Shared Mobility for Last-Mile Delivery

Many regions in the world are experiencing two socioeconomic transformations: 1) The sharing economy, in which people share access to goods and services, is prospering. One of the key sectors that is being impacted is transportation, with leading companies (e.g., Uber, Lyft and Car2Go) disrupting the traditional business of people-riding transit. 2) Meanwhile, retail e-commerce sales is expanding rapidly worldwide, with an annual growth rate of around 20%, and is projected to reach $3.5 trillion in 2021 according to a recent report by eMarketer. To advance their logistics competitiveness, some major players have kept piloting new delivery services (e.g., Walmart To Go, Google Express and Amazon Fresh, etc.) during the past several years.

A question that naturally arises from these phenomena but has not been well addressed is: Is it possible for retail e-commerce to rely on crowdsourced shared mobility for delivery services on a large scale? Until recently, such practice has remained in its infancy.

The goal of this paper is to evaluate whether and how to foster the large-scale adoption of shared mobility for last-mile home delivery services. The evaluation is mainly from the perspective of a logistics service provider, who minimizes total costs of both operating a fleet of short-haul trucks for bulk transportation and outsourcing shared mobility for the last-mile delivery. Also considered is the perspective of a local government, which aims to abate greenhouse gas (GHG) emissions.

The first part of the paper develops planning models for this prospective mode of sharing logistics. The models are based on a one-transshipment logistics setting: a fleet of short-haul trucks are dispatched from a depot and unload goods at terminals of service zones. Passenger cars nearby
with available mobility are attracted to each terminal, each picking up a ration of goods and delivering them within the service zone to their destinations. Contrasting the conventional mode where dedicated vehicles travel closed-loop routes, a salient feature of the shared mobility is its one-way nature: a car starts an outbound trip by approaching the closest destination and the service ends once it drops off the last package. Numerically solving 9,600 different instances of this open vehicle routing problem reveals the structural properties of the route patterns. To characterize these properties, a continuous approximation (CA) model is developed, along with a lower-bound analysis to establish the suboptimality of the approximation. Then a wage-response model is derived to determine the wages paid to car drivers to induce supply of shared mobility from ride-share services. Combining this CA model and the wage-response model with the CA model of short-haul truck routes results in strategic service zone deployment in the form of a closed-form expression of the optimal areas of zones as well as the associated optimal cost.

In the second part of the paper, a case study calibrates this optimal design with empirical parameter estimates in a setting of 15 zip-code areas in the East San Francisco Bay Area. By considering various operating scenarios and exploring the structure properties of the models, the paper presents managerial implications regarding the economic viability and environmental impact of this sharing logistics paradigm.

The contributions of this paper are as follows:

1) This work designs and analyzes the logistics system that features large-scale integration of shared mobility for home delivery services, using analytical models and empirical parameter estimates. In particular, the asymmetry of passenger cars’ one-way routes invalidates existing CA models for vehicle routing problems; the CA model in this work and the lower-bound construction fill this gap in literature. The wage response model and the model of interplay with the ride-share
market can be useful for studies of dynamically compensating drivers for delivery services.

2) The paper finds that crowdsourcing shared mobility is not as economically scalable as the conventional truck-only system in terms of the operating cost, unless the pool size of shared mobility keeps pace with the increase in demand density. The difference in scalability is driven by their different payment structure. Unlike the conventional truck-only system where drivers are hired and paid a fixed rate, the payment to crowdsourced drivers is route-specific and accounts for the competition with the ride-share service market.

3) A major finding is that the value of shared mobility is not direct operating cost savings, but rather its ability to reduce the truck fleet size and the additional operational flexibilities. Specifically, the paper identifies four operational prescriptions: i) to pilot this business model in low-demand-density areas since it’s not as economically scalable as the conventional truck-only system, ii) to replace regular-size delivery vans with heavy-duty trucks to enhance inbound-trucking efficiency, iii) to deliver during off-peak hours to pay lower wages to car drivers, and iv) to load more packages in cars to exploit the economies of scale of last-mile trips and also dampen the competition with the ride-share market. Moreover, these insights are insignificantly affected by dynamically adjusting wages and prices in the ride-share market.

4) The paper identifies a twofold environmental impact: i) This paradigm may incur more GHG emissions, because the emission efficiency gains from cars’ open-loop routes and smaller per-km emission rate are offset by the demerit that the total car trip distance is much longer than that by trucks because of cars’ smaller capacity. ii) Even exclusively minimizing operating costs does not significantly increase emissions relative to the minimum level of emissions, because the cost objective function and the emission objective function share a similar transshipment structure that is robust to the service zone sizing decisions.