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

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**Introduction**

Fast, cheap, and low-emitting public transportation systems are essential for major cities worldwide to thrive. Houston is a vibrant and rapidly expanding city with a wealth of jobs and opportunities. Despite its position as a promising major city, Houston has limited public transit options and the majority of its citizens rely on cars for mobility. Transportation costs individual Houstonians hundreds of hours, thousands of dollars, and tonnes of carbon dioxide emissions each year. Houston needs a modern solution to transform its public transportation system, support its expected growth, and increase the quality of life for its citizens. Autonomous vehicles have the ability to transform public transportation by encouraging the move from a system with a small number of fixed-route, fixed-timetable vehicles to a system boasting a large number of demand-responsive vehicles that provide a better service through frequent trips and end-to-end mobility solutions. They serve as a possible forward-thinking solution that can provide faster services (including wait times, in-vehicle travel times, and walking times), reduce emissions, and be self-financing even if priced at existing public transport fare prices (assuming certain ridership thresholds).

**Need for Public Transit in Houston**

Houston is the fourth most populous city in the United States with 7 million inhabitants in the Greater Houston Metro Area [1] [2]. It has seen the fastest growth out of any American metro area in the past 25 years and is projected to grow to 10 million inhabitants by 2040 [3] [4]. Central Houston is not only a residential city, but also a major employment center, hosting 3.1 million jobs [2] [5]. In order to continue to grow and thrive, Houston needs an effective public transit system. Houston’s reliance on automobiles leads to a variety of negative consequences including high emissions, air quality issues, traffic, lost time, high costs, and a reduction in safety. 48% of Houston’s emissions result from the transportation sector, illustrated in Figure 1 [6].
Along with greenhouse gases, Houston’s air also hosts high levels of particulates and ozone, leading to degraded air quality for 85 days in 2016 [7]. In addition, it is extremely time-consuming and expensive for commuters to travel to work. Houstonians have one of the longest commutes in the United States, averaging at 59 minutes round trip [8]. This means that Houston drivers lose 10 days each year just to driving [9]. Houstonians have the second most expensive commute in the nation, spending $174,000 over their lifetime on fuel and vehicle costs [10]. Finally, Houston’s roads are the deadliest in the nation with 640 deaths each year due to road related incidents [11]. Effective public transport can mitigate emissions, increase public health, and save commuters time, money, and possibly their lives.

The Role of Autonomous Vehicles

To encourage commuters to eschew private car use, a public transit system must be more attractive than car travel. Autonomous vehicles (AVs) hold the key to transforming public transport. AVs can serve first mile/last mile needs; offer frequent, small services; and provide flexible, demand-responsive services. The first/last mile of transit refers to the beginning (first mile) and end (last mile) of an individual journey. There is often limited connectivity between an individual’s initial location and the transit pick-up or between the transit drop-off and their intended destination. This can prevent commuters from using public transit if they have no easy way of getting to and from the transit system. Because AVs can be applied to the first/last mile of transit, they can attract more users who previously did not have convenient access to existing transit systems. This would help create a fully integrated and accessible
system that can get a user from point A to point B. Because they do not require a driver, AVs allow for frequent small services. This transforms the transportation system from one with a small number of large vehicles to one with a large number of small vehicles. More frequent services reduce commute times and increase convenience. If a public transportation system is comprehensive so that commuters can get from anywhere to anywhere with short wait times, it can challenge the dominance of cars and thus change the face of transit with a big impact for the people of Houston. Though the larger dissertation describes the use of different sized vehicles in various geographic locations in Houston, this article focuses on large autonomous buses used to transport commuters from the suburbs to central Houston.

**Demand for Connectivity Between the Suburbs and Central Houston**

Most people who identify as Houstonians (67%) do not live within Houston’s city limits [1][2]. As Houston’s population grows, the urban core will remain the job center while 80% of new Houstonians are expected to move to the suburbs [12]. Even without taking future growth into account, a large demand already exists for a system to transport commuters from the suburbs to central Houston. The current average daily inflow of commuters during the peak AM hour is shown in Figure 2. The existing Park & Ride system only services 3% of this demand. Autonomous buses can be run on barrier-separated paths on the high occupancy vehicle (HOV) lanes to provide a quick, cheap, and low-emissions journey for commuters.

![Fig. 2 Design Hour Inbound Passenger Flow][13]
Vehicle and Infrastructure

One choice for an autonomous bus is a MicroMetro, a very narrow, 60-passenger, electric mass transit vehicle, shown in Figure 3 [14]. The MicroMetro was designed for use in Milton Keynes, UK with the aim of "serving the high-volume, fixed route demands which are primarily defined by commuters," [14]. This goal applies to Houston’s transit needs.

![Fig. 3 MicroMetro Vehicle](image)

As stated previously, the MicroMetro would run on the HOV lanes, which are 5.94 meters wide, wider than the space required by the MicroMetro system[15]. An illustration of an HOV lane adapted to accommodate the MicroMetro system is depicted in Figure 4 with the dimensions marked in millimeters. This figure shows two lanes for vehicles travelling bidirectionally, an emergency walkway, and a concrete barrier.

![Fig. 4 MicroMetro Cross-section with Dimensions in Millimeters](image)
The current HOV lanes run inbound to central Houston in the morning and outbound to the suburbs in the afternoon [15]. The MetroNext Plan calls for reverse commute options and two-way Park & Rides [16]. The MicroMetro vehicles are narrow enough that the HOV lanes could be bidirectional, thus satisfying these requests.

The infrastructure required includes barrier-separated lanes, a short concrete wall between the roadways to prevent crashes between vehicles and serve as an emergency walkway, and at-grade stations at the start and end of each route with charging infrastructure.

Houston is poised to be the leader in deploying autonomous bus systems because it already has the necessary infrastructure to segregate autonomous buses from regular traffic in the form of barrier-separated HOV lanes. The HOV lanes would be shut off for the exclusive use of the MicroMetro system. This existing infrastructure avoids the costs of building a lane safe for autonomous buses. The infrastructure costs of a pathway at grade is $5M per two-way km, amounting to a total of $1.42B if Houston were to build brand new barrier-separated pathways for the MicroMetro system [14]. Building this system on the HOV lanes avoids the majority of infrastructure costs, making Houston the ideal candidate for pioneering an autonomous bus system.

**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.

![Fig. 5 Public Transit System Considerations](image)
Social

The single journey time; including end-to-end in-vehicle time, maximum waiting time, and walking time; is shown in Figure 6. The MicroMetro has the shortest journey time because it can travel at higher speeds (assumed average speed of 60mph) because it would be separated from normal traffic. Beyond that, the MicroMetro is capable of traveling at 99mph, so the journey time could be further decreased assuming an increase in Houston’s speed limits. In addition, the MicroMetro would be more frequent than the current Park & Ride system, with an average wait time of 1 minute compared to 8 minutes.

![Fig. 6 Single Journey Time Including Maximum Wait, End-to-end In-Vehicle Time, and Maximum Walking Time Comparison by Mode](image)

Financial

The cost breakdown of the MicroMetro system is shown in Figure 7, which is a fraction (14%) of the proposed spending for the Metro Next transport plan.
The autonomous system has the potential to be profitable from a system operator’s point of view assuming the fare prices are the same as the current Park & Ride system with 28% ridership. Figure 8 shows the cumulative profits over the 10 year period. This graph presents the initial capital outlay ($675 million) as the first point of the graph, the payback period (62 months) as the point where the graph crosses the x-axis, and cumulative profits after the 10 year period ($836 million) as the end point of the graph.

Fig. 8 Cumulative Profits of MicroMetro System Over 10 Year Period with $3.84 Fare, 28% Final Ridership, and 3 Years to Reach Final Ridership Level
The threshold for the system to be profitable is 14% ridership, which is much higher than the 3% ridership level of the existing Park&Ride system [17] [18]. This would require capturing 52,000 new daily riders.

The return on capital employed (ROCE), defined as the operating income divided by the initial capital employed, stabilizes at 14%, higher than the average ROCE value for non-financial corporations in the UK (12%) [19]. Therefore, the proposed system would use capital to generate profits more efficiently than the average UK company.

**Environmental**

The emissions comparison between the autonomous bus system, Park & Ride system, and personal car use is displayed in Figure 9. The autonomous system yields the lowest emissions per passenger kilometer. As the energy supply transitions to low-carbon sources, the emissions would further decrease. The emissions of the autonomous system with Vermont’s electricity supply (the cleanest of the states) is also shown in Figure 9.

![Fig. 9 Emissions Comparison by Mode](image)
Conclusion

Autonomous transport systems have great potential in Houston. This article has suggested that AVs can be quick, cheap for consumers, profitable for a system operator, and less emissions-intensive than current options. AVs are rapidly changing the transportation ecosystem, and Houston transit organizations should consider this new technology when making future transit plans. Otherwise, the new transit systems that the Metro Next plan will implement (light rail, bus rapid transit, and expanded local bus networks) run the risk of becoming obsolete in the face of competition from new and disruptive technologies. Houston already boasts millions of job opportunities along with a diverse array of leisure activities. Effective public transit is the missing piece of the puzzle that Houston needs to top the list of best cities to live in. Houston should be a leader in developing an autonomous bus system, therefore transforming Houston into a more livable city and increasing the quality of life of its citizens.
References


[9] Steve Goldstein. Here are the typical commutes for every big metro area. MarketWatch, 2015.


