DESIGN AND IMPLEMENTATION OF A SHARED AUTONOMOUS VEHICLE SYSTEM IN AUSTIN, TEXAS

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ABSTRACT

Autonomous vehicles (AVs) and shared autonomous vehicles (SAVs) have the potential to significantly change society's transportation systems and land-use patterns, thereby impacting the quality of life for urban dwellers. A shift to self-driven cars affects what people do in their vehicles, their values of travel time, road safety, traffic congestion, and the natural environment. Cities and other government agencies will have the opportunity to integrate SAV technologies systemically within roadway networks to further promote these concepts, as well as to provide low-cost transit options, further propagating the benefits.

The assumptions enabling this forward thinking will provide initial insight into AV technology and their application within the Austin network. The station and queuing geometry utilizes context sensitive design, promoting multi-modal access. This insight into SAV dynamic ridesharing (DRS) systems enables potential initial integration of this technology, given the benefits logistically of fleet systems. Different station locations are examined, (and can serve as a template for other special trip generators in cities across the globe) serving different areas of the metropolitan region, and providing a differing level of service to the users of the Austin transit system. This culminated in the decision of electric cars providing service to four regionally distributed station systems, generating a benefit-to-cost (B/C) ratio of 4.42.

Key Words: Shared autonomous vehicles, autonomous taxi system design, electric vehicles, dynamic ride-sharing

INTRODUCTION

Implementation of shared, self-driving vehicles may completely alter society's experience of transit. One socially-equitable implementation of fully-autonomous self-driving vehicles (AVs) is a shared (SAV) fleet system, which will provide sustainable and cost-effective transit for communities. The ability to allow for expanded mobility and environmental benefits was part of the impetus to provide a forward-looking perspective into the geometrical renderings of this future transit option. Dynamic ride sharing (DRS) is the use of chained trips, which will allow for varied level of service depending upon patron preferences, providing an increased system capacity while rewarding patrons for ride sharing.

The designs developed here integrate a DRS-SAV fleet into the Austin, Texas setting with the assumption that fully operable SAV technology is market-ready. The fleet system builds upon Kornhauser's (2013) DRS-SAV simulations in New Jersey, which contained hub centers where SAVs would function to serve patrons. Jorge and Correia's (2013) notion of one-way transit options bolstered the idea of the ride-sharing program. Ride-sharing, which has its benefits if implemented in more mass, led to a 40% reduction in cumulative trip length if ridesharing had more systematic influence (Resta, Santi et al 2014). Additionally, DRS outperforms non-ridesharing systems in multiple performance measures, including environmental (Zhang and Guhatharkurta 2015). These four different station locations (explained schematically later in this paper), provide service to special trip generators, along with door-to-door service. Benefits from promoting transit systems, ride-sharing, reduction of individual car-ownership, and the enhanced safety of these vehicles allow the City of Austin to grow within the existing roadway infrastructure. Each AV is assumed to replace 14 traditional vehicles from the network (Zhang and Guhathakurta 2015). This proposal provides an insight into the future of transit systems within the urban setting, paving the way for cities to implement this type of technology. With a base fee of a dollar per person and a dollar for each mile traveled, the transit system rivals comparable alternatives as displayed in Table 1.

Table 1. Cost Comparison for Similar Transportation Alternatives in Austin

User Cost of Different Shared Vehicle Systems from Austin Bergstrom Airport to Dowtown's Seaholm Station Area (11.2 miles)	
Uber	$26
Lyft	$33
Car2Go	$14
Yellow Cab	$31
Proposed SAV System	$13

FRAMEWORK FOR THE TRANSIT SYSTEM

An AV is defined as a car that can "perceive its environment, decide what route to take to its destination, and drive it" (Yeomans 2014). There are different levels of autonomy, varying by the amount of driver assistance needed to operate the car. Current market technology includes adaptive cruise control, self-parking capabilities, and "pilot-assist" technology for congested conditions (Kessler et al 2015). This assumption of market-ready level 4 technology is used here for design and system functionality, which is critical for determining how the car operates within the roadway network and the role of those inside.

At the fully-autonomous stage, the car would be able to navigate itself in known and unknown situations. Vehicle control systems that automatically brake and accelerate provide much more efficient reaction times than an average driver (Preliminary Statement of Policy Concerning Automated Vehicles). Because of the eventual removal of human decision making on the roadways, AV technology will have the capabilities to decrease headways between vehicles, thereby drastically increasing the roadway capacity without having to add additional infrastructure. According to the Environmental Protection Agency in 2010, the value of life was estimated at around $9.1 million (Appelbaum 2011). Every year on the road, 93% of traffic accidents are due to human mistake, which cause 1.3 million deaths and 50 million injuries worldwide (Yeomans 2014). Therefore, implementing cars that can fully drive themselves would have the potential to decrease collision rates and increase human productivity since everyone sitting in the vehicle will be a passenger capable of performing activities other than driving (Litman 2015).Many major companies like Mercedes-Benz, GM, and Google have already developed working AV prototypes. More recently, vehicles already equipped with sensors may be able to receive software updates to enable level 2 or 3 autonomy, as seen with the recent Tesla software updates to allow for autonomous features such as autopark, autosteer, auto-lane change, traffic-aware cruise control, and side collision warning (Teslamotors.com).

Currently, autonomous technology, excluding vehicle cost (note that some technology cannot be retroactively inserted), costs around $20,000-$80,000 which is much higher than most travelers are willing to pay (Litman 2013). Cost, along with the legal system and regulations, are the top three barriers to autonomous vehicle usage (Southwest Research Institute 2015).

System Technology Relating to the Network

The outlined boundaries of the Austin network are illustrated in Figure 1, encompassing 90 square miles. The system boundaries were determined by incorporating the most densely populated areas. This varies from the AV fleet system modeled by Fagnant and Kockelman (2014), which utilized a 12x 24 mile-bounded network. However, their simulation data serves here as a base measure for principles of vehicle relocation, person-trips to be served per SAV per day SAV and daily VMT per SAV. System-wide modeling is not used here, with individual vehicles loading individual network links and responding to specific customer calls on SAVs.

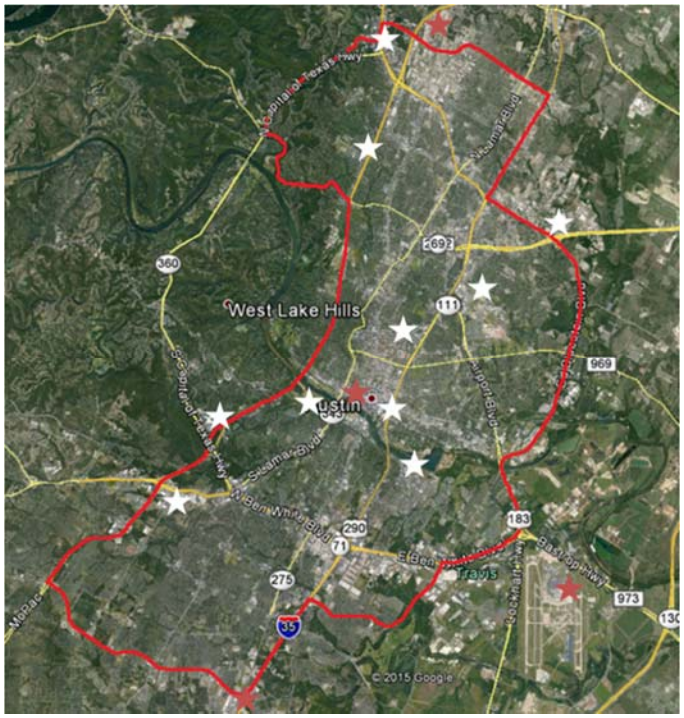

FIGURE 1. Project Limits with Station Locations (Source: Google Earth)

Figure 1 shows all station locations. Station placement was determined through a look at Austin's top travel corridors, population and jobs density maps, and reasonably equitable distribution of stations across the region, to help limit vehicle redistribution costs. Figure 1's red-star locations are top stations, with high demand and high levels of service frequency expected. These major stations differ from the white-star queuing areas; which are more common and allow for quicker alighting times at a reduced cost for the system operator. These system attributes are part of the parameters that would be geo-coded by a fleet operator in order to determine permissible drop-off areas in high density and high traffic areas. System design and operations decisions should also account for periods of peak demand (like the morning rush-hours), when more ride-sharing opportunities will exist. All of the data described above can be used in system-management software that will function and interact with patrons, similar to any transportation network company.

User Attributes

Understanding the system's users and how they will interact with the team's proposed product will help provide adequate and desirable amenities. Per assumptions, the basis of charging the passenger \$1.00 per mile of a non-shared trip (with the potential for that cost to decrease with sharing), the affordability of the product should not dissuade a significant percentage of travelers (Fagnant 2015). The DRS-SAV system rivals many other transit systems in the Austin area, as seen in Table 1, due to the elimination of driver costs. The costs related to this system and factors of sensitivity related to the variability of the costs of this product will be discussed in further detail in the cost analysis.

Barriers to public participation in this transit alternative are access to smartphones and one's psychological acceptance to cede control of the vehicle. However, this system can incorporate a wider array of patrons through personalization and a reflection of this personalization in the cost of the service. Examples of this personalization can range from the users preferred and maximum wait times, as well as increased levels of service (e.g., as in the use of tolled express lanes). Having the user interact with a mobile application will allow for data collection and suggestions regarding amenities for future stations, and will be helpful in creating shared knowledge and integration of new technologies.

Ridesharing Methodology

A typical ride will consist of the following: a traveler arrives at the station, and his or her willingness to share the ride will dictate where he or she is placed in the network's service queue. A third of U.S. ridesharing occurs between the hours of 7-8 AM and 5:30-7:30 PM (Zhang and Guharkakurta 2015). If a ride request occurs during these peak times of day, increased ride-sharing or system overuse may occur, which would then mean all rides must be shared, to the greatest extent possible, to protect fleet seat capacity, and avoid not meeting traveler requests. Depending upon the time of day and the station, different vehicle relocation strategies as well as rider-distribution strategies will be utilized. One benefit of self-driving technology is the ability to provide door-to-door service. The transit system promotes ridesharing with stations in attractive destinations, but an added door-to-door service charge could be a way to further promote public-transit-type operations. Door-to-door service will be discouraged in high-density areas where alighting can be disruptive of traffic flows and/or dangerous to pedestrians. For a lower charge, patrons can be dropped off in designated areas, such as hotel valet parking areas, business driveways and hospital drop-off areas. Optimization techniques will reduce total service time even when additional stops are needed to accommodate more passengers (Fagnant 2015). Such techniques effectively increase the "true average vehicle occupancy" while minimizing average user wait times.

DESIGN OVERVIEW

The proposed designs of these stations are backed by research, standards regarding transit systems, and an understanding of the amenities needed for the patrons and for the vehicles themselves. The design of each station has its own uniqueness in capacity, land-use, and clientele. Each of the four schematic drawings below was constructed using MicroStation and Google Earth. Figure 2 displays the location of the main station center in the downtown region, where new mixed-use projects will be attracting permanent residents who may prefer the freedom associated with not owning a vehicle.

FIGURE 2. DRS-SAV Station at Seaholm Site, Profile View (CBD Mixed-Use Setting)

DRS-SAV STATION ATTRIBUTES AND LOCATIONS

DRS-SAV station attributes consider the people being served by that station as well as each station’s surroundings. Station locations were determined based on the attractiveness of the surrounding businesses and relative areas. It is important to understand the surrounding businesses and land-uses to ensure that proper amenities are provided, such as having enough pick-up and drop-off spots. For example, many commuters may want to use a high-density area that is peripheral of the central business district (CBD) (which will serve peak-hour travelers) and park their vehicle within close proximity of the station. More densely packed areas that can serve a variety of passengers will need multi-modal access, promoting transit use and reducing the amount of personally owner vehicles, as well as additional infrastructure to support patrons. Selected locations will also require charging stations if EVs are pursued, which will be situated where vehicles are queued for significant time periods or stored overnight. The following four stations which were selected and evaluated in the project analysis correspond to a housed vehicle fleet of 400 AVs. This fleet size rivals competitors such as Yellow Cab Austin (461 permits), but the SAV-DRS system outperforms Yellow Cab Austin with regards to average passengers per month (342,000 vs. 276,738 respectively) (Derr, 2014).

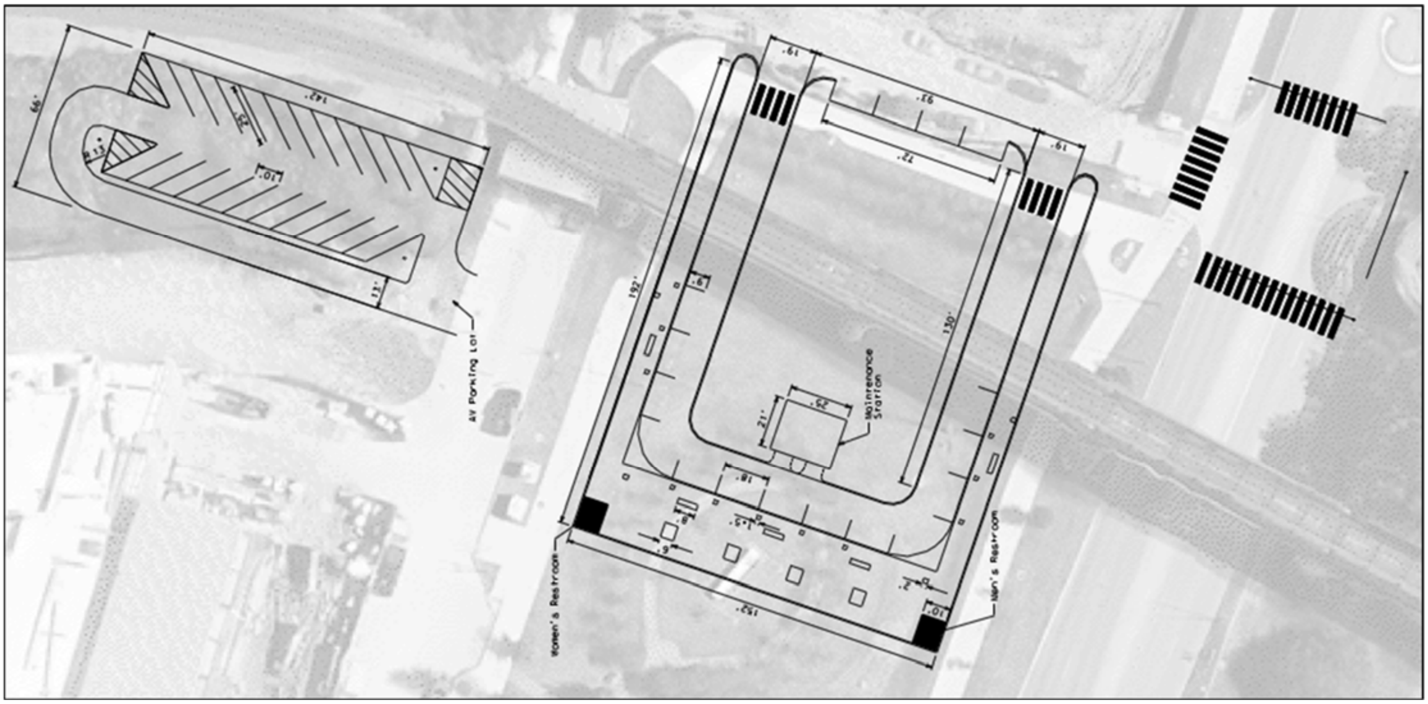

FIGURE 3. DRS-SAV Station Design at Seaholm Site, Plan View (CBD Mixed-Use Setting)

CBD Mixed-Use Design

Mixed land use in a CBD proves an attractive transit destination for many people, suggesting a strong demand and need for SAV stations. With a focus on a high level-of-service and quick alighting times, the pedestrian area is segregated from SAV traffic. As seen on Figure 3, pedestrian amenities are centered towards the northwest of the station, conveniently situated across from apartments as well as bike and car-sharing programs. Due to the high anticipated traffic at this station, additional pedestrian amenities were provided such as restrooms and shaded waiting areas to provide comfort to patrons who may choose to wait for a shared-vehicle. Allowing for pedestrians to comfortably wait without impeding additional SAVs from entering the system mimics the design of many taxi areas for airport facilities. These SAV storage areas use diagonal parking to maximize the space and to allow for easy electric-vehicle (SAEV) charging access. City of Austin parking standards require 17’6” x 9’ space minima (www.municode.com), but SAVs do not need to accommodate human access while parked, and many can be of compact or mini size; so their parking space standards can be reduced, in addition to eliminating striping and its maintenance. A benefit of this system is its ability to utilize presently unwanted or unused space, as shown in Figure 3, which incorporates the land below a heavy-rail line just west of Austin’s CBD.

The Seaholm redevelopment project, a major mixed use area in the Austin CBD, poses as an exciting backdrop for a major metropolitan SAV station. The City of Austin owns a significant amount of property in this area; and, with the addition of a brand new public library, the city will be looking for different modes of transit to accommodate a growing amount of residents living in the area. The Seaholm station is the most capable station to hold a large fraction of the fleet system, given the projected density of the area, spurred by significant private investment as well as the current accessibility of land underneath the railway. The capacity of this fleet station is 31 vehicles (about 8% of the fleet analyzed here). The design incorporates three different components: an AV charging and storage area, a pick-up/drop-off area, and a waiting area complete with patron amenities.

Airport Alighting Design and Application

The following airport alighting design has considerable transferability to any major transit hub that would currently service taxis or rentals cars. Due to the similarities of the two systems, space may be able to be bought from existing infrastructure. Given the fixed drop-off locations in airports and the ease of implementation in terms of vehicle programming, this technology could also be seen as a way to transport people between terminals. Additional similarities to rental vehicle systems include the incorpation of a mixed-fleet (e.g., SUVs and hybrid electric vehicles), which can appeal to commuters outside of the major metropolitan region. The airport is a location of high demand in the Austin region, producing and attracting more daily trips than almost any other location in the region (Jin 2015). The need for public transit at this location is amplified due to the fact that users attempt to avoid costly parking fees by leaving their personal vehicles at home. These factors make the airport very appealing for one of the four major stations.

The airport, being a unique piece of infrastructure, offers a major challenge, one with huge benefits if the design can encourage a portion of the 10.7 million of people that use the Austin Bergstrom International Airport annually. This design displays 20 parking spaces (offered to 5% of total 400 fleet vehicle system), which serves as an initial number to be scaled up longer-term. The Airport DRS-SAV station will be highly visible as potential customers leave the airport and its proximity to the airport’s exits allows for easy access by DRS-SAV users. Speed of service will remain competitive with taxis due to a well positioned garage exit ramp that can be reached from the Airport DRS-SAV station.

High Commercial Traffic Applications

A potentially successful application of this system can be found in repurposing additional car park space for transit stations, providing use for impervious cover that may be underutilized. Attracting more patrons to these commercial areas would benefit neighboring retailers with increased traffic from a diverse group of people who may not otherwise have access to these areas. Applications regarding SAVs in high commercial areas have already seen implementation in Milton Keynes, expanding their test fleet to over 40 vehicles at the end of the calendar year (Gordon-Bloomfield 2015). SAV investment options suggest that densely developed commercial and retail areas, as well as self-contained environments (like university campuses, airports, and hospital campuses) are good initial candidates for SAV services. This relates to the broader idea of taking these car-friendly commercial areas and applying mixed-land use in coordination with a SAV fleet system to help reduce personal automobile usage. Very few materials were put into the roughly 200' x 85' area that was designated for this SAV fleet station. The 10-foot-wide raised pedestrian median provides SAVs with two designated routes on either side of the structure, which can house 14 AVs. Additional SAV parking is located in a nearby parking garage which will accommodate an additional 20 vehicles. Furthermore, benches, charging stations, and covered areas are all made available on the 140' x 10' median (Figure 4). Since the proposed design is to use already existing concrete slab and striping, the design's difficulty will be greatly reduced. This commercial applicability is continued at Southpark Meadows,south of Austin's CBD, providing as a potential transit station for commuters coming from San Antonio.

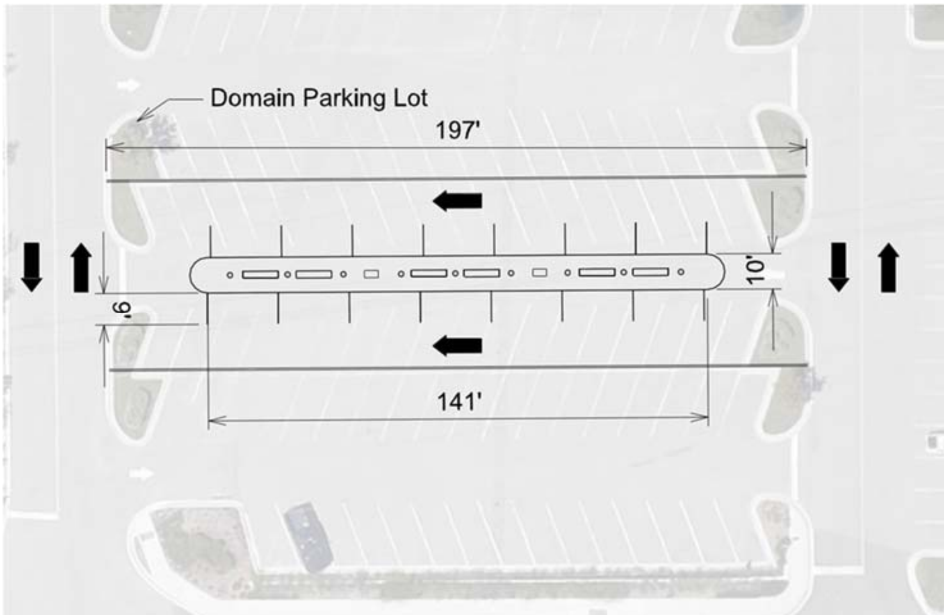

FIGURE 4. Domain Site's DRS-SAV Station Design (Mixed-Use Shopping Center)

Queuing Areas Attributes and Locations

Aside from the areas listed above for AV stations, the following areas were deemed attractive locations for rapid queuing areas. When considering the average wait time for a DRS-SAV system was less than two minutes, this further justifies these cost-effective queuing stations (Zhang 2015). These areas were chosen for queuing because although they do not have the land capable of supporting an entire station and do not need significant amenities, they still have the demand to support fleet usage. Similar to a bus pick-up stop, the station will provide customers with the bare-essentials in terms of amenities while allowing for quick pick-ups in high-density areas with a significant amount of turnover. The locations of these smaller facilities are dictated primarily on the trip volumes in that area and its ride-sharing attributes. Due to the limited number of queue spots, origin and departure time for the patron can vary but arrival-departure layover time for each vehicle will be relatively short, especially if there is a high demand at the station which would require additional queue space. The last two preliminary designs are standard designs for queuing areas that may be scattered about Austin. The first design is positioned along Rainey Street, a popular neighborhood-bar area near the Austin Convention Center. The second is located in Zilker Park, home to Austin City Limits Music Festival as well as other events. These designs can be translated with ease to other areas of the city, providing a streamlined system to cut down on design costs while providing a recognizable queue area for patrons.

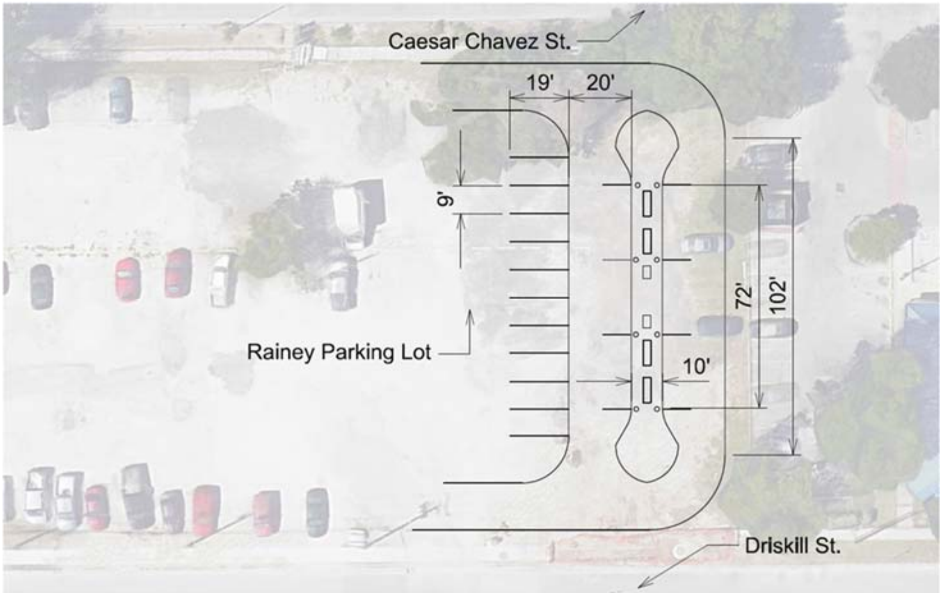

FIGURE 5. Queuing Station for High Vehicle Turnover (Local Parking Lot)

The Rainey queuing area mimics the design of the Domain location in that it provides a single entry and exit point with a raised median separating two lanes of SAV thru traffic (Figure 5). In total, the land area covers roughly 8,425 square feet. This area contains a ten foot bulb-in median curb with benches, and a covered area. The total median length is around 102 feet. Other design specifications include curbs on either side to allow for steady flow of traffic through the DRS-SAV pick-up/drop-off area which can house six AVs (three on either side). Additional considerations relating to the segregation of SAV with human operated vehicles will help to avoid delays associated with confused drivers potentially utilizing the system analysis.

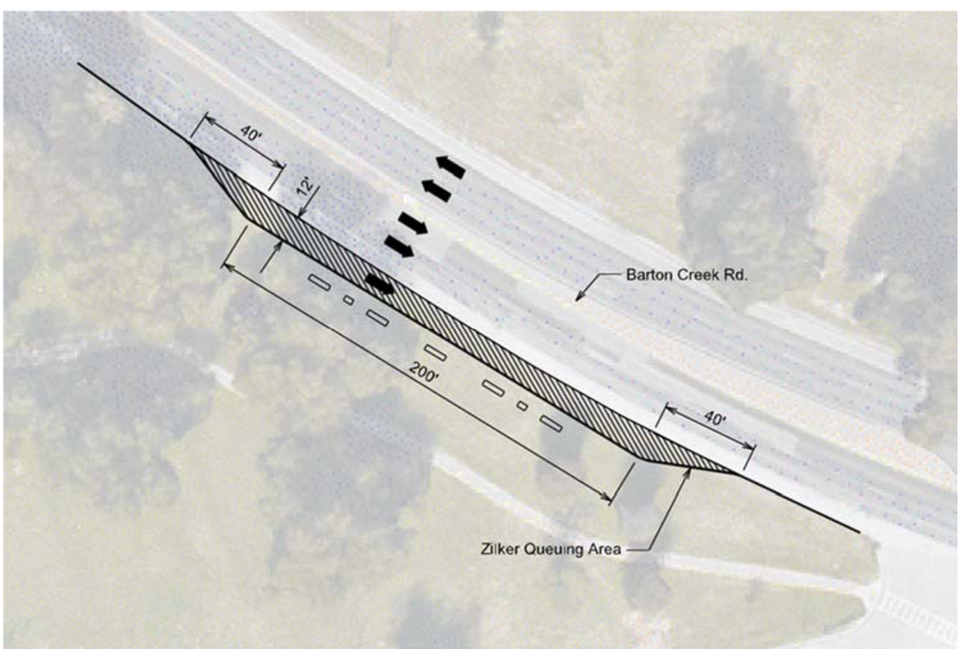

FIGURE 6. Zilker Park Queuing Station Design (Roadside Site)

This design will be implemented in four other locations scattered throughout Austin: Arboretum mall, Mueller neighborhood, Barton Creek Square, and Sunset Valley queuing areas. Areas that already enjoy good transit access are valuable for SAV stations to function as a last-mile travel provider, if warranted or preferred by travelers. The additional four designs are to follow the Rainey Street design above with small variances due to site characteristics. See Table 2 for additional queuing area information.

The Zilker queuing area is the last given design option for high-patron turnover. This is the most basic design given its specific focus on high turnover. Figure 6 shows the designated queuing areas meant for AVs. The project area specifications include a 12' wide, 200' long parking accessibility zone and a total square footage of around 2,700 square feet for the area of the project. This design, if relevant to the preferred alternative, will be implemented in four other locations scattered throughout Austin: University of Texas, Tuscany Business Park, Riverside, and Far West queuing areas.

Table 2. Queuing Area Overview

Name	Location	Capacity (# AVs)	Cost Estimate ($)	Special Features
Rainey Street	Downtown near Sixth Street & the Warehouse District	15	$4,366,400	Proximity to Trip Attractors such as the Convention Center, Town Lake, & bar-districts
Arboretum	US 183 South & Great Hills Trail near the North Capital of Texas Highway	10	$1,802,500	Mixed-use area with housing, offices, shops & restaurants as well as transit stops & pre-existing transit park & ride centers
Mueller	Central Austin east of I-35	15	$1,803,500	Mixed-use redevelopment where alternative modes of transit are encouraged by the community
Barton Creek Square	Intersection of Loop 1 & Capital of Texas Highway	15	$1,803,500	Close Proximity to highways as well as commercial areas
Sunset Valley	South of downtown at the intersection of Mopac & SH-71	15	$1,803,500	Small rural resident community which allows access to the hill country, a prime trip attractor & heavily commuted corridor into the CBD
Zilker Park	South Austin east of Mopac	10	$655,500	Access to trip attractors such as Town Lake, Barton Springs & a multitude of events that occur in this area (Austin City Limits Festival, The annual Trail of Lights)
Far West	South of US 183, North of 2222, West ofMopac	10	$655,500	Mixed-use with a high density of student population, often without access to a vehicle

Tuscany Business Park	Northeast central Austin at intersection of Highway 290 & US 183	10	$655,500	Serves an area of east Austin that has a recent influx of tech companies as well as access to tolled facilities which could support a park & ride for commuters out of the system
University of Texas	Central Austin, next to I-35	15	$655,500	350 acre main campus, with 51,000 students, 24,000 faculty & staff
Riverside	Along Lady Bird Lake, east of I-35	10	$655,500	Major housing area as well as access to music venues & close proximity to a major interstate

VEHICLE SPECIFICATIONS

Electric vs. Gas Powered

Two major variables were experimented with when choosing the alternatives: number of locations and vehicle energy source. EVs were chosen for the AV fleet in alternatives 2 and 4. These vehicles are relatively inexpensive to fuel and comparatively minimize polluting their surroundings with noise and emissions. EVs offer a move away from gasoline usage which decreases dependence on foreign markets for energy. EVs are often associated with "range anxiety" but this is assuaged through advances and technology and EVs have significant amount of chargeable breaks when applied in a shared environment (Zhang et al 2015).

PROJECT ALTERNATIVES EVALUATION

The alternatives that include station and queuing areas, in addition to an increased vehicle fleet size (800 SAVS), offer the highest levels-of-service to the Austin network by providing a variety of locations and a larger AV fleet of 800 vehicles. These alternatives will be capable of accommodating more users than their counterparts (stations only with 400 vehicles, and a variance of gas and EV powered vehicles). However, the added queuing locations increase initial project cost and may not warrant the additional infrastructure initially.

Using the assumptions found in a similar study (Fagnant 2015), an average trip length of six miles was chosen for these alternatives with unoccupied vehicle miles travelled (VMT) accounting for 8% of this distance. The average trip length for alternatives with the additional infrastructure was adjusted to ten miles with unoccupied VMT also increasing to 20% of AV travel (due to increased location spacing). These adjustments account for the difference in average radii needed (around each location) to cover the entire network. Increased infrastructure may lead to shorter trips and less unoccupied VMT, if priced favorably to encourage system use in a transit-like setting and emphasis on ride sharing. Each of the alternatives offer benefits in the form of decreased hourly value of travel time from $16.30 (Fagnant, 2014) to $5.00 due to passengers' ability to use their travel time productively or leisurely. These alternatives will also encourage ridesharing (achieving an average of 1.3 people per vehicle) and reduce the number of crashes.

PREFERRED ALTERNATIVE AND PROJECT ANALYSIS

This project was designed for a ten-year period, enabling a testing period suitable for studying how well the AV system will function in the Austin traffic environment. Emphasis was placed on the B/C ratio in this evaluation as it offers a better summary of project impacts. Monetizing the parameters to give an economists' perspective on the system was critical in defining the benefits this system produces when adopted full scale. Table 3 shows the benefit of using an AV in terms of the traveler's value of travel time.

Table 3. Alternative 2 Sensitivity Analysis

Value of Travel Time		
Number of Vehicles (NoV) =	200	AVs
Person Trips Per Day (PTPD) =	28.5	trips
Vehicle Trips Per Day (VTPD) =	21.9	trips
Average Trip Length (ATL) =	10.0	miles
Daily Miles Traveled per Vehicle (DMT) =	219.2	miles
AV Yearly Miles Traveled (YMT) =	16,014,808	miles
Occupied Yearly Miles Traveled (OYMT) =	13,345,673	miles
AV VOTT =	5.0	$/hr
Non AV VOTT =	16.3	$/hr
Difference =	11.3	$/hr
Average Vehicle Speed (AVS) =	26.0	mph
Occupied Yearly Travel Time (OYTT) =	513,295	hours
VOTT Yearly Savings =	5,800,235	$
Unmanned Miles Traveled =	2,669,135	miles/year

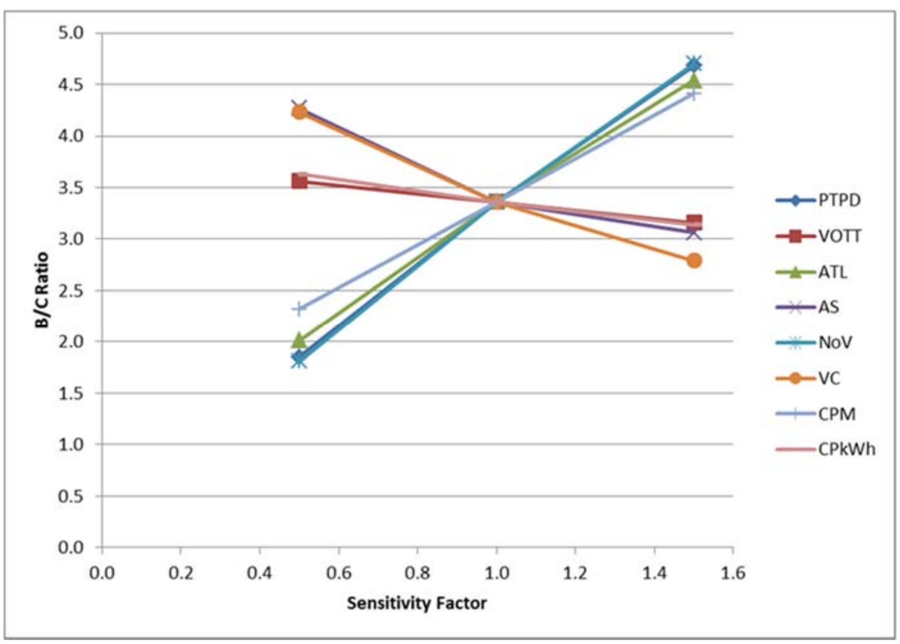

FIGURE 7. 400 EVs Utilizing 4 Stations: Sensitivity Analysis

The alternative using EVs with 4 station hub centers utilizing 400 EVs had the highest B/C ratio of 4.42, corresponding with an IRR of 103%. This selection reasoned with the fact that additional construction and maintenance of a larger fleet system with queuing areas outweigh the benefits of having a larger network. The higher fuel costs associated with gas-powered vehicles shifted the selection in favor of an EV fleet. Two additional benefits of utilizing electric vehicles are reduced dependence on foreign markets and long term sustainability.

The sensitivity analysis performed (illustrated in Figure 7 with corresponding data in Table 4) reveals important relationships. Number of vehicles, person-trips-per-day, average trip length, and cost per-mile proved to be the parameters with the most significant impact on B/C Ratio. Therefore, the accuracy of certain assumptions made in this report could have significant impacts on the system's success. The sensitivity analysis provides knowledge that can be used to make informed decisions regarding adjustments and their likely effects on the system.

Table 3. Alternative 2 Sensitivity Analysis

Sensitivity Analysis				
Variable	Value	Sensitivity Factor	B/C	IRR (%)
Person Trips Per Day	14.25	0.5	1.85	24
	28.5	1.0	3.36	58
	42.75	1.5	4.68	90
Value of Travel Time ($/hr)	2.5	0.5	3.56	62
	5	1.0	3.36	58
	7.5	1.5	3.16	54
Average Trip Length (mi)	5	0.5	2.01	28
	10	1.0	3.36	58
	15	1.5	4.54	87
Average Speed (mph)	13	0.5	4.27	76
	26	1.0	3.36	58
	39	1.5	3.06	52
Number of Vehicles	300	0.5	1.81	23
	600	1.0	3.36	58
	900	1.5	4.70	90
Vehicle Cost ($)	30,000	0.5	4.23	72
	60,000	1.0	3.36	58
	90,000	1.5	2.79	48
Cost Per Mile ($)	0.5	0.5	2.32	36
	1	1.0	3.36	58
	1.5	1.5	4.41	79
Cost Per kWh ($)	0.075	0.5	3.63	60
	0.15	1.0	3.36	58
	0.225	1.5	3.14	57

Due to this unique endeavor, starting small may make initial financial sense, but system-wide adoption and the need for increased mobility may see exponential affects and high demand.

FURTHER SYSTEM ENHANCEMENTS

The proposed enhancements offer a variety of differing options and amenities, which can meet a multitude of patron preferences. Dealing with fleet options, a multiplicity of vehicles would allow for a variety of customers, providing differing levels of service. With the use of a fuel-efficient hybrid fleet, patrons could travel between cities (i.e. Austin-Dallas) and skip the hassle often associated with flying. Short-term car rentals at the periphery stations could allow for increased service, but additional consideration will focus on increased unmanned vehicle time and increased collaboration to find cost-efficient ways to return the vehicle once the one-way destination has been served. The data from Zhang (2015) may suggest fewer patron amenities at stations, with the average wait time with a 700 vehicle fleet only at 1.7 minutes. This data lends itself to borrowing space in unused parking lots and only the need to provide signage to notify patrons on where to wait. This minimalistic approach can serve underutilized areas for a fraction of the calculated station cost. Project simulation to complement and possibly validate results of others' simulation would be useful to pursue, as an extension of this research. Further emphasis should be added to encourage and build systems in place for disable patrons and older individuals who may not have access to smart phones.

ALTERING OUR URBAN ENVIRONMENTS: RIPPLE EFFECTS OF AN SAV-DRS SYSTEM

SAVs and DRS may transform the automotive industry, much like Henry Ford's Model T. Urban areas have the ability to become even more land efficient by opening doors to new opportunities with their extra space. Zhang's (2015) base simulation called for over 90 percent in parking reductions, with only a small market penetration of the vehicles on the roadway. All in all, this would amount to drastically planned urban environments, allowing for more density and the opportunities for cities to revitalize their CBD area.

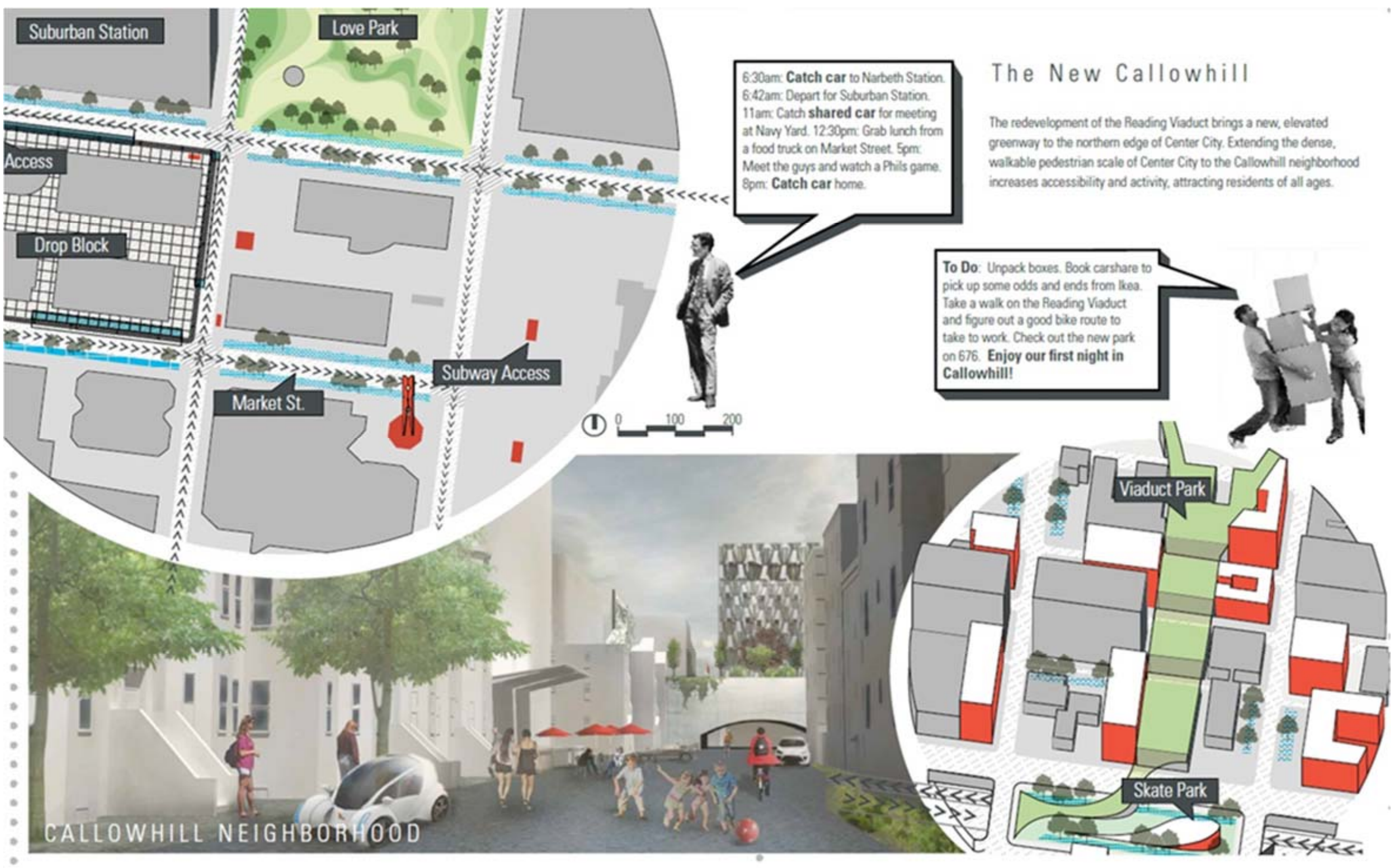

FIGURE 8. Benefits of SAVs are seen in a redevelopment concept (Baker et al 2014)

Many cities could then shift their focus on how to provide infrastructure to suit these reduced transit needs and could further enhance the SAV system. Parking for these vehicles would be more efficient and cost effective as the cars can be packed in together, eliminating pedestrian traffic (Zhang and Guhathakurta 2015). Many of the cities in the US created their planned areas based on the automobile and the predicted reductions due to SAVs could change our urban environment as seen in the Indepenndense design regarding land-use due to AVs (Baker et al 2014). Will tolled roads alter their infrastructure to attract these vehicles to increase throughput on their roadways? Could property values near these roadways increase if signage is eliminated and congestion is prevented? Will our roads be able to transform from thoroughfares for AVs during morning and afternoon peak to pedestrian friendly areas during the lunch hour? Urbanites also could be looking at the pavement for innovation and reap the benefits among the asphalt areas which can be modified for business or environmental benefits.

CONCLUSIONS

Automobiles previously had no concerns systematically but, will soon provide increased usable area for our roadways. SAVs operate more often than traditional personally owned vehicles, and by serving trip generators, allow for increased trip-chaining as well as utilizing active transit. Land-use and parking infrastructure are some of the areas with which SAVs have the ability to transform and eliminate, respectively. The design elements regarding this SAV system highlight vehicle amenities as well as station amenities. This 400 vehicle fleet system serves as an indication of this system's financial possibilities, producing a benefit/cost ratio of 4.42. Through a basic cost evaluation and monetized systematic benefits, a pilot electric-vehicle fleet system will serve 11,400 people per day and each SAV has the potential to eliminate 14 vehicles of the roadway network. Further vehicle incorporation should be the next step in noticing an increasing amount of benefits given to vehicles that can communicate between each other and outperform their human counterpart in operating a vehicle.

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