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

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Introduction

The Texas Medical Center (TMC) is home to the world’s largest medical complex and is classified as the 8th largest business district in the United States [1]. In 2.1 square miles, TMC employs 106,000 people in over 42 institutions while boasting 10 million patient visits each year [1] [2]. The efficient movement of people is necessary to support the thousands of employees and patients entering and exiting the medical center each day. For this, transportation is a key ingredient in the functionality of the medical center.

Demand for Connectivity within the Medical Center

The Medical Center is an example of a closed-loop system within Houston in need of transport options. Currently, the transport options within the Medical Center are a Medical Center-operated shuttle system or Metro-operated light rail. Currently, many Medical Center employees drive to work and park in the Smith Lands or South Extension parking lots located on Old Spanish Trail, approximately 1.5 miles from the heart of TMC [3] [4]. These employees need a transit system to travel the remaining 1.5 miles to work. The Medical Center encourages its employees to arrive at the parking lot 30 minutes prior to their clock in time in order to arrive at work on time [5]. These employees need a more efficient system. Beyond that, employees and visitors need more options to travel within the heart of TMC.

The shuttle system is more comprehensive than the light rail (has more stops) while the light rail is faster and more frequent than the shuttle system. Autonomous vehicles can provide a transit service within TMC that is comprehensive (like the shuttle system), fast (so as not to add half an hour to an employee’s commute), and frequent (like the light rail system).

Vehicle and Infrastructure

The TMC shuttles hold between 38 and 65 passengers while one light rail car holds 150 passengers [6]. For the autonomous system to operate more frequently, smaller vehicles (20-passenger) were chosen. A 20-passenger autonomous vehicle designed by Ohmio is depicted in Figure 1.
The AV system infrastructure would consist of stations and segregated pathways. The stations would be located in the Smith Lands and South Extension lots. When not in use, the autonomous pods would be stored and charged in the stations. The pods would run along segregated routes rather than integrating with normal traffic to make them safer, faster, and adopted quicker.

**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 the bus and the 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 and each route (red, white, or blue) is illustrated in Figure 3.

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

The pods would have the shortest single journey time because commuters using the comprehensive and frequent AV system would not need to walk as far as those using the light rail and would not need to wait as long as those using the shuttles. This analysis was performed by replicating the current shuttle routes in order to provide a benchmark for the performance of the AV system. In reality, the routes could be demand-responsive and therefore the AV system could be even more convenient for users.

Financial

The total annual cost breakdown of the TMC AV system is depicted in Figure 4.
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 light rail system with 6,000 rides per day. Figure 5 shows the cumulative profits over the 10 year period. This graph presents the initial capital outlay ($7.5 million) as the first point of the graph, the payback period (57 months) as the point where the graph crosses the x-axis, and cumulative profits after the 10 year period ($11 million) as the end point of the graph.
The threshold for the system to be profitable is that 35% of employees who park at the Smith Lands and South Extension Lots use the system (only slightly higher than the 33% ridership level of the existing shuttle system) and a fare price of $0.87 \[11\] (far lower than the light rail price of $1.25).

The return on capital employed (ROCE), defined as the operating income divided by the initial capital employed, stabilizes at 16%, higher than the average ROCE value for non-financial corporations in the UK (12\%) \[12\]. Therefore, the proposed system would use capital to generate profits more efficiently than the average UK company.

If the proposed system were to capture less than 35\% of the employees that park in the Smith Lands and SE lots as customers, it would be far less attractive for a system operator as it would require a public subsidy or different form of revenue. TMC could charge more for the parking spots to raise additional revenue. If TMC raised the price of the parking spots to cover the difference between the current shuttle system and the autonomous system, each parking spot would need to cost $10 extra each month (13\% increase in price) for a total of $88/month. This is realistic because the remote surface lots (including the Smith Lands and South Extension lots) offer the cheapest parking option \[13\]. Even if the parking spot prices increased to reflect the additional cost of the autonomous pod system, the remote surface lots would still be the cheapest choices for parking.

**Environmental**

During peak conditions, the AV system would have the lowest emissions. In addition, the AV system would use smaller, demand-responsive rather than large, fixed timetable vehicles like the current transport options. For this, the vehicles would have higher average load factors than the current systems. The TMC shuttles and light rail run at 45\% of their seated capacity on average, meaning they are half empty \[14\] \[6\] \[15\]. Because the vehicles run at lower occupancy, the average emissions per passenger kilometer are higher than the emissions during the peak. It was assumed that the AV system would run at 75\% capacity on average. The peak and average emissions comparisons are illustrated in Figure 6.

As the Texas energy supply relies more upon renewable sources and less on fossil fuels, the emissions per kilowatt hour of electricity produced will decrease. Vermont is the U.S. state with the lowest emissions per kWh of electricity produced (26 g\(CO_2e\)/kWh) because it relies heavily upon biomass, hydroelectric power, and other renewables \[16\] \[17\]. If Texas could reach the emissions per kWh that Vermont currently boasts, the emissions for the AV system would sharply decrease to 1g\(CO_2e\)/passenger km when running at full capacity. The emissions comparison of the three systems at peak and average capacity for the Texas and Vermont energy breakdowns is presented in Figure 6.
The emissions comparison suggests that the implementation of the AV system would decrease transport emissions in the Texas Medical Center. In addition, an effective public transit system could encourage TMC employees to choose public transit over personal vehicles for their entire journey to work, further decreasing transport emissions.

**Conclusion**

The Texas Medical Center has as many jobs and visitors as a major city’s central business district and thus should have the same public transit options. TMC 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. This way, Houston can become more livable.
References


