Scheduling of daily activities: an optimization approach

Janody Pougala
Tim Hillel
Michel Bierlaire

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Activity-based models

Socio-economic characteristics
Social interactions
Cultural norms
Basic needs

... (Chapin, 1974)

Activity demand → Travel demand

Time and space constraints

( Hägerstrand, 1970)
Activity-based models

Utility-based models

Decision is made by maximizing utility derived from activities

e.g.
Bowman & Ben-Akiva, 2001
Bhat et al, 2004

Criticisms:
Lack of behavioural realism
Oversimplified models

Rule-based models

Decision is made by considering context-dependent rules

e.g.
Gollegde et al., 1994
Arentze & Timmermans 2000

Criticisms:
Lack of flexibility
Data requirements
Proposed framework

- Utility-based approach based on first behavioural principles

- Mixed integer optimization model to generate a distribution of likely schedules

- Simulation strategy to draw from this distribution
Fundamental concepts

- Activities

![Diagram of activities with start time, duration, travel, and feasible time interval]
Fundamental concepts

- Activities

Location
Mode

Location 2
Mode 2

... 

Location n
Mode m
**Fundamental concepts**

- **Utilities**
- Individuals are time sensitive:
  - Preferences for start time, duration and/or end-time
Fundamental concepts

- Flexibility

![Diagram showing the relationship between utility and time, with categories of not flexible, moderately flexible, and flexible.](image-url)
An individual $n$ considering an activity $a$ with a flexibility $k$ derives the following utility:

$$U_{an} = U_{const} + U_{early} + U_{late} + U_{long} + U_{short} + U_{travel} + \epsilon_{an}$$
An individual $n$ considering an activity $a$ with a flexibility $k$ derives the following utility:

$$U_{an} = U_{const} + U_{early} + U_{late} + U_{long} + U_{short} + U_{travel} + \varepsilon_{an}$$
Utility function

- An individual $n$ considering an activity $a$ with a flexibility $k$ derives the following utility:

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

Start time deviations:

$$U_{early} = \theta_{ek} \max(0, x_a^* - x_a)$$
$$U_{late} = \theta_{lk} \max(0, x_a - x_a^*)$$
Utility function

- An individual \( n \) considering an activity \( a \) with a flexibility \( k \) derives the following utility:

\[
U_{an} = U_{const} + U_{early} + U_{late} + U_{short} + U_{long} + U_{travel} + \varepsilon_{an}
\]

Duration deviations:

\[
U_{short} = \theta_{dsk} \max(0, \tau_a^* - \tau_a)
\]

\[
U_{long} = \theta_{dlk} \max(0, \tau_a - \tau_a^*)
\]
An individual $n$ considering an activity $a$ with a flexibility $k$ derives the following utility:

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

Disutility of travelling:

$$U_{travel} = \theta_t t_a$$
An individual $n$ considering an activity $a$ with a flexibility $k$ derives the following utility:

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

Error components:

$$\sum_{v} \sum_{i} \delta_{iv} \varepsilon_{iv} + \xi_{an}$$
Individuals maximize the total utility, subject to constraints:

\[ \Omega = \max \sum_a \omega_{an} U_{an} \]

Decision variables:

- \( \omega_{an} \): indicator variable for activity participation
- \( z_{abn} \): indicator variable for succession between activities a and b
- \( x_{an} \): start time
- \( z_{an} \): duration
Mixed integer optimization problem

- Individuals maximize the total utility, subject to constraints:

\[ \Omega = \max \sum_a \omega_{an} U_{an} \]

- Constraints:
  - Time budget
  - Schedule starts and ends at home
  - Time windows
  - Succession constraints
  - Timing consistency between successive activities
  - No duplicates
Simulation

- The output of the problem is conditional on the multivariate distributions of the parameters

- Simulation procedure:
  - Draw $\theta^*$ from distribution of $\theta$
  - Draw $\varepsilon^*$ from distribution of $\varepsilon$
  - Solve $\Omega$ for $(\theta^*, \varepsilon^*)$
  - Repeat $N$ times
Results

- **Dataset:**
  - 10 individuals
  - Weekly and daily considered schedules
  - Considered locations for all activities
  - Considered modes
  - Flexibility
  - Timing preferences
  - Travel time matrices computed using Google Directions API
Example for 1 individual, different draws of the parameters
Results

- 2015 Swiss Mobility and Transport Microcensus

  - 1 day trip diaries
  - Available information:
    - Performed activities
    - Trip times
    - Modes
    - Location

  - Used heuristics to approximate the rest
Results

- Example for 1 individual, different draws of the parameters
Conclusion

Summary:
- Utility-based optimization problem
- Probabilistic output, simulation required
- Consistent results
- Data is a significant limitation

Further work:
- Validation metrics
- Parameter estimation from data: \( f(\beta | Y) \propto L(Y | \beta) f(\beta) \)
  - Hierarchical Bayes estimation
  - Maximum likelihood estimation
Thank you!

janody.pougala@epfl.ch
tim.hillel@epfl.ch
michel.bierlaire@epfl.ch
Bibliography


