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Vehicle Rebalancing in a Shared Micromobility System with Rider Crowdsourcing

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  - Data Driven Logistics and Supply Chain Optimization
  - Design and Analysis of Optimization Algorithms
  - Energy Systems Optimization
  - Transportation System Planning

- A two-stage stochastic mixed-integer program:
  - make the initial vehicle allocation decisions;
  - subsequent make relocation decisions to maximize the expected profit.

- **A micromobility operator:**
  - **3PL;**
  - **Crowdsourced Riders.**

2. Related literature

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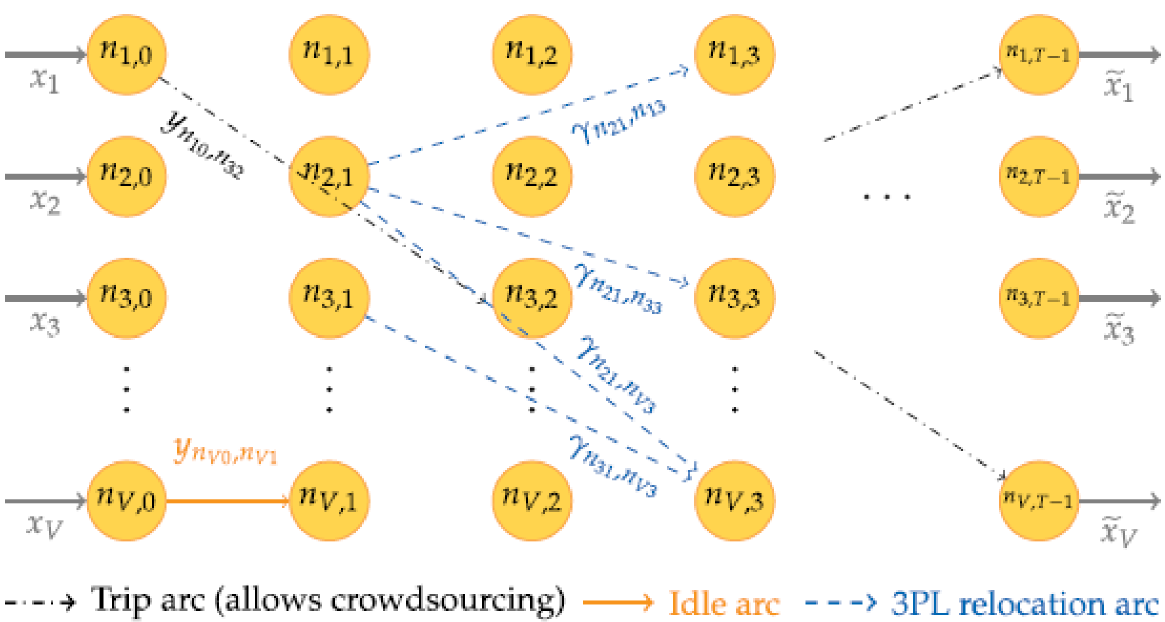
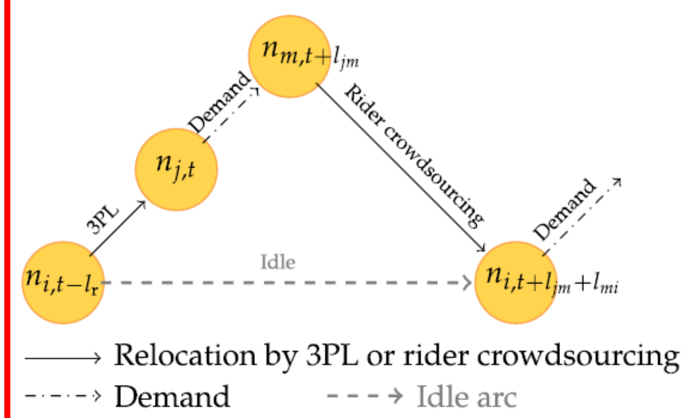
Related area	Research content	Published research	Research Gap
OM in shared mobility	vehicle-sharing systems: rent or hail cars from individual	He et al. (2017); Chang et al. (2017); Lu et al. (2018)	Cars vs bike/ e-bike
	Shared micromobility	Kabra et al. (2020); Shu et al. (2013)	Optimize the bicycle flows; initial allocation is given
Fleet operations of shared mobility	inventory redistribution or transshipment (cars)	Benjaafar et al. 2022; Miller-Hooks (2011); He et al. (2020)	Focus on shared cars
	inventory redistribution or transshipment (bicycle)	Dell'Amico et al. (2014); Freund et al. (2020); Li and Liu (2021)	Ignore the capacity design; two relocation strategies
Crowdsourcing	Crowdsourcing in last mile delivery operations	Qi et al. 2018; Fatehi and Wagner 2022; Kafle et al. 2017	two relocation strategies under different temporal demand patterns

3. Model

Construct a time-space network with multiple service regions:





$\mathcal{V}$ set of service regions $\mathcal{V} = \{1, 2, \ldots, V\}$

$\mathcal{T}$ operational horizon $\mathcal{T} = \{0, 1, \ldots, T-1\}$

x_i number of vehicle allocated to region $i \in \mathcal{V}$

$\tilde{x}_i$ number of vehicles in the ending period $T-1$ in region $i \in \mathcal{V}$

y_a realized flow on arc $a = (n_{it}, n_{j,t+l_{ij}}) \in \mathcal{A}^{\mathrm{i}} \cup \mathcal{A}^{\mathrm{t}}$

γ_a number of vehicles relocated by the 3PL from region i in period t to region j for each arc $a = (n_{it}, n_{j,t+l_{\mathrm{r}}}) \in \mathcal{A}^{\mathrm{r}}$

3. Model

The operator optimizes the vehicle allocation decisions

$$\Gamma = \min_{\mathbf{x}} \sum_{j \in \mathcal{V}} c_j x_j + \Theta(\mathbf{x})$$

$$\text{s.t.} \quad \mathbf{x} \in \mathcal{X} = \left\{ \mathbf{x} \in \mathbb{Z}_+^{|\mathcal{V}|} \,\middle|\, x_j \le B_j,\, j \in \mathcal{V},\, \sum_{j \in \mathcal{V}} x_j \le N \right\}, \quad (\mathcal{M})$$

where Θ(x) is realized in the second stage as the operator optimizes the vehicle relocation using rider crowdsourcing and the 3PL.

$$\Theta(\mathbf{x}) = \min_{\mathrm{Y}^k \in \mathcal{Y}(\mathbf{x}, \boldsymbol{\lambda}^k),\, k \in \mathcal{K}} \left\{ \sum_{k \in \mathcal{K}} p^k \left[\sum_{a \in \mathcal{A}^{\mathrm{t}}} \left(C_{\mathrm{p}} \eta_a^k + \phi_a^k - R l_a (y_a^k - \Lambda_a^k) \right) + \sum_{t \in \mathcal{T}(l_{\mathrm{r}})} C_{\mathrm{r}} z_t^k \right] \right\}. \quad (\mathcal{P})$$

Given the initial vehicle allocation x, the expected net cost Θ(x) in the second stage can be determined by solving the network flow optimization problem.

4. Comments

■ Positive comments:

- ✓ Construct a time-space network (fit the problem)
- ✓ Captures the main features of the problem (initial allocation; vehicle relocation; budget; travel time; penalty cost, etc.)
- ✓ Decomposition and acceleration strategies (based on time and scenarios)
- ✓ Good data and good figures

■ Negative comments:

- ✓ The method of dealing with demand uncertainty is crude (number of the scenarios is too large)

$$\Theta(\mathrm{x}) = \min_{\mathbf{Y}^k \in \mathcal{Y}(\mathbf{x}, \boldsymbol{\lambda}^k),\, k \in \mathcal{K}} \left\{ \boxed{\sum_{k \in \mathcal{K}} p^k} \left[\sum_{a \in \mathcal{A}^{\mathrm{t}}} \left(C_{\mathrm{P}} \eta_a^k + \phi_a^k - R l_a (y_a^k - \Lambda_a^k) \right) + \sum_{t \in \mathcal{T}(l_{\mathrm{r}})} C_{\mathrm{r}} z_t^k \right] \right\}. \qquad (\mathcal{P})$$

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Thank You!

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