Event-based modeling approach for the multi-agents daily scheduling problem

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Outline

- Introduction
- Multi-agents Daily Scheduling Problem
- Event-based modeling
- Interest of the model and further steps

Transport demand modeling

Activity-Based Models

- Participation in activities.
- How people plan activities $\rightarrow$ transport demand

Simultaneous Choice Modeling

- Choices are not made sequentially.

The Daily Scheduling Problem

- Variables: Activity participation, Scheduling and Transport mode.
- Objective: Maximize agent's utility over the day.

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Literature Review

Previous work on the Daily Scheduling Problem.

	[Pougala et al., 2022]	[Rezvany et al., 2023]	[Cortes Balcells et al., 2023]
Method	MILP	MILP	Dynamic programming
Scope	One agent	Household	One agent
	No private vehicle	Private vehicle	Additional constraints

Table 1: Comparison of DS models.

What we will see: a new formulation of the Multi-agents Daily Scheduling Problem as a minimum cost flow problem in a graph.

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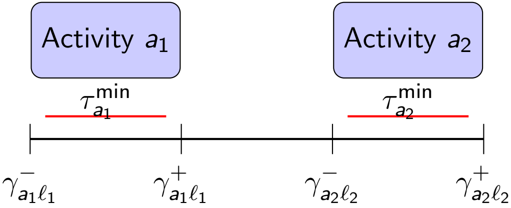
Multi-agents Daily Scheduling Problem: activities

- N: set of agents.
- A_n: **activities** that can be performed by agent n.
- A_n^{mand}: mandatory activities of n.



- L_a: **locations** for activity a.
- $c_{a\ell}$: cost of performing activity a at location ℓ.
- $[\gamma_{a\ell}^{-}, \gamma_{a\ell}^{+}]$: opening hours for activity a at location ℓ.
- τ_a^{min}: minimum duration for activity a.
- C_a: maximum capacity of activity a.
- N_a: collection of agents needed to perform a.

Multi-agents Daily Scheduling Problem: transport modes

- $M_n^{k\ell}$: available **transport modes** between locations k and ℓ for agent n.
- $\rho_{k\ell m}$ and $d_{k\ell m}$: cost and duration of trip (k, ℓ) with mode m.

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Multi-agents Daily Scheduling Problem: transport modes

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Problem: Schedule the full day T of every agent (activities, time, trips) under budget constraint (B) and to maximize the aggregate utility.

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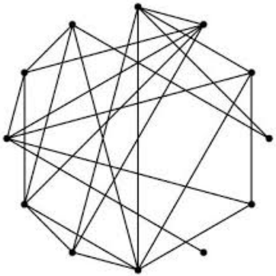
Outline

Event-based modeling approach

- Inspired by Dial-a-Ride models [Gaul et al., 2022]
- Minimum cost flow in a graph $G = (V, E)$ with additional constraints.



1. **How do we build the graph ?**
2. **What are the additional constraints ?**

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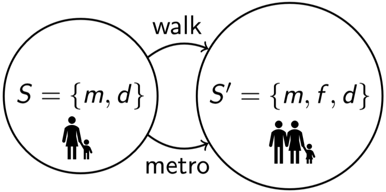
Vertices in the Graph

- For each activity a and location $\ell \in L_a$, define a vertex $v = (a, \ell, S)$.
- $S \subseteq N$ is a subset of agents satisfying:
  1. $S \subseteq \{n \in N \colon a \in A_n\}$
  2. $|S| \leq C_a$
  3. $\exists X \subseteq S$ such that $X \in N_a$
- Interpretation: S is a subset of agents performing activity a at location ℓ.

Edges in the Graph

- Let $v = (a, \ell, S)$ and $v' = (a', \ell', S')$ be two vertices.
- If $S \cap S' \neq \varnothing$, for every mode $m \in \bigcap_{n \in S \cap S'} M_n^{\ell\ell'}$, there is a directed edge $e = (v, v')$ with label $m_e = m$.
- (Multiple directed edges can exist between two vertices.)

Example: $v = (a, \ell, S)$ and $v' = (a', \ell', S')$.
$M_m^{\ell\ell'} = \{$ walk, metro, bike $\}$, $M_f^{\ell\ell'} = \{$ walk, metro, bike $\}$, $M_d^{\ell\ell'} = \{$ walk, metro $\}$.



Min cost flow with additional constraint

Now that we have G, the problem becomes:

- compute one directed path in G for each agent
- a starting time x_v and a duration τ_v for each visited vertex v
- under **combinatorial** constraints, **time-consistency** constraints and a **budget** constraint.
- maximizing the aggregated utility.

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Additional Constraints

Combinatorial Constraints.

- Path of agent n only visits vertices (a, ℓ, S) where $n \in S$.
- Path of agent n visits at least one vertex (a, ℓ, S) for each $a \in A_n^{\text{mand}}$.
- If a path of agent n visits (a, ℓ, S), then paths of all agents in S must visit that vertex.

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Time-Consistency Constraints.

- If vertex $v = (a, \ell, S)$ is visited, then $x_v \in [\gamma^-_{a,\ell}, \gamma^+_{a,\ell}]$ and $\tau_v \geq \tau_a^{\min}$.
- If arc (v, v') labeled with m is visited, then $x_v + \tau_v + d_{\ell,\ell',m} = x_{v'}$.
- For each agent, the duration of activities and trips should cover the whole day T.

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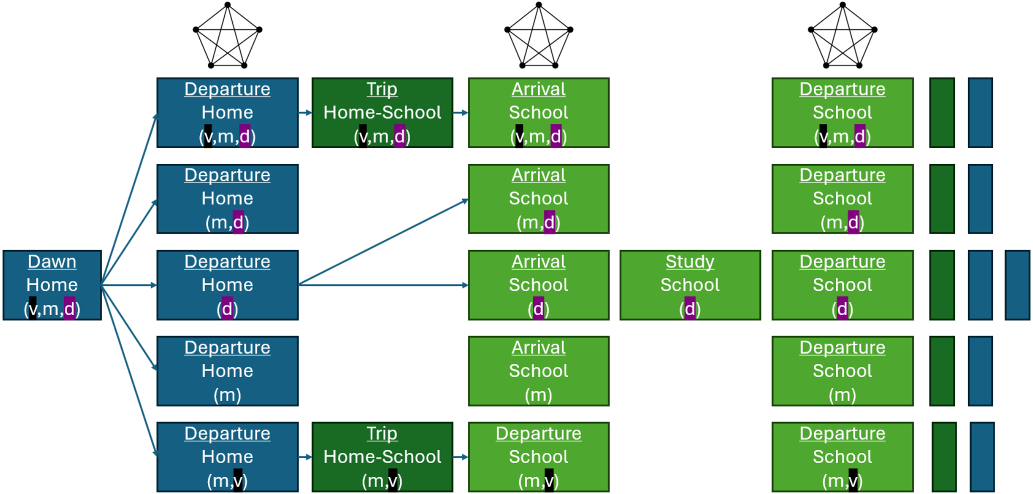
Budget Constraints. For each agent, the cost of activities and trips performed during the day should not exceed the daily budget B.

Example: a household with a private vehicle

Let's apply this model to an example, what we need to do:

1. define A_n for each agent $n \in N$; the set L_a, the capacity C_a, the collection of agents N_a for each activity $a \in A \rightarrow$ **VERTICES**
2. define $M_n^{k\ell}$ for each agent $n \in N$ and for every couple of locations $(k, \ell) \rightarrow$ **EDGES**
3. define the MILP $\rightarrow$ solve the problem :)

Example: a household with a private vehicle



Outline

Interest of the model and further steps

Advantages:

- Compact formulation
- Allows to model a wide range of problems
- Can derive a path-based formulation $\rightarrow$ efficiently solved by decomposition methods (e.g. column generation)

Further steps:

- Specify which problems are covered by this model.
- Compare its computation performance with the previous models.

Thank you for your attention!

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