Carpool Services for Ride-sharing Platforms

1 Motivation

There has been rapid growth in on-demand ride-hailing platforms that serve as an intermediary to match individual service providers with consumer demand. Ride-hailing platforms are essentially intermediary firms that connect self-scheduling and earnings-sensitive drivers who decide whether and when to work, with price-sensitive customers, who submit ride requests randomly. The growth of some of the well-known players in this market has been phenomenal: It took Uber just six months to reach 2 billion rides and the company operates in 60 counties. China’s Didi Chuxing processes more than 20 million rides on an average day.

The emergence and astounding growth of ride-sharing platforms have attracted considerable attention from the OM/OR community, and researchers have shown great interest in examining the impact of the sharing economy on production, consumption and social welfare, to explore the intermediary role of a platform matching supply with demand. Our work is mostly related to the stream of research that examines the problem of capacity management via dynamic pricing, and in particular, how on-demand platforms can adjust service prices and agent wages to coordinate supply and demand effectively, e.g., Gurvich et al. (2016), Cachon et al. (2017), Tang et al. (2016), Hu and Zhou (2017), Cohen and Zhang (2017), and Taylor (2017). Within the on-demand ride-hailing market, several major players have introduced a carpool service, such as uberPOOL by Uber and Lyft Line by Lyft. The carpool service option enables the driver to pick up multiple passengers heading in the same direction and the passengers share the ride. The platform typically offers a discount for carpool rides at the expense of service quality due to the lack of privacy and longer trip duration if detours are made to pick up or drop off other passengers. Although it is generally believed that carpool can provide environmental benefits, rigorous research on its operational, economical and social implications is scarce.

Our goal in this paper is to study (1) the operational issues faced by a ride-sharing platform in the presence of carpool services, and in particular, how should a ride-sharing platform design the price and wage schemes to maximize its profit; (2) what operational, economical and social implications will carpool services lead to. It is worth pointing out that, beyond carpool services for ride-hailing platforms, the methodologies and results in this paper can also be adapted to devise policy recommendations for other two-sided marketplaces in the sharing economy, such as bike-sharing (Mobike) and lodging-sharing (Airbnb) platforms.
2 The Model

We consider a ride-sharing platform that offers both normal services with quality \( v_n \) (i.e., rides with a single passenger) and carpool services with quality \( v_p \) (i.e., rides with more than one passenger). The quality difference \( \Delta := v_n - v_p \geq 0 \) reflects the difference between the two service modes regarding factors such as waiting time, privacy, and comfort. To model the heterogeneity among riders without losing tractability, we assume that a rider’s type, denoted by \( \theta \), is uniformly distributed on the interval \([0, 1]\), and a type-\( \theta \) customer’s valuation from taking a normal ride is \( v_n \theta \) whereas that from taking a carpool ride is \( v_p \theta \). The platform decides the price rates per service unit that customers pay for normal services and carpool services, and the wage rate per service unit it pays to the drivers. Given the platform’s pricing decisions, customers either choose a normal service, or a carpool service, or not to request a ride at all, based on whichever gives them the highest utility. On the supply side, each registered driver decides whether or not to work based on the expected earnings from the platform compared with his/her outside option. Therefore, the “supply” of participating drivers and the “demand” of customer requests are endogenously dependent on the price and the wage specified by the platform. To hedge against demand uncertainty and ensure that the customers do not wait too long after submitting a request for service, we require that the average driver utilization (i.e., the ratio between the number of drivers in service and the number of drivers that opt to work) cannot exceed a pre-specified threshold. The platform’s optimization problem is to choose the price rates (for both normal and carpool services) and wage rate with the objective of maximizing its own profit.

3 Main Results and Insights

Our main results and contributions are summarized as follows. Comparing with a benchmark case where the platform only offers normal services, we show that providing carpool services enables the platform to achieve a larger market coverage, and the platform should offer carpool services if and only if the customer dis-utility (represented by the quality difference \( \Delta \)) for a shared ride is not too high. We further examine the implications of carpool services on the pricing decisions of the platform. The optimal price for carpool services is lower than the optimal price for normal services due to the quality difference. More interestingly, we show that the optimal price charged for the normal services in the presence of carpool services is lower than the optimal price for normal services in the benchmark model. Hence, providing carpool services not only enables the platform to expand market coverage, but also allows customers to enjoy cheaper rides with the same quality. In the presence of carpool services, it is optimal for the platform to adopt the surge pricing strategy for both services, i.e., the platform would raise the prices for both the normal service and the carpool service when the customer arrival rate increases. In the face of a demand spike, however,
the price increase for the carpool service is lower than that for the normal service. As another leverage to match supply with demand, the carpool service partially alleviates surge pricing and, as a consequence, riders will gradually switch from normal services to carpool services when the demand traffic increases.

Besides the implications of the carpool service for the platform, we also study what societal influences the carpool service would have. As for the rider and driver surplus, we find that offering carpool services always benefits the riders, since it gives riders more service options to choose from. However, offering carpool services may improve or hurt the driver surplus. On one hand, the presence of carpool services expands market coverage and brings more demand for the drivers. On the other hand, carpool services also enlarge the total supply (capacity) and thus decrease the need for a particular driver. The overall impact of both effects may benefit or hurt the drivers.

We complement our theoretical analysis with computational studies with inputs of a real data set offered by the San Francisco County Transportation Authority. We show that, in the presence of volatile rider arrival streams, offering carpool services can reduce the variability of the prices compared with the benchmark model. We further examine the strategic relationship between carpool services and surge pricing. We show that carpool services and surge pricing are strategic substitutes if the total number of registered drivers is neither too large nor too small compared with the total demand rate, whereas these two operations levers complement each other when there exists extreme imbalance between the total supply and demand.

References


