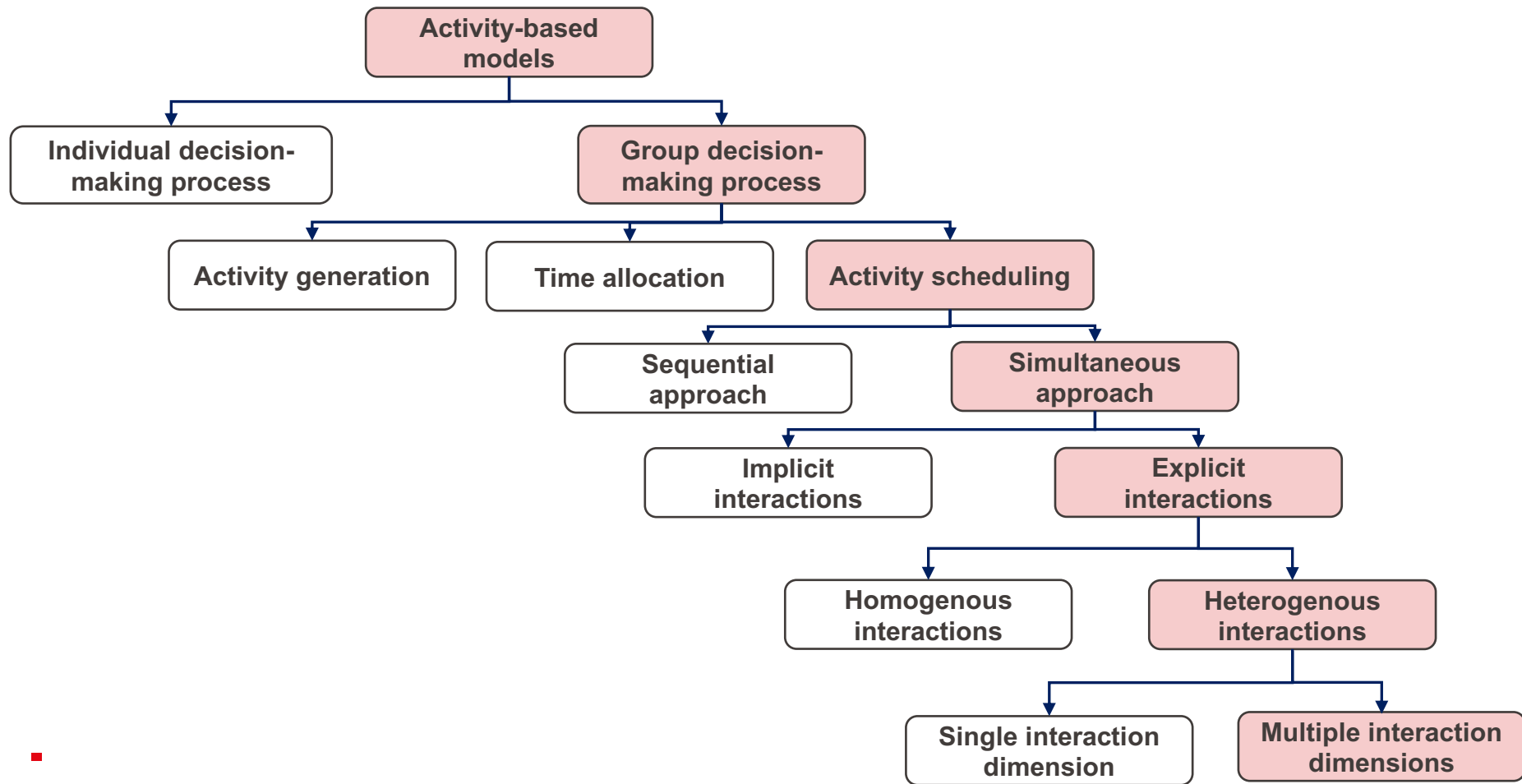
Sharing resources

- How can intra-household interactions affect the schedule of individuals?
  - Policies directly affecting the activity and travel patterns of an individual, such as earlier school starting times, can affect the schedule of multiple household members.
  - Joint activities require coordination between the schedules of participating individuals.
  - Resource constraints affect the scheduling choices of individuals.
  - The escorting duty affects the schedule and travel patterns of the adult members as they should accommodate the pick-up and drop-off activities into their schedule.
-  Considering the interpersonal dependencies in a household, the activity schedule should be addressed from a **group decision-making point-of-view** rather than isolated agents.

- Activity scheduling process has been of interest to transportation activity-based modelers in the last decades (e.g. *Hilgert et al. 2017*, *Bhat et al. 2004*, *Bowman & Ben-Akiva 2001*, *Chapin 1974*, *Hagerstrand 1970*) as the **demand for travel** is assumed to be driven by **participation in activities distributed in space and time**.
- Most of the **conventional** activity-based models in transportation research are based on **individual decision-making process** where the individuals are treated as **isolated agents** whose choices are **independent** of other decision-makers.
- However, **ignoring** the **interdependence** between household members causes a **biased** simulation of activity-travel schedules as the schedule of household members are **mutually dependent**.
- Studies on group choice models are **limited**.
- Only a **limited** number of studies examine **household decision-making perspectives** and consider the **effect of intra-household interactions** in their activity-based models (e.g. *HAPP*, *TASHA*, *MDCEV*, etc).







- A framework to **simulate the daily activity schedules of individuals in a household, explicitly accommodating multiple interactions**:
    - **Group decision-making** paradigm
    - **Simultaneous simulation** of different **choice** dimensions
      - More behavioural realism compared to conventional sequential models.
      - Captures complex trade-offs between different choice dimensions.
    - **Explicit** interactions
      - Ensures consistency of choices.
    - **Multiple interaction** dimensions
    - High level of **flexibility**
      - Based on an optimization-based framework.
      - Interactions and dependencies can be comfortably incorporated by modifying the constraints and/or terms of the objective function of the optimization problem.
    - Both **in-** and **out-of-home** scheduling are simulated within the same framework
      - Allows modelers to capture the trade-offs between in- and out-of-home activities (e.g. in- and out-of-home activity location choices).
      - Understanding behaviour and interactions throughout the day is the key to better demand-side management and adapting infrastructure systems (e.g. transportation, energy) to deliver critical services that meet the needs of society.
-

- We build on the **Optimisation-based Activity Scheduling Integrating Simultaneous choice dimensions (OASIS)** framework (*Pougala et al. 2022*):
  - A mixed-integer utility optimization approach
  - Explicitly captures **trade-offs** between choices
  - At the level of **isolated** individuals
  - Focuses on **out-of-home activity** schedules
  - Is defined under a set of **constraints** that determines the **validity** of the schedules at an **individual-level** such as:
    - Time budget constraints,
    - Time window constraints,
    - Participation constraints,
    - Sequence constraints, and
    - No duplicates.

- Objective:  $\Omega_n = \max U_n$
- Utility of a schedule:  $U_n = \sum_{a_n} U_{a_n}$
- For individual  $n$ , considering activity  $a_n$ :

Utility purely associated with  
participation in activity,  
irrespective of timing and trips

Duration deviations

Error term

$$U_{a_n} = \boxed{U_{a_n}^{partic}} + \boxed{U_{a_n}^{start}} + \boxed{U_{a_n}^{duration}} + \boxed{\sum_{b_n \in A^n} U_{a_n, b_n}^{travel}} + \boxed{\varepsilon_{a_n}}$$

Start time deviations

Travel from activity  $a_n$  to  $b_n$

# OASIS with interactions:

## Agents with intra-household interactions

- **Fundamental assumption:** individuals do not plan their day in isolation from other members of the household.
- The framework considers the **household** as a **single decision-making unit** while encompassing the activity scheduling behaviour of all agents through the utility that each agent derives from their schedules.
- Agents schedule their day to **maximize the total combined utility** of the **household**.

$$\Omega = \max \sum_{n=1}^{n=N_m} \boxed{w_n} U_n$$

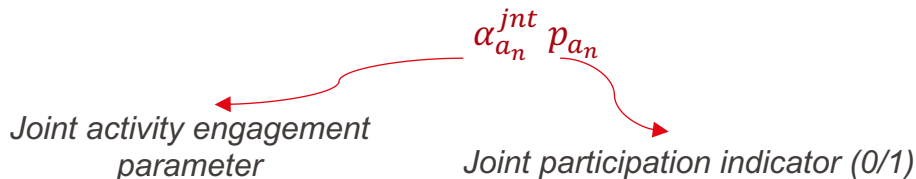
agent priority parameter

- It accounts for **both individuals' constraints** and the **constraints** that appear due to **interpersonal dependencies** within household members.

- We first ensure that the possible interaction aspects are captured in the utility function.
  - A term capturing the reward of joint activity participation with other member(s) of the household, compared to solo participation in the activity.

$$U_{a_n}^{partic} = \boxed{U_{a_n}^{joint}} + U_{a_n}^{escort} + U_{a_n}^{location}$$

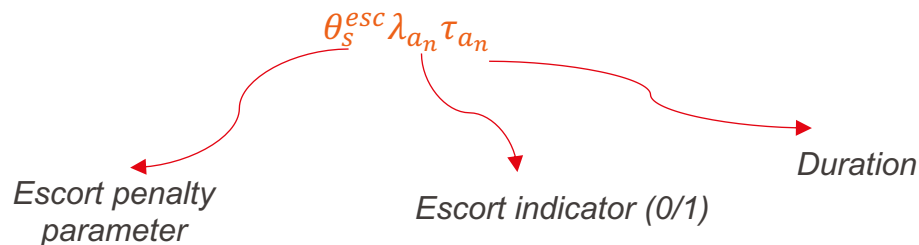
Joint activity participation



- We first ensure that the possible interaction aspects are captured in the utility function.
  - A term capturing the penalty of escorting other agent(s).

$$U_{a_n}^{partic} = U_{a_n}^{joint} + \boxed{U_{a_n}^{escort}} + U_{a_n}^{location}$$

Escort



- We first ensure that the possible interaction aspects are captured in the utility function.
  - a term capturing the utility of different activity location choices.

$$U_{a_n}^{partic} = U_{a_n}^{joint} + U_{a_n}^{escort} + \boxed{U_{a_n}^{location}}$$

location

$\alpha_{l_{a_n}}^{loc} l_{a_n}$

Location-specific parameter

Location indicator



- Agents in the household solve an optimization problem with the objective to maximize the household utility:

$$\Omega = \max \sum_{n=1}^{n=N_m} \sum_{a_n \in A^n} w_n U_{a_n}$$

$$\Omega = \max \sum_{n=1}^{n=N_m} \sum_{a_n \in A^n} w_n (U_{a_n}^{partic} + U_{a_n}^{start} + U_{a_n}^{duration} + \sum_{b_n \in A^n} U_{a_n, b_n}^{travel} + \varepsilon_{a_n})$$

- Specify the model constraints such that they allow the **integration of in-home activities** alongside activities **outside** the home in **a single framework**.
- Define **household-level constraints** to **explicitly** capture the interplays as **within-household interactions** lead to **additional and more complex** constraints.
  - Household private vehicle ownership,
  - Allocation of the resources to household members,
  - Sharing household maintenance responsibilities,
  - Joint participation of household members in activities,
  - Joint travels, and
  - Escorting.

# OASIS with interactions:

## Agents with intra-household interactions

### Inputs:

- Household composition,
- Scheduling preferences,
- Activity flexibilities,
- Activity choice set, and
- Household resources and their associated events set.

### Decision variables:

- Activity participation,
- Start time,
- Duration,
- Succession between activities.

$a_n$  :

Location 1  
Mode 1  
Participation mode 1



⋮

Location n  
Mode n  
Participation mode n



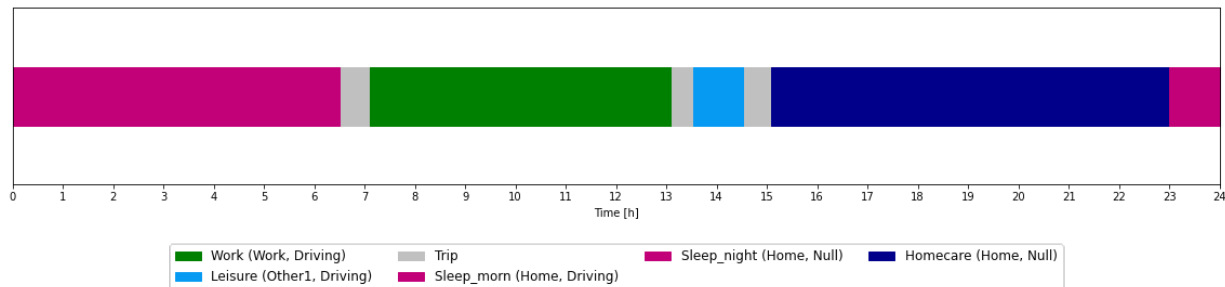
### Output:

- A **realisation** from the **distribution of valid schedules**, under both **individual-** and **household-level constraints** and **preferences**.

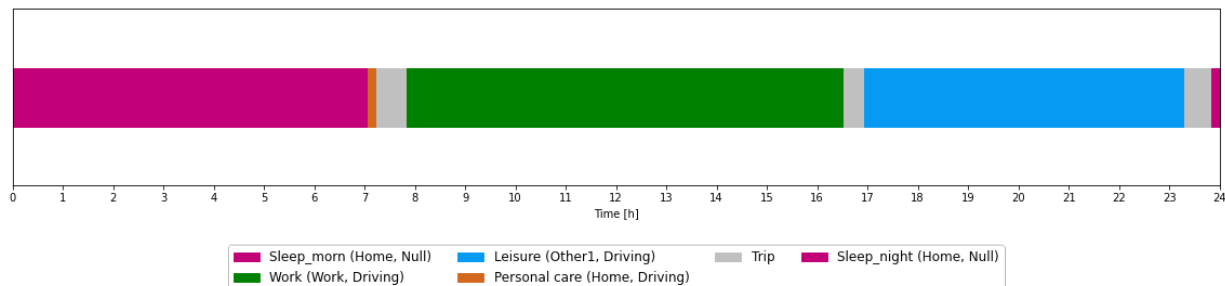
# Simulation

## From isolated individuals...

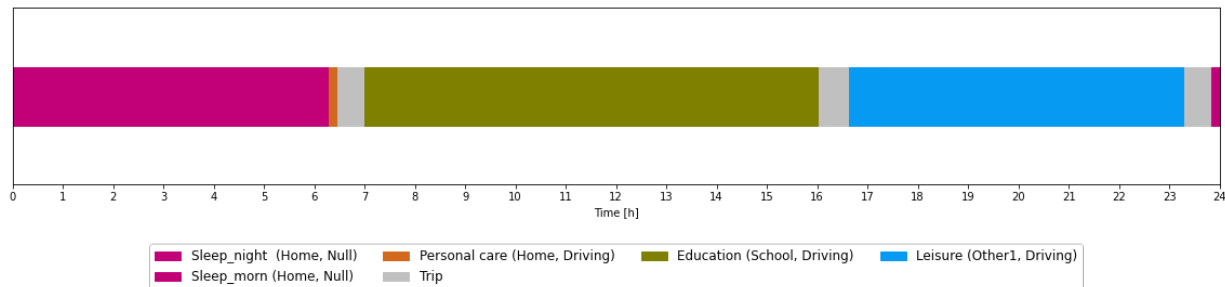
Sara



David



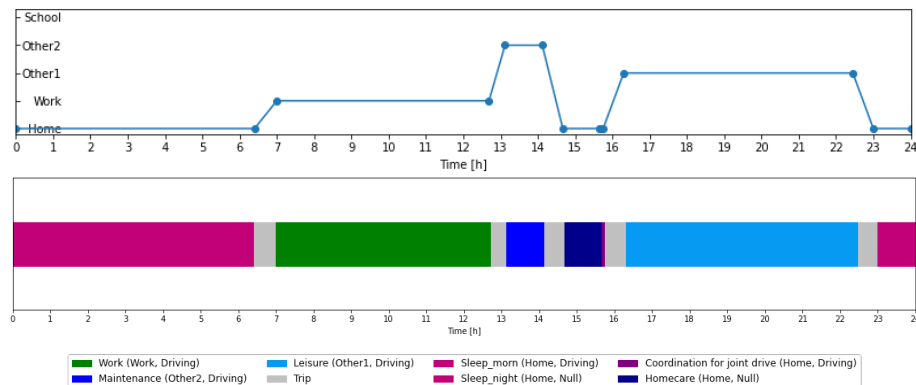
Alice



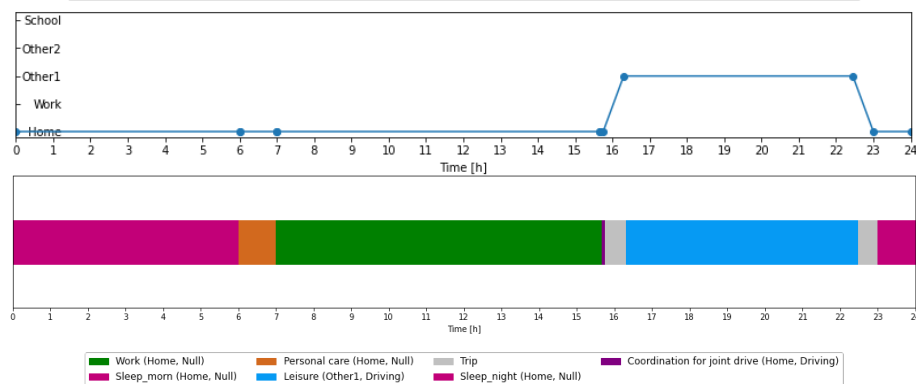
# Simulation

## To family of 2; 2 adults with no children...

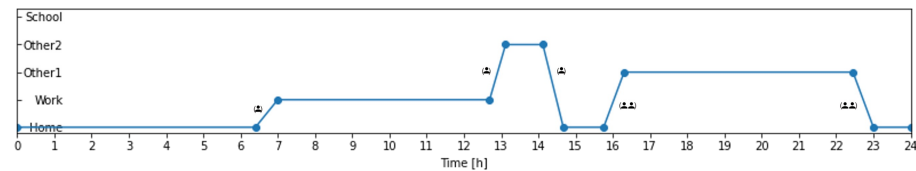
Sara



David



Car



## Family of 2; 2 adults with no children

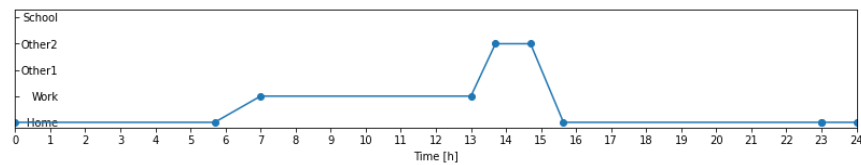
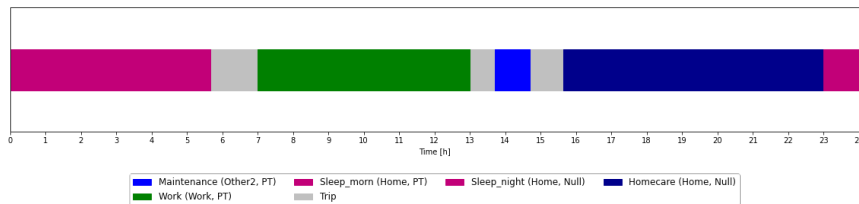
Table 1: Car location sequence and occupancy in the example of family of 2

Location	Start time (hh:mm)	End time (hh:mm)	Duration (hh:mm)	Person using	Parked_out indicator	Car occupancy
Home	00:00	6:24	6:24	-	0	0
On the road	6:24	7:00	0:36	1	0	1
Work	7:00	12:41	5:41	1	1	0
On the road	12:41	13:07	0:26	1	0	1
Other2	13:07	14:07	1:00	1	1	0
On the road	14:07	14:40	0:33	1	0	1
Home	14:40	15:45	1:05	-	0	0
On the road	15:45	16:18	0:33	1&2	0	2
Other1	16:18	22:27	6:08	1&2	1	0
On the road	22:27	23:00	0:33	1&2	0	2
Home	23:00	24:00	1:00	-	0	0

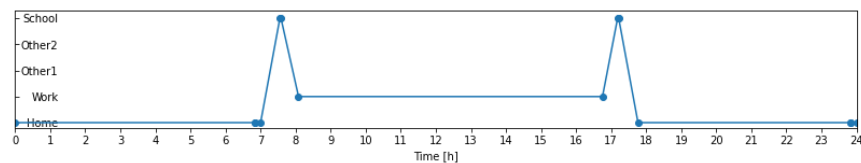
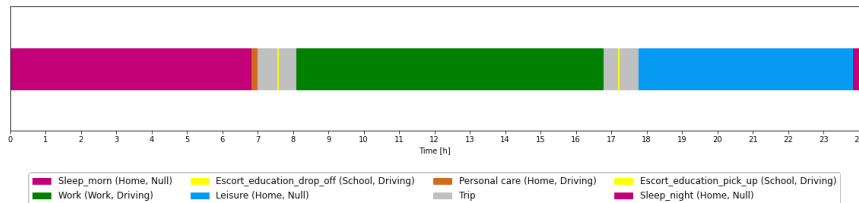
# Simulation

## To family of 3; 2 adults and 1 child...

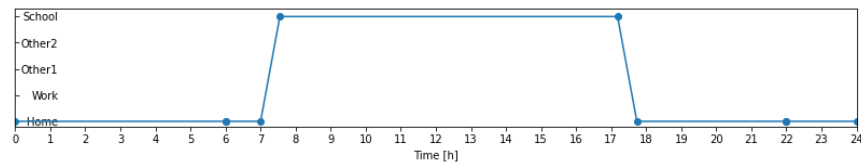
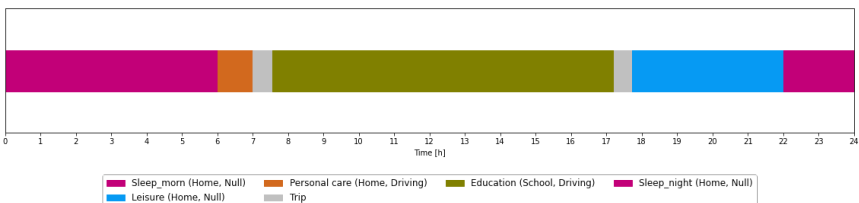
Sara



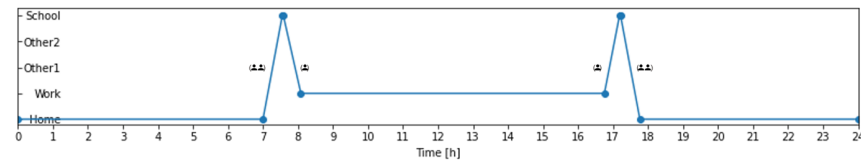
David



Alice



Car

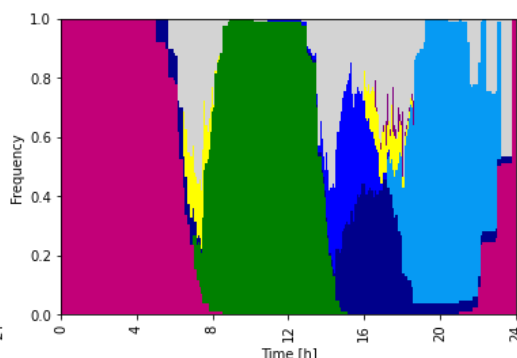
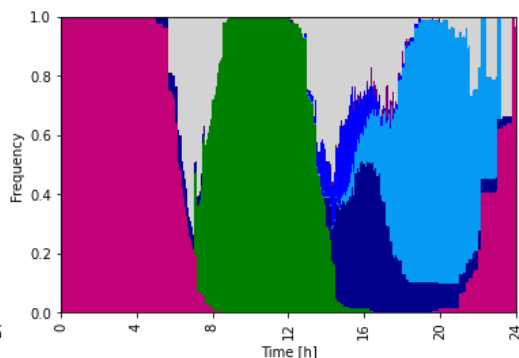
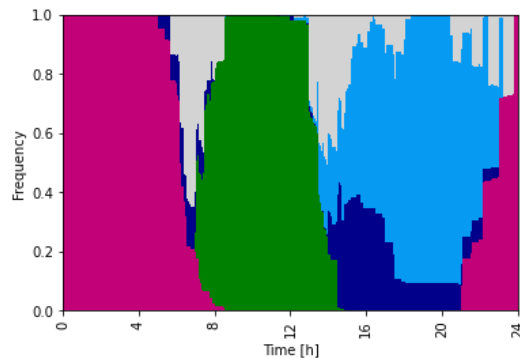


Isolated individual

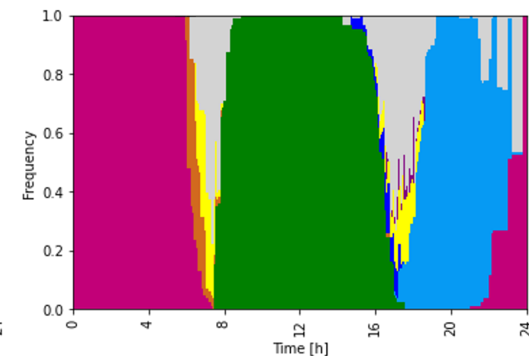
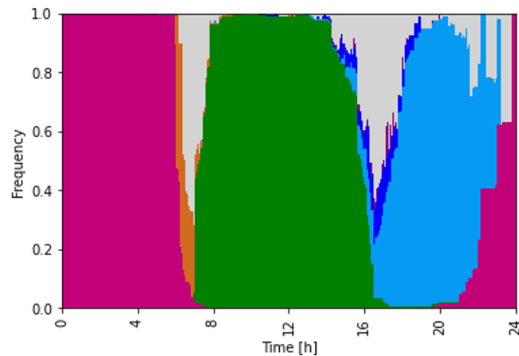
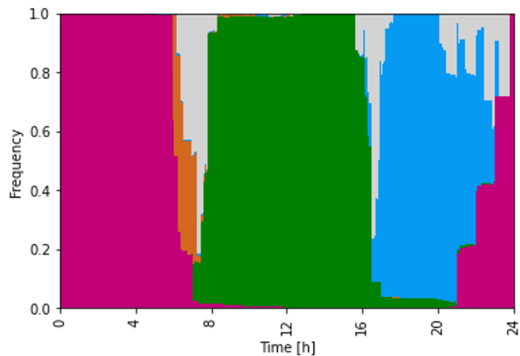
Family of 2

Family of 3

Sara

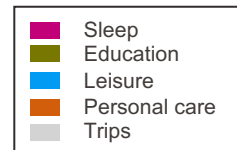
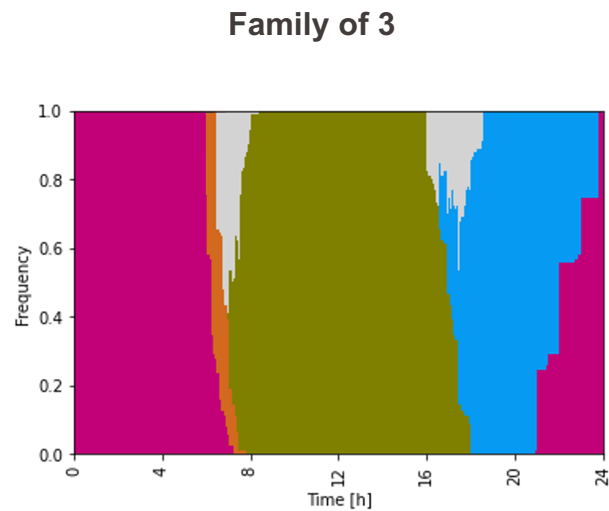
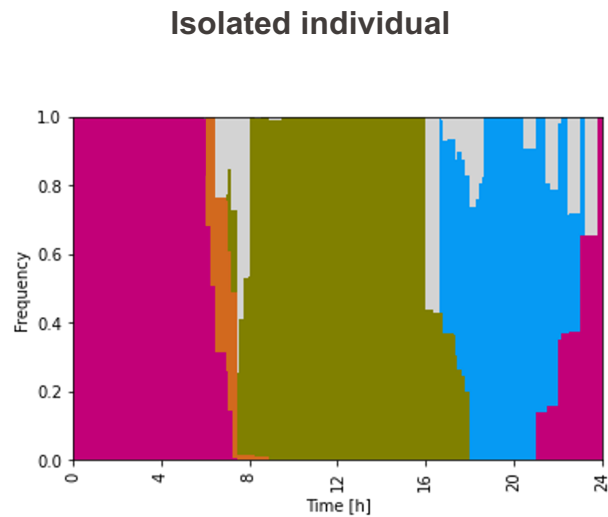


David





Alice



## Summary:

- General framework
- Group decision-making mechanism; activity scheduling at the level of the household
- Explicit interactions
- Capture resource constraints
- Flexible framework; interaction dimensions can be arbitrarily added

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**EPFL**



**Thank you!**

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