Dynamic model for assignment in "sky-car" transit system—spatial interactions with other common transport modes

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01 BACKGROUND AND MOTIVATION
02 THE TRAFFIC MODEL
03 CONCLUSIONS & FUTUR WORK
01 BACKGROUND AND MOTIVATION

Personal Rapid Transit
Transport and Mobility

- Focus: Traffic modeling in Demand Responsive System equipped (DRS) with Personal rapid maglev travellers
- Traffic Demand optimization inside the DRS
- Reactive dynamical assignment - Stochasticity - Relocation
- Multimodality - Spatial interactions of the DRS with other common transport modes
1 - Background and Motivation

Transport and Mobility

Lagrangian traffic model for Demand responsive system
1 - Background and Motivation

Traffic congestion

Lagrangian traffic model for Demand responsive system
New traffic game area - Personal maglev rapid travellers
**Definition:**

Personal rapid transit (PRT), also called podcar, is a public transport mode featuring small automated vehicles operating on a network of specially built guideways. PRT is a type of automated guideway transit (AGT), a class of system which also includes larger vehicles all the way to small subway systems.
02 THE TRAFFIC MODEL

How do the sky-pods move?
Intersection model
Demand optimization
Mutimodality - Spatial interactions
Representation of portals, sky-lines

\[ x_{a+1}(t) \quad x_{a}(t) \quad x_{a-1}(t) \]

- Arrival pole
- Departure pole
- Deceleration lane
- Acceleration lane

Lagrangian traffic model for Demand responsive system
2.1 - The Traffic Model

How do the sky-pods move?

Motion of sky-pod in Lagrangian coordinates

- \( a \) sky-pod label
- \( t \) time-step
- \( x^j_a(t) \) position of sky-pod \( a \) at time \( t \) on the arc \((j)\)
- \( r^j_a(t) \) distance between the leader \( a - 1 \) and the follower \( a \)
- \( u_p^a \) velocity profile depending on its mission

\[
\begin{cases}
    x^j_a(t+1) = x^j_a(t) + \delta t \ u^j_a(t) \\
    u^j_a(t) = \min\left( U_e(r^j_a(t)), u_p^a(x^j_a(t)) \right)
\end{cases}
\]

Choice of \( U_e(r^a(t)) \):

\[
U_e(r) = U_{\text{max}} \left( 1 - \exp\left( -r + \delta r \right) \right)
\]
2.2 - The Traffic Model

Intersection model

**Deceleration Problem**

\[ \text{Dist}_{\text{dec}} = \frac{U_{\text{max}}^2}{2\gamma_a}; \text{ (braking safety distance)} \]

\[ u_a(t) = U_{\text{max}} - (t - t_0)\gamma_a; \text{ (} t_0 \text{ the instant we decelerate)} \]

\[ x_a(t) = x_0 + U_{\text{max}}(t - t_0) - \frac{(t - t_0)^2}{2}\gamma_a \]

\[ t_{\text{dec}} - t_0 = \frac{U_{\text{max}}}{\gamma_a} \]

**Speed profile in Merging and Diverging zones**
2.3 - The Traffic Model

Demand optimization

\[ W(t) \in \mathbb{R}^+_{N_S} : \] the workload at time \( t \) in the system, i.e.
\[ W_s(t) \] is the number of users at station \( s \) at time \( t \).
At time \( t \), a user at station \( s \) requires service independently of the others with probability
\[ \frac{1}{s' \in V_s W_{s'}(t)} \]. This user receives service if he is the only user requiring service in \( V_s \) at time \( t \) and when there is available offer at the station \( s \) or in its neighborhood.
2.4 - The Traffic Model

Mutimodality - Spatial interactions

Combined networks - Route and mode choices

Assumption:
Any pair OD pair could be joined with the below choices:

- **mode** $m_1$: use of road vehicle, then parking search availability to park and parking, and pedestrian walk for attending final destination, or
- **mode** $m_2$: use of sky-car and pedestrian walk, or
- **mode** $m_3$: use of modes $m_1$ and mode $m_2$.

Logit-based rules

For $\forall k \in \{1, 2, 3\}$ (k being the index of the mode) and for $\forall w = (o, d)$,

$$
\pi_{od}^k = P[\text{choice} = m_k \mid (o, d) = w \in W] = \frac{\exp(-\theta C_{od}^{mk})}{\sum_{p \in \{1, 2, 3\}, (o, d) = w \in W} \exp(-\theta C_{od}^{mp})}
$$

The probability of choosing a mode well verifies:

$$
0 \leq P[\text{choice} = m_k \mid (o, d) = w \in W] \leq 1, \quad \forall k = 1, 2, 3, \quad \forall w = (o, d) \in W,
$$

Lagrangian traffic model for Demand responsive system
Combined networks - Route and mode choices

Assumption:
Any pair OD pair could be joined with the below choices:

- **mode m₁**: use of road vehicle, then parking search availability to park and parking, and pedestrian walk for attending final destination, or
- **mode m₂**: use of sky-car and pedestrian walk, or
- **mode m₃**: use of modes m₁ and mode m₂.

Logit-based rules

For \( \forall k \in \{1, 2, 3\} \) (k being the index of the mode) and for \( \forall w = (o, d) \),

\[
\pi_{od}^k = P[\text{choice} = m_k \mid (o, d) = w \in W] = \frac{\exp(-\theta C_{od}^{mk})}{\sum_{p \in \{1,2,3\}, (o,d)=w \in W} \exp(-\theta C_{od}^{mp})}
\]

The probability of choosing a mode well verifies:

\[
0 \leq P[\text{choice} = m_k \mid (o, d) = w \in W] \leq 1, \\
\forall k = 1, 2, 3, \forall w = (o, d) \in W, \\
\sum_{k=1}^{3} P[\text{choice} = m_k] = 1.
\]
Combined networks - Route and mode choices

Assumption:
Any pair OD pair could be joined with the below choices:

- **mode** $m_1$: use of road vehicle, then parking search availability to park and parking, and pedestrian walk for attending final destination, or
- **mode** $m_2$: use of sky-car and pedestrian walk, or
- **mode** $m_3$: use of modes $m_1$ and mode $m_2$.

Logit-based rules

For $\forall k \in \{1, 2, 3\}$ (k being the index of the mode) and for $\forall w = (o, d)$,

$$
\pi_{od}^k = P[\text{choice} = m_k \mid (o, d) = w \in W] = \frac{\exp(-\theta C_{od}^{mk})}{\sum_{p \in \{1,2,3\}, (o,d) = w \in W} \exp(-\theta C_{od}^{mp})}
$$

The probability of choosing a mode well verifies:

$$
\begin{cases}
0 \leq P[\text{choice} = m_k \mid (o, d) = w \in W] \leq 1, \\
\forall k = 1, 2, 3, \forall w = (o, d) \in W, \\
\sum_{k=1}^3 P[\text{choice} = m_k] = 1.
\end{cases}
$$
03 Conclusions & Futur work
Lagrangian model for Sky-pods in motion

- We provide intersection model for autonomous Demand-responsive system of personal maglev rapid travellers
- Demand optimization due to a Random Multiple Access Protocol with Spatial Interactions.

**Challenges:**
- Method to reduce computational tasks in Large-scale Autonomous Demand responsive system of Personal maglev rapid travellers.
- Traffic simulation.
3 - References

Some references


Bilge Atasoy, Takuro Ikeda, Moshe E. Ben-Akiva. The Concept and Impact Analysis of a Flexible Mobility on Demand System.


THANKS FOR YOUR ATTENTION

QUESTIONS?

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