Integrated in- and out-of-home scheduling framework:
A utility optimization-based approach

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Outline

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Introduction
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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?

Activity-based models

- Rule-based/Computational process models
- Utility-based models
  - Econometric models
    - Sequential approach
    - Joint approach
  - Micro-simulation models
    - Sequential approach
    - Joint approach
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
In order to address these shortcomings, Pougala et al. (2021) proposes a new scheduling framework:

- Treats *individuals* as *utility maximizers*
- Defined as a mixed-integer optimization problem for each *individual*, 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)
- Generates distribution of schedules from which likely schedules can be stochastically drawn
- **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) \( \rightarrow \) the resulting schedules do not contain any information on activities performed at home

\[
\omega_{in} \text{ indicate activity participation (0/1)}
\]

\[
\Omega_n = \max \sum_i \omega_{in} U_{in}
\]

Individual \( n \)

Activity \( i \)
Model framework

- 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

$$\omega_{in}: \text{indicate activity participation (0/1)}$$

$$\Omega_n = \max \sum_i \omega_{in} U_{in}$$
What are the differences between scheduling activities in-home and out-of-home?

Out-of-home activities

- Hard time-window constraints
- Mostly more sensitive to schedule deviations
- Include trips and mode choice

In-home activities

- Soft time-window constraints
- Mostly more flexible to schedule deviations
- No trips
- Space and resource constraints explicitly affect household members’ schedules
- Interactions within household members

- Time budget
Empirical investigation

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

- Cleaning the data
- Aggregate consecutive 10-min intervals with the same “primary activity” and “location”
- Calculate activity start time, end time, and duration based on aggregated primary activity data
- Reclassify 31 activity categories to 8 activity classifications

Readable schedules

- Categorize individuals into 3 groups based on employment status (Student, Employed, Not working)
  - For each employment status category (Student, Employed, Not working)
    - Plot the distribution of “start_time” and “duration” of each activity category
    - Determine the preferences of each activity category for each employment status group

Scheduling preferences

* Click and drag diary
Scheduling model

- Scheduling preferences
- Feasible time windows
- Flexibility profiles
- Penalties

Scheduling model simulator
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?
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
- 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)

   \[ \Omega = \max \sum_n \sum_i \omega_{in} U_{in} \]

   Individual \( n \) Activity \( i \)

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

3. Capture **resource constraints**

   \[ \sum_n \omega(t)_{in} r_m \leq C_m \quad \forall t \in [0, period], \forall m \]

   Activity participation (0/1) at time \( t \) Resource \( m \)
References


Thank you!