Ride solo or pool: The impact of sharing on optimal pricing of ride-sharing services

Ride-sharing service providers (RSPs) such as Uber and Lyft, act as two-sided platforms where peer-to-peer interactions between potential drivers and passengers take place for one-time car-sharing services. Passengers can either ride alone (solo) and pay full fare, or share the ride with a fellow passenger (pool) and pay a reduced fare. We give special focus to ride-pooling, whereby the passengers reduce their fare by choosing to share the ride with a fellow passenger (e.g., UberPOOL, Lyft Line). The downside to this money-saving option for the passenger is the additional time spent for finding a passenger willing to share the ride, and the inconvenience and the potential compromise on privacy, space, and security associated with riding with a stranger. We define this disutility as the cost of sharing.

A vast literature exists on optimal service policies and the design of queueing systems based on minimizing the expected delay or waiting time exists (Hassin and Haviv 2003, Hassin 2016). The literature on pricing of services with queues often assumes the main criteria influencing customer choice are the cost of waiting and the price charged. An important component often missing from such discussion is the cost of sharing. Through this paper, we contribute to the active and fast-growing research area of a ride-sharing economy, by capturing the non-monetary costs in passenger decision making and optimal pricing schemes by the RSP. We show why researchers and practitioners should include the cost of sharing in their study on ride-sharing, and why failure to account for such costs, apart from delay costs and monetary costs, could lead to erroneous results. We study the effectiveness of providing a pooling option, decision variables that operations managers can leverage, and the impact of the number of cars on performance metrics.

Assuming passengers differ in their cost of sharing and cost of waiting (delay sensitivity), and given the difference in expected sojourn time and pricing, we analyze the equilibrium that arises when passengers decide whether to pool or ride solo. For simplicity, assume every passenger has the same starting point
and destination (single ride) and that the RSP is the only ride-share provider (monopoly). We find that for distinct pairs of the cost of waiting and cost of sharing values, the passengers may choose to ride solo or pool or a mix between the two. We then solve the RSP's revenue-maximization problem and find whether the RSP should offer the pooling option, and if so, under what market conditions and price. We characterize the revenue-maximizing pricing strategy based on the willingness to pay and the arrival rates of each type of passengers.

For a homogeneous passenger base, the optimal (revenue-maximizing) strategy for the RSP is to offer only solo rides. However, under heterogeneous market conditions with two types of passengers, assuming unlimited availability of cars, the RSP should offer either solo rides with a high price, solo rides with a low price, or both solo and pooled rides, depending on the market parameters. The number of passengers per car (occupancy rate), is higher under pooling than solo, potentially resulting in less pollution and traffic congestion. However, we find that offering a pooling option may not be optimal for the RSP, depending on the ratio of arrival rates of high and low types and the ratio of their difference in expected costs of pooled and solo rides. We find that offering both options becomes more favorable as the difference between the cost of sharing for high and low type increases.

With limited number of cars and heterogeneous passengers, a monopoly RSP's revenue-maximizing pricing scheme is to offer one of the following options: (1) only solo rides with high fares, (2) only solo rides with low fares, (3) only pooling with high fares, (4) only pooling with low fares, (5) both solo and pooled rides with price-induced passenger self-selection. Offering only pooled rides becomes optimal when congestion is high due to shortage of cars, along with a high arrival rate to ensure a high degree of success in matching passengers and that the total pooling fare per journey time is more than the solo fare per journey time. Although we did not explicitly consider dynamic pricing, our paper shows the optimal pricing scheme
changes as arrival rates change, indicating dynamically adjusting the prices according to passenger arrival or demand and thereby matching supply and demand is beneficial to the RSP.

When the number of cars is limited, social welfare is maximized when the RSP forces everyone to pool (increase occupancy per car by offering only pooling) and/or allowing only the high type to ride (by charging a high price). But with a higher number of cars, social welfare is maximized when the RSP allows everyone to ride (by charging a low price) and/or offers the higher-quality ride option (solo) and not just pooling. To minimize the blocking probability (probability of a passenger request rejected) when offering pooling, the RSP should wait until a match is found for every pooling request. The RSP's revenue and the passenger's probability of being accepted into the system and finding a car to ride in also increase as the number of cars increases. We find that total revenue is increasing and concave in the number of cars, and offering only pooling is never optimal when there is unlimited number of cars.

Driver independence and an endogenous supply of cars are defining features of on-demand ride-sharing, and were explored. When the drivers are independent and free to choose when to work, the number of cars available is endogenous and the optimal pricing policy depends on the drivers' reservation price. Unlike traditional taxi-dispatch services, the RSP has no direct control over the supply of cars. The pricing policy should account for both sides of the platform, which is a result that holds in other two-sided markets as well. Although we acknowledge limitations in our modeling, this paper can serve as a starting point for research that focuses on the sharing aspect in on-demand ride-sharing. We conclude by suggesting future research directions.

References