Late passenger arrival and ride-pooling systems' performance

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Ride-pooling

Pooled ride:

1. two or more travellers can be matched into a pooled ride and travel in the same ride-hailing vehicle.
2. vehicle picks them up from origins and drops-them off at their destinations,
3. both pickup and travel times deviate from the desired or minimal ones,
4. this inconvenience needs to be compensated with a lower fare compared to an individual ride,
5. service provider can now:
   - better utilise its capacity
   - charge several users for a ride
   - while paying a single driver commission.
6. at the cost of adding uncertainty to the system

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This study

objectives

problem

The uncertainty of ride-pooling systems stems not only from travel times but also from **unique** features of sharing, such as the **dependency** on other passengers' arrival time at their pick-up points

In this work:

- we theoretically and experimentally analyse how late arrivals at pick-up locations impact shared rides' performance.

Phenomena

late passenger arrival

Uncertainty:

supply	traffic congestion, platform operations (exogenous, similar to other modes)
demand	**late passenger arrival** (specific to ride-pooling, unexplored)

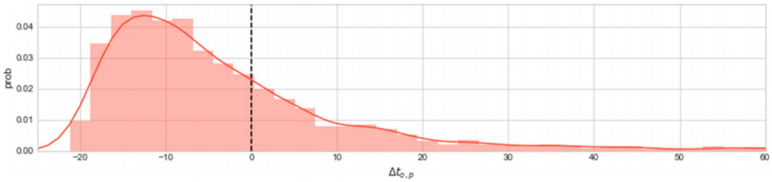

Figure 3. Lognormal distribution of passengers' lateness, we control the probability that this random variable is larger than zero (30% of the cases) and the delay variability (σ^2).

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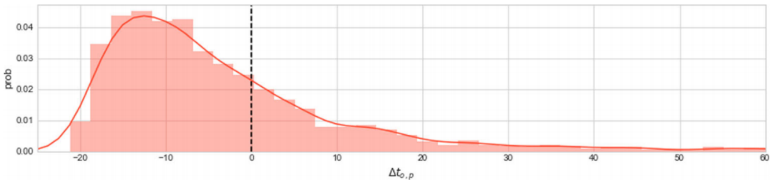
Phenomena

late passenger arrival



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data

no empirical data - big datasets from NYC, Chicago, DiDi do not store this information

we use synthetic simulated data based on arbitrary assumptions

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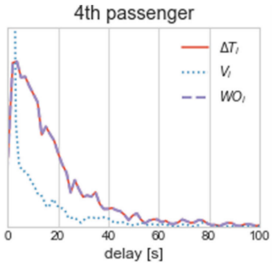
Simulation

synthetic data to analyze impact of late arrival

Experimental setting:

- We simulate 2000 realisations of a shared ride, each time independently drawing the delay of each passenger according to a given distribution
- We assume that each passenger has a probability $p = 0.3$ of being late, and when they are late, L_i follows the positive part of a lognormal distribution (with $\sigma^2 = 15$s)
- The degree (number of users with whom the trip will be shared) ranges from one to ten
- we analyze **FIFO** (sequential) rides - i.e. at first, all passengers are picked up, and then they are dropped off in any order
- driver is never late at first pick-up



Methodology

delays composition

Total Delay = Origin Delay + In-vehicle delay

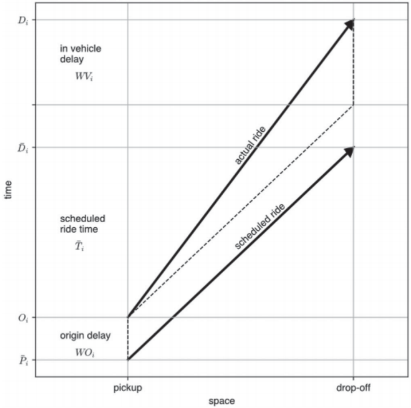


Figure 2. Scheduled and realised ride travel time $\hat{T}_i$, delayed due to origin WO_i and in-vehicle WV_i delays.

Results

2000 realisations of a ride shared by 4 travellers

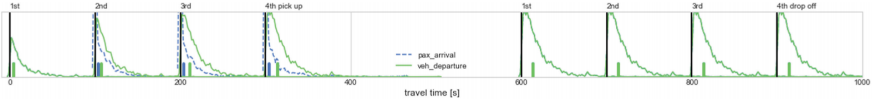


Figure 4. An itinerary of a ride shared by four passengers and its realisations. The scheduled times of consecutive pick ups and drop offs are marked with black lines. The curves represent results from 2000 Monte-carlo simulations, dashed blue for passengers' (late) arrival at consecutive pick up points, and green solid for the vehicle's departure (first at pick up points and then at drop offs).

Results

impact of degree (number of co-travellers)

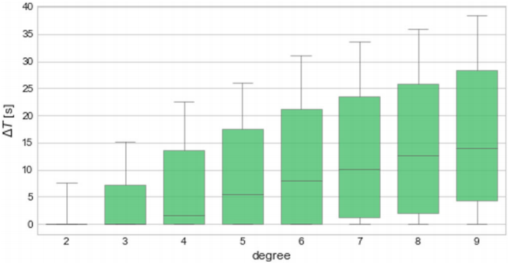


Figure 6. Average delay varying with the number of co-riders (trip degree).

impact

the larger is the number of sharing travellers, the more relevant is the lateness, but this increase becomes less significant when N is greater

Results

changes with the pick up position of the passenger

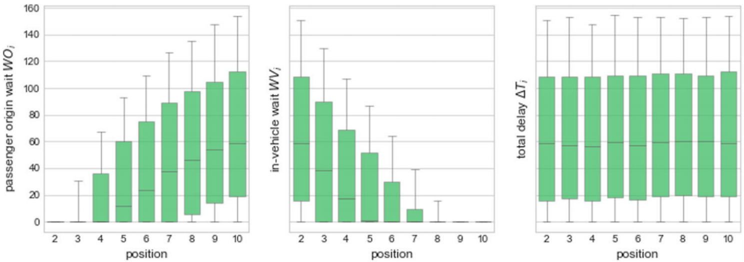


Figure 7. Distribution of delays (box-plots of 2000 Monte-Carlo runs) for consecutive passengers in a ride shared by ten of them. While total delay ΔT_i is stable (c), the origin waiting time (a) increases for subsequent passengers and in-vehicle waiting time (b) decreases.

impact

Total delay is fixed, but its composition shifts from waiting in-vehicle (early travellers) to waiting at origin (further travellers).

Results

varying lateness

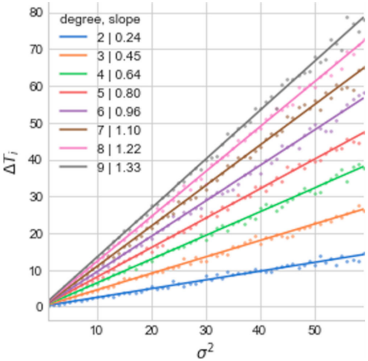


Figure 8. Vehicle's delay V_N plotted against the variance of the lateness in passengers' arrival, for various ride degrees. Trends are linear for each degree, but the sensitivity (slope) is greater for rides of higher degree.

impact

delay increases when lateness does, yet notably, the change is more relevant for rides of higher degree: an almost linear growth can be observed within each trip degree, but the slope is much steeper as the number of users increases

Results

strategic arrival (game)

Strategy:

1. each traveller may decide to be punctual or being late
2. with impact for himself and for others

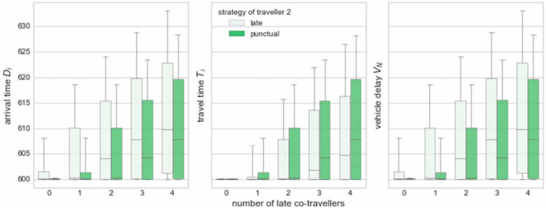
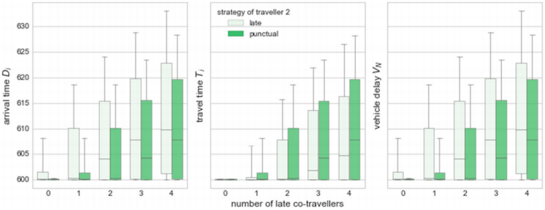


Figure 9. Three outcomes of alternative strategies (being punctual - right bar, and being late - left bar), for a passenger picked up second in a ride shared by five passengers, depending on how many co-travellers are late: arrival time (a), travel-time (b) and vehicle delay (c).

Results

strategic arrival (game)

1. the more passengers deciding to be late, the more negatively it impacts both the system (represented by the disutility of the vehicle) and other passengers.
2. if the passengers aim to arrive at the destination as soon as possible, the strategy of being punctual is dominant regardless of others (left figure).
3. if the passengers aim to minimise their own travel time (elapsed time between their arrival at the pick up point and the drop off at destination), it is better being late (central figure).
4. Yet, such a strategy is likely to deteriorate the system's performance (right figure).



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Results

system-wide impact

System-wide:

1. we employ ExMAS[1] (`pip install ExMAS`) to estimate network-wide pooling scheme.
2. we first assume that travel times are as scheduled (no lateness), and then gradually increase the magnitude of late arrival (σ^2).

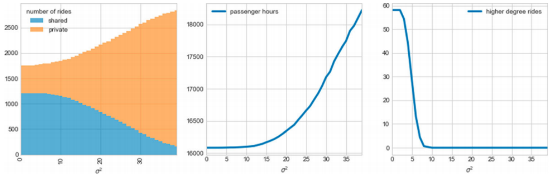

Figure 10. Impact of varying lateness σ^2 of passengers on matching of 3000 passengers into attractive shared-rides. The percentage of travellers opting for shared vs. private rides (a), total travellers costs (b), number of high degree rides (three or more travellers) in the solution (c).

impact

there are two system-wide effects of variability, which are reached at two different thresholds of σ^2. First, when passengers start avoiding rides of high degree (which are more sensitive to delay), and second, when they avoid shared rides at all.

[1] Kucharski R. , Cats. O 2020. Exact matching of attractive shared rides (ExMAS) for system-wide strategic evaluations, Transportation Research Part B 139 (2020) 285-310 `https://doi.org/10.1016/j.trb.2020.06.006`

Questions

Discussion

Thank you!

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pre-print

MaaSSim – agent-based two-sided mobility platform simulator Rafał Kucharski, and Oded Cats arXiv preprint arXiv:2011.12827 (2020) [http://arxiv.org/abs/2011.12827]

[2] This research was supported by the CriticalMaaS project (grant number 804469), which is financed by the ERC and Amsterdam Institute of Advanced Metropolitan Solutions.