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The benefits of meeting points in ride-sharing systems

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ABSTRACT

We investigate the potential benefits of introducing meeting points in a ride-sharing system. With meeting points, riders can be picked up and dropped off either at their origin and destination or at a meeting point that is within a certain distance from their origin or destination. The increased flexibility results in additional feasible matches between drivers and riders, and allows a driver to be matched with multiple riders without increasing the number of stops the driver needs to make. We design and implement an algorithm that optimally matches drivers and riders in large-scale ride-sharing systems with meeting points. We perform an extensive simulation study to assess the benefits of meeting points. The results demonstrate that meeting points can significantly increase the number of matched participants as well as the system-wide driving distance savings in a ride-sharing system.

1. Introduction

In ride-sharing, individuals with matching itineraries and schedules share a ride in a personal vehicle. The driver and rider(s) typically share the associated costs (e.g. fuel, tolls, parking fees) so that each benefits from the shared ride. Additionally, drivers may save time because they are able to use high-occupancy vehicle lanes reserved for the exclusive use of vehicles with two or more occupants, while riders may appreciate that they do not need to drive or even own a vehicle.

Ride-sharing can significantly reduce the number of cars needed to satisfy the mobility needs of participants and, thus, reduce congestion and other externalities related to heavy traffic when people rely on individual transportation to satisfy their mobility needs. It will, at the same time, also reduce the need for parking space, which is becoming an increasingly scarce and expensive commodity in most urban areas. (Congestion and parking are interrelated as searching for parking space prolongs driving time and can thus contribute to congestion.) Challenges related to high congestion and limited parking space arise in a myriad of urban areas around the world. In the USA, for instance, urban congestion is an acute problem with far-reaching consequences. It is estimated that the cost of extra time and fuel in 498 urban areas in the USA in 2011 alone was roughly $121 billion. Congestion in the USA is expected to grow in the foreseeable future in spite of the planned measures to curb it (Schrank et al., 2012). In this context, ride-sharing appears as an interesting possibility since it may result in significant effects without large investments.

Ride-sharing services on the market range from simple online bulletin boards to complex systems that can be accessed through web and mobile applications offering automated matching, routing and payment (see Furuhata et al., 2013 for an

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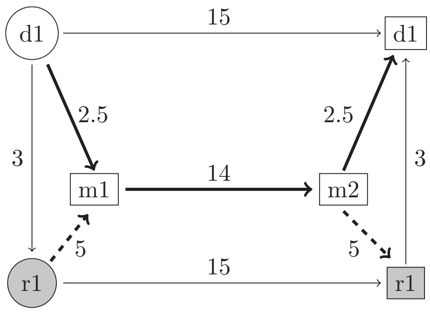

Fig. 1. Feasible match because of meeting points.

overview). In this paper, we focus on systems that offer automated matching of drivers and riders within an urban area. An example of a provider offering such a service is Flinc (https://flinc.org). The service provider is receiving a large number of ride-share offers and requests from its users. Riders looking for ride-share opportunities need to be matched with drivers that are offering rides and the resulting trips need to be scheduled. Time windows and other restriction imposed by the system or the users need to be respected.

In ride-sharing, each driver has a specific itinerary and is willing to pick-up and drop-off riders en route. To accommodate the riders, the driver has to make a detour and make extra stops. The length of the detour and the number of extra stops depend on the driver's willingness to extend his trip time. This distinguishes genuine ride-sharing from services in which the drivers act as de facto taxicab drivers, e.g., Uber (https://www.uber.com). The level of service in such systems may be higher due to the flexibility of the drivers, but this comes at a higher cost to the rider compared to genuine ride-sharing. With the exception of shared taxi services, such services also do not necessarily reduce congestion.

Limited flexibility in drivers' itineraries and schedules is a major challenge in ride-sharing. It may result in many drivers and riders not finding a match. In the simulations performed by Agatz et al. (2011), approximately 15–40% of riders and drivers remained unmatched (depending on the setting of the simulation). The simulations also showed that the ratio of matched participants predominantly depends on the distribution density of announced trips in space and time. Settings with very low density (e.g., recently launched ride-sharing services, off-peak hours, rural areas) suffer from the so-called chicken-and-egg problem (Furuhata et al., 2013), where demand for trips is not sufficient to attract sufficient supply and vice-versa. Such a situation may lead to stagnation or implosion in the number of users. To overcome such a situation the ride-sharing system has to be designed well and must employ an effective matching algorithm, so as to ensure that the largest possible number of participants is matched and the system has satisfied users. Only users that have been successfully matched and have had a positive experience can be expected to continue to use the service and promote the ride-sharing service to others. Thus, a high matching rate is a critical success factor for a ride-sharing service.

That being said, ride-sharing systems also have to minimize the effort and inconvenience for the participants. One way to achieve this is to restrict the number of riders per trip to at most one rider. In a single rider match, at most one pickup and drop off take place during a driver's trip. This minimizes the inconvenience of the driver and also makes it easy to divide the trip costs between rider and driver.

In this paper, we investigate benefits of introducing meeting points to take advantage of any flexibility on the part of the riders. Meeting points allow the construction of routes with smaller detours, while maintaining a satisfactory level of service for the riders. Riders may be picked up and dropped off at meeting points that are within an acceptable distance from their origin or destination. (A pick up or drop off can, of course, still take place at the rider's origin and destination as well.) By exploiting the rider flexibility, more matches may be found. Furthermore, meeting points allow a driver to be matched with multiple riders without increasing the number of stops on the driver's trip.

Consider the example depicted in Fig. 1 with driver $d1$ and rider $r1$ and two meeting points $m1$ and $m2$, where the number above an arc represents the time it takes to travel between the nodes, and where the driver is willing to accept an increase in trip time of at most 5 min. Without the use of meeting points, a match between $d1$ and $r1$ is not feasible because the required increase in trip time (6 min) exceeds the driver's limit. If, however, the rider is willing to walk 5 min to and from a meeting point, a feasible match between $d1$ and $r1$ is possible, because $d1$ has to make a smaller detour. (The rider's trip will be 9 min longer than if he drove by himself, but he will loose no time finding a parking space and he will not be using his own car.)

Note that the savings in driving distance in the example above is about 37% (where the savings in driving distance is obtained by comparing the driving distance when both participants drive by themselves to the driving distance when they are matched, i.e., 30 versus 19 in the example above). It is customary to consider a match distance feasible if there is a positive driving distance savings and also to measure the value or benefit of a match by the driving distance savings. Capturing the value of a match in this way may not be perfect, but it is pragmatic. Not all riders for which no match can be found will drive themselves. Some may ask a friend to drive them or use public transportation; others may not undertake the planned trip at all. Ride-sharing has the potential to provide increased mobility to those that do not own their own vehicle, but it is hard to capture and quantify this benefit. Therefore, we, as has been done in previous studies, focus on driving distance savings.