Scheduling of daily activities: an optimization approach

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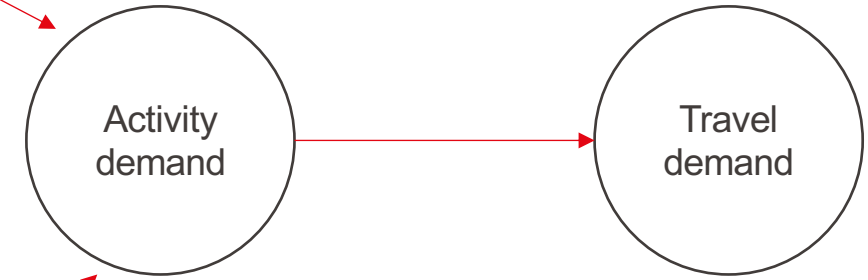
Activity-based models

Socio-economic characteristics
Social interactions
Cultural norms
Basic needs
…
(Chapin, 1974)



Time and space constraints
(Hägerstrand, 1970)

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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

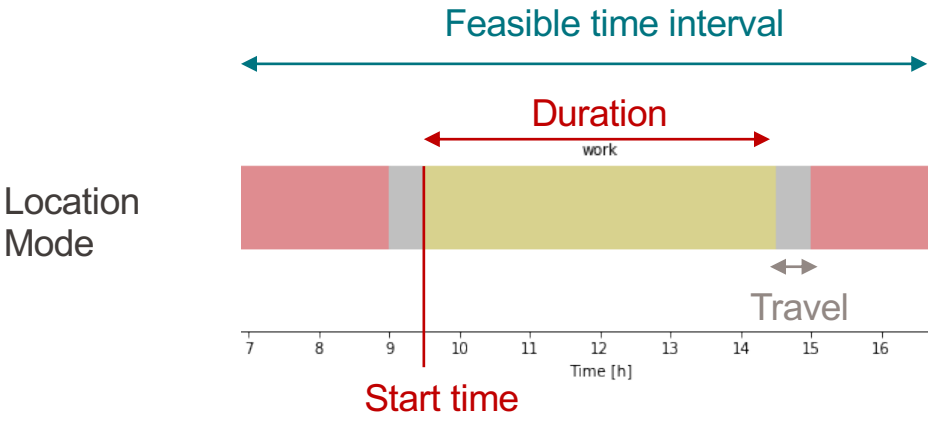
Criticisms:
Lack of flexibility
Data requirements

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**



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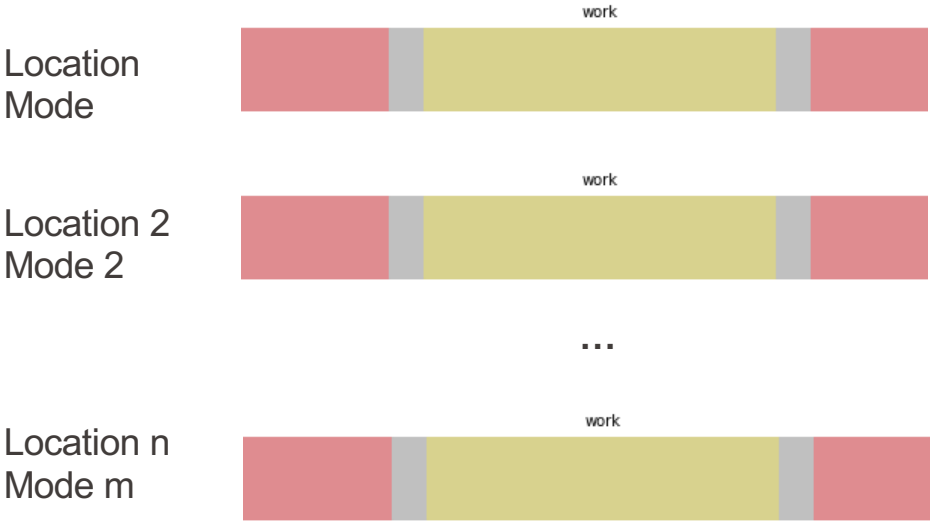
Fundamental concepts

- **Activities**



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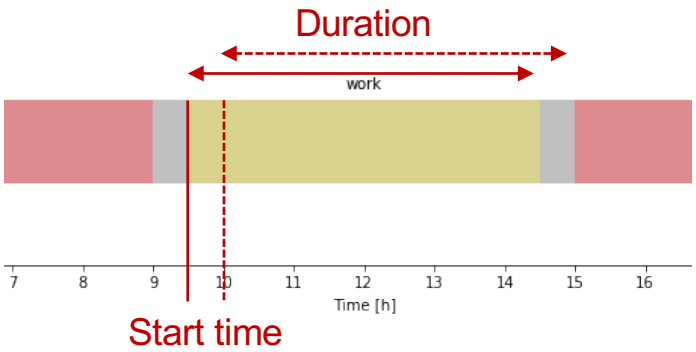
Fundamental concepts

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



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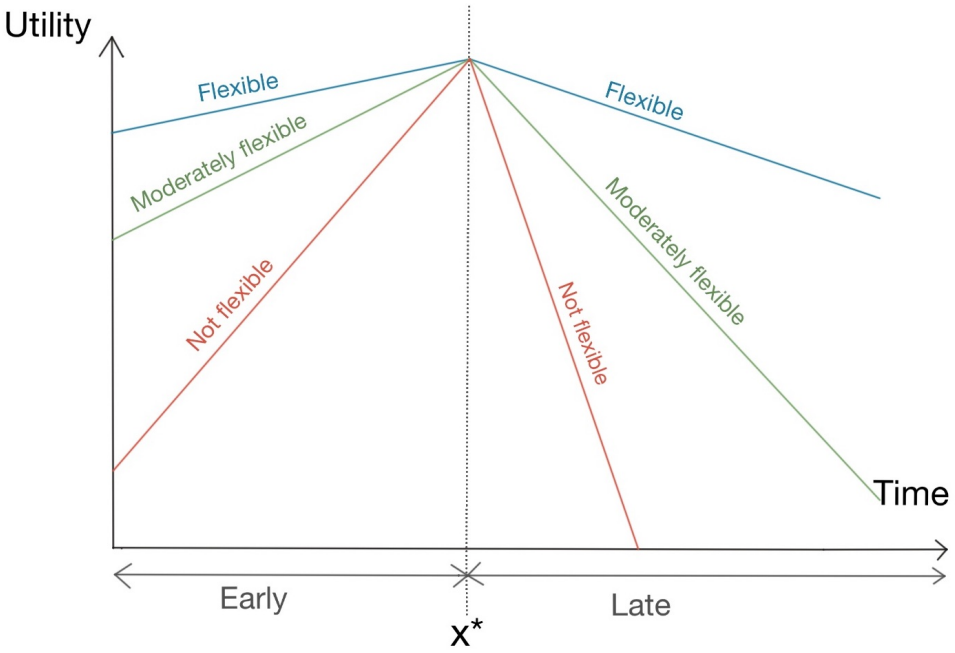
Fundamental concepts

- **Flexibility**



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Utility function

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

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

Utility function

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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:

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

Duration deviations:

$$U_{short} = \theta_{dsk} \max(0, \tau_a^* - \tau_a)$$
$$U_{long} = \theta_{dlk} \max(0, \tau_a - \tau_a^*)$$

Utility function

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

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

Disutility of travelling:

$$U_{travel} = \theta_t t_a$$

Utility function

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

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

Error components:

$$\sum_{v}\sum_{i} \delta_{av}^{i}\, \epsilon_{iv} + \xi_{an}$$

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Mixed integer optimization problem

- Individuals maximize the total utility, subject to constraints:

$$\Omega = \max \sum_{a} \omega_{an} U_{an}$$

- Decision variables:
  - ω_{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

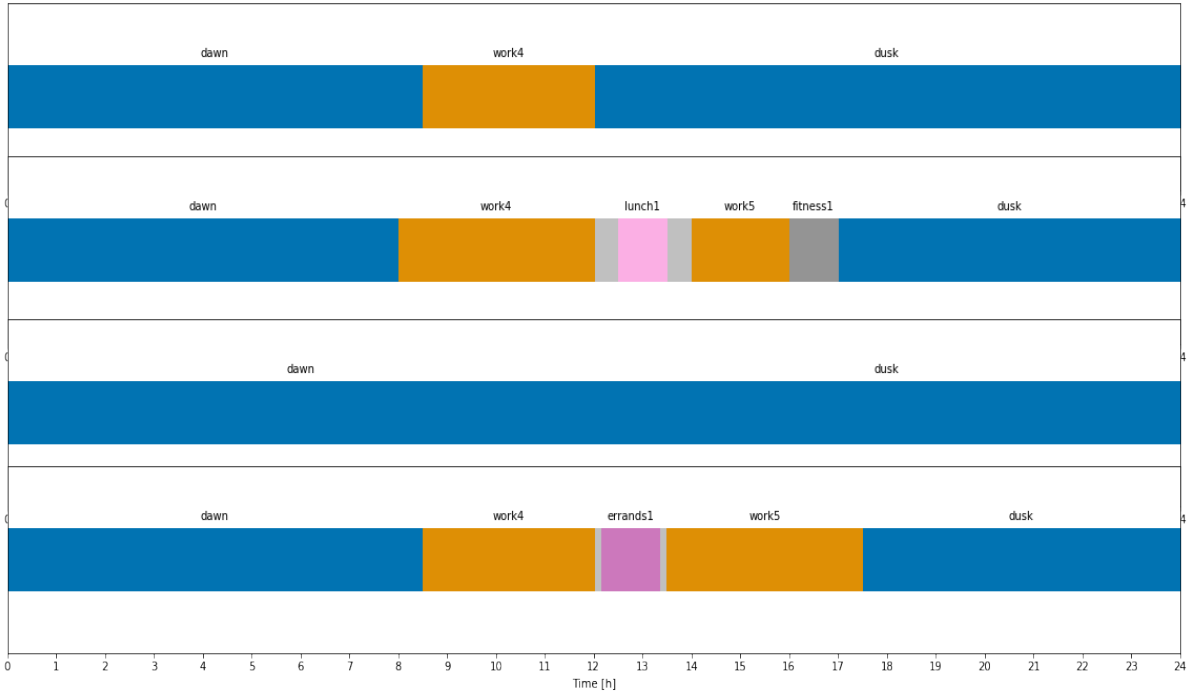
- Simulation procedure:
  - Draw θ^* from distribution of θ
  - Draw ε^* from distribution of ε
  - Solve Ω for $(\theta^*, \varepsilon^*)$
  - Repeat N times

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

Results

- Example for 1 individual, different draws of the parameters



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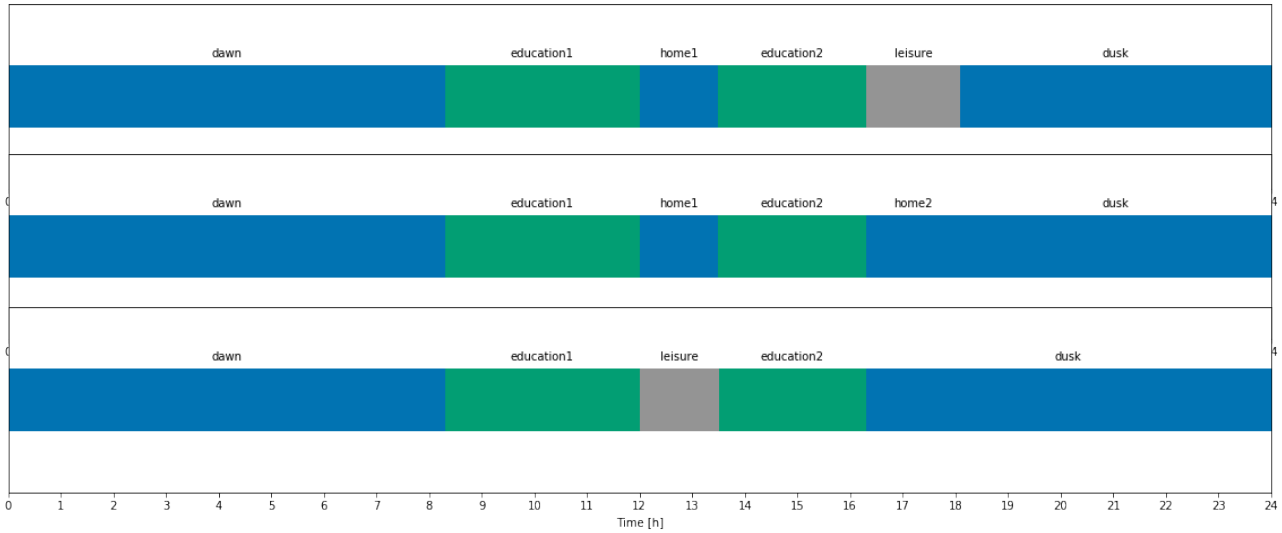
Results

- 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



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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 !

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