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Ride-split revenue optimization on ride-sourcing service level and traffic operation

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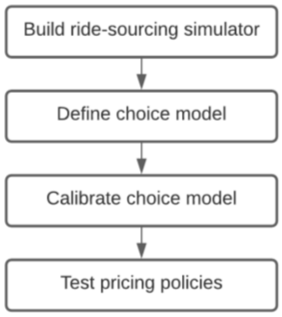
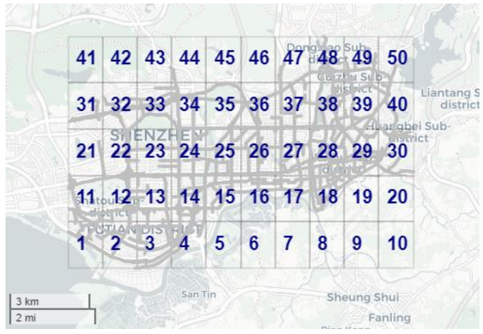
INTRODUCTION

- Ride-splitting services such as UberPool offer a discount if a user accepts to travel with another rider; discount is **independent of actual detour**
- Pooling can reduce waiting time and prevent unserved requests, but **only if rider accepts** to share given the trip costs and duration
- This project **models rider acceptance under different pricing policies** by creating a discrete-event simulation in a congestible network, and investigates the prospect of ride-splitting as a measure for **demand imbalance reduction**



Project workflow



Simplified road network and zones in Shenzhen, China

SIMULATOR FRAMEWORK

- 3-hour simulated non-uniform taxi demand with 40'000 trips/h in the 1st and 3rd hours, and 80'000 trips/h during the 2nd hour [1]
- Next-event time advance mechanism implemented in Python to carry out matching, pick-up, drop-off, and vehicle movements
- Greedy per-request matching, no knowledge on future demand
- Modal split: ride-sourcing (15%) and private vehicles (85% and abandoned ride-sourcing requests)
- Congestion dynamics: reduction in average velocity as a function of vehicle accumulation n in the system, calibrated with MFD [1]

$$v(n) = \begin{cases} 36e^{\frac{29}{600}m} & \text{if } m \le 36, \\ 6.31 - 0.28(m-36) & \text{if } 36 < m \le 60, \\ 0 & \text{if } m > 60. \end{cases} \quad \text{where } m = \frac{n}{1000}$$

CHOICE MODEL

When matching two riders for a shared trip, given the corresponding incentives and detour, the probability that a rider n accepts to share is formulated below [2], where $\vec{\beta}, \beta_0$ and ε^n will be calibrated.

- Binomial logit model:

$$P^n_{share} = \left(1 + e^{-\vec{\beta}\cdot\overrightarrow{X^n} - \beta_0 - \varepsilon^n}\right)^{-1}$$

- Linear part:

$$\vec{\beta}\cdot\overrightarrow{X^n} = \beta_t \cdot \Delta^n_t + \beta_w \cdot \Delta^n_w + \beta_p \cdot \Delta^n_p$$

$$= \underbrace{w_t \cdot \beta_t \cdot \Delta^n_t}_{\text{extra travel time}} + \underbrace{w_w \cdot \beta_t \cdot \Delta^n_w}_{\text{reduced waiting time}} + \underbrace{\beta_p \cdot \Delta^n_p}_{\text{discount}}$$

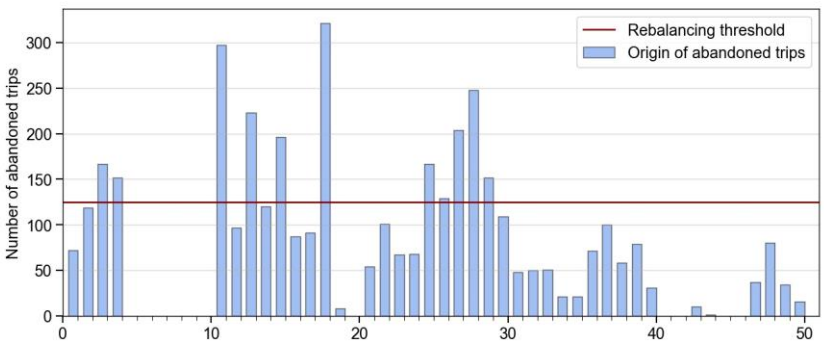
- Value of time, ~N(20, 5^2) \$/hour:

$$VOT = \frac{\Delta_p}{w_t \cdot \Delta_t + w_w \cdot \Delta_w}$$

PRICING STRATEGIES

Six simulation-level incentives are tested to compare their impact on service level, minimum average velocity (v_{min}), and average revenue.

Pricing	Description
U	solo \$2.20 + x · \$1.00/km, shared \$2.00 + x · \$0.80/km
PR	$max\ P^n_{share} \cdot R^n_{share} \forall n \in \{i,j\}$
U+PR	U during the 1st hour, PR for the remaining 2 hours
PPR	$max\ P^i_{share} \cdot P^j_{share} \cdot (R^i_{share} + R^j_{share})$
U+PPR	U during the 1st hour, PPR for the remaining 2 hours
Urebal*	U, except PPR for rebalancing in the last 2 hours

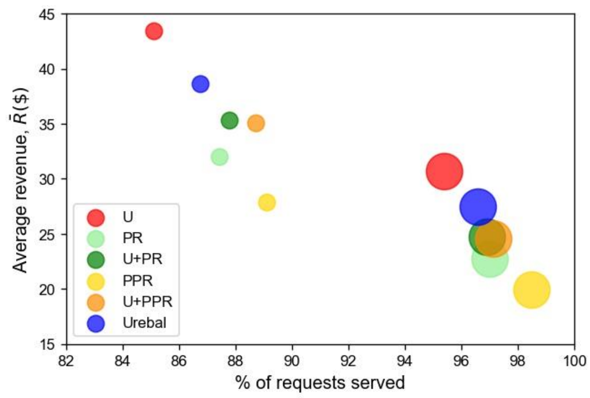


*Urebal: if shared trip's destination zone (x-axis) has high abandonment, use PPR

RESULTS

Fleet size: 2500	% shared	% mismatch	v_{min}(km/h)
U	32.82	50.17	9.96
PR	79.03	16.64	10.34
PPR	91.14	0.78	10.46

Fleet size: 4000	% shared	% mismatch	v_{min}(km/h)
U	28.05	53.94	8.52
PR	74.82	12.28	8.75
PPR	89.89	0.64	8.93



Comparison for fleet sizes of 2500 (small circles) and 4000 (large circles)

CONCLUSION

- Rider **preference models are necessary** for anticipating the magnitude of operational improvements from ride-splitting, but careful calibration is needed
- User-based incentives can effectively **address temporal and spatial demand imbalance**, and **avoid congestion impacts** from large fleet sizes
- Future direction: request-level sharing incentive optimization to target trips that lead to the largest service level improvement; multimodal interaction with transit users

REFERENCES

[1] C. V. Beojone and N. Geroliminis, "On the inefficiency of ride-sourcing services towards urban congestion," *Transportation Research Part C: Emerging Technologies*, vol. 124, p. 102 890, 2021, issn: 0968-090X. doi: 10.1016/j.trc.2020.102890.

[2] P. Stokkink and N. Geroliminis, "Predictive user-based relocation through incentives in one-way car-sharing systems," Feb. 2020. [Online]. Available: https://transp-or.epfl.ch/heart/2020/abstracts/HEART_2020_paper_96.pdf