The customer is always right: A value-based matching mechanism for customer-centered ride pooling

Paul Karaenke, Maximilian Schiffer, Stefan Waldherr
Technical University of Munich, karaenke@in.tum.de, schiffer@tum.de, stefan.waldherr@in.tum.de

1. Motivation

Recently, sharing economy related mobility services such as car sharing and ride hailing have been valued as promising concepts to reduce congestion and emissions in inner-city passenger transport. However, a main criticism on car-based road transport, its poor utilization rate, remains as a significant obstacle, and induced demand from ride-hailing systems may even worsen congestion and emission levels in metropolitan areas (Hu 2017). To mitigate these externalities, experts envision ride pooling as a promising concept to increase a vehicle's utilization: Herein, a mobility service provider (MSP) matches customers to share vehicles with other passengers who requested similar rides. The customers receive a discount for (potentially) caused inconveniences, while the MSP tries to increase her revenue by better utilizing her fleet and collecting a share of the resulting cost savings.

In recent years, Uber and Lyft complemented their services with ride-pooling options such as Uber Pool or Lyft Line. In theory, such ride-pooling options offer a win-win situation by decreasing costs for passengers and increasing revenues for providers. In practice, several obstacles remain. Often, providers lose money because participating passengers receive a discount, independent of the providers success to find a matching ride. If matched, customers often perceive a maximum loss of comfort due to poor matchings. These effects relate to two main reasons: first, the share of customers that are willing to accept a shared ride is insufficient to allow for consistently good matchings. Second, today's ride-pooling matching algorithms are mostly base on an economic objective and consider only side constraints to limit the customers' additional discomfort.

Contribution: We propose a customer-centered matching mechanism that facilitates a win-win situation between providers and customers in ride-pooling services. The contribution of this work is threefold: First, we propose a new pooling paradigm, which captures the customers' discomfort and preferences via their value of time. Second, we develop a matching mechanism that allows to apply this pooling paradigm in practice. Third, we present extensive numerical studies that show the benefit of such a ride-pooling matching mechanism based on real-world data.

2. Problem Statement

We focus on an online ride-hailing problem where customers request transportation services from an MSP. Formally, each request is a quadrupel (o_c, d_c, t_c, ϕ_c), stating for each customer c, her origin location o_c, destination location d_c, the time of the request t_c, and her value of time ϕ_c. The MSP tries to maximize her profit through serving these requests by assigning cars to customers such that the customers' maximum waiting times are not exceeded. Each customer can choose to share her ride with another customer in exchange for a monetary discount. In this case, the MSP may pool customers with similar requests into the same vehicle. Accordingly, the MSP assigns each customer request to a vehicle, considering individual and pooled rides based on the customers' preferences.

Here, the MSP must decide upon a compensation scheme for poolable customers and side constraints that limit customers' dissatisfaction due to detours. In this work, we compare different matching and compensation mechanisms with regards to their advantages for MSPs and customers.

3. Approach

For our studies, we assume that customers behave economically rational. Accordingly, we model a customer's cost $\gamma_c = \pi_c + \phi_c \cdot (\tau_c - t_c)$ as the sum of her paid fare π_c and her value of time ϕ_c spent on the ride, which results from her arrival time τ_c and her request time t_c. Here, π_c can be the fare for an individual ride ($\pi_c = \pi_c^S$) or a discounted fare based on a matching mechanism. The MSP maximizes her profit by assigning each customer to a vehicle such that the total *distance* driven is minimized.

So far, proposed matching algorithms solely focused on modeling customer preferences (and inconvenience) as constraints, e.g., a maximum detour factor (see, e.g., Pelzer et al. 2015, Alonso-Mora et al. 2017). We refer to such an approach as a provider-centered (PC) mechanism. In this work, we compare such an approach against a customer-centered (CC) mechanism. These mechanisms differ as follows.

Provider-centered matching mechanism: The MSP offers a fixed-discount factor $\delta \in [0, 1]$ to customers in exchange for being potentially pooled on shared rides. Then, the customers' fare reduces to $\pi_c = (1 - \delta)\pi_c^S$. The MSP tries to match the customer to a shared ride in the most cost-efficient way and considers the customers' inconvenience solely as a (homogeneous) constraint, e.g., on the maximum detour.

Customer-centered matching mechanism: The MSP tries to capture each individual customer's preferences by considering the respective value of time. Accordingly, the MSP considers customers' options, comparing the costs for individual rides to the costs of the most beneficial pooled rides. Then, the MSP assigns each customer to her cost-minimal option. Two customers are only pooled if the matching yields a cost saving for both parties, where the savings (minus the operator's share, modeled as a fixed change fee) are split proportionally to each customer's resulting discomfort.

We conduct a large-scale simulation to evaluate the effects of different matching mechanisms of MSPs. We leverage geographical data from Open Street Map as well as real-world customer data in a discrete event simulation framework. Our simulation framework considers customer request, pickup, and drop-off events and simulates vehicle movements according to the geographical data. The simulation was implemented in the Java programming language and routing is based on the OSM2PO library.[1] We use this simulation framework to compare the impact of the two different matching mechanisms on both the MSP and the customers.

4. Experimental Study

Our experiments base on the New York Taxi and Limousine Commission data,[2] which includes the origin-destination pairs of taxi trips in New York City. We focus on a representative sample of 9,410 trips, originating and ending in Manhattan, south of Central park on August 27, 2015, between 9am and 10am. We create a customer request for each trip and draw a value-of-time ϕ_c uniformly over the interval $[0.166\$/min, 0.283\$/min]$ (cf. Wadud 2017). We account for a maximum customer waiting time of two minutes and consider an MSP with a fleet of 2,000 vehicles. We compare PC and CC matching mechanisms for this setting.

Figure 1 exemplary shows both the customers' cost (consisting of their value of time and the fares paid) and the MSP's profit dependent on different pooling acceptance rates (PARs, i.e., the probability a customer is willing to get pooled) and for different matching mechanisms: PC matching with a 25% ($\triangle$) and a 15% ($\diamond$) discount, as well as CC matching with a \$1.75 ($\circ$) and a \$2.25 ($\star$) change fee. Further, we consider an unpooled scenario ($\square$) with solely individual rides as a baseline. All matching mechanism and parameter (i.e., discount/change fee) combinations reduce the customer costs on average. The PC mechanism with a 25% discount dominates the other treatments and the CC mechanism with a change fee of \$1.75 outperforms the remaining two variants. Focusing on the MSP's profit, the PC mechanism with a 25% discount reduces the MSP's profit compared to the setting with solely individual rides. Accordingly, it is unlikely, that an MSP would implement such a mechanism in practice. A CC mechanism with a change fee of 2.25\$ yields the highest profit for the MSP.

Tables 1 details the split of individual customer savings. Here, we compare the costs of each pooled customer to the cost this customer would have paid for an individual ride. As can be seen, substantially more customers receive a large saving when a CC matching mechanism is used.

[1] https://osm2po.de/

[2] https://www1.nyc.gov/site/tlc/about/tlc-trip-record-data.page

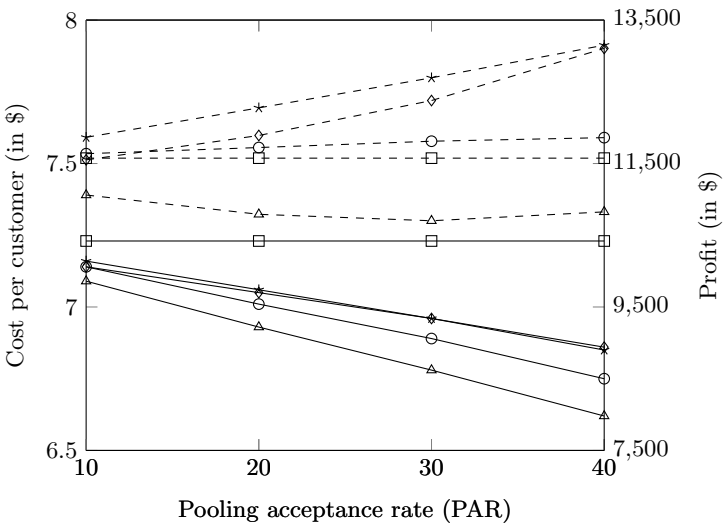


Figure 1 **Customer costs (solid) and provider profits (dashed) for different matching mechanisms.**

	PC, 25%		PC, 15%		CC, $1.75		CC, $2.25	
PAR	0$	2$	0$	2$	0$	2$	0$	2$
10%	390	1	235	1	383	70	261	34
20%	937	0	578	0	990	192	746	78
30%	1521	2	961	1	1585	321	1222	133
40%	2193	8	1348	6	2287	458	1769	185

Table 1 **Individual profit compared to solitary rides**

5. Conclusions

We presented a customer-centered matching mechanism for ride-pooling services and compared this mechanism to a standard, provider-centered mechanism that considers customer preferences solely by additional constraints. Our results show that our customer-centered matching mechanism results in a win-win situation for customers and providers, where customers incur sufficient savings in terms of trip costs. Applied in practice, such a matching mechanism may lead to higher incentives for customers to participate in ride pooling services. This may yield more matching opportunities, which again allow for a better pooling and can help to overcome the chicken-and-egg dilemma in today's ride-pooling platforms.

References

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