The Use of Autonomous Systems in Delivering a Public Transport Service in Houston, Texas

Nikhila Krishnan

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Introduction

Downtown Houston is the largest business district in the region, hosting approximately 150,000 employees in 1.84 square miles [1] [2]. Those employees are distributed among 50 million square feet of office space for over 3,000 businesses [1] [2]. Beyond employment, Downtown Houston is a destination for 10 million visitors each year and home to professional sports teams, Broadway musicals, theatre and ballet performances, an aquarium, and 342 retailers [1].

Due to its high-density employment and the influx of visitors each year, transport is a priority for many governmental and transportation organizations, including the Downtown District, Central Houston, the City of Houston, METRO, and the Texas Department of Transport. The Downtown District states that “improved access and mobility […] continues to be a major focus” for the area [2]. Therefore, they are open to the idea of autonomous vehicles, imagining “a Downtown featuring electric vehicle charging stations, dedicated lanes for autonomous buses, and pickup and drop-off zones for ride-sharing vehicles and autonomous taxis” [3].

Existing Transport Options

Downtown is the most connected area of Houston regarding public transport. There are many options for Downtown-goers, including 28 Park & Ride routes, 3 light rail lines, 15 bus routes, 2 circulator buses, taxi cabs, bike rentals, and a 6.5 mile walkable tunnel system [1] [4] [5] [6]. Currently, 32% of Downtown employees use public transportation and 11.2% use alternative modes of transport [1]. Though this is impressive compared to the 2.4% of public transit users in Greater Houston, the target should be closer to 100% ridership for the most connected area of town [1].

Vehicle and Infrastructure

The frequency of the light rail system is 6 minutes while the average frequency for the bus system is 21 minutes [7]. In addition, the current buses stop at every other corner, meaning they are comprehensive but slow [8]. Though the light rail system is faster and more frequent, an expansion would be very expensive. Autonomous vehicles can provide a frequent, quick, and inexpensive form of public transit in Downtown.

The light rail vehicle capacity is 150 individuals during crowded peak conditions, while the capacity of the buses range from 34 to 57 individuals [9]. More frequent services could be provided if Downtown offered smaller transit vehicles, such as the two-seater pod shown
in Figure 1. These small autonomous vehicles are conducive to a fast, frequent, anywhere to anywhere system.

Fig. 1 Daimler 2-Seater Pod [10]

Many employees arrive in Downtown from 6 major highways and 47 roads that feed into Downtown from every area in Houston [11] [12] [5]. Then, they head to their place of work, distributed over 3,000 businesses that call Downtown their home [2]. This distributed network requires a system that can transport customers from anywhere to anywhere. For this, the routes were determined to be demand-responsive, flexible routes rather than fixed routes. This means that the Downtown system would follow the Mobility as a Service model where customers can use smart phones to hail rides.

Downtown would be closed off for the exclusive use of the AV system. Therefore, the pods would be free-roaming without the need for segregated lanes. There would be 6 pod stations at the perimeter of Downtown where the 6 major highways feed into Downtown. The stations would include charging infrastructure.

**Public Transit System Evaluation Criteria**

A mass transit system should be planned with three considerations in mind: the social, environmental, and financial impact of the system.
Social

The maximum single-leg journey time of the pods compared to car and light rail, including the walk to the pick-up station, the wait for the vehicle, the ride to the drop-off station, and the walk to the destination for each mode is illustrated in Figure 3.

![Fig. 3 Single Journey Time Including Maximum Wait, End-to-end In-Vehicle Time, and Maximum Walking Time Comparison by Mode](image)

The autonomous system would provide the fastest rides because it would be frequent (and therefore has a short wait time), quick, and end-to-end (and therefore has no walk time).

Financial

The cost breakdown for the Downtown AV system is shown in Figure 4.
The autonomous system has the potential to be profitable from a system operator’s point of view. Figure 5 shows the cumulative profits over the 10 year period. This graph presents the initial capital outlay ($67.6 million) as the first point of the graph, the payback period (29 months) as the point where the graph crosses the x-axis, and cumulative profits after the 10 year period ($275 million) as the end point of the graph.
The threshold for the system to be profitable is that 22% of Downtown employees (33,000 people) use the system, which is less than the current percentage (32%) of Downtown employees that use public transit [1].

Ideally, public transportation could service all of Downtown Houston and personal vehicle travel would be banned except in extreme cases. For this, all the space currently used for parking would be freed up and used for something more productive. The Downtown district could finance this project by replacing parking lots and garages with office, residential, or retail space. Currently, much space Downtown is dedicated to the 60 parking garages and 64 surface lots in Downtown, shown in Figure 6.

![Fig. 6 Downtown Parking Garages and Surface Lots on Map of Downtown [13]](image_url)

**Environmental**

The autonomous vehicles would emit 41 gCO₂e/passenger km. This is compared to the emissions from buses and light rail, shown in Figure 7.
Fig. 7 Emissions Comparison by Mode [14] [15] [16]

The AV system would yield the highest emissions per passenger kilometer due to the low number of passengers per vehicle, the high energy requirement for air conditioning (12% of the total energy requirement), and the conservative energy requirement estimates used. Despite the high emissions, the AVs would be part of an integrated public transit system that could encourage people to abandon their cars in favor of public transport, thus decreasing overall transport emissions. These emissions correspond to Texas’ current breakdown of electricity generation by source. As electricity generation shifts from fossil fuels to nuclear and renewable sources, the emissions associated with the electric vehicles would decrease. If Texas were to have the energy breakdown of the lowest emitting state, Vermont, the emissions would decrease to 2 gCO$_2$e/passenger km [17].

**Conclusion**

Downtown serves as an example of how to design a closed-loop system to travel within a densely-populated area of town. This example can be extended to other areas of town with connections between the different areas to provide a comprehensive service that works for all of Houston, making Houston more livable and increasing the quality of life for its inhabitants.
References


