Group decision-mechanisms in activity-based models

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Overview

Introduction

- **Activity-based models (ABMs)**: portray how people plan their activities and travels over a period of time.
- Traditional ABMs treat individuals as **isolated entities** $\rightarrow$ Based on **individual decision-making**.
- Individuals do **not** plan their day in **isolation** from other members of the household.
- Various **interactions**, **time arrangements**, **constraints**, and **group decision-making** exist for individuals making decisions as a member of a household.

Hence, models dealing with individual choices need to be revisited to take into account the intra-household interactions.

Example intra-household interactions

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

Joint participation in a recreational activity

A family dinner at home

Example intra-household interactions

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

Escorting children

Sharing a ride

Example intra-household interactions

- **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

Household activity scheduling model

- How to incorporate **in-home** and **out-of-home activity scheduling** in a **single** scheduling model with **intra-household interactions**? Rezvany et al. (2023)
  - An econometric ABM framework to simulate the joint scheduling process of a household comprising several household members, capturing intra-household interactions.

Rezvany, N., Bierlaire, M. Hillel, T. (2023), 'Simulating intra-household interactions for in- and out-of-home activity scheduling', Transp. Res. Part C Emerg. Technol. 157.'

Household-level OASIS with interactions

- Activity scheduling framework.
- Builds on the individual-level OASIS framework (Pougala et al. 2021).
- Treat scheduling as a **mixed-integer utility optimisation** problem.
- The schedule of each agent is a sequence of activities over a time horizon T, resulting from the agent's choices.
- Considers **multiple scheduling decisions** (e.g. activity participation, start time, duration, location, transport mode, accompaniment) **simultaneously**.

Household-level OASIS with interactions

- **Objective**: Maximise the household utility.

$$\max \text{HUF}$$

where:

$$HUF = f(U_{n_1}, U_{n_2}, \ldots, U_{N_m})$$

- Subject to set of individual schedule continuity constraints and **constraints** that appear due to inter-personal dependencies within household members, such as:
  - Allocation of the resources to household members,
  - Sharing household maintenance responsibilities,
  - Joint participation of household members in activities, and
  - Escorting.

Household-level OASIS with interactions

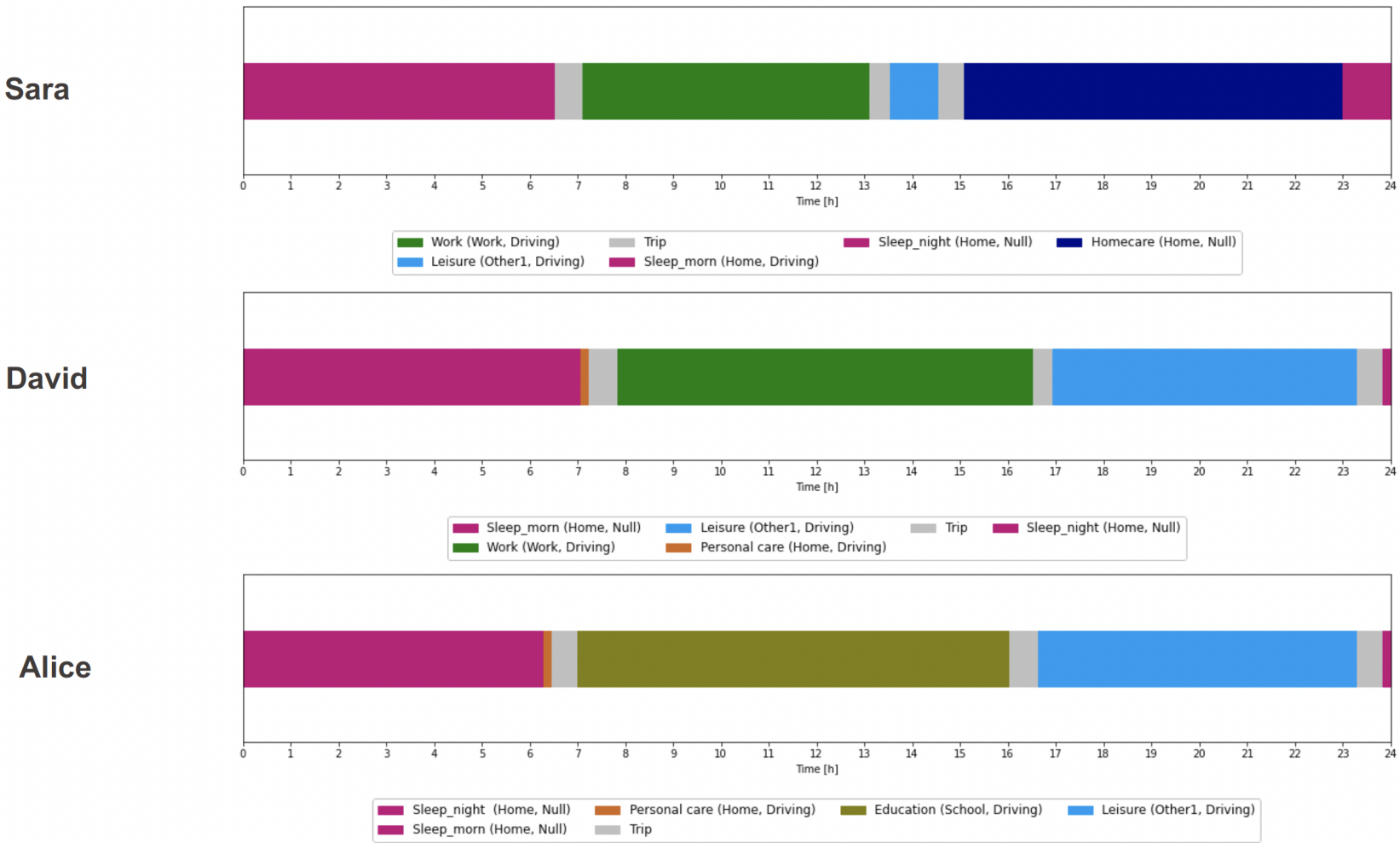
- Household-level daily schedule **simulation** framework, **explicitly** accommodating **multiple interactions**:
  - **Simultaneous simulation** of different choice dimensions.
  - **Group decision-making** paradigm.
  - **Explicit** interactions.
    - Ensures consistency of choices.
  - **Multiple interaction** dimensions.
  - High level of **flexibility**.

Household-level OASIS with interactions

- **Inputs:**
  - Household composition,
  - Household resources,
  - Activity choice set, and
  - Scheduling preferences.
- **Decision variables:**
  - Activity participation,
  - Start time,
  - Duration,
  - Succession between activities.
- **Output:**
  - A realisation from **distribution of valid schedules**, under individual **preferences**, **household requirements** and available **resources**.

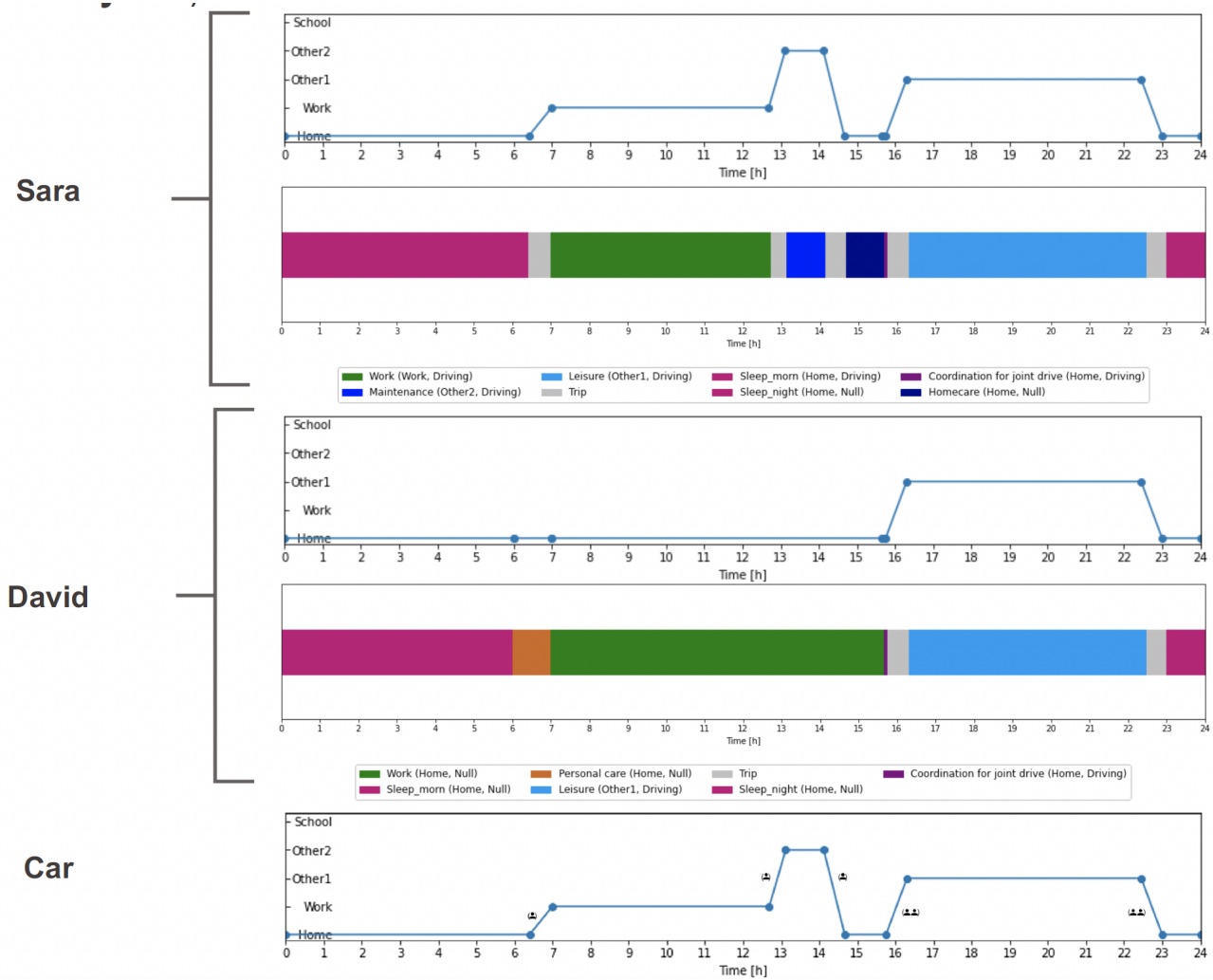
a_n :

Simulation
From isolated individuals. . .



Simulation

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



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

Group decision-making

$$\Omega = max \text{ HUF}$$

- Group decision mechanisms can **vary within different households**.
- Different group decision-making mechanisms can **affect choices of individuals**.
- Group decision-making models are still **limited** in **transportation**, though there have been **advances** in this matter in **other fields** such as economics and marketing.

There exist diverse general household decision-making mechanisms, which are crucial to explicitly integrate them to ABMs.

Scope

- Review key studies on group decision strategies.
- Investigate the development of integrated models of household decision-making and activity-travel patterns.
- Incorporate example cases of group decision strategies into household scheduling model.

This can contribute to a better understanding of household decision-making behaviour in transportation, and discuss some future research directions for ABMs.

Group decision-making

- Different members within a household have **different relative influences** in joint decision-making.
- This relative influence may differ dependent on their **roles** and **activity agenda**.
- Involvement of household members in the decision-making process differs based on **decision types**.
- The members' involvement varies across **stages in the household life cycle**.
- To arrive at a joint decision, household members may use **different group decision strategies**, including **bargaining**, **turn-taking** and **compromising**.

Group decision models in Economics of Family

Unitary Models	**Non-Unitary/Collective Models**
Households perceived as single units driven by a **unique decision-maker** and **identical preferences**.	Household members are considered **separate decision makers** with bargaining weights, and they coordinate their schedules to achieve the **Pareto optimal** of the household as the outcome of a **bargaining process**.
Decision-making process viewed as a **black box**, with no insight into individual preferences or conflicts.	**Collaborative** decision-making dynamics within households; feature concepts specific to **within-family interactions** (e.g., bargaining, altruism, and Pareto optimality).
Diverging interests among members **disregarded**.	Acknowledge **different preferences** among household members.

- In reality, many decisions in households are made by **not** just a **single decision-maker**.
- A significant **shift** in field of Economics of Family, where **non-unitary** models were introduced.

Gaps

- Lack of consensus on how household interactions should be modelled and the **form of household utility functions**.
- Example studies integrating household decision-making on long-term decisions (e.g. household residential location, and vehicle ownership). Applying them to **short-term** decisions such as daily activity scheduling should be looked into further.
- There still remains room for **integrating household decision-making strategies** into **operational ABMs**.

Representing group decision mechanisms

1. **Multi-linear group utility function** (Zhang et al. 2002):

$$\begin{aligned} \text{HUF} = & \sum_{n=1}^{N_m} w_n U_n \\ & + \sum_{n_1} \sum_{n_2 > n_1} w_{n_1 n_2} U_{n_1} U_{n_2} \\ & + \sum_{n_1} \sum_{n_2 > n_1} \sum_{n_3 > n_2} w_{n_1 n_2 n_3} U_{n_1} U_{n_2} U_{n_3} \\ & + \ldots \end{aligned}$$

- w_n: Agent weight parameter; capture **relative influence**.
- $w_{n_1 n_2}$, $w_{n_1 n_2 n_3}$, ... : Interaction parameters; **moderate power effect** and reflect agents' concern for achieving **equality** in agents' utilities.
- The **larger** the **interaction parameters**, the **higher** the households' collective desire to choose an activity-time allocation such that **utilities of all agents** are **more or less equal**.

Representing group decision mechanisms

2. **Group decision-making formulation** (Zhang & Fujiwara 2006):
   - The iso-elastic class of social welfare function (Atkinson 1970) is adopted as the household utility function:

$$\text{HUF} = \frac{1}{1-\alpha} \sum_{n=1}^{n=N_m} w_n \; {U_n}^{1-\alpha}$$

   - w_n: Agent weight parameter, capture **relative influence**.
   - α: **Atkinson's measure of aversion to inequality**, describes the household preferences in trading off utilities between its members.

- Different values of w_n and α represent different decision-making mechanisms.

Special cases; group decision strategies

- **Utilitarianism/Additive-type household:** the group behave in a Bayesian rational manner, assuming that agents try to maximise the resulting mixture function from weighted sum of agents utility.

$$\text{HUF} = \sum_{n=1}^{N_m} w_n U_n$$

- **Compromise-type household**: If the household members have equal weights (Curry & Menasco 1979).

Special cases

- **Nash-type household:** each agent first identifies his/her most preferred outcome. The household then compromises by averaging along the resulting negotiation frontier.

$$\text{HUF} = \prod_{n=1}^{N_m} {U_n}^{w_n}$$

Special cases

- **Minimum-type household:** the household regards the utility of its weakest agent (agents with lowest relative influence w_n) as the household utility and maximises it.

$$\text{HUF} = U_n, \quad n = \underset{i \in \{1,2,\ldots,N_m\}}{\text{argmin}} \; w_i$$

Special cases

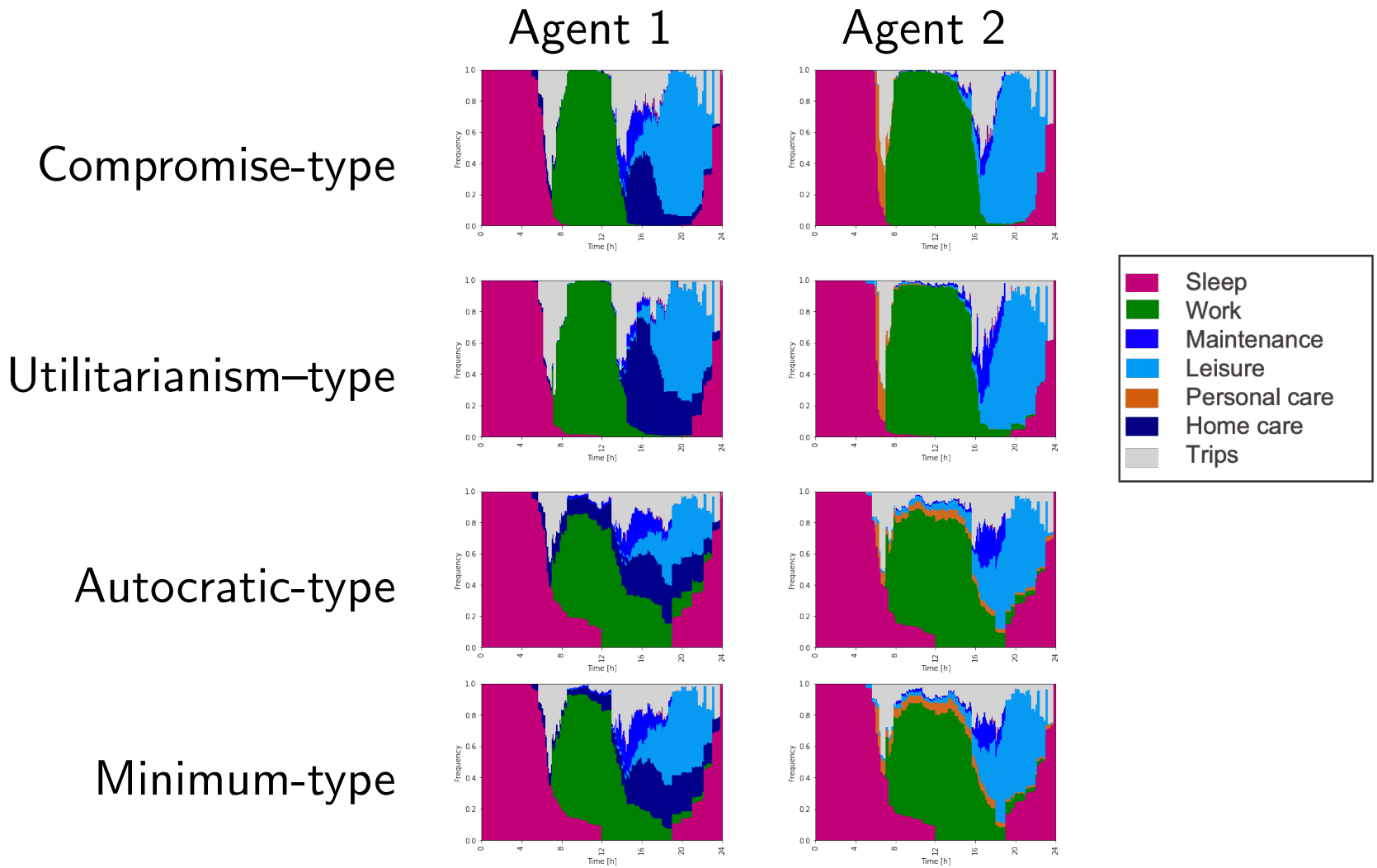
- **Autocratic-type household:** the household regards the utility of its strongest agent (agents with highest relative influence w_n) as the household utility and maximises it.

$$\text{HUF} = U_n, \quad n = \underset{i \in \{1,2,\ldots,N_m\}}{\text{argmax}} \; w_i$$

Illustrative example

- Showcasing example group decision-making mechanisms and relative power of agents in a household causing variations in schedules of agents.
- 4 special group decision strategy cases:
  - Utilitarianism-type household with **equal** power within its agents (Compromise-type),
  - Utilitarianism-type household with **unequal** power within its agents
  - Autocratic-type household, and
  - Minimum-type household.
- Data: 2016 UK Time use survey (TUS).
- Simulation setup: 500 iterations.

Simulation Distributions



To conclude

Summary:

- Operational multi-individual ABM.
- Key studies on group decision-making strategies.
- Preliminary investigation on integrating group-decision models into ABMs.

Household ABM research directions:

- What econometric methods should be used to estimate preferences?
- Parameter estimation: Challenge of unobserved and combinatorial choice set, with consistent alternatives for household members (Rezvany et al. 2024).
- Estimation of agents' relative power and interaction parameters.
- Generic integrated group-decision activity-based travel demand systems and dynamic traffic assignment models.

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Thank You!

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