Title: Modeling and Simulation of Potential Use-cases for Shared Mobility Services in the City of Ann Arbor

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Keywords: Shared mobility; dynamic shuttle; transportation modeling

Introduction

The transportation ecosystem has seen significant changes over the last decade both as a result of technological advances and the influx of transportation network companies (TNC) such as Uber and Lyft. The mobility-on-demand services presented by TNCs are affecting how people move within cities, especially among millennials. Shared mobility as a new mode occupying a spectrum between traditional public transit and privately-owned vehicles, has been studied and tested in various research and business models. Like transit, these new modes are shared across a wide swath of the travelling population over the course of a day. Yet they would also be assigned to meet passenger demand flexibly in time and space, as opposed to running along fully fixed routes and schedules as with traditional transit (*1*). Service performance may vary based on service constraints, scale of deployment and types of trips. In view of presenting future mobility solutions, it is requisite for companies to comprehend transportation from the perspective of travel patterns and the impact of different mobility solutions on traffic congestion and the environment.

Regarding modeling approaches employed to study shared mobility, agent-based models (*2*, 3), network assignment models (*4*, *5*), and aggregate strategic models (6, *7*) stand out in the literature. Researchers have studied key performance indicators (KPIs) including passenger wait time (*8*, *9*), cost of operation (*5*, *10*), daily utilization (*3, 11)*, vehicle-to-passenger distance ratio (*12*), environmental effects (*13*), and system costs (*6*). Other studies focus on vehicle service types (*14*), the service area or context of shared mobility deployment (*10*), and the market share for MaaS (*15*). Most of these studies, while in-depth, focus on one or few key performance indicators (KPI) to analyze the quality and impact of shared mobility services, but very few *(16, 17)* provide a comprehensive overview of how all of those KPIs may be affected by the constraints and configuration of the service to be provided.

In this study, we model special use-cases of shared mobility services for the City of Ann Arbor. Shared mobility as used here refers to a wide range of mobility options served by motor vehicles, everything between private public vehicles and public transit. We present and evaluate a suite of different service types that can potentially complement existing transportation services in the city. Findings indicate that while generic shared mobility services do not have vehicle occupancies much higher than tradition private vehicles at approximately 1.4, aggregating demand by increasing trip density, can result in slightly improved vehicle occupancies. Furthermore, aggregating demand by moving from "many-to-many" routing as with generic dynamic shuttle services (e.g. UberPool) to "many-to-one" routing as in the Park & Ride shuttle service can have substantial improvements in system efficiency, such as by increasing vehicle occupancy from 1.4 to almost 2. We also discuss potential benefits in terms of reduced congestion and parking needs in this report.

Methodology

In this study we built a validated network assignment model for Ann Arbor by utilizing data from the Washtenaw Area Transportation Study (WATS) travel demand model (Figure 1). Subsequently, we designed services by segmenting the origin-destination data as input for shared mobility simulations. The shared mobility modeler uses the vehicle routing problem with time windows. Optimization is targeted at serving all trip requests with a minimum fleet size. To simulate a demand profile for analyses, we assumed a certain percentage of private vehicle trips would use the designed services since we lacked real world data. With a target of serving all trips, and by defining input constraints on wait time, detour factors, and fleet size, we determined service performances based on the estimated vehicle occupancy, experienced detour, and system level reductions in vehicle miles/hours traveled. Hundreds of distinct simulations were run to support this study, but for efficiency, we condensed this work into four main scenarios. Each scenario has three sub-scenarios representing three levels of demand, calibrated to 3, 9, and 15 percent of all private vehicle trips in the city.

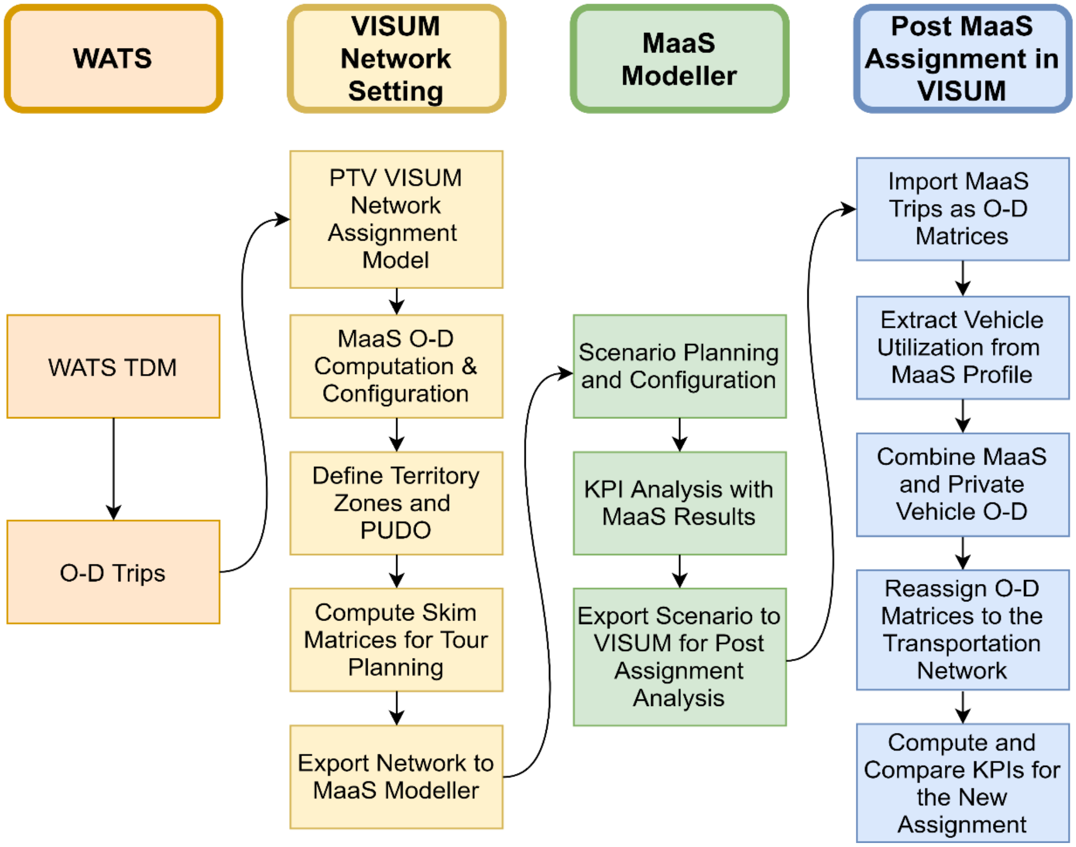
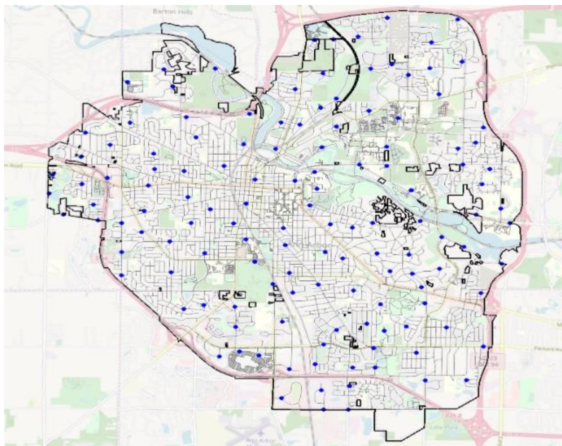


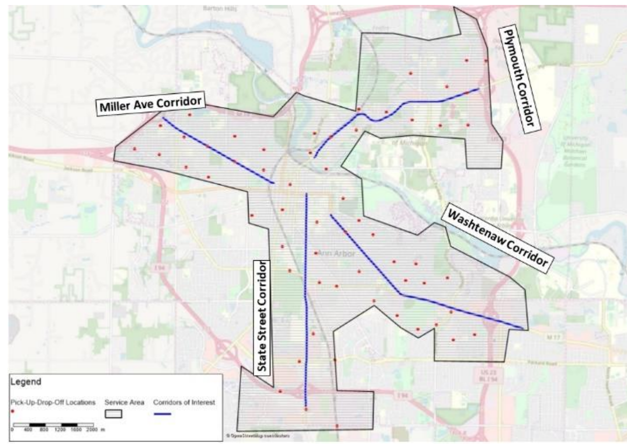
Figure 1. Shared mobility simulation process

- *Scenario 1*: *Generic Dynamic Shuttle Service* - This is base case shared mobility shuttle service in Ann Arbor for serving the three demand levels of all private vehicle trips starting and ending within the city.
- *Scenario 2: Corridor-Based Shuttle Connection Service* - This is a shuttle connection service operating along given corridors. Specifically, this scenario represents shared mobility vehicles serving demand within a half-mile of the State Street, Plymouth, Washtenaw Avenue, and Miller Avenue corridors, reaching to downtown Ann Arbor. This service type complements existing transit options serving the designated corridors.
- *Scenario 3: Park & Ride Shuttles* - Here, shared mobility serves the State Street, Miller Road, and Plymouth Park & Ride locations, which shows promise in alleviating congestion in downtown areas where parking tends to be an issue. Importantly, all trips either have an origin or a destination in one of the Park & Ride locations, thus substantially aggregating demand. This represents a class of services with "many-to-one" routing; another would be first-mile last-mile shuttle connections.
- *Scenario 4*: *Transit-Complementary Shuttles* - Here, shared mobility covers underserved areas. To model this, we first develop a process for identifying these transit zones with lower transit service performance and classifying those areas as high opportunity zones. These are essentially locations with high trip densities but longer transit trip times relative

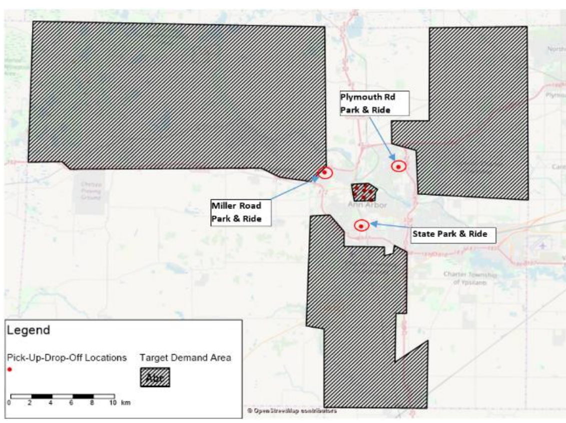
to private vehicle times. We then assign proportions of the transit trips from those areas to shared mobility services in order to improve access. In simplest terms, this service represents a replacement of some of the least-efficient and most expensive traditional transit trips with shared mobility shuttles.



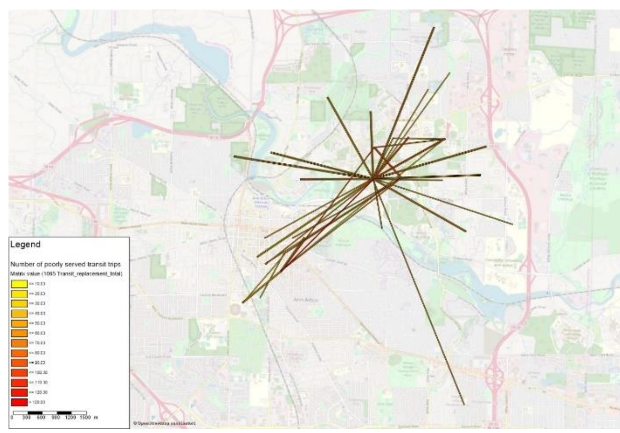
Generic dynamic shuttle service showing PUDO locations



Corridor-based shuttle connection service showing corridors & PUDOs



Park & Ride shuttle service showing Park & Ride locations & PUDOs



Desire lines showing poorly served transit trips in Ann Arbor

Figure 2. Shared mobility dynamic shuttle services

Results

By constraining shared mobility shuttle operations to two service periods, results indicate that vehicle occupancies are between 1 and 1.37 for the base case (Table 1). However, limiting the scenarios for shuttle connection and Park & Ride showed significant improvement from the base case. For the day time shuttle service, this represents 17.5%, 22.86%, and 42.45%, increases in vehicle occupancy at demand levels of 3, 9, and 15 percent respectively. Results from post-assignment indicated only minor reductions in congestion. The generic dynamic shuttle and Park & Rides cases showed 0.7% and 4.5% reductions in congestion respectively for 15% demand level. It follows that while we observe few trips removed from the network, reduction in congestion is not substantial.

Table 1. Summary of results

Demand (%)	6:00 - 22:00 (day to evening time)				22:00 - 6:00 night time		
	Generic Dynamic Shuttle Service	Corridor-based Shuttle Connection	Park & Ride Shuttles	Transit-Complementary Shuttles	Generic Dynamic Shuttle Service	Corridor-based Shuttle Connection	Park & Ride Shuttles
Total demand for shared mobility shuttle services							
3%	5,871	1,045	496	233	255	56	14
9%	17,612	3,135	1,487	698	764	168	41
15%	29,354	5,226	2,479	1,164	1,274	280	68
Optimal fleet size for shared mobility shuttle services							
3%	72	10	8	6	22	5	3
9%	200	26	18	14	60	10	3
15%	340	40	25	18	85	15	5
Vehicle utilization (hours) for shared mobility shuttle services							
3%	6.83	6.02	5.43	3.14	1.07	0.96	0.45
9%	6.46	5.33	5.40	3.38	0.98	1.10	1.13
15%	6.11	5.16	5.71	4.11	1.11	0.97	1.12
Vehicle occupancy for shared mobility shuttle services							
3%	1.20	1.41	1.30	0.70	1.02	1.03	1.12
9%	1.35	1.75	1.75	0.79	1.27	1.33	1.44
15%	1.37	1.96	1.96	0.88	1.36	1.53	1.49

Findings and Conclusions

There are six main findings from this study:

1) Generic dynamic shuttle services that do not aggregate demand do not have vehicle occupancies much higher than tradition private vehicles at approximately 1.4

2) Aggregating demand by increasing trip density, such as by going from 3% to 15% of total demand of looking only at high density corridors could slightly improve vehicle occupancy and increase overall system efficiency, but the gains are typically incremental.

3) Aggregating demand by moving from "many-to-many" routing as with generic dynamic shuttle services to "many-to-one" routing as in the Park & Ride shuttle service could have substantial improvements in system efficiency, such as by increasing vehicle occupancy from 1.4 to almost 2.

4) Focusing on less dense service areas, such as with transit-complementary service, does not substantially degrade system efficiency as compared to the base case. Therefore, shared mobility remains a very attractive service for underserved communities where traditional fixed-route transit may be under performing.

5) Shared mobility shuttle services could slightly reduce the number of vehicles on roads, however, these services solely are unable to solve congestion problems. Congestion

reduction ranges from 0.7% for the shuttle connection service to 4.5% for the Park & Ride shuttle service.

6) Even if congestion mitigation is relatively minor, parking reduction could be substantial, as shared mobility vehicles are freed to head off to serve other passengers after dropping off people in dense areas. This reduction will range based on the service type; each shared mobility vehicle could save between 8 and 12 parking spaces in the generic dynamic shuttle service but between 16 and 24 spaces in the Park & Ride shuttle service.

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