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Impact of ride-pooling on the nature of transit network design

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ABSTRACT

This paper examines the basic design trade-off in six distinctive transit systems, including two state-of-the-art fixed-route systems and four hybrid systems that use ride-pooling as an integrated feeder service. The systems are analyzed using a continuous approximation approach, and the resulting optimal design problem is formulated and solved as a mixed integer program. We find that ride-pooling changes little the fundamental laws inherent in transit design. Specifically, all six systems, despite their seemingly vastly different design features, display the following laws: (1) that the per capita agency cost correlates linearly with the per capita user cost, (2) that both costs are power functions of the demand density with an exponent close to $-\frac{1}{3}$ and -0.4 for agency and user costs, respectively, and (3) that the per capita agency cost is not significantly affected by city size but the user cost is. This finding suggests that ride-pooling may have a rather limited impact on the economy of scale in mass transit systems. However, mixing ride-pooling with fixed-route services does promise modest improvements to the overall system efficiency. It also tilts the balance of trade-off considerably in the user's favor, at the operator's expense.

1. Introduction

The idea of mobility-as-a-service (MaaS) promises to fundamentally transform the transportation industry (Goodall et al., 2017). It is envisioned that, rather than accessing mobility through owning and driving automobiles, travelers would most likely consume it as a service offered by *mobility service providers* (MSPs), of which the current generation of transportation network companies (TNCs)—Uber, Didi Chuxing and Grab, to just name of a few—are a prototype. MSPs are not unlike conventional transit agencies in what they wish to provide. Yet, with the seemingly inevitable arrival of autonomous driving technology, serving mobility to the general public looks more profitable than ever before. While TNCs still largely focus on the niche market of door-to-door services at present, they are moving aggressively to compete as an alternative to existing mass transit systems. For example, TNCs have begun to roll out dynamic ride-pooling (e.g. Uber Pool and Lyft Line) and semi-transit (e.g. Uber Pool Express and Lyft Shuttle) services. Another TNCs' initiative is to partner with public transit agencies by offering themselves as a cheaper and more user-friendly first- and last-mile solution (Jaffe, 2015). A number of pilot studies have demonstrated the benefit of such an "integrated" system (Kane et al., 2016; Kaufman et al., 2016; Lindsay, 2017).

One way or the other, it seems that future MSPs would have to marry the efficiency of having some structured routes (to consolidate demand) and the flexibility to "hail a ride" at will (to improve accessibility). Such an idea has actually been explored since 1970s, when the dial-a-ride service was proposed as a feeder to fixed-route transit (FRT) (Wilson et al., 1976;

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