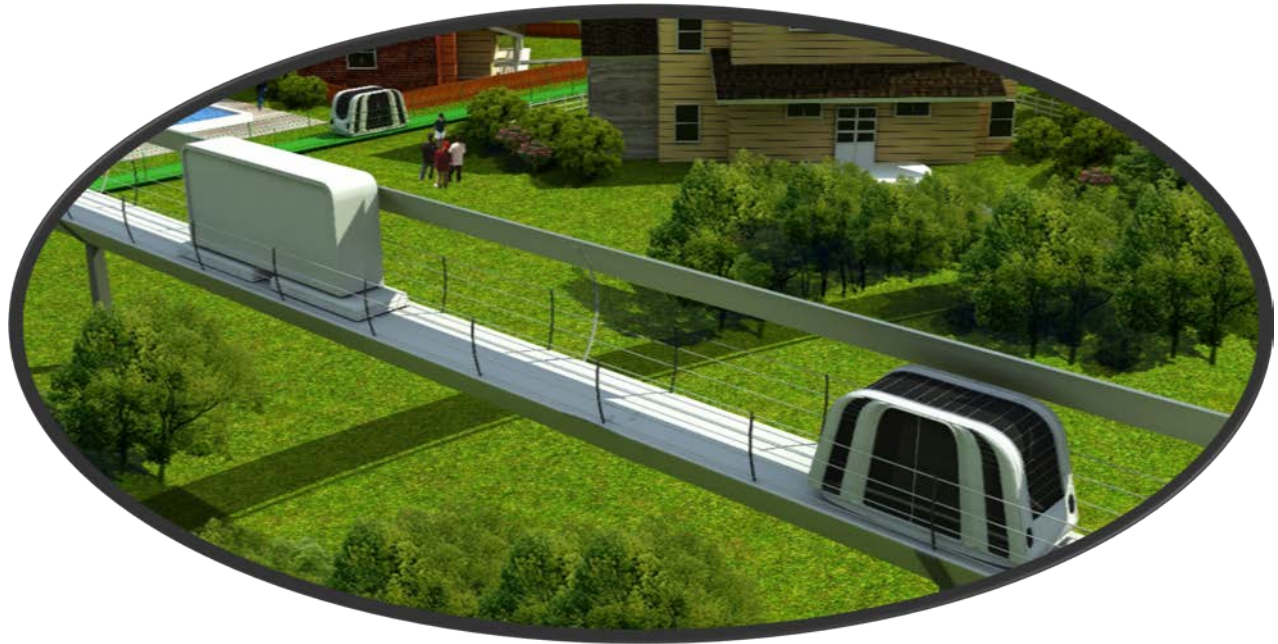


# *Transportation Options for Greenville*



PREPARED FOR

GREENVILLE COUNTY ECONOMIC DEVELOPMENT CORPORATION

BY:

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# TRANSPORTATION OPTIONS FOR GREENVILLE

## EXECUTIVE SUMMARY

Many people in the Greenville area suffer daily mobility problems that include getting stuck in traffic, having too many wrecks and fatalities, and transit services that are slow and/or difficult to access. Unfortunately, these problems are only getting worse. There are insufficient funds to continue maintaining and widening roads and existing funding streams could be threatened by the promise that driverless cars could solve congestion. In a worst-case scenario, funding could dry up at the same time that we discover driverless cars actually increase congestion. The resulting gridlock could bring an economic downturn to Greenville. On the bright side, autonomous (driverless) vehicle systems could be deployed that would decrease congestion while providing quick, affordable and reliable transportation for all. Before we can choose which future scenario we want to pursue, we must understand the options.

There are four primary ways in which transportation in the Greenville area could be improved. They are not mutually exclusive and the optimal solution may include some aspects of each.

1. Continue the historical path of expanding existing car and transit solutions. This option is failing and shows no signs of being able to significantly improve mobility.
2. Wait for driverless cars to reduce congestion. It is likely that driverless cars will first increase congestion and relief could be 30 or more years away.
3. Driverless taxis could reduce the cost of taxis and Uber-like services. They could thus provide a mobility option for short trips for those without access to cars. However, they will not help reduce congestion and will not work well in congested areas.
4. Automated small vehicles running on elevated guideways would immediately help relieve congestion. However, such systems, known as automated transit networks (ATN), require new infrastructure and fairly extensive networks are necessary before they are viable.

It is clear that we are not going to get rid of our vehicles and road system any time soon. However, if multi-modal options can divert sufficient traffic from congested portions, thereby obviating the need for expansion, this should free up the funds necessary to keep current roads and bridges in good condition. An ATN system focused initially on downtown Greenville, but with expansions towards Greenville-Spartanburg International Airport (GSP) and Clemson, could improve mobility for many, while also relieving congestion. The viability of such a network could be further improved by expansions to serve additional key nodes. The service area could be supplemented by a system of driverless taxis and by integration with existing bus services.

An ATN solution does not require that the ATN system carry the bulk of the traffic. Rather, the ATN system functions as a catalyst, removing sufficient traffic from the roads to relieve congestion and making the existing transit system work better by expanding it. In short, a multi-modal transportation system will have the spare capacity that allows it to work much better. This also means that it will be better able to absorb the needs of driverless cars and to leverage the abilities of driverless taxis.

Nonetheless, the ATN system will not be self-supporting unless sufficient trips are diverted to it. ATN trips are proportional to the utility of the system, which in turn depends heavily on the number of stations. A two-station shuttle could be feasible in an airport environment but an urban system will require many stations to be viable. GSP Airport has studied options for an ATN shuttle system between remote parking lots and its renovated terminal. A GSP Airport application could serve to

introduce Greenville to the technology. At the same time CU-ICAR is investigating driverless car or automated taxi solutions that could help supplement an ATN solution.

A relatively large ATN deployment serving most of the City of Greenville appears capable of funding itself through fare-box revenues. This could allow Greenville to deploy such a solution in a public-private-partnership with very little financial outlay.

Future ATN vehicles may be able to leave the guideways and function as driverless taxis providing door-to-door connectivity. New developments may be able to be mostly car free – providing the ability to live and work in a park-like environment.

ATN is a key ingredient in any mix of transportation solutions. The costs involved in implementing an ATN solution are expected to be recovered many times over in the benefits of improved mobility, safety and reduced congestion. Greenville could be a leader in exploring this option. If the benefits outweigh the costs and leaders want an ATN-facilitated transportation solution, a private-sector approach could be within reach.



**Live and work in a park-like environment**

## INTRODUCTION

The Metro Greenville, South Carolina, Urbanized Area (UZA) is looking for innovative transport solutions that can help the region maintain and improve its quality of life. Clemson University professors at its International Center of Automotive Research (CU-ICAR) say that Automated, Connected, Electric, and Shared (ACES) vehicles and systems are the future of mobility. Many Greenville UZA leaders are open to automated transport network (ATN) solutions. A recent Advanced Transit Association (ATRA) report proposed “A New Transportation Paradigm That Facilitates High Quality City Living” – see Appendix A.

The new paradigm offers a Small Automated Roadway Transport (SmART) system as an improvement over conventional ATN systems wherein passengers and freight are accommodated in one system and vehicles can leave the guideway and travel down streets in mixed traffic. The beauty of the SmART system is that it can immediately reduce congestion while being economically self-sustaining from the beginning. The developers of the new paradigm were invited to review Greenville’s past and current situation and suggest options for innovative transportation solutions to be used in the Greenville UZA planning process. To fully understand this Greenville analysis, one must begin with an understanding of the appended study.

This paper assumes familiarity with the new transportation paradigm, reviews current transportation issues in the Greenville area and then briefly applies the various proposed solutions. ATN solutions are considered in more depth – in particular a solution covering most of the area of the City of Greenville. While it is an ambitious undertaking, a large network analysis is necessary to depict the significant benefits that could accrue and to demonstrate the possible economic viability of an ATN system. A smaller, downtown network is also discussed and would be more suitable for an initial deployment. A number of other small applications are briefly presented.

The paper examines the benefits and hurdles involved with an ATN deployment and presents a plan for moving forward. It suggests that Greenville needs to decide if it wants such a solution and, if it does, the private sector could potentially provide it.



## THE PROBLEM

According to the 2010 Census, Greenville's metropolitan statistical area (MSA) has a population of 400,492 and is the 92<sup>nd</sup> largest MSA in the U.S. with a population density of 1,236 per square mile. Nonetheless the area suffers traffic congestion similar to that of a far larger community. In addition, its vibrant economy is leading to rapid growth – South Carolina ranked ninth in the nation in 2014 for population growth. Any road widening projects are only going to be temporary solutions until growth causes congestion to return. For proof of the lack of progress in mitigating congestion, compare today's situation with that shown for 2005.<sup>1</sup>

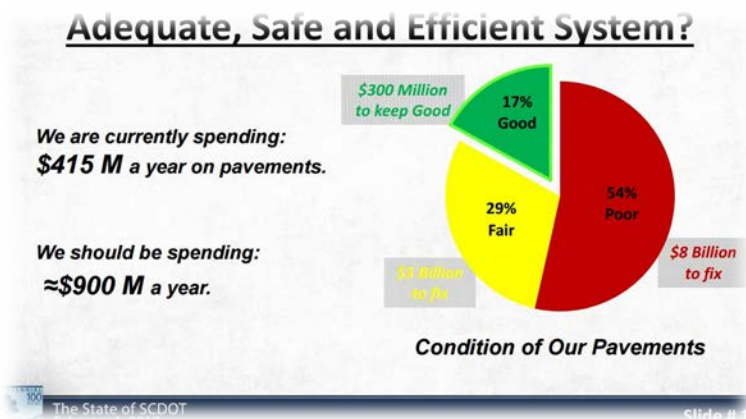


**2005 Congested Corridors**

Source: GPATS 2030 Long Range Transportation Plan

The simple fact is that there are insufficient funds to adequately maintain and expand our road systems. South Carolina Secretary of Transportation Christy A. Hall presented the “State of SCDOT” report for 2017 to the Senate Transportation Committee on February 1, 2017. The annual review provided the current status of South Carolina’s transportation network, including the funding situation. Here some highlights of Secretary Hall’s overall assessment:

- Legislative funding increases (both recurring and one-time) in both 2013 and 2016 have resulted in some progress in SCDOT’s interstate widening, resurfacing and bridge replacement programs.
- However, long-term funding shortfalls over decades have created the need to reconstruct over 50% of the pavement in the state’s 41,000 mile system. Hundreds of bridges remain structurally deficient.



Source: Secretary Hall’s State of SCDOT Address

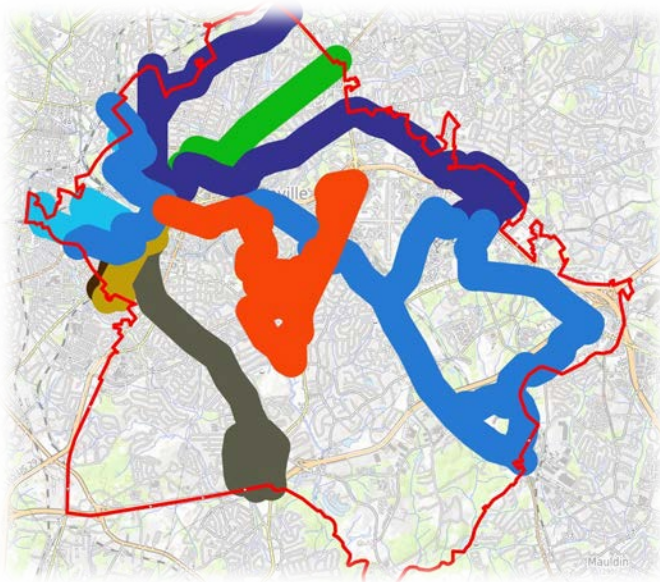
<sup>1</sup> [http://www.gpats.org/\\_uploads/2011/12/GPATS-Chapter-31.pdf](http://www.gpats.org/_uploads/2011/12/GPATS-Chapter-31.pdf)

- Years of deferred maintenance have contributed to South Carolina's ranking as #1 in the nation in highway deaths.

In addition to being in poor repair, pavements comprise the primary use of urban land, taking up some 50% of land space. They increase storm-water runoff and add to the heat-island effect.

According to the National Highway Transportation Safety Administration, motor vehicle traffic fatalities are at a pace to exceed 35,000 in 2016 based on the January – June number of 17,775 killed. The first half year fatality rate per 100 million vehicle miles of travel was 6.7% higher than that in 2015 which itself was 4.0% higher than 2014. This increase in fatality rates is troubling in light of the deployment of many new cars with automated driver-assist functions intended to reduce the rate of accidents.

While traffic problems hamper drivers, those without access to cars are in an even more difficult situation. Considering only the City of Greenville, which has a population density of 2,350 per square mile, we find that less than one half of the area is within one quarter mile of a bus route. Of course the served areas are likely to be of higher density, but clearly a large proportion of residents and some jobs are not conveniently close to bus routes. For those that are close to a bus route, the buses only run once an hour at an average speed of about 15 mph. They currently operate between 5:30 AM and 7:00 PM weekdays, 8:30 AM and 6:30 PM Saturdays and not at all on Sundays or Holidays.



**Bus accessibility within city limits**  
Each route is depicted ½ mile wide

According to published schedules, the maximum time to reach any bus stop within the City limits from the Greenlink downtown transfer station is approximately 45 minutes. To this you would need to add the average 30-minute wait time and a five-minute walk at each end for a total trip time of 85 minutes.

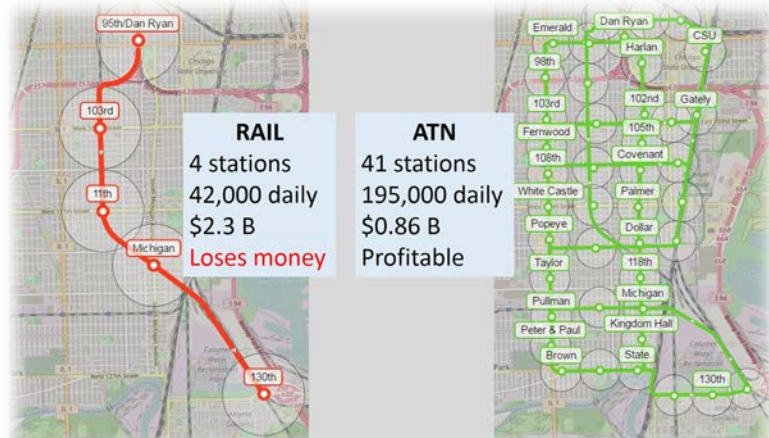
Things become considerably more complicated for trips that do not have downtown as an origin or destination. For example, consider a trip from the Bi Lo on Mauldin Road to The Shops at Greenridge. The travel time would be 80 minutes and the total trip time would be an even two hours assuming both required transfers are successful.

An on-going study of local transportation problems by Piedmont Health Foundation<sup>2</sup> identified in 2015 that “Greenlink, the public transit system, has problems with “a limited geographic reach, long wait times between buses and a limited running schedule.” The article explains that “For

<sup>2</sup> <http://www.greenvilleonline.com/story/news/2015/12/10/transportation-study-identifies-weaknesses-needs/77042572/>

those who don't own a car or can't afford to operate it, or who can't drive because of age or disability, the bus is a logical alternative. But ... found that more people borrowed a car or caught a ride from a family or friend than took the bus, often because of the bus system's limitations." And "Only 10 percent of survey respondents said the current bus schedule met their needs, according to the study data."

An additional problem is the way in which we think about solutions to transportation problems. Since the days of the stagecoach, we have thought transit must be constrained to serving stations located along long linear corridors. While there is some clustering around transportation corridors, homes and businesses are generally developed over wide areas and would be far better served by a web of networked transportation corridors, as illustrated.



Chicago Red Line Extension Alternatives

## POTENTIAL SOLUTIONS

### EXPAND EXISTING TRANSPORTATION SYSTEMS

As pointed out above, the existing car- and bus-based transportation systems suffer from congestion and poor service respectively. In addition, they are based on infrastructure that is crumbling and inadequately funded. They are unsafe and both environmentally and economically unsustainable.



Utilizing improved versions of existing systems such as bus rapid transit (BRT) does not appear to be a feasible solution. The Greenville County Economic Development Corporation's 2010 Multimodal Transit Corridor Alternatives Feasibility Study found that, while BRT was the preferred alternative, it did not generate sufficient ridership to warrant Federal funding.<sup>3</sup>

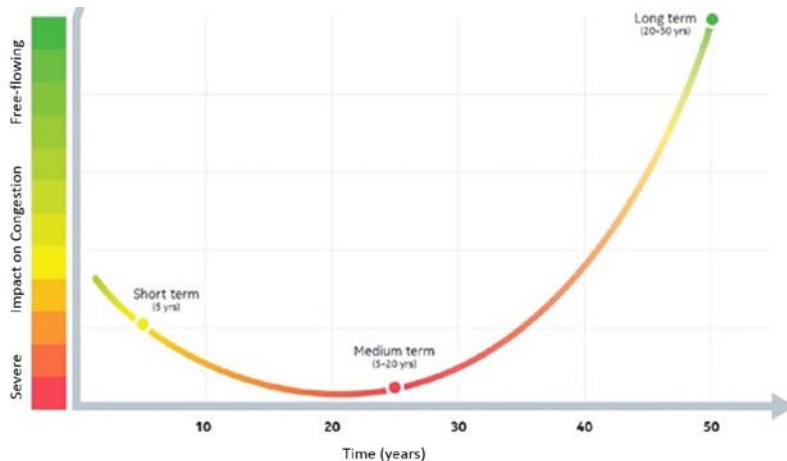


**BRT Level boarding platform**  
Source: GCEDC 2010 Multimodal Transit Corridor Alternatives Feasibility Study

Expanding the existing systems just does not appear to be a viable option. Yet, until fairly recently, there have been no alternatives to trains, buses or cars.<sup>4</sup>

#### DRIVERLESS CARS

Present-day cars provide great door-to-door mobility except when they get stuck in traffic and/or parking is not available. All automotive original equipment manufacturers are investing huge resources into self-driving vehicles. Driverless cars may overcome most parking issues, if car sharing is popular, but may not solve all congestion problems – in fact they are likely to make congestion worse before they make it better. Some of the primary factors related to how driverless cars may affect congestion are discussed below.



**Driverless cars could increase urban congestion for the next 30 to 40 years**

Source: ITS International

A common claim is that more driverless cars and trucks could fit in a lane if they followed each other very closely. However, they will probably not overcome the hazards involved with following closely because these hazards are more a function of the tire/road interface than the slow reaction times of human drivers. They may however be able to travel very close to each other in platoons (both very short and very long spaces between cars are safe – it is the intermediate spacing that is dangerous). This would increase road capacity and thereby reduce congestion. However,

<sup>3</sup> [http://www.greenvillecounty.org/gcpc/transportation\\_planning/pdf/rail\\_corridor\\_final\\_report.pdf](http://www.greenvillecounty.org/gcpc/transportation_planning/pdf/rail_corridor_final_report.pdf)

<sup>4</sup> [http://www.greenvillecounty.org/gcpc/transportation\\_planning/pdf/gcedc\\_prt\\_evaluation\\_final.pdf](http://www.greenvillecounty.org/gcpc/transportation_planning/pdf/gcedc_prt_evaluation_final.pdf)

forming and breaking up platoons is problematic and platoons on multi-lane roads make lane changing difficult. The South Carolina legislature is working to pass a Truck Platooning Bill to allow AV trucks to operate on our roads.

Narrower lanes would allow existing pavements to support more lanes and therefore more traffic. Narrow lanes would require all driverless cars to be able to perform to the same standards of lane-keeping and additional lanes would add to the difficulties of lane-changing alluded to above. However, these problems are probably solvable.

Ridesharing could reduce congestion. However, ridesharing has been the holy grail of congestion reduction for decades without having significant impact. It is unclear how removing the driver from the vehicle will make people more willing to share rides than they are now. People do not now share their cars or their taxi rides to any significant extent. Driverless taxis should be cheaper and thus the financial incentive to share will be less.

Driverless cars are likely to increase vehicle miles traveled (VMT) since people may choose to live further from work and to send their cars looking for cheap parking (perhaps even all the way home). A recent study in Sweden found that, only by making the most optimistic assumptions is ridesharing sufficient to offset the additional VMT induced by the driverless fleet.

Other human factors could adversely affect congestion in unanticipated ways. For example, knowing that driverless vehicles will be super-cautious, pedestrians may just step in front of them. This type of behavior could lead to a kind of revolution where pedestrians retake the surface and prevent cars from uninterrupted travel between designated crossings.

Constructing elevated overpasses to relieve congestion will be possible. To the extent that driverless cars are fully developed with reliable functionality and meeting standardized requirements, these overpasses may be quite significantly narrower and lighter than overpasses presently constructed for road traffic and could be more like ATN guideways. Nonetheless, they are costly to build and will likely face many of the same hurdles facing present-day road expansion, including a significant lack of funding.

Failure to relieve congestion fully implies that driverless car passengers will still get stuck in traffic and, when they do, they will remain as unable to move as they are today. Even the fact that they may be able to work, relax or entertain themselves while in traffic could itself exacerbate the situation, since some may choose to no longer avoid the rush hour the way they do now.

The much-touted safety improvements may not be all that significant. There is already an awareness in the industry of how difficult road safety is to achieve. It is being suggested that driverless cars should only be required to be twice as safe as driven cars.

Unintended consequences such as rogue pedestrian behavior or distracted driving may plague the development of driverless cars. Many unknowns remain and many of these relate to how driverless cars will be accepted and used by humans.

Driverless cars will certainly help improve mobility for many and help improve safety. They may eventually help improve congestion. However, driverless cars are just an easy partial solution to a few of many problems and the extent to which they will be successful is in doubt. The promise of driverless cars is reminiscent of the 1980s promise of paperless offices.

#### DRIVERLESS TAXIS

Driverless taxis are a form of shared driverless cars. CU-ICAR leaders tell us that future mobility will be ACES: automated, connected, electric and, shared. The exact business model is likely to be varied, with some acting just like taxis or Uber/Lyft. Others may be in some kind of pooled ownership arrangement. The primary point is that they will provide transportation services without requiring car ownership. Since drivers will be unnecessary, they should be much cheaper than present-day taxis. However, they may well be more expensive than present-day buses. For this reason, and because they are unlikely to relieve congestion, driverless taxis will be most useful for short trips. In Greenville, they could help those not adjacent to transit routes to access transit or other daily activity locations. For example, it has been suggested that people who live within a mile or two of the Legacy Charter School could benefit from driverless-taxi shuttle service between their home and nearby places where they work, shop, learn, heal, or play. Greenville is partnering with corporate and non-profit entities to deploy automated vehicles on public roads near CU-ICAR, Verdae, or Legacy as soon as possible.

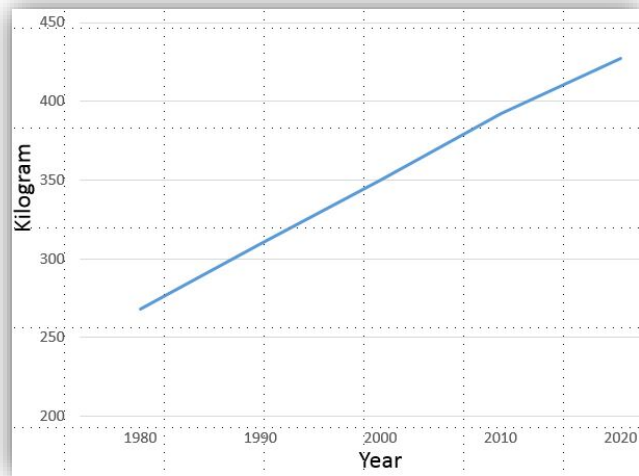
Some say that driverless cars could reduce congestion if sufficient people would share rides. Driverless taxis are the primary way in which ridesharing could occur. However, since the costs will be lower than today's taxis, which are not shared much, the incentives to share will also be lower. Ridesharing apps could facilitate sharing but it is unlikely this will be sufficient to offset the extra VMT caused by empty taxis repositioning to pick up the next fare.

Note that driverless taxis will drive around most of the day instead of sitting in a parking lot or garage. This will reduce the number and size of parking facilities needed, which will also slightly improve walkability.

Since one car will replace many automobile trips per day, less cars will be needed. However, as stated previously, VMT will increase. Thus if a car's lifetime is determined by the number of miles traveled, they will wear out quicker and just as many, or more, cars will need to be manufactured and sold every year. This is good news for the automobile businesses in Greenville.

#### AUTOMATED TRANSIT NETWORKS (ATN)

The above solutions are hampered by the fact that they all rely on our existing road infrastructure, which is inherently unsafe and falling apart, with no prospect of sufficient maintenance and expansion funding becoming available. A new solution is needed that provides a service level



Per capita US paper consumption

high enough to attract sufficient riders for it to pay for its own separate infrastructure – an infrastructure that will fit within existing rights-of-way and take up very little new space. Fortunately, such a solution is available and already proven in public service. It is called automated transit networks (ATN), aka personal rapid transit (PRT) or Podcars.

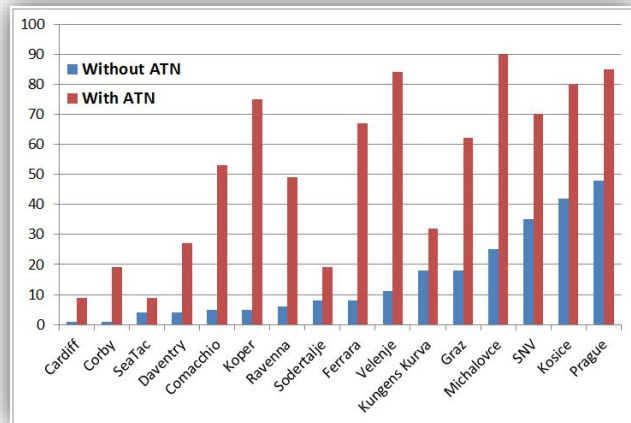


The systems shown above have been in public operation for six years on average.

ATN uses small, automobile-sized driverless vehicles on guideways that are usually elevated, but can be at- or below-grade. Because the vehicles are small, many are needed, resulting in little or no waiting time. Small vehicles only require small, light guideways which are quick and economical to build. Switching is in the vehicles, rather than the rails. This allows the vehicles to follow each other closely (within seconds) and facilitates offline stations. Offline stations allow direct, nonstop travel. In addition, adding an offline station does not slow mainline traffic so stations can be closely spaced, reducing walking distances.



The key to the success of ATN systems is the high level of service provided – more like that of a car than a bus. ATN systems provide nonstop origin-to-destination travel with little or no waiting. All passengers are seated and walking distances are short. Many studies around the world show that adding ATN to the transit mix greatly increases transit mode share.



**Impact of ATN on transit mode share**

The reader may wonder how a system of small vehicles could possibly provide mass transportation. There are two answers. First, cars (relatively small vehicles carrying about 1.4 passengers each) are the major mass transportation system in the world today. Second, we do not immediately need a mass transportation system. All we need is a system to relieve the pressure from existing systems – a catalyst if you will. If we remove ten to twenty percent of peak hour traffic from the roads, congestion will disappear. Then we need to keep expanding the new ATN system’s capacity to prevent the load on the roads from increasing.

Modern ATN vehicles typically have four to six seats with room for groceries or luggage. 2getthere has a group rapid transit vehicle that can carry more than 20 and is well suited to high-capacity applications with few stations. ATN guideway capacity typically ranges between about 2,000 and 10,000 passengers per hour per direction (equivalent to 1 – 4 freeway lanes).

Maximum speeds range from 25 to 40 mph. Since most trips are nonstop, average speeds are close to maximum speeds, unlike conventional transit where average speeds are typically less than half of maximum speeds.

All ATN systems are electrically-powered. Some get their traction power from on-board batteries while others get wayside power from a third rail. ATN guideways are suitable for supporting solar panels which can help make the system energy independent.



**Solar panels also help shade the vehicles**

Some ATN systems are rail based. In these systems the rails steer the vehicles. Open-guideway systems steer themselves. These systems often include features such as sidewalls or buried magnets that assist with navigation. GPS navigation is not accurate enough for these systems that must maintain their desired position to within centimeters. Open guideway vehicles are well suited to being adapted to also travel on streets in mixed traffic.

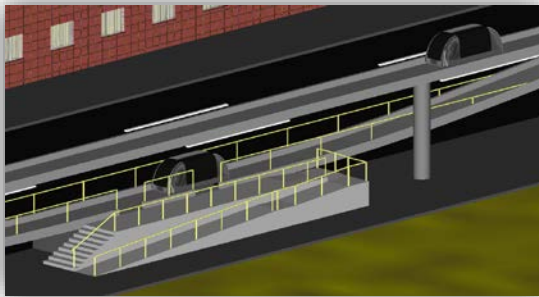
## POSSIBLE ATN LAYOUTS

Important decisions include where ATN stations should be placed and how guideways should be routed to interconnect these stations. These decisions should be made based on much public input and careful consideration. Elevated guideways should be routed away from sensitive viewscales.

Stations can be elevated or at-grade, attached to buildings or free-standing. They should be approximately one half mile apart, keeping walking times down around five minutes.



**Free-standing elevated station**



**Station close to grade  
Shelter structure omitted for clarity**



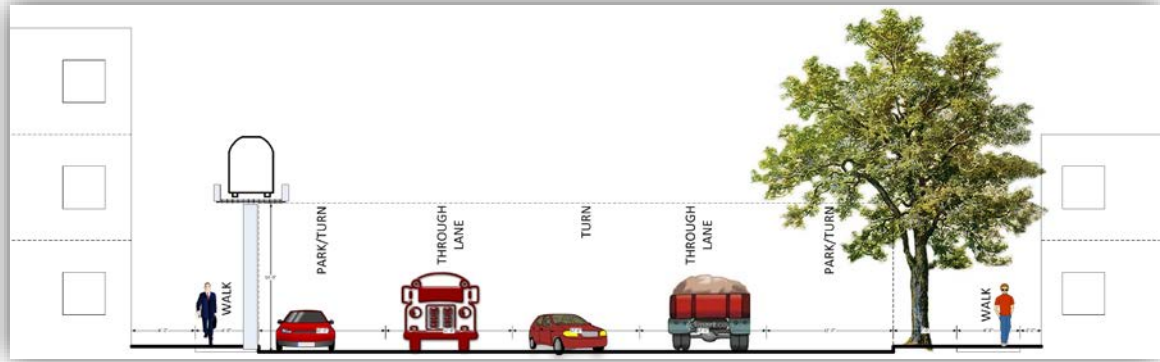
**Station attached to building**

ATN guideways are up to about seven feet wide and are typically supported on columns up to about three feet in diameter. The impact of installing a guideway along a street is thus not much more than that of an overhead powerline with column spacing on the order of 60 to 120 feet. In some situations, ugly overhead powerlines could be incorporated into an aesthetically-designed guideway.



**Urban ATN guideway rendering**  
Credit: Taxi 2000

The illustration below shows an option for locating an ATN guideway in an existing street right-of-way. Note that concerns about passengers being able to see into adjacent windows, or private areas such as back yards, could be alleviated by automatically fogging the vehicle windows where necessary.



**ATN guideway retrofitted into existing street**

While ATN guideways may be bi-directional, facilitating corridor applications, uni-directional guideways forming inter-connected loops are usually more effective in urban environments. Initial systems may take the form of a single loop or short corridor section. Additional loops can then be added to expand the system. Although not yet proven at large scale, there is no theoretical limit to the number of loops that could be added.

Five potential Greenville ATN layouts are depicted below. It should be noted that some of these layouts have been developed with significant public and stakeholder input (e.g. Downtown to Currier Airport corridor and GSP Airport), but the others have not had sufficient input. They have been provided merely to depict the connectivity that ATN could provide. The station and guideway locations shown are illustrative only.

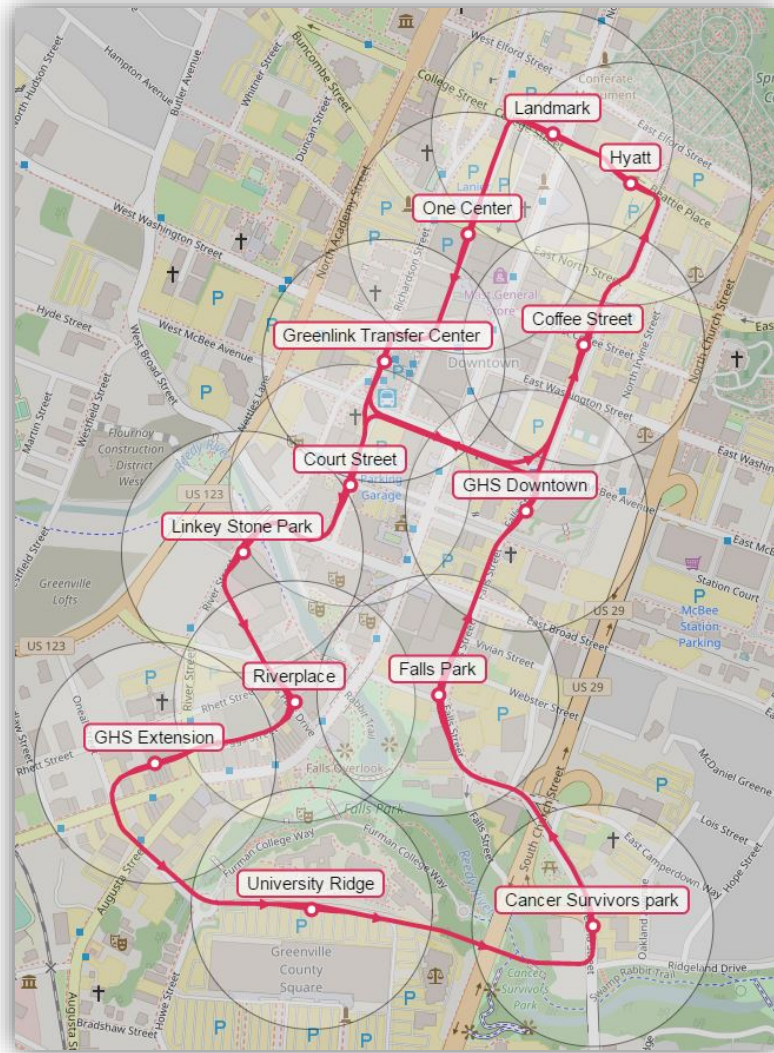


## DOWNTOWN ATN LAYOUT

The Downtown ATN layout has thirteen stations, 3.6 miles of one-way guideway and 0.2 miles of two-way guideway. Every station is within six minutes of the Greenlink Transfer Station.

This ATN layout will greatly improve the inter-accessibility of all key downtown facilities including most parking decks. It will facilitate parking on the periphery and then still having easy access to all of the downtown area. It should reduce downtown traffic congestion quite significantly.

The southern portion of this layout has a station at University Ridge which is an area proposed for redevelopment by Greenville County.<sup>5</sup> This station and the associated ATN network could have a significant impact on the way this 37 acres of prime property, that is the current County Square site, is redeveloped.



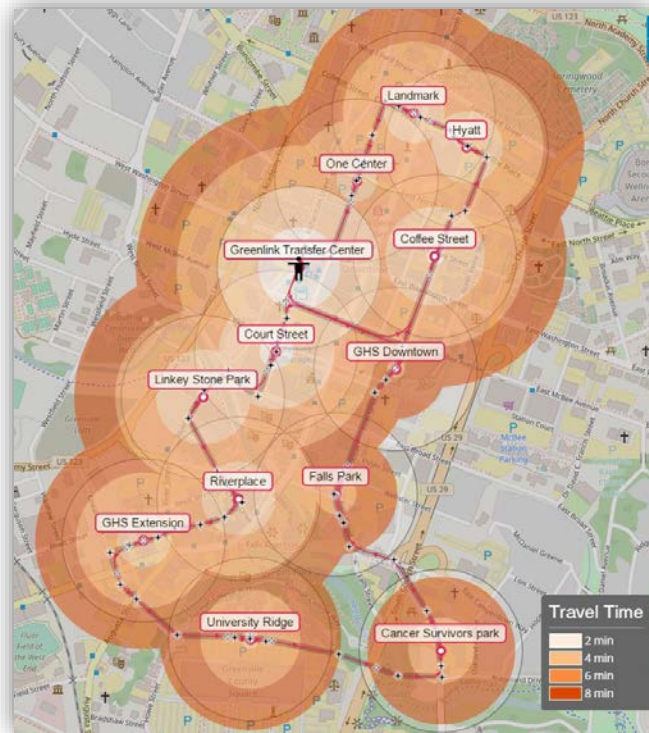
**Conceptual downtown ATN layout  
Station access circles are depicted ¼ mile wide**

<sup>5</sup> <http://www.greenvillecounty.org/apps/procurementpdf/Uploads/UniversityRidgeDevelopmentFINAL.pdf>



Perhaps one of the most important impacts of this system could be its effect on the downtown ambiance. Downtown Greenville is already exceptional with its restaurants, trees, parks and trails. Keeping the ATN system on streets one block away from Main Street will add to the accessibility without detracting from the ambience. In addition, the ATN system is likely to become a favored attraction for both locals and tourists

In addition to providing transportation among attractor locations in the downtown area, this ATN layout could enable some changes when combined with other automated transit systems. One consideration could be to close a portion of Main Street to automobile traffic and turn it into a pedestrian mall. Parking lanes could be turned into expanded sidewalks with sidewalk cafes. Some, or all, of the road itself could be maintained for use by driverless/automated electric shuttles. These vehicles would operate at low speeds, yielding to pedestrians and providing accessibility for those of limited walking ability. In addition to picking up and dropping off passengers along main street, they would also provide connectivity to ATN stations and bus stops.



**Travel times (including walking and waiting) from the Greenlink Transfer Center**



**Automated shuttle**

Automated shuttles (aTaxis) could be operated as part of the Greenlink services. Ticketing might be facilitated with a Smart Travel Charge Card that recognizes individuals and allows them to park in an open space on the street or in a deck, and move seamlessly between a trolley, bus, aTaxi, and ATN vehicles. Different aTaxi shuttles could travel between North Main Street (NoMa

Plaza), Heritage Green, and the Fluor Field area or over to the Kroc Center, and the new City Park.

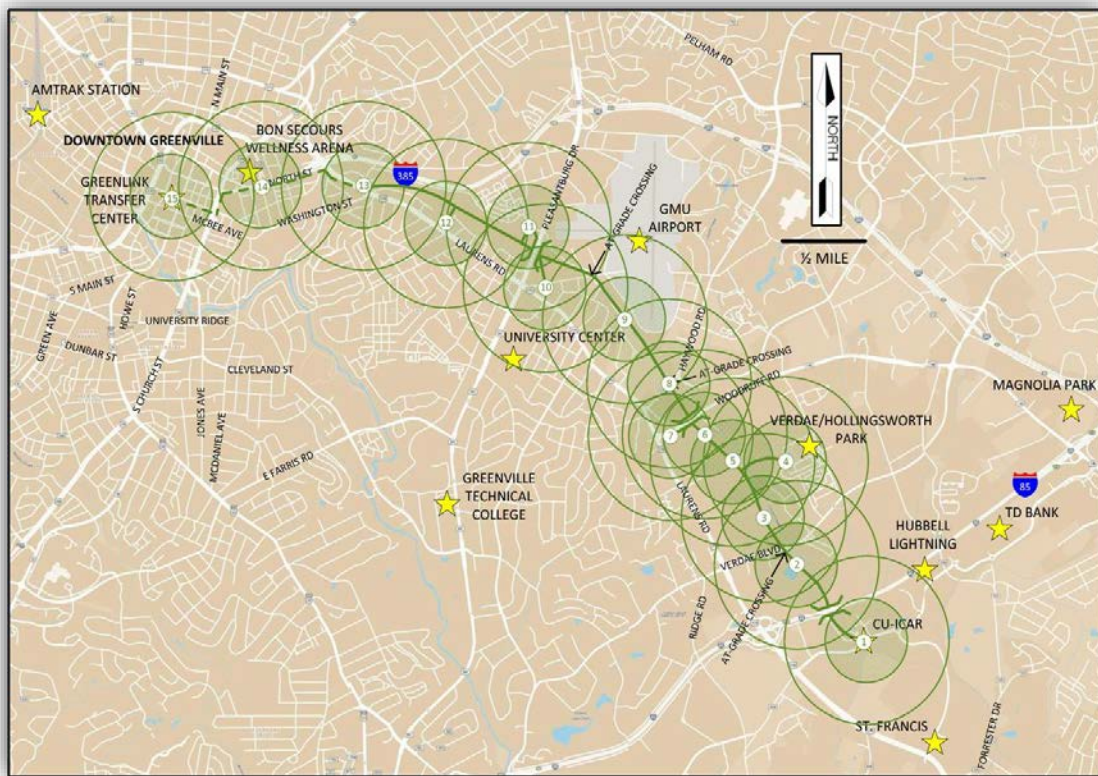
Academic campuses like Bob Jones or Furman University might use aTaxis to shuttle students, faculty, and staff between classes. Perhaps aTaxis could best serve mobility-challenged students or retirees.

An ATN system could also connect Downtown along Church Street/ Mills Avenue to the GHS complex with its 6,000 hospital employees, 400 USC Medical School students, and the new IMED campus with corporate researchers and office staff.

A recent feasibility study for a new convention or conference center recommended not to proceed with any of the sites that were identified as possible locations. There was a suggestion that Greenville try to better utilize existing facilities, which would be a real possibility if an on-demand ATN system connected Downtown hotels and restaurants to the TD Center off Pleasantburg. The direct rapid “horizontal elevator” service from a rider’s origin to their destination would be very attractive to tourists.

## DOWNTOWN GREENVILLE TO CU-ICAR ATN LAYOUT

This layout was developed and considered in a 2014 study<sup>6</sup> undertaken as a supplement to a 2010 Multimodal Transit Corridor Alternatives Feasibility Study<sup>7</sup> which examined transit alternatives for a 3.42-mile rail corridor owned by the Greenville County Economic Development Corporation. The 2010 study compared bus rapid transit, diesel light rail transit, light rail transit, commuter rail, and streetcar options and found bus rapid transit (BRT) to be the preferred solution. The 2014 supplement considered ATN alternatives (several modern ATN systems had gone into public service since the 2010 study) and found that the solution depicted here would have similar costs to the BRT solution but attract three and a half times as many riders. While the required subsidy per passenger was far less than for the BRT solution, the ATN solution was not self-funding and did not project sufficient ridership to warrant federal funding.



**Downtown Greenville to CU-ICAR ATN Layout**  
Station access circles are depicted 1/2 mile and 1-mile wide

This ATN routeway follows an old railroad track that parallels Laurens Road. The community is very interested in extending the Swamp Rabbit Trail (SRT), a bicycle – walking path, along the track during 2017. The track is also a logical routeway for an elevated ATN system. If this ATN section were built, it could reduce the demand for a new highway parallel to Woodruff Road, saving about \$40 million in road construction costs. It would also improve access to the University Center and the TD Convention Center, located off Pleasantburg Drive.

<sup>6</sup> [http://www.greenvillecounty.org/gcpc/transportation\\_planning/pdf/gcedc\\_prt\\_evaluation\\_final.pdf](http://www.greenvillecounty.org/gcpc/transportation_planning/pdf/gcedc_prt_evaluation_final.pdf)

<sup>7</sup> [http://www.greenvillecounty.org/gcpc/transportation\\_planning/pdf/rail\\_corridor\\_final\\_report.pdf](http://www.greenvillecounty.org/gcpc/transportation_planning/pdf/rail_corridor_final_report.pdf)



## GREENVILLE – SPARTANBURG INTERNATIONAL AIRPORT ATN LAYOUT

This layout was developed during a 2015 PRT feasibility study<sup>8</sup> for Greenville-Spartanburg (GSP) International Airport. The study found that an ATN solution was viable, had lower life-cycle costs than a shuttle bus system and provided higher levels of service. It led to follow-on work including an ATN system provider procurement process. The project is presently on hold pending the outcome of the Airport Master Plan Study.



Greenville – Spartanburg International Airport ATN Layout

<sup>8</sup> PRT Consulting, Inc. Greenville-Spartanburg Airport District Preliminary Personal Rapid Transit Feasibility Study <http://prtconsulting.com/reports.html>

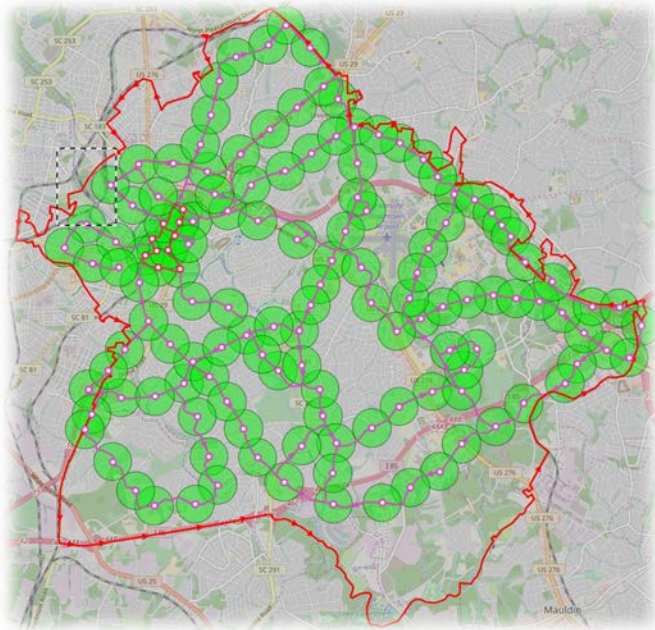


## CITY OF GREENVILLE ATN LAYOUT

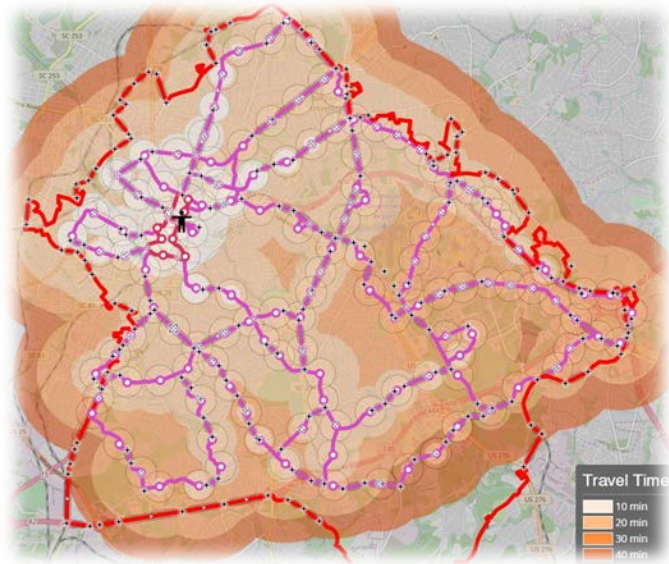
The utility of a transit system increases roughly as the square of the number of stations. Doubling the number of stations approximately quadruples the connections that can be made. However, the cost of adding stations remains approximately the same. For this reason, a large network is far more likely to be cost-effective than a small one.

For the above reason, we need to investigate a sufficiently large ATN network if we are going to consider the viability of ATN in Greenville. Once we venture beyond the city limits, determining population density becomes too complicated for this analysis and the chosen “large” layout has therefore been restricted to city limits for simplicity of analysis purposes only. This would probably not be a factor for the design of a large network in the Greenville area.

The figures in this section show a possible city-wide ATN deployment. Almost the entire city will be within a half-mile of a station. While the area within a ¼ mile of a station is similar, or a little larger than the area within ¼ mile of a bus route, the travel times are about one half to one quarter the bus times when you include walking and waiting times. The differences in level of service between an ATN solution and the present bus system are summarized in the table below.



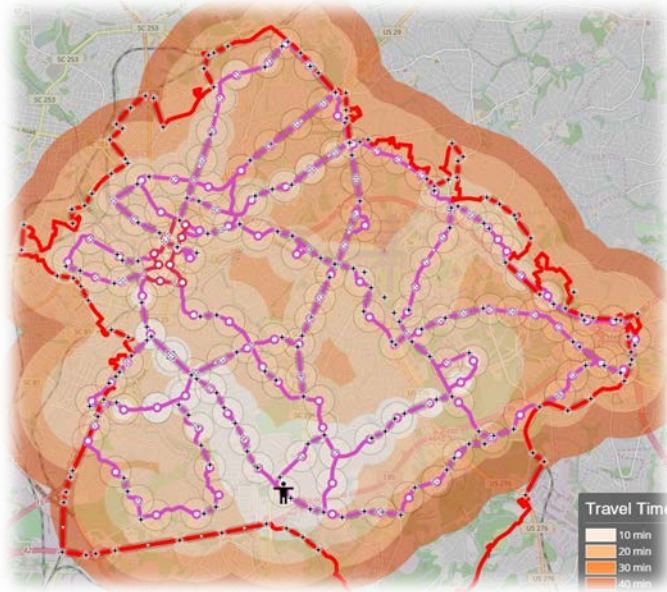
**ATN accessibility within city limits**  
Station access circles are depicted ½ mile wide



**Accessibility from Greenlink Transit Center:**  
By ATN plus walking, almost all populated areas of the city are within 30 minutes from the Greenlink Center including a one-minute wait time

The ATN system clearly has a much higher service level than the bus system. This is particularly significant when you take into account the well-established fact that transit users rate waiting time at approximately double riding time. In addition, transit users rank reliability high and the ATN system is about ten times more reliable than the bus (assuming the buses operate at transit level of service B).

Next we will consider whether building a system similar to that depicted is feasible for the Greenville area. Please remember that the depicted ATN application has been restricted to the Greenville City limits only for the purpose of facilitating analysis. A better solution may well include service to areas outside the city limits, while perhaps reducing service to some areas within the limits.



**Accessibility from I-85 & Mauldin Road Bi-Lo:  
By ATN plus walking, almost all populated  
areas of the city are within 30 minutes from the  
Mauldin Road Bi Lo including one-minute wait time**

#### ATN Versus Bus - Service Level Comparison

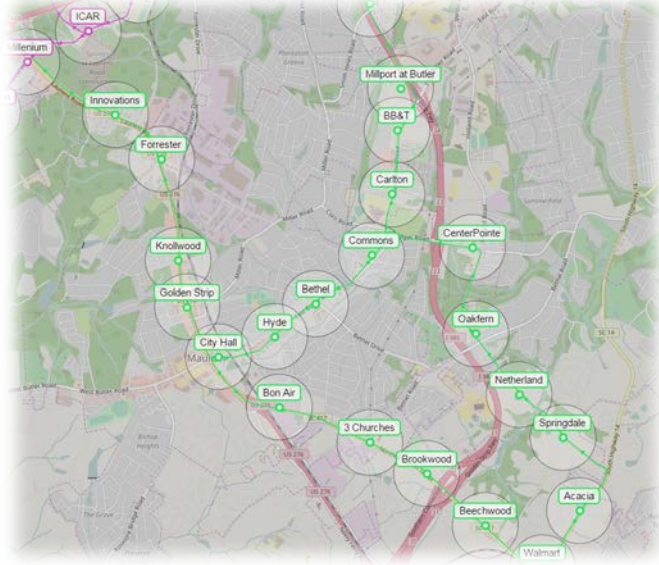
Criterion	ATN	Bus
Walking distance assumed	¼ mile	¼ mile
Average wait time	1 minute	30 minutes
Total trip time Downtown to Mauldin Road Bi Lo	25 minutes	65 minutes
Total trip time Bi Lo to Shops at Greenridge	32 minutes	120 minutes
On-time reliability	99.5%	95%
Guaranteed seat	Yes	No

## MAULDIN ATN LAYOUT

Mauldin is a city south of Greenville that is part of a separate urbanized area that is experiencing significant growth. This map is an example of an extension of the Greenville ATN layout. It links residential areas to government offices, jobs and other amenities.

The above five ATN layouts represent opportunities from small to large. Initial small deployments are likely to be the way to start but two factors must be born in mind – small systems are unlikely to be financially viable and future expansions must be planned for. A deployment covering the areas outlined below should be the long-term goal.

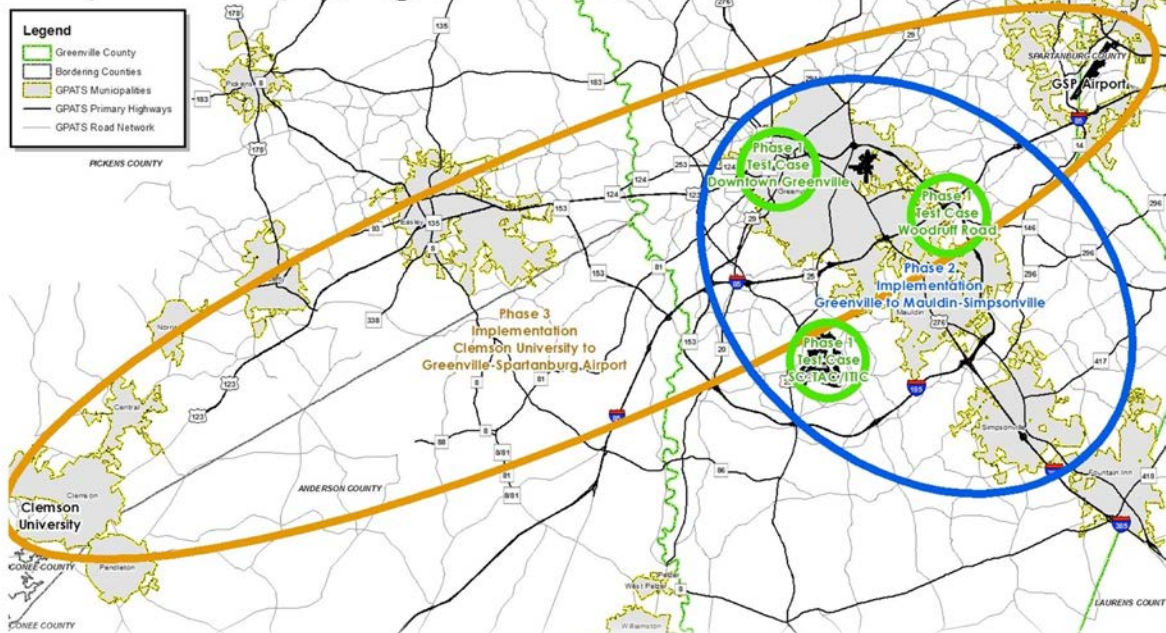
Greenville's 2016 USDOT Smart Cities Challenge developed a vision for innovating transportation for the Greenville-Pickens Area Transportation Study Urbanized Area (UZA) . This vision included three small pilot study sites for aTaxis or ATNs, circled in green; one ATN corridor connecting Greenville to Verdae/ CU-ICAR and on to Mauldin, outlined in blue; and a GSP to Clemson ATN Corridor through Greenville, outlined in orange.



**Mauldin ATN Layout**  
Station access circles are depicted ½ mile wide



# Greenville Smart Cities Challenge Proposal Map



**Key Greenville Transportation Nodes**  
Credit: Greenville Smart Cities Challenge

## CONCEPTUAL ATN FEASIBILITY

This very high-level analysis is intended only to provide an indication of feasibility. Feasibility is assumed to mean the ability of an ATN application to pay for its own capital and operating cost through fare-box revenues and without subsidies. In addition to estimating the capital and operating costs of the system, we must estimate other external costs as well as projected fare-box revenues.

Capital and operating costs for the City of Greenville ATN layout have been calculated based on the bid prices received by GSP Airport. These prices are probably conservative since they are for a relatively small system.

The major potential external cost is the cost of right-of-way. Since the ATN is anticipated to mostly fit within existing street right-of-way with very little disruption to existing services, this cost has been assumed to be zero. The community should benefit greatly from an ATN application and it would seem pointless for it to charge for space that is generally available. In some situations, additional right-of-way will be needed (e.g. for stations and parking) but these costs are assumed offset by the additional opportunities for revenue (e.g. advertising and station-area redevelopment) that have not been estimated in this study.

Fare-box revenues depend on the average fare charged and the number of daily riders. A previous study found that Greenville ridership will start dropping off around \$3.00 per single ride and a fare of \$2.50 per ride is assumed here. The number of daily riders is far more difficult to



estimate and beyond the scope of this paper. The best that can be done here is to assume a range of mode shares, from 5% to 30%, and determine the derived results.

The City-wide ATN application has approximately 74 miles of one-way guideway and 115 stations with a service area of about 55 square miles. The area within a five-minute walk of a station is approximately 17 square miles. The remaining area will serve passengers willing to walk further or to use other modes to reach a station. Assuming the service area is that area within one half mile of a station, the population is approximately 340,000 assuming the average population density in the city. According to the USDOT, this population will generate approximately 12,240,000 person miles of travel a day. At a 5% mode share, this results in 612,000 passenger miles on the ATN system and 122,400 daily trips assuming a 5-mile average trip length.

At \$2.50 per ride, these trips will generate \$306,000 in daily revenue for an annual total around \$82 M. Assuming that the peak hour demand is 10% of the total daily demand, we find we need to accommodate 61,200 passenger miles in the peak hour. With an average vehicle occupancy of three, this requires about 20,400 vehicle miles in the peak hour which can be provided by 816 vehicles with an average speed of 25 mph. Adding a 30% allowance for empty vehicles results in a vehicle demand of 1060. Similar calculations have resulted in the projected annual numbers for the different mode shares shown in the table below.

**City-Wide ATN Characteristics**

<b>Mode Share</b>	<b>Guideway Length (Miles)</b>	<b>Stations</b>	<b>Vehicles</b>	<b>Daily Trips</b>	<b>Annualized Capital &amp; O&amp;M (Millions)</b>	<b>Annual Revenue (Millions)</b>
<b>5%</b>	74	115	1,060	122,400	108.2	82.3
<b>10%</b>	74	115	2,120	244,800	170.0	164.6
<b>15%</b>	74	115	3,180	367,200	231.7	246.9
<b>20%</b>	74	115	4,240	489,600	293.5	329.2
<b>25%</b>	74	115	5,300	612,000	355.3	411.6

As can be ascertained from the table above and, perhaps more easily, from the chart below, a mode share of approximately 11% is needed for a city-wide ATN system to fully pay for itself from fare-box revenues. The big question becomes; can an 11% mode share be reasonably attained? TranSystems (see Appendix B) reported a Greenville mode split of 12% for the present bus system with hourly service. They estimated a PRT system would have a mode share of over 40%. For a business case to be presented to prospective ATN suppliers, the above analysis needs to be verified in more detail and for this application in particular.

In addition to verifying the mode share, the system capacity needs to be analyzed more accurately. Two thousand vehicles on a 74-mile system is around the capacity of today's PRT systems. Either the vehicle size must be increased from the assumed four passengers to six passengers (which some suppliers can do) and/or coupled vehicles are needed and/or the minimum headway (time between vehicles) needs to be reduced (the SmART system is under development to do this). Note that the higher speeds and capacities proposed by the SmART system and other systems under development such as Skytran and TransitX will result in improved business cases. Higher speeds have the double effect of both increasing ridership and reducing the number of vehicle required.

It should be noted that the above results pertain to a (more-or-less) city-wide ATN system. This may not be the most cost-effective deployment. A more cost-effective deployment may be one more focused on relieving congestion and less on serving suburbia.

As stated previously, a smaller deployment with less stations will have fewer station pairs to offer the traveler and will thus likely attract less mode share. However, a small deployment focused on Downtown, for example, may be quite viable if it can generate additional ridership and/or revenues by virtue of its location and the facilities served.

The following sections address the merits of an ATN deployment in Greenville and the considerations and actions needed to make it a reality.

## POTENTIAL BENEFITS

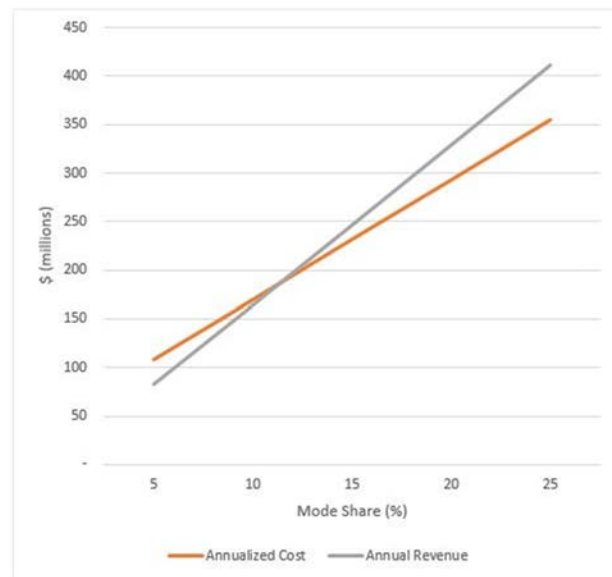
This section discusses the benefits likely to derive from an ATN deployment. Some of these benefits are readily quantifiable while others are not. Similarly, some of the benefits are easily monetized to help pay for the ATN system while others are not.

### ECONOMY

Economic benefits will derive from improving accessibility to jobs which should help people find and keep jobs and help companies find and keep reliable employees. People who spend less time fighting traffic or waiting for transit are likely to be more productive at work. Less congested streets will result in more reliable deliveries of goods and services. Families that can use the ATN system to reduce the number of cars they own will save thousands of dollars each year. Real estate located close to high-quality transit has been proven to increase in value. A community that is free from congestion will have many economic advantages,

The development and construction of the ATN system will itself help improve the economy. It will bring new jobs to Greenville along with the increased need for accommodations and supplies. In addition, numerous ATN-related business opportunities could arise, including vehicle design and manufacture, system maintenance and operation, research and development, educational and trade conferences, etc. Greenville could become the U.S. center for ATN education, development and deployment, further boosting the region's reputation for innovation and entrepreneurship.

Impacts on tourism could be quite significant. The ATN system will itself be a tourist attraction. In addition, it will increase tourist mobility allowing a family with one car to easily split up and visit different destinations. Bars and restaurants will likely do better when they are more accessible and designated drivers are no longer needed.



Costs and Revenues plotted against Mode Share

The cost of road infrastructure maintenance and expansion is a significant issue for Greenville. As stated previously, the State of South Carolina is only spending \$415 M annually on its road system against estimated needs of \$900 M. Such underfunding will have very serious impacts on future generations if continued unabated. A self-funding transportation infrastructure-based solution like ATN will go a long way to relieving the pressure on road expansion, reducing the need for road-widening costs and allowing more highway money to be focused on maintenance of existing assets.

An ATN solution could also reduce the need for parking facilities. Parking needs will reduce in proportion to the number of drivers that switch to using ATN. Furthermore, expensive parking decks could be replaced by more remote surface lots connected by ATN. Opportunities could also exist to better utilize existing parking facilities not well utilized during office hours (e.g. at malls and/or sports facilities) by, for example, connecting them to downtown. Appendix C includes an endorsement of this potential cost savings and value to developers building new projects by parking expert, Mike Martindill.

A Greenville Metro UZA ATN system should be integrated into the GreenLink and CATbus systems serving Greenville and Clemson. ATN could reduce or eliminate the need for bus services along ATN corridors. This would result in savings that could be used to help fund collector bus routes and to improve service to areas outside the City limits. Integrating bus and ATN services so that they each support the other and improve overall transit services is a goal.

While some existing bus drivers may lose their jobs, these jobs will be replaced by ATN system operation and maintenance jobs which will likely be less stressful and better paying. Those not wishing to work on the ATN system will now be freed up to commute to work in new jobs, upgrade workforce skills, or take college classes to prepare for higher paying jobs.

Measuring some aspects of the economic impacts should be possible while others may prove more difficult. Similarly, monetizing some of the economic benefits back to the ATN system may be easier than others. Quite a number of the economic impacts will result in increased property or other taxes. To the extent which they could be linked back to the ATN system, it could become the beneficiary of increased tax revenues.

#### MOBILITY

The mobility benefits of an ATN system that attracts more than about a ten percent mode share are very significant. Traffic congestion will mostly vanish. People with poor access to jobs, schools and other amenities will suddenly have the access they need. Mobility that is slow, unreliable and/or expensive is a heavy burden that many have had to come to terms with. The improvements in quality of life brought about by on-demand mobility that is quick, reliable and affordable could have a ripple effect through the community.

To the extent that mobility improvements result in ATN ridership, they will be quantifiable and capable of being monetized to help pay for the system.

#### SAFETY

To the extent that people switch from cars, buses, bikes or walking to ATN, their safety will be improved. ATN systems around the world have completed over 200 million passenger miles without a serious injury accident.

Safety improvements will result in measurable societal cost savings related to fatalities, injuries and property damage. Monetizing these savings to help pay for the ATN system will likely be difficult.

#### SUSTAINABILITY

The ATN system will use about one third the energy per passenger mile of cars and buses. In addition, being electrically-powered, it will reduce point-of-use emissions and, potentially all emissions, depending on the power source which could be guideway-mounted solar panels.

Another aspect of sustainability is that the elevated guideway structures are likely to have a much longer life with less maintenance requirements than surface roads which are more susceptible to damage from heavy trucks, ground water penetration, snow and ice, etc. Furthermore, ATN vehicles will each carry many more passengers per day than cars do and will not be subject to damage from potholes or accidents.

Sustainability aspects such as greenhouse gas emissions will be quantifiable. Reduced energy use and maintenance costs are monetized in that they are accounted for in capital and O&M cost estimates.

#### OVERALL QUALITY OF LIFE

The above-mentioned benefits will combine to improve the overall quality of life for the citizens of Greenville. These benefits derive from retrofitting a community not designed around ATN. Additional potential exists for future land developments to be designed around ATN. These new developments could explore ways to limit automobile access and the need for pavements. They could result in people living and working in park-like settings.



**Live and work in a park-like environment**



## PROBABLE HURDLES

Implementing an ATN solution similar to the one shown here will not be easy and there are many hurdles to be overcome. This section discusses the major hurdles and the following section suggests how they may be mitigated.

### NEED TO DEVELOP COMMUNITY SUPPORT

This is a community-wide project and it must have broad-based community support. Public support for transportation projects, even necessary road projects, is difficult to secure. There is a mistrust of new ideas until innovation is experienced. Even with a majority in favor of it, a project like this could be stopped by vociferous minority opposed to it. Opposition to projects like this generally results from groups that feel they have been left out of the decision-making process and do not like some aspect of the project. While their concerns may be mistaken or unfounded, they may also be quite legitimate. A project of this magnitude might be for the greater good but it is also likely to have a negative impact on some.

There is growing wide support for advanced transit in the Greenville area. Greenville County recently passed the resolution in Appendix D supporting Greenville as a pilot site in the State of South Carolina for the research, development, testing, and deployment of multimodal, intelligent, automated transportation systems and management technologies initiatives. In addition, an Innovation and Economic Development initiative is being formed by the County and the State of South Carolina published a new innovation plan in early 2017.<sup>9</sup> Greenville County was recently featured by the National Association of Counties under Connected Counties.<sup>10</sup>

### NEED TO DEVELOP A STRONG BUSINESS CASE

Once community support is confirmed, a good business case must be established. The costs of building and operating the system can be estimated with reasonable accuracy. The revenues which could be generated by an ATN solution are more difficult to estimate. The biggest unknown is the fare-box revenue which relates to the fare charged and the daily ridership.

In addition to fare-box revenues, there are a number of other hard-to-predict revenue sources such as, advertising, sponsorships of vehicles and station names, rental incomes, and possible savings to be considered in a business case. The Advanced Transit Association (ATRA) provides the following examples:

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<sup>9</sup> [http://sccommerce.com/sites/default/files/all/the\\_south\\_carolina\\_innovation\\_plan\\_1-11-17.pdf](http://sccommerce.com/sites/default/files/all/the_south_carolina_innovation_plan_1-11-17.pdf)

<sup>10</sup> <http://www.naco.org/resources/connected-counties-tech-innovations-transportation>

	<b>Revenue Streams</b>	<b>Savings</b>
ATN System	<ul style="list-style-type: none"> <li>▪ Farebox</li> <li>▪ Sponsorships – stations</li> <li>▪ Advertising - vehicles</li> </ul>	<ul style="list-style-type: none"> <li>▪ Low Capital Expense</li> <li>▪ Low Operating Expense</li> </ul>
Employee Commuter Rider Retail Customer Riders Visitor Riders	<ul style="list-style-type: none"> <li>▪ Sponsored Tickets</li> <li>▪ Subsidized grant tickets</li> <li>▪ Visitor “package” tickets</li> </ul>	<ul style="list-style-type: none"> <li>▪ Higher staff productivity</li> <li>▪ Reduce travel time</li> </ul>
Property Owners / Developers	<ul style="list-style-type: none"> <li>▪ Increase rents &amp; fees</li> <li>▪ Public transit access increases property value</li> </ul>	<ul style="list-style-type: none"> <li>▪ No disruption to services</li> <li>▪ Minimal footprint</li> </ul>
Local Governments	<ul style="list-style-type: none"> <li>▪ Increased property taxes from development</li> <li>▪ Access fees/ encroachment fees</li> <li>▪ Increased parking fees</li> </ul>	<ul style="list-style-type: none"> <li>▪ Reduction in traffic congestion</li> <li>▪ Reduction in pollution and emissions</li> </ul>
Other	<ul style="list-style-type: none"> <li>▪ 3rd party partnerships</li> <li>▪ Grants</li> </ul>	

Transit projects involving trains and metro systems are very expensive, ranging from \$50 to \$500 million per mile, and typically require substantial subsidies even in dense cities such as New York and Washington DC. ATN has an ultralight infrastructure and lower costs, and the potential to cover its own operating and even capital costs given sufficient ridership. However, this has not yet been accomplished in any current operating systems and the combinations of population density, size of network and other factors to allow viability are unknown. Thus it is very difficult for an ATN supplier to build a bankable business case for an ATN deployment with discretionary riders. All the more so in a community with a relatively low population density like Greenville.

Community leaders are aware that adequate information must be provided to develop successful public private partnerships. New information on projected increased property values from economic development and resulting increased property tax incomes along transit corridors has been estimated by Dr. Robert Brookover. Summaries of his calculations are included in Appendix E. These income estimates suggest potential public revenue that can help cover infrastructure capital costs.

**DEMONSTRATION/STARTER SYSTEM PITFALLS**

It seems reasonable to want to build some sort of demonstration/starter/test system before committing to the full application. This has the advantage of allowing the community to “kick the tires” and of providing “proof of value” of the system. However, there are a number of potential pitfalls that should be considered.

As discussed earlier, any system with few stations is unlikely to have much utility. Generally, the ridership will be low and there is a danger that people will not understand its true horsepower. The Las Vegas Monorail has suffered a number of bankruptcies because it has too few stations and does not serve the airport. Low ridership makes it difficult for the system to be profitable. It is

very difficult to convince investors that expanding it will make it more viable. Thus a “too small” starter system can be self-defeating.

An exception to the “too small” starter situation would be where the starter system is a “Disney-like ride” that attracts large numbers of tourists or could be viable by itself, such as the well-publicized Ultra system from a remote parking lot to Terminal 5 at Heathrow Airport. A potentially viable situation exists at Greenville-Spartanburg International Airport where an ATN system connecting the parking lots to the terminal has been found to cost less to build and operate than shuttle buses. Thus the GSP Airport is an ideal location for an ATN demonstration system. However, even at the Airport, the business case is not crystal clear. If the Greenville community wants an ATN solution, they may do well to evaluate how they can support the Airport in building its system. A successful airport system could expand to nearby manufacturing, office, and commercial facilities, and ultimately extend to Downtown Greenville.

Both the International Transportation Innovation Center (ITIC) and the Clemson University – International Center of Automotive Research (CU-ICAR) have suggested collaborating with ATN companies to build one or more test tracks to conduct research and development of ATN equipment and to validate ATN standards. This could be a good way to establish Greenville as a preferred location for start-up systems and as a way to reduce risk prior to a venture into ATN.

There are already a number of suppliers with adequate ATN systems proven in public service. Other suppliers have systems in development that have not yet been commercialized or put into public service. The community may choose to consider an unproven ATN system not yet in public service, but with innovative developments that seem superior to commercially-available systems.

Greenville leaders have indicated all suppliers must bring a private team with three demonstrable strengths: 1) an engineering, procurement, construction (EPC) company responsible for designing, bonding (to cover the cost of removal in the event of failure), building and certifying operational safety of the ATN system; 2) an ATN control company that will own, operate and maintain the system according to a franchise agreement; and 3) private funding for phased capital infrastructure and start-up operational costs.

As their part of a public private partnership, the public sector will provide non-exclusive access to public rights-of-way. It may provide partial repayment for infrastructure and start-up costs based on TIF or MCIP-type agreements to qualify for up to 5% of the gross system incomes.

## PLAN OF ACTION

### BUILD COMMUNITY SUPPORT

The way to build community support is to engage developers, property owners, major business and corporate leaders, as well as technical and governmental leaders. Be as open about the project as possible. Publicize the project, develop informational websites and create “buzz”. Hold meetings and workshops to encourage community outreach and involvement. Share the issues, concerns and potential solutions with the community and genuinely listen to the feedback. Encourage involvement from and dialogue with naysayers. Be prepared to drop the project if there is real opposition. It is better not to start than to begin and get derailed.

People are likely to be upset about stations being too close to them or too far from them, the view of and from elevated guideways, the cost of a ticket, etc. The best way to placate these concerns, in addition to explaining how they could be mitigated, is to have the community consider the issues

and how best to solve them, including the pros and cons of each solution. Generally, the benefits of an ATN solution will outweigh the concerns for most people. Those who do not value the benefits over the concerns should see that they are in the minority. If they are given the opportunity to try to suggest alternate solutions, but these are not popular, they will usually accept the solution favored by the majority. If the majority is not overwhelming, this may not be a good enough solution.

Community support is vital not only to overcome opposition, but also to build political support. Key political supporters are essential for projects like this. While a few political champions are likely to see the vision and take up the mission, they will need support from their fellow politicians. This support will be far easier to come by if local politicians see that this is what their constituents want.

#### UNDERTAKE A BENEFIT/COST ANALYSIS

While the community outreach efforts should be among the first, so should a detailed benefits/cost analysis, the results of which will help inform the community. Both the potential benefits and costs have been discussed previously. The purpose for the benefit/cost analysis is to see if the benefits outweigh the costs. Here all benefits and costs should be considered. The quantifiable benefits and costs are used to determine the benefit/cost ratio which should be greater than 1 (the benefits should be more than the costs). The non-quantifiable benefits and costs should also be considered – if they also appear to have a positive ratio, this can help bolster a weak quantifiable ratio. The difference between benefit/cost and business case is that the business case only considers costs and revenues that can be monetized. A project may have a benefit/cost ratio larger than one but not have a good business case. In this event the community may consider subsidizing it.

#### STRENGTHEN THE BUSINESS CASE

##### Undertake a Ridership Study

Once community support is confirmed, a good business case must be established. The costs of building and operating the system can be estimated with reasonable accuracy. The revenues which could be generated are more difficult to estimate. The biggest unknown is the fare-box revenue which relates to the fare charged and the daily ridership.

Studies completed in Greenville since 2014 (summarized on p 21 & 22) suggest that a Greenville ATN will attract 3.5 times more riders than a bus system and that the ATN will attract a mode share of 40% while a bus system will attract a 12% mode share. Obviously, those numbers need to be reviewed today, and a more detailed study based on the specific layout being considered would be helpful.

A potential solution is for the community to undertake a ridership study. This work should establish the daily riders to be expected and the average fare to be paid. It needs to have as much credibility as possible and should be undertaken by a large transportation planning firm such as Arup or Kimley-Horn. Armed with this information, ATN suppliers should be able to develop bankable business cases. Of course the ridership study may show insufficient fare-box revenue. In this event, other revenue/funding sources must be developed or the project must be abandoned.

The ridership study cost is likely to be insignificant compared to the capital cost of a City-wide ATN system. If the ridership study is timely, it can inform the benefit/cost analysis.



### Investigate Alternate Revenue Sources

There are a number of ways in which a new transit system could generate additional revenue and each should be investigated to add credible strength to the business case. Some possibilities include sponsorship and/or advertising in and on both vehicles and stations; station-related revenue development such as a coffee shop located within/below the station; and station-area real estate development.

Service-area property tax increases could be applied to transportation systems under various mechanisms. One of these is through the creation of multi-county or city industrial and business parks. According to Haynsworth Sinkler Boyd, P.A., such parks can probably not include owner-occupied residential property but may be able to include commercial residential property such as apartment complexes where units are rented to residents.

### Investigate Possibilities for Leveraging Existing Businesses

There are a number of businesses in the Greenville area that could benefit from a new infrastructure-based transit system. These include universities, planning and engineering firms, vehicle manufacturers, driverless taxi companies and engineering procurement and construction (EPC) companies. All of these organizations could benefit, not only from the project itself, but also from the opportunity of getting in on the ground floor of a new transportation paradigm.

### Investigate Alternate Funding Sources

With strong community support, a good benefit/cost ratio and a credible ridership study the ATN solution is likely to compete well for federal and state funding for innovative transportation infrastructure. While such funding is liable to bring additional requirements with it, it may be the best way to make the project happen.

### Investigate Public-Private-Partnerships

Examples could include the public sector providing the right-of-way, facilitating permits & regulatory approvals, and some of the funding from Tax Increment Financing (TIF) or Multi-County Industrial & Business Park (MCIP) sources. Private sector ATN franchise partners will provide innovative automation technology, operate and maintain the system; while EPC partners will bond, build, and validate safe operation the system.

### **CONSTRUCT A DEMONSTRATION/STARTER SYSTEM**

Build a demonstration system that is viable by itself such as at the Greenville-Spartanburg International Airport (GSP) where an ATN system connecting the parking lots to the terminal has been found to cost less to build and operate than shuttle buses. Once up and running, this system can be used as a magnet for conferences and workshops about ATN and how to apply it to urban transportation problems.

A GSP system could be followed up by a Downtown Greenville system. One or the other system could be expanded over time until they were joined. In this event, it would be preferable, but not essential, that the two systems were interoperable. If not, the transfer from one to the other should be as seamless as possible – for example, a cross-platform transfer with less than a minute's waiting time. The combined system could be expanded to serve additional developed areas. A system could be developed in Clemson that could ultimately be expanded to join with the Greenville system. As higher-speed ATN systems become available, more communities could be linked together.

#### DEVELOP A NEXT-GENERATION ATN SYSTEM

The opportunity exists to develop a dramatically-improved ATN system that has much higher speeds and capacities than current systems. Transit Control Solutions, Inc., a California-based company has developed control software that can achieve one second headways (time between vehicles) at speeds in excess of 60 mph. This is about twice the speed and three times the capacity of current ATN systems.

While the benefits of additional capacity may be obvious, the benefits of additional speed are much more than just allowing people to complete their trips quicker. Doubling the speed reduces the number of vehicles by approximately half, saving on both capital and operating costs. Higher speeds also reduce trip times – a major factor in mode choice. This means significantly more riders. Extra speed thus results in higher revenues combined with lower costs and a greatly-improved business case. Appendix A describes how a next-generation ATN system could be used to accomplish significant improvements in quality of life.

As EPC companies learn about these opportunities they are likely to become interested in leveraging next-generation ATN systems to generate infrastructure projects they can undertake. Greenville could become a place where such development and testing takes place as well as a location for implementation of such solutions.

#### DEVELOP A DRIVERLESS TAXI SYSTEM

Driverless taxis could expand the accessibility to transit by feeding the ATN system and legacy bus systems. Work with CU ICAR to start testing these systems. Work with agencies and developers to start deploying these systems.

#### MAINTAIN, BUT DO NOT EXPAND EXISTING ROADS

Maintain the existing road system to serve both driven and driverless cars. Avoid widening roads to relieve congestion, thereby maintaining pressure for people to use the ATN system.

Seek opportunities to turn key areas into car-free zones and/or develop new communities with no, or fewer, roads. This will enhance walkability, reduce the need for pavements and allow increased landscaping. The new developments should cost less, yet have higher real estate values.

#### CONCLUSIONS

The opportunity exists for the Greenville metropolitan area to have a high-quality automated transit system that will improve mobility and safety while reducing congestion and bringing widespread economic benefits. Such a system will likely more than cover its own operating and maintenance costs through fare-box revenues. Fully funding the capital costs will probably require innovative enhancements to the business case and/or federal funding, some, or all, of which should be feasible.

This opportunity to improve the quality of life for all citizens by ensuring they have access to public mobility that is on-demand, quick, reliable, affordable and sustainable seems realistic. The cost of investigating the viability of a wide-area ATN network will likely be a tiny fraction of the capital cost of the network. Without this level of investment (in the order of a million dollars), serious consideration of this project by suppliers, bankers and/or large engineering procurement and construction companies seems unlikely. Does Greenville want to invest in a possible future that could take its quality of life to the next level?

## APPENDICES

- A. A New Transportation Paradigm That Facilitates High Quality City Living
- B. Greenville, SC PRT Study, Ridership Evaluation
- C. Personal Rapid Transit (PRT) and Connective Parking Infrastructure
- D. Greenville County Resolution No. 1579
- E. Estimate of Tax Revenue Growth for the Laurens Road Corridor 2015-2045

## APPENDIX A

A NEW TRANSPORTATION PARADIGM THAT  
FACILITATES HIGH QUALITY CITY LIVING



# A NEW TRANSPORTATION PARADIGM

THAT FACILITATES

## HIGH QUALITY CITY LIVING



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# A NEW TRANSPORTATION PARADIGM

THAT FACILITATES

## HIGH QUALITY CITY LIVING

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# EXECUTIVE SUMMARY

Metropolitan mobility is failing in five key areas:

1. Congestion costs Americans \$124 billion a year
2. The typical American city dweller can only reach 30% of jobs in 90 minutes on public transport
3. The highway fatality rate is rising despite new automated driver-assist functions
4. Pavements take up 50% of suburban land space
5. \$170 billion is needed annually to significantly improve roads and only \$91 billion is available.

In short, metropolitan mobility is unreliable, unsafe and not widely available. The very infrastructure on which it is based takes up an enormous amount of land space and is crumbling, with no real prospect of being adequately rebuilt in the near future.

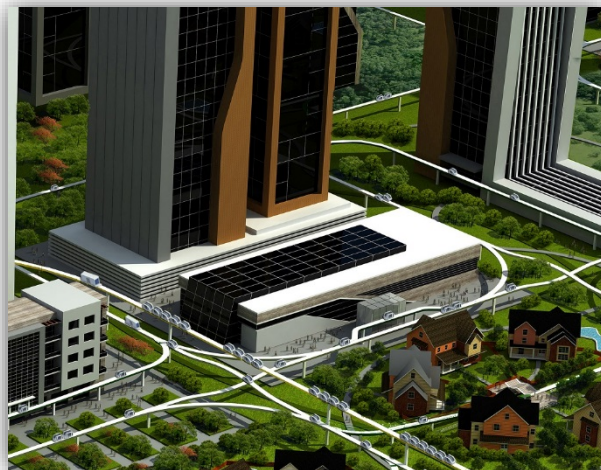
Poorly-performing cars are not the problem and making them driverless is merely a Band-Aid solution. The car-infrastructure system is the real problem. Existing infrastructure was not designed for driverless vehicles and is not the best system for such vehicles.

Not only was the road infrastructure never systematically designed, neither was the road/vehicle/pedestrian system. About half of our road infrastructure has failed, or is about to fail. There are no funds to adequately rebuild. The time is ripe to consider a new infrastructure-based solution - one wherein the vehicle/infrastructure/pedestrian system is systematically designed.

America's transportation infrastructure can be reinvigorated by elevating most motorized transportation using small driverless vehicles on guideways that cost less to build and maintain than roads – so much so that the revenues generated will cover most of the costs. The automated transit network (ATN) technology to do this already exists and needs only to be improved upon. ATN uses small driverless vehicles on exclusive guideways that have flyover crossings and offline stations. ATN has already completed over 200 million injury-free passenger miles (50 times better than cars).

ATN systems cost far less than other fixed-guideway modes like light rail. One mile of one-way guideway complete with vehicles and stations ranges in cost from about \$10 million to \$ 30 million. Lower cost applications are at grade and have lower capacity while elevated, high capacity applications cost more.

We could reclaim the surface for walking, biking and landscaping. We could live and work in park-like settings.

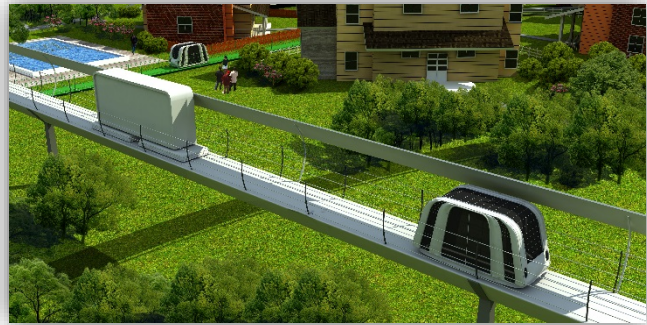


We can live and work in park-like settings

ATN level of service is more like that of cars than trains and buses. Trips are characterized by:

- Little or no waiting
- No transfers
- Nonstop, seated travel
- Very short walking distances due to numerous stations

The Small Automated Roadway Transport (SmART) system is an improvement over conventional ATN systems wherein passengers and freight are accommodated in one system and vehicles can leave the guideway and travel down streets in mixed traffic. The SmART system combines higher speeds and capacities with short offline stations. The beauty of the SmART system is that it can immediately reduce congestion while being economically self-sustaining from the beginning.



Passengers and freight on one system

Our lack of mobility has a negative impact on our quality of life. Driverless cars could help a little, retrofitting the SmART system to the existing built environment could help more, but the large benefits come from leveraging the SmART system to build new urban forms. A comparison of these three alternatives is summarized below.

	Driverless Car	Retrofit SmART	SmART
<b>Mobility</b>	✘	●	✔
<b>Logistics</b>	●	●	✔
<b>Safety</b>	✘	●	✔
<b>Security</b>	✘	●	✔
<b>Land Use</b>	✘	✘	✔
<b>Walkability</b>	✘	✘	✔
<b>Infrastructure Costs &amp; Funding</b>	✘	●	✔
<b>Real Estate Value</b>	✘	●	✔
<b>Sustainability</b>	✘	●	✔
<b>Likelihood of Success</b>	✘	✔	●

Poor ✘ Intermediate ● Good ✔

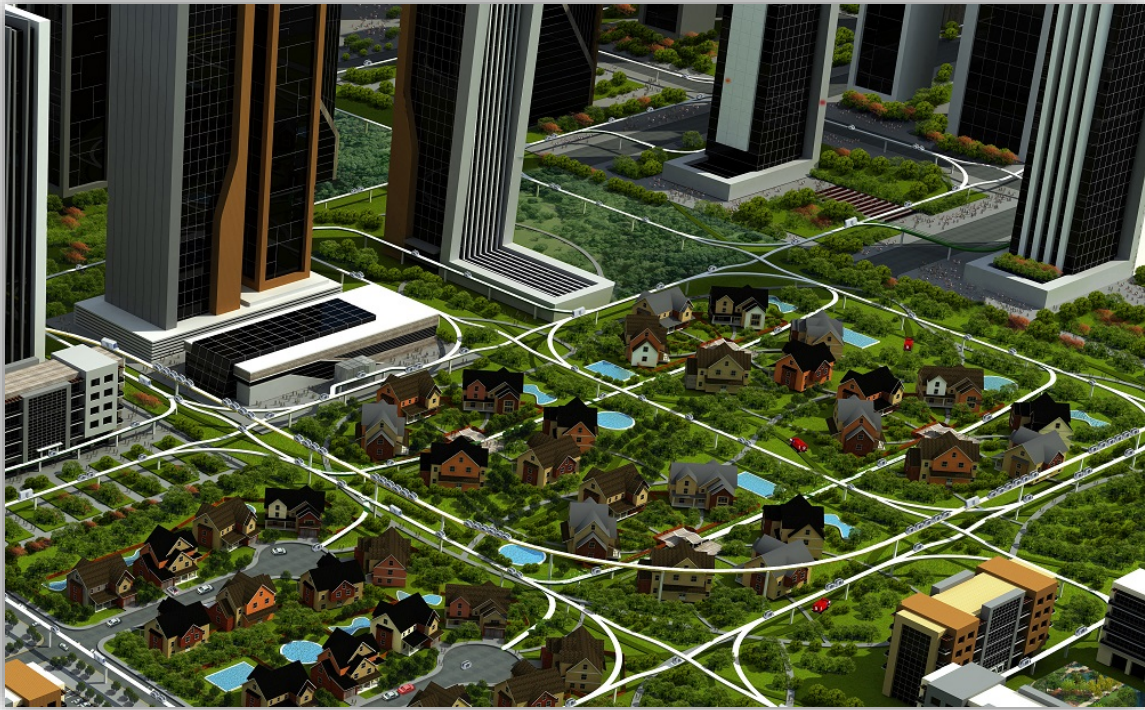
We have the privilege of being able to choose between sitting back and letting market forces bring us the few benefits driverless cars can provide, or moving towards a future that promises great mobility with a markedly improved quality of life. Do we want to settle for more of the same, or do we want the truly high quality-of-life promised by infrastructure-based transportation improvements to our cities?



## INTRODUCTION

The city experience often adds stress to our lives with a major source being commuting to work. Quality of life is diminished by failing transportation infrastructure and inadequate funds for maintenance and expansion. While motorists face congestion, those without access to cars have to put up with inadequate and slow transit services. Imagine living and working in a park-like setting and yet being in the midst of a dense city with quick, reliable, affordable and sustainable mobility on demand.

Many have recognized that metropolitan mobility is not what it could be and talk of making our cities more livable. A better goal is to move cities beyond just being livable, to being truly great.



Some cities will become truly great

If we take the time to understand the full extent of the mobility problem facing today's cities we will discover that the solutions presently being proposed do not go far enough. While they may alleviate some problems, they will not solve them completely and they totally ignore other serious issues.

Replicating the past with continued technology-based incremental attempts at improvement is short-sighted and will not serve our future well. What is needed is a solution based on new infrastructure that greatly improves mobility while freeing up the surface for much higher uses

than transportation – a new solution that can be retrofitted to the existing built environment while also allowing entirely new urban forms to arise.

Surprisingly, moving beyond livable cities is within our reach. The technology is available and proven. The costs are manageable, since the solution will mostly pay for itself. All we need is an understanding of the extent of the problem and the beauty of the solution. Once the right people grasp the possibilities, existing cities will begin to transform themselves into much better cities and many could become truly great.

# THE METROPOLITAN MOBILITY SITUATION

Metropolitan mobility is failing in five key areas:

## CONGESTION

Congestion costs Americans \$124 billion a year according to Forbes. This is over and above the 55 minutes the average driver spends driving each day

## ACCESSIBILITY

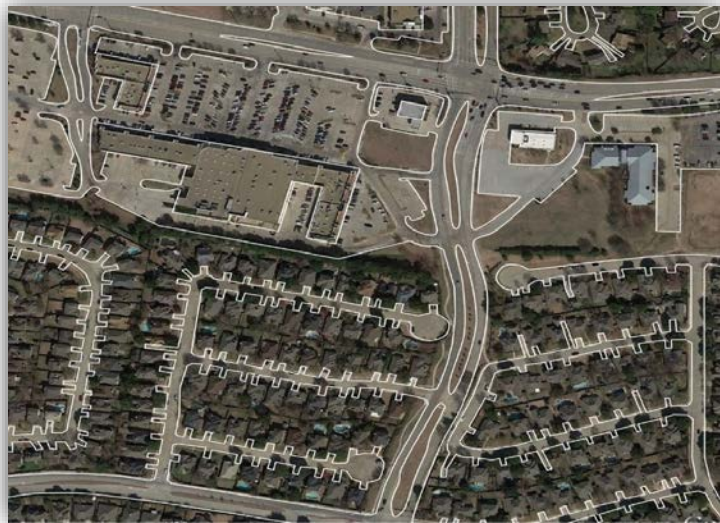
The alternative is worse - according to the Economist, the typical American city dweller can reach just 30% of jobs in their city within 90 minutes on public transport. But many have no alternative than public transport. Based on the US Census over 30% of the population (92.6 million people) are not drivers or have no access to cars.

## SAFETY

According to the National Highway Transportation Safety Administration, motor vehicle traffic fatalities are at a pace to exceed 35,000 in 2016. The first half-year fatality rate per 100 million vehicle miles of travel was 6.7% higher than that in 2015 which itself was 4.0% higher than 2014. This increase in fatality rates is troubling in light of the deployment of many new cars with automated driver-assist functions intended to reduce the rate of accidents.

## LAND USE

The primary use of metropolitan land is for transportation. Pavements typically take up 50% of land space, increasing storm water runoff and the heat island effect, as well as discouraging walking and biking. People live and/or work in concrete jungles.



Pavements dominate land use

## INFRASTRUCTURE

The American Society of Civil Engineers rated our roads D and bridges C+ in 2013 where C indicates mediocre and D indicates poor. The lowest possible grade is F for failing.

The Federal Highway

Administration estimates \$170 billion is needed annually to significantly improve road conditions and performance, while only \$91 billion is available.

In summary, metropolitan mobility is unreliable, unsafe and not widely available. The very infrastructure on which it is based takes up an enormous amount of land space and is crumbling, with no real prospect of being adequately rebuilt in the near future.

## THE REAL PROBLEM

There is a lot of press about how unsafe the roads are and how driverless cars will save us from this problem. There is also much discussion about congestion and some think driverless cars are the solution here also. There is much less discussion about accessibility, land use and infrastructure. The conclusion seems to be that poorly-performing cars are the problem and making them driverless will solve this problem. What this overlooks is that *the car-infrastructure system is the real problem* and, without improving cars and infrastructure together as a system, we are only putting a band aid on the problem which will continue to fester. The best driverless cars can bring is some improvements in safety and accessibility. In the very long term they may also help congestion but this may be at the price of actually making it worse initially.

We cannot sit back and hope to be saved by driverless cars. We must focus on the existing infrastructure which, in addition to being on the verge of total collapse, is the fundamental cause of congestion, accidents and a myriad of other problems. The existing infrastructure was not designed for driverless vehicles and is not the best system for such vehicles.

## DRIVERLESS CARS

There are numerous reasons why driverless cars are unlikely to help congestion much. They could actually increase congestion, because they will increase vehicle miles travelled (VMT) and may even require longer headways (time between vehicles) – especially during inclement weather.

Driverless cars are expected to sometimes drive around empty – looking for cheap parking for example. These empty vehicle trips will add to VMT. Ridesharing could help, but recent studies have found that this will not be sufficient to offset the induced additional VMT. Narrower lanes are difficult to implement but could bring some congestion relief, once sufficient driverless cars are on the road.

Once all vehicles are driverless, significant improvements may emerge. However, considering that we have fifty year-old vehicles on the road today, it is likely to take 50 or more years before all vehicles are driverless.

Despite present trends in the wrong direction, driverless cars will most likely improve safety. However, the difficulties involved should not be underestimated. The ability of driverless cars to dramatically improve road safety is brought into question by recent suggestions that driverless car safety standards should only require them to be twice as safe as present cars. The implication is that, even once all cars are driverless, traffic accidents could still be killing 17,000 people annually (and many more if VMT growth is accounted for).



Driverless cars will certainly help improve mobility for many and help improve safety. They may even help improve congestion. However, driverless cars are just an easy partial solution to a few of many problems and the extent to which they will be successful is in doubt. The promise of driverless cars is reminiscent of the 1980s promise of paperless offices.

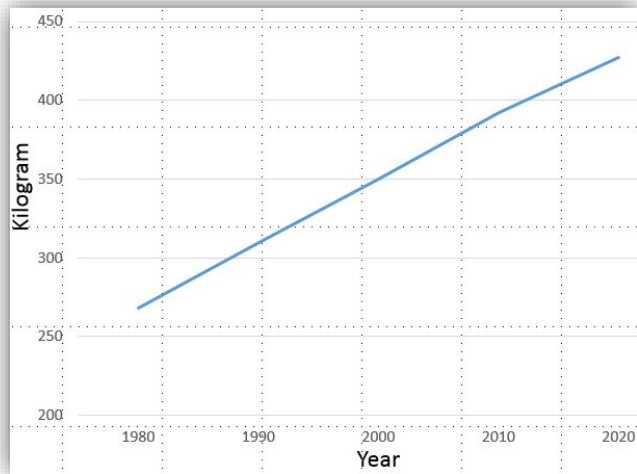
## INFRASTRUCTURE

American road infrastructure is broken. It never was systematically designed, but just evolved from cart tracks in the ground. Surface transportation works fine for low-volume low-speed systems like horses, pedestrians and bicycles. As soon as two large vehicles cross paths at speed, potentially fatal conflicts arise. The best solution transportation planners have found is freeways, where crossing traffic uses flyovers and all other maneuvers involve merging and diverging only. However, most cities are out of room for new freeway lanes and freeways do not accommodate bicycles and pedestrians.

The present road infrastructure does a terrible job of keeping travelers safe. 2016 is on target for 35,000 road deaths. The accident rate is increasing, despite new computerized safety devices in cars. While one or other driver is usually found liable for an accident, the truth is that the road system is designed in a way that requires constant undivided attention to avoid accidents. We have allowed ourselves to accept poor infrastructure design because it crept up on us in small increments. An example is two-way roads where vehicles travel in opposite directions at speed, separated only by a painted line.

Giving up the majority of metropolitan area land to pavements has been taken for granted. The cost of this wasted space is rolled into our cost of living and we just accept that for what it is. With few exceptions, such as cycling, hardscapes are no fun. We suffer them only because we see no options.

Rail infrastructure is safer than roads but also suffers from lack of adequate maintenance funding. In addition, transit systems are relatively slow and, rather than taking passengers from A to B, tend to go from D to H with stops at E, F and G. Furthermore, rail modes only account for 1.4% of all surface passenger miles and so legacy rails systems are not considered further in this document.



Per capita US paper consumption



Fatal conflict



## THE REAL PROBLEM

The infrastructure is the fundamental problem. For this reason, driverless cars alone cannot be the solution.

Not only was the road infrastructure never systematically designed, neither was the road/vehicle/pedestrian system, with the possible exception of the interstate highway system, which eliminates pedestrians.

About half of our road infrastructure has failed, or is about to fail. There are no funds to adequately rebuild. The time is ripe to consider a new infrastructure-based solution - one wherein the vehicle/infrastructure/pedestrian system is systematically designed.

## THE SOLUTION

Systems engineering indicates that transportation infrastructure for motorized vehicles should be designed to minimize collisions. This can be accomplished by avoiding crossings and only having merges and diverges. Where crossings are necessary, they must be grade separated or involve very low speeds only. In addition, motorized traffic should optimally be separated from pedestrians and cyclists. Where it cannot be separated, very low speeds must be used. Finally, motorized vehicles should be small to facilitate nonstop door-to-door travel and to minimize infrastructure costs, allowing fare-box revenues to cover operating costs as well as most capital costs. Significant added benefits result if the system can also carry goods and freight. By automating such a system (not just the individual vehicles) it becomes very safe and efficient.

Almost all of today's passenger transportation is already accomplished in small vehicles (cars). Most large trucks carry small items that could fit in small vehicles. The primary reason for large trucks, buses and trains is the cost of drivers. Accommodating large vehicles on roads is enormously expensive. In addition to the extra space needed and the added harm caused in collisions, the road damage caused by one large truck is six thousand times that of one car, according to the Asphalt Institute. Utilizing small automated vehicles for freight transportation will eliminate most of the need for heavy transportation infrastructure.

America's transportation infrastructure can be reinvigorated by elevating most motorized transportation using small driverless vehicles on guideways that cost less to build and maintain than roads – so much so that the revenues generated will cover most of the costs. The automated transit network (ATN) technology to do this already exists and needs only to be improved upon.

ATN uses small driverless vehicles on exclusive guideways that have flyover crossings and offline stations. ATN has already completed over 200 million injury-free passenger miles (50 times better than cars). The elevated guideways are ideal for supporting solar panels, enabling it to be self-powering. There are zero emissions and energy use per passenger mile is less than a third that of conventional transit systems.



Modutram, Guadalajara, Mexico



2getthere, Masdar City, UAE



Ultra, Heathrow Airport, UK



Vectus, Suncheon, Korea



2getthere, Rivium, The Netherlands



Vectus, Uppsala, Sweden



Free-standing small station

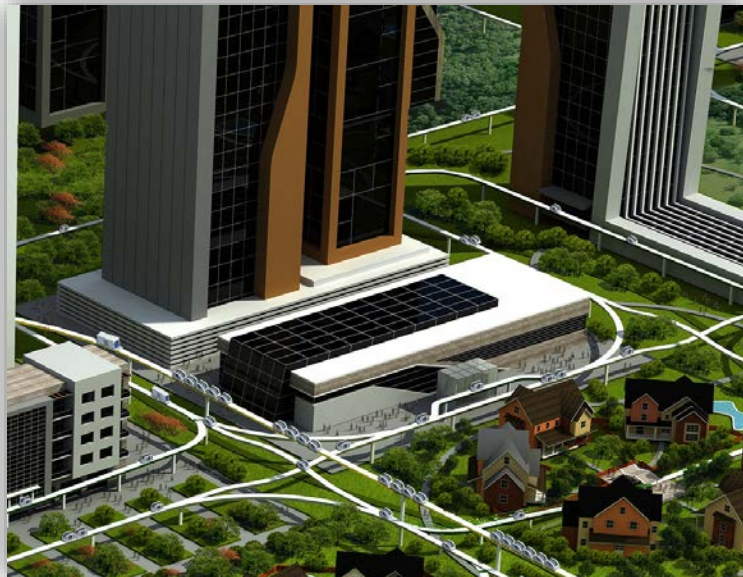


Small station attached to building

Stations can be elevated or at grade. They can be free-standing and incorporate vertical circulation systems such as stairs, elevators and/or escalators. Some stations can be attached to buildings – preferably opposite elevator lobbies to facilitate vertical circulation.

ATN systems cost far less than other fixed-guideway modes like light rail. One mile of one-way guideway complete with vehicles and stations ranges in cost from about \$10 million to \$30 million. Lower cost applications are at grade and have lower capacity while elevated, high capacity applications cost more.

We could reclaim the surface for walking, biking and landscaping. We could live and work in park-like settings. Every large building will have its own station and smaller buildings will be clustered around stations. Everyone can have access to quick, reliable, affordable and sustainable mobility. Road congestion and accidents will be eliminated.



We can live and work in park-like settings

While some roads will still be needed for transporting large items like boats or wind turbine blades, almost all transportation will be in small, driverless, electrically-powered vehicles. These small vehicles will make less noise, require much smaller infrastructure and provide far more frequent and reliable service than conventional transit systems. The small infrastructure will be less expensive to build and maintain. In addition, using the same system for people and goods will make it more efficient. Funding of transportation infrastructure will no longer be a problem since fare-box revenues will cover capital and operating costs.



Vehicles can leave the guideway

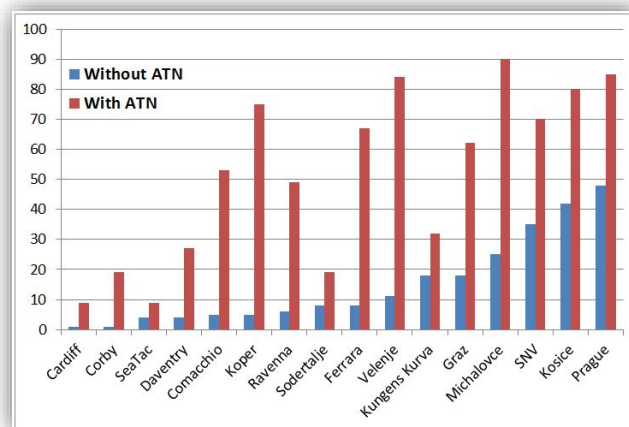
The beauty of this concept is that, in addition to being self-funding, it is easy to implement in stages.

We can start building it today with ATN technology that is already in public service. As soon as we move people off freeways and onto the elevated system, we will see congestion decrease. Many studies show that adding ATN dramatically increases transit mode share.

The primary reason why ATN systems increase transit mode share so much is the high level of service they provide. Trips are characterized by:

- Little or no waiting
- No transfers
- Nonstop, seated travel
- Very short walking distances due to numerous stations

This level of service is more like that of cars than trains and buses. As road congestion increases and ATN performance improves, with more widespread closely-spaced stations, ATN will provide better service even than cars.



Impact of ATN on transit mode share

The solution proposed here - the Small Automated Roadway Transport (SmART) system is based on the ATN concept with some proposed improvements. The SmART system uses automated small vehicles operating on exclusive guideways. The vehicles steer themselves on the roadway-like guideways and have the ability (most useful in retrofit situations) to leave the guideway and travel on side streets in mixed traffic.

ATN systems typically have the following characteristics and benefits:

- They utilize small vehicles each carrying passengers traveling to one, or very few destination stations and nonstop trips are the norm



- Numerous stations are provided, with most being on sidings, so walking distances are short and stations can be bypassed without stopping
- Vehicles run on a network of dedicated guideways linking all stations and separated from pedestrian and other traffic, thus enhancing safety and alleviating surface congestion
- Integration with legacy transit systems is facilitated by very short waiting times that effectively eliminate the perceived transfer penalty associated with transit transfers

In addition, the SmART system has the following added characteristics and benefits:

- Vehicles can leave the guideway and, like driverless cars, travel down streets in mixed traffic and at low speeds – eliminating the first/last-mile problem
- Guideways have higher speeds and capacities
- Stations are shorter – even those attached to high-speed guideways
- There is an emphasis on attaching stations to all larger buildings and clustering smaller buildings around stations
- Goods and freight are accommodated on the system using special freight vehicles that have the same chassis as the passenger vehicles. Two freight vehicle chassis can support a 20' x 8' x 4' container designed so that two will fit inside one standard 20' shipping container
- Guideways and stations support solar panels from which most, or all, of the system's power requirements are generated
- The fact that vehicles are supported by, not suspended from, the guideway facilitates the guideway accommodating electrical and other utility lines.



Passenger and goods vehicles use the same infrastructure.  
Note the solar panels shading the vehicles

The beauty of the SmART system is that it can immediately reduce congestion while being economically self-sustaining from the beginning. An example would be retrofitting a SmART system along an existing congested freeway corridor, using existing rights-of-way, and connecting it to

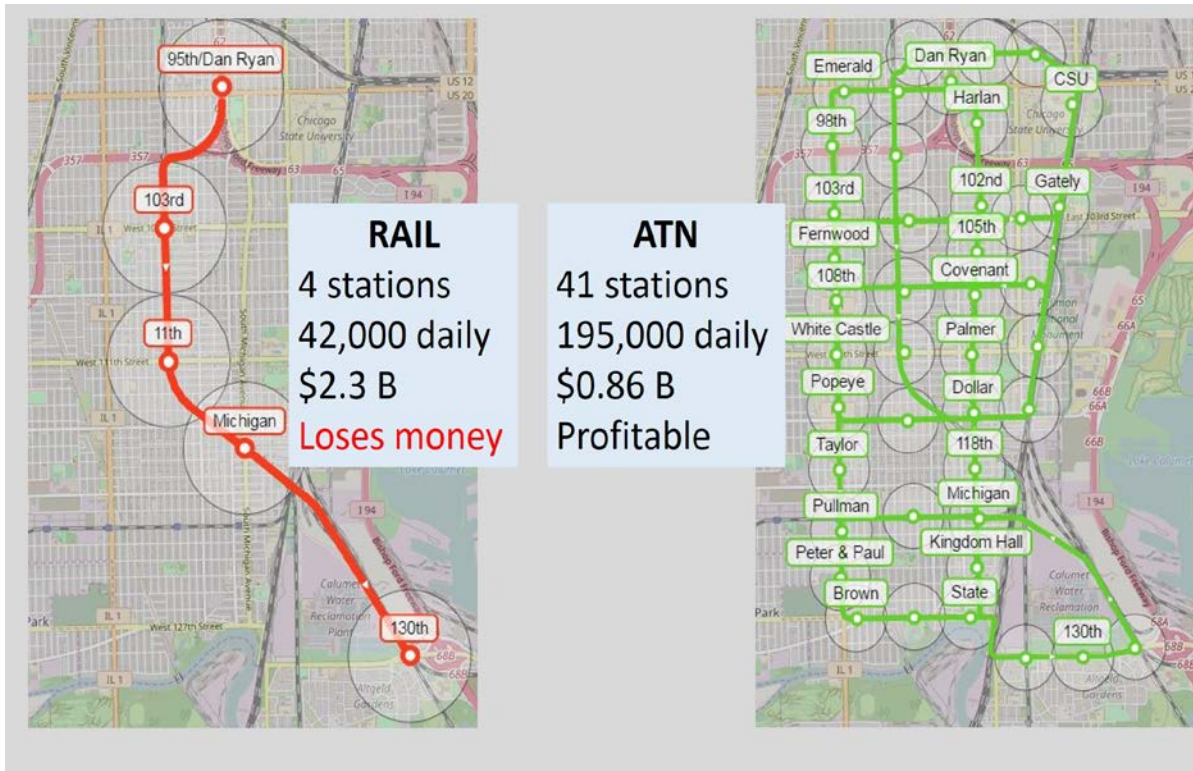


Rail station connection  
Credit: WSP



legacy transit systems. Studies have shown that such a system would generate sufficient fare-box revenue to fully pay for itself.

A specific retrofit example that would have immediate quality-of-life ramifications is the planned \$2.3 billion, five-mile, four-station extension of the Chicago Red Line south of the Dan Ryan Station. A solution utilizing existing ATN technology could take the form of a network of guideways in existing street rights of way connecting 41 stations. This would increase the area within walking distance ten times at a cost of only \$0.9 billion. The improved accessibility could help revitalize the entire neighborhood.



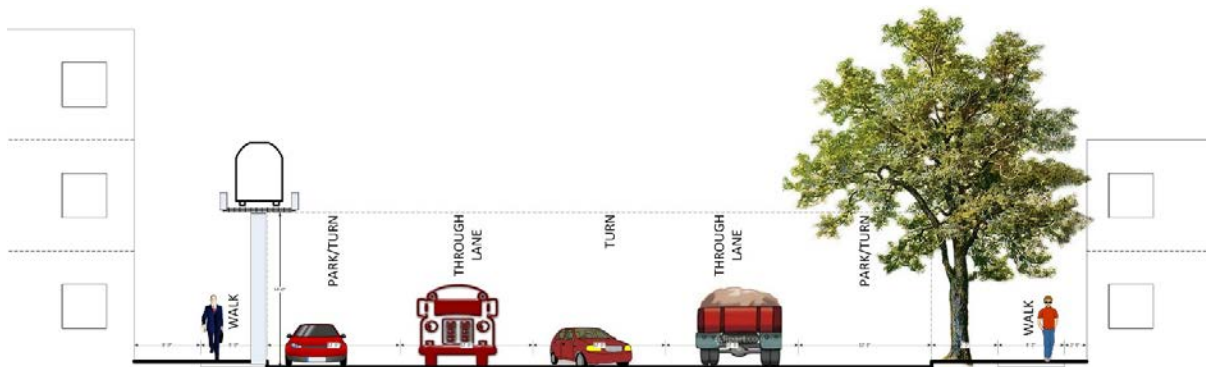
Chicago Red Line Alternatives

Note that the above scenario is based on commercially-available ATN systems. With its higher speed and capacity, the SmART system would attract more riders and require fewer vehicles, thus providing better service while being even more economically viable.

More widespread retrofitting of existing cities will result in additional benefits. All benefits will be realized once we start developing new communities that incorporate many car-free zones.

In a car-free community each building would have its own station. Where this is not practical, such as for single-family houses, the buildings would be clustered around a station.

Starting with driverless cars and adding elevated guideway-like overpasses where they are unable to overcome congestion is a band-aid solution that will face most of the problems faced by present-day road-widening projects. It is better to start with a systematically-designed guideway system that evolves to allow its vehicles to travel on the streets than with driverless cars that incorporate guideways on an ad-hoc basis.



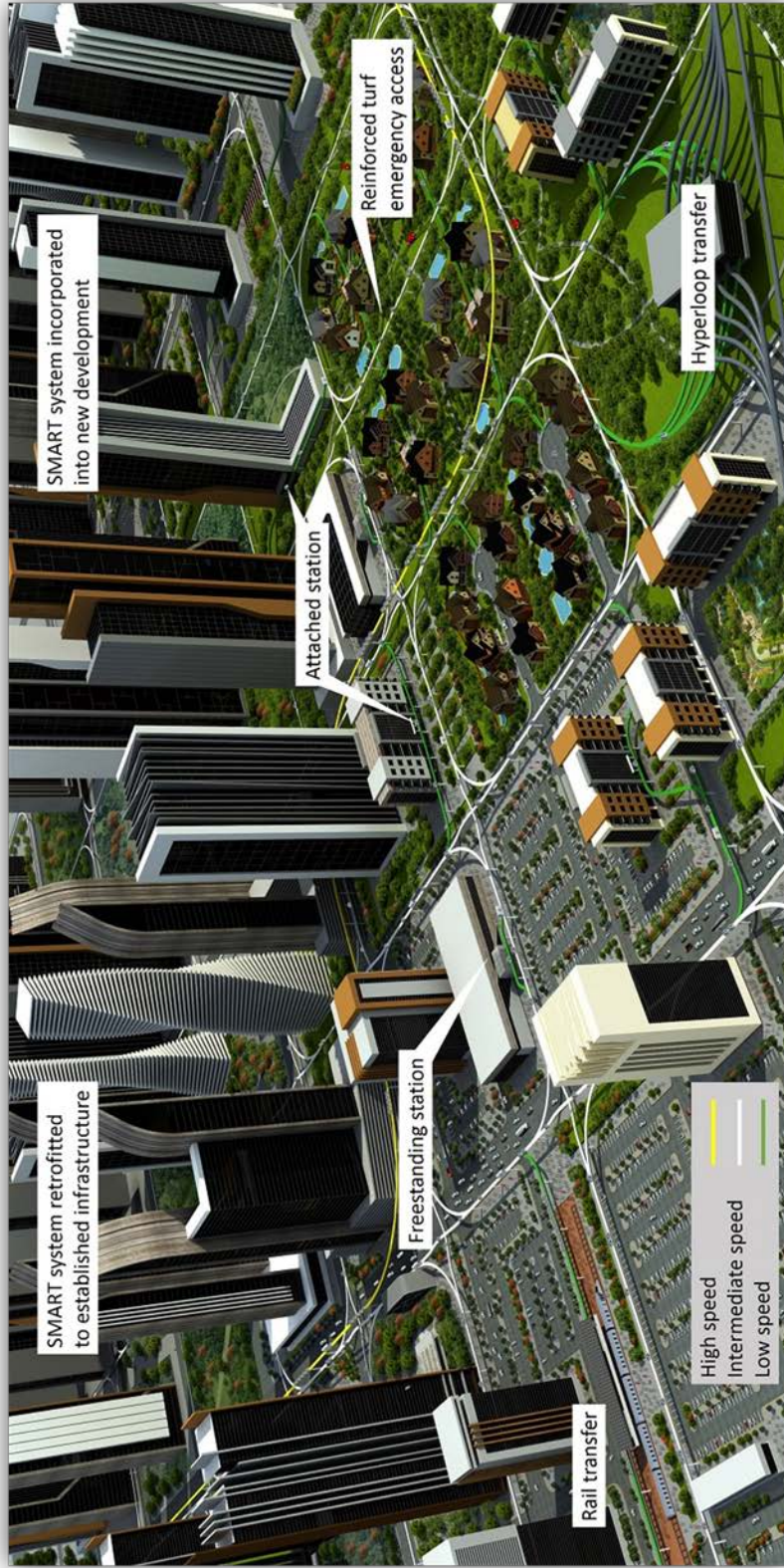
Small infrastructure fits in existing ROW



Houses clustered around an at-grade station

Moving to a better, more sustainable transportation infrastructure makes sense, costs less and could improve everybody's quality of life.





The SmART System

# IS IT THE RIGHT SOLUTION?




## BACKGROUND

Some proponents of driverless cars believe that they will solve all of our transportation issues. Given enough time (probably more than thirty years) they will likely solve, or reduce the impact of, some of the issues plaguing our existing transportation system. Almost certainly they will have a positive impact on road safety. Their impact on mobility and congestion is far less certain. Impacts on other issues such as logistics, security, land use, walkability, real estate value, and sustainability are not commonly discussed. Impacts on infrastructure costs and funding are usually ignored altogether. All of these important quality-of-life issues are addressed here.

## QUALITY OF LIFE

Let's examine the quality of life that could emerge given the following three scenarios:

- a mostly successful driverless car network supplemented by some ATN systems
- a SmART system that has been extensively retrofitted into an existing metropolitan area
- a new metropolitan area designed around an extensive SmART system.

For each of these alternatives (driverless car, retrofit SmART system and SmART system) we will consider the following quality of life issues (in no particular order): mobility; logistics; safety; security; land use; walkability; visual intrusion; infrastructure costs and funding; real estate value; and sustainability. Finally, we will discuss the likelihood that the assumptions made for each mode will be fully realized in 30 years. Each alternative will be given a relative score (compared to the others) of good  ; intermediate  or poor  . It goes without saying that any of the alternatives considered will be an improvement on the existing situation with its 35,000 annual deaths, widespread congestion and collapsing infrastructure.

Introducing driverless cars will have little or no impact on infrastructure other than potentially reducing parking needs if ridesharing catches on. Therefore, the driverless car scenario has not been illustrated. The retrofit SmART system and the SmART system have been illustrated below to highlight the differences.



Retrofit SmART System



## MOBILITY

**DRIVERLESS CAR:** Present-day cars provide great door-to-door mobility except when they get stuck in traffic and/or parking is not available. If most driverless cars are shared-use vehicles like taxis, they may overcome most parking issues but may not solve all congestion problems – see the discussion under “Likelihood of Success”. However, in this section, we give driverless cars the benefit of the doubt and assume they will relieve most congestion.

According to the 2010 US Census over 30% of the population (92.6 million people) cannot drive or use cars in any capacity other than as passenger. Just making cars

driverless will help some of these people who presently cannot drive. However, many adaptations, such as making them wheelchair accessible and subject to parental controls will be necessary before all can be helped.

Poor ❌

**RETROFIT SMART SYSTEM:** In this scenario, the SmART system has been implemented to relieve congestion. Since it will provide quicker, more reliable travel at less cost than cars, it is likely to attract a higher ridership than that necessary to relieve congestion. Thus the roads will be free-flowing at almost all times. Studies have shown that such implementations will pay for themselves (both capital and O&M costs) through the fare box at typical transit rates. SmART system deployment in less congested/dense areas may need to be subsidized.

Note that congestion relief could start within a few years because the fundamental technology is already available. There will be no need to wait for driverless cars to first become available and then enter widespread use.

Under this scenario, the SmART system will be available to all users capable of travel. Drivers will have access to roads that are mostly free of congestion.

Intermediate ●

**SMART SYSTEM:** Being stuck in traffic will become a thing of the past when the SmART system is fully deployed. Passengers should experience less complete vehicle breakdowns. When these



SmART System




do occur, the following vehicle will typically push the failed vehicle into the next station with less trip disruption than a typical small traffic jam.

The SmART control system is designed to allow key links in the network to operate continuously at 100% maximum capacity without ever causing a traffic jam. If demand exceeds capacity for a key link, vehicles will seek an alternative route. If all routes are taken, destinations requiring those routes will be temporarily unavailable. Any backups will occur on station platforms where passengers still have options, including becoming more aggressive in seeking to share rides (thereby ensuring each vehicle is full and thus actually increasing capacity). Next, they may look for alternative destinations, decide just to wait, or choose to walk if their destination is close by. Having all these options will be far preferable to being stuck in traffic.

Some existing ATN systems have line capacities of 5,000 to 10,000 passengers per hour per direction (pphpd). This is about 2 to 25 times more people per hour than present lane capacities. Future SmART system urban line capacities are anticipated to approach 40,000 pphpd.

The SmART system will be ADA compliant with roll-on, roll-off accessibility. All stations and vehicle interiors will be CCTV monitored. Audio assistance will be available at the push of a button and will often be offered preemptively when the intelligent video monitoring system automatically notices unusual behavior. The high level of safety and personal security within the system will allow lone travel to extend to large portions of the population, such as children, not presently privileged to do so.

Good 



Roll-on, roll-off accessibility  
Credit: Ultra/Heathrow

## LOGISTICS

*DRIVERLESS CAR:* The application of driverless car technology to logistics is presently confined to eliminating truck drivers from the following trucks in platoons. This will do little for the efficiency of delivery of goods and freight. However, for this purpose, it is assumed most large trucks are replaced with much smaller vehicles, that could travel directly from the factory to the retailer, eliminating the need for sorting facilities. In addition to making freight movement more efficient, this could also go a long way to alleviating the high cost of road maintenance. According to the Asphalt Institute one forty thousand-pound tandem axle causes as much road damage as 6,867 two thousand-pound single axles!

Intermediate 

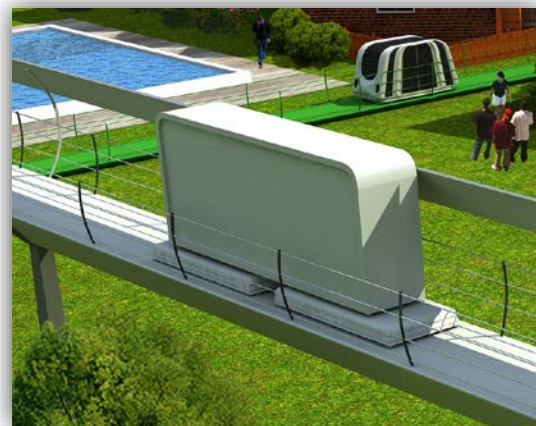
*RETROFIT SMART SYSTEM:* In this scenario the SmART stations will mostly be too far apart to efficiently handle goods and freight. SmART vehicles could leave the guideway for the final link of the trip to the door of the destination but this may not be much better than delivery by driverless vehicles on roads and could prevent the SmART system from carrying significant volumes of goods and freight. Some dedicated freight stations are likely to be established to receive and dispatch SmART containers.



2getthere freight vehicle

Intermediate ●

*SMART SYSTEM:* In this scenario every large building has a SmART station and small buildings are clustered around stations. These stations could be set up for the automated delivery and/or pickup of goods and trash and their movement would mostly occur during off-peak periods for transit demand. This would help pay for the investment in infrastructure and make the whole system more economical. Passenger vehicles could be adaptable to receive small cargo containers and thus serve double duty. Special cargo vehicles will be able to automatically load and unload cargo and/or trash. Two such vehicles could together carry one 20' x 4' x 8' (length x width x height) container designed so that two will fit inside one standard 20' shipping container.



Containerized cargo vehicle

Good ✓

#### SAFETY

Safety is measured by the vulnerability to accidents.

*DRIVERLESS CAR:* Removing the human from behind the wheel and then removing the wheel altogether will likely improve road safety. However, there will still be accidents where children, cyclists, etc. cross the path of a vehicle so suddenly that they cannot be avoided. In addition, despite all the cars that now have automated safety features, the National Safety Council reported that 2015 saw the largest percentage rise in motor vehicle deaths in the past 50 years. The fatality rate rose faster than the rise in VMT. Could the safety features be enabling more distracted driving? The path to driverless car safety may involve additional unintended consequences. Furthermore, driverless car proponents are proposing safety standards that only improve safety by two times over driven automobiles.

Poor ✗

**RETROFIT SMART SYSTEM:** The SmART system will itself be remarkably safe. This is borne out by the fact that existing ATN systems have completed over 200 million injury-free passenger miles (about 50 times safer than cars). However, in this scenario, most surface streets and highways will remain and the very high safety of ATN will only be experienced by those passengers that choose to use it – perhaps fifty percent of travelers.



Reinforced turf emergency access

Intermediate ●

*SMART SYSTEM:* In this scenario pedestrians and cyclists do not intermingle with motorized traffic, almost all of which travels in exceptional safety on exclusive guideways.

Good ✓

#### SECURITY

Security is measured by the vulnerability to malicious acts by others.

*DRIVERLESS CAR:* With many different local and foreign suppliers providing vehicles operating in very close proximity to each other, the opportunities for malicious hacking are bound to be higher than in a closed ATN or SmART system with limited suppliers. If driverless car safety is reliant on vehicle-to-vehicle or, worse, vehicle-to-infrastructure wireless communications, the hacking opportunities will be even greater.

With large freeway interchanges remaining in use, these will continue to present reasonably attractive terrorist targets.

Poor ✗

*RETROFIT SMART SYSTEM:* Security will improve to the extent travelers use the SmART system (say 50%),

Intermediate ●

*SMART SYSTEM:* The guideway portions of a SmART system (ultimately intended to be over 99% of the system) will limit wireless communication distances to a few inches between the guideway surface and the underside of the vehicle. These short-range transmissions will be very difficult to hack. In addition, safety-critical hardware and software will be developed and manufactured by a limited number of approved suppliers. All safety-critical functions will be overseen by independently-developed automated systems capable of corrective actions in the event of abnormal behaviors such as over-speed.

The SmART system guideway network will be designed to distribute heavy demand among fairly closely-spaced guideways. Heavy demand will never be accommodated by providing multiple lanes in one direction. Besides its main purpose of conquering heavy demand by dividing it, this design feature avoids large interchanges that could be points of vulnerability to terrorist attack.



Good ✓

Interchanges will be small

#### LAND USE

*DRIVERLESS CAR:* Many suburban areas have over 50% of land devoted to the automobile. If car ownership dwindles and driverless taxis predominate, many parking lots may no longer be needed and could be redeveloped for other purposes. However, streets, roads and highways will still likely be the single most predominant use of land. They will continue to sever our communities, make walking difficult and contribute significantly to storm water runoff as well as the heat island effect.

Driverless cars are likely to promote urban sprawl. If commute time can be put to good use, why not live in the countryside?

Poor ✗

*RETROFIT SMART SYSTEM:* It has been assumed that this system will mostly relieve congestion. Reductions in land areas needed for road widening will probably not significantly improve land use issues.

Poor ✗

*SMART SYSTEM:* The impacts on land use will be very significant. Pavements, which constitute today's primary metropolitan-area land use, will be dramatically reduced in area. In many areas pavements will disappear, except for pedestrian and cycling paths. The primary land use other than buildings will become landscaping. Studies have indicated that natural surroundings contribute to feelings of wellbeing. The sensation of living and working in a densely-populated area that is nonetheless more like a park than today's concrete jungles is expected to result in improved health, economy and sense of community.

SMART system guideway economics and permitting requirements could potentially curb urban sprawl to some degree.

Good ✓

#### WALKABILITY

This includes all forms of non-motorized transportation such as cycling and rollerblading.



*DRIVERLESS CAR:* Surface streets will remain as barriers to pedestrians while most large parking lots could be removed. Driverless taxis could extend the range of walking trips (or even biking trips, if bicycles can be accommodated). People may be enticed to rely on walking as a mode of transportation for short trips, if they knew they could get a ride easily in the event of inclement weather.

Poor ❌

*RETROFIT SMART SYSTEM:* Frequent stations and the ability to accommodate bicycles will extend the range of walking and cycling trips. Also, the reduced traffic on the roads would make crossing a bit easier. However, many walking and biking trips will still be subject to difficult road crossings.

Poor ❌

*SMART SYSTEM:* There will be no barriers to walking and cycling becoming the mode of choice for short trips. While the system will obviate the need for walking more than a few hundred feet, the environment will be such as to hopefully entice people to walk much more than they do presently.

Good ✔️

#### VISUAL INTRUSION

Visual intrusion is a highly subjective matter but an important issue nonetheless. Most will agree that overhead powerlines are not desirable. Is an aesthetically-designed overhead guideway, on which futuristic pods silently glide along, also undesirable? To some it would be. Others might enjoy the dynamic, ever-changing view. What if the previously undesirable powerlines were now hidden inside the guideway?

Are urban streets visually objectionable? Which is better – an urban street with minimal landscaping or an elevated guideway partly hidden amongst extensive trees and landscaping?



Visual intrusion  
Credit: Arup



Visual intrusion can be objectionable in two directions. It can be undesirable to have a guideway obtruding into a view-scape. It can also be undesirable to have passengers looking down into a private backyard. The SmART system will be carefully designed to minimize these issues. Guideways will be routed away from landmark buildings and scenic views. Guideways in single family neighborhoods will typically be at grade and run between privacy fencing. Guideways overlooking sensitive or private areas will have the vehicle windows automatically fog over for that segment of the journey.



Visual intrusion  
Credit: Taxi 2000

Because this is such a subjective issue, the alternatives have not been rated. The reader can insert his/her own ratings in the summary table which follows.

#### INFRASTRUCTURE COSTS AND FUNDING

*DRIVERLESS CAR:* The introduction of driverless cars and trucks is not expected to have much impact on the cost of building and maintaining road infrastructure. It has been optimistically assumed that the cost of any vehicle-to-infrastructure communication systems is offset by savings in maintenance due to a move to smaller trucks. Funding of road infrastructure will not be facilitated simply because the vehicles are driverless.

Poor ❌

*RETROFIT SMART SYSTEM:* The SmART system deployed to relieve congestion will, by definition, carry a lot of traffic. It will therefore pay for its own capital and operating costs through the fare box. The reduced need to expand roads will thus be a significant relief to the funding problem.


Intermediate ●

*SMART SYSTEM:* As discussed above, busy sections of the SmART system will pay for themselves. In the suburbs one seven-foot wide guideway will replace a typical 30'-wide street. While portions of suburban guideways will be elevated, their cost will still be less than that of the street they replace. In addition, elevated structures have design lives in the order of 50 – 100 years compared to 20 – 40 years for surface structures, so maintenance costs will be far less. The SmART system is anticipated to be self-funding – through the fare box and/or through savings in real estate development costs. Additional revenues from items such as advertising or station-area revenues will enhance the business case.

Good ✔

## REAL ESTATE VALUE

*DRIVERLESS CAR:* It is difficult to imagine driverless cars having a significant impact on real estate value other than a reduced need for homes to have driveways and garages and commercial buildings to provide parking facilities.

Poor 

*RETROFIT SMART SYSTEM:* To the extent that specific areas see improved public transit, these areas are likely to experience significant increased real estate value. Many studies have shown this to be the case with legacy transit systems.


Intermediate 

*SMART SYSTEM:* New real estate will cost less to develop (no driveway or garage, reduced pavements and storm water) and yet have more value. Imagine the value of a single family home in a park connected to its own rapid transit system with direct access to the entire metropolitan area.

Good 

## SUSTAINABILITY

*DRIVERLESS CAR:* The fact that cars are driverless will do nothing to change sustainability. There might be small benefits if trucks become smaller and if ridesharing increases.

Poor 

*RETROFIT SMART SYSTEM:* Sustainability benefits will accrue to the extent that more people ride the guideways than the roads.

Intermediate 

*SMART SYSTEM:* The SmART system infrastructure will be light and durable. Vehicles will be light because they will not need to be crash-worthy. Ridesharing will be prevalent (it is already proven in ATN systems). Trips will mostly be at constant speeds. High speed trips will be in aerodynamically-efficient platoons.

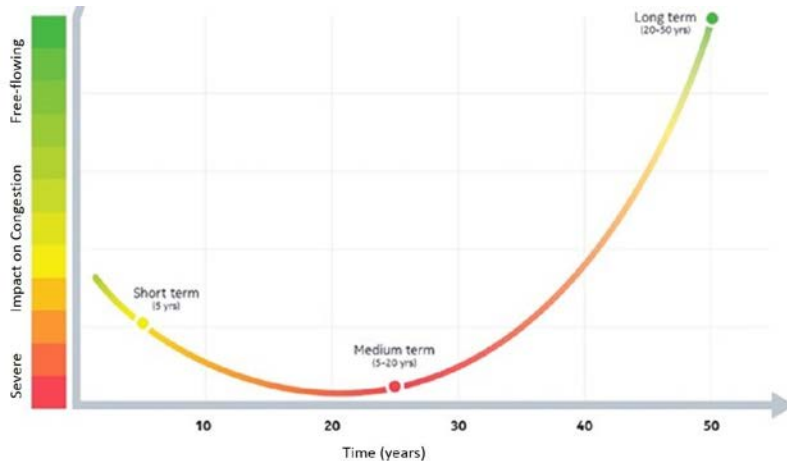
Much of our present built metropolitan environment consists of pavements and is unsuitable for solar panels (with the exception of parking lots). SmART system guideways, on the other hand, are ideal for supporting solar panels. A four-foot wide solar panel extending the length of the guideway will provide sufficient motive power for the system in most locations.

Good 

## LIKELIHOOD OF SUCCESS

This is the likelihood of each option considered above coming to fruition, as described on page 17 for each of the three scenarios, after a concerted implementation effort.

**DRIVERLESS CAR:** Present-day cars provide great door-to-door mobility except when they get stuck in traffic and/or parking is not available. Driverless cars may overcome most parking issues if ridesharing is popular but may not solve all congestion problems – in fact they are likely to make congestion worse before they make it better. Some of the primary factors related to how driverless cars may affect congestion are discussed below.



Driverless cars could increase urban congestion for the next 30 to 40 years  
Source: ITS International

A common claim is that more driverless cars could fit in a lane if they followed each other very closely. However, they will probably not overcome the hazards involved with following closely because these hazards are more a function of the tire/road interface than the slow reaction times of human drivers. They may however be able to travel very close to each other in platoons (both very short and very long spaces between cars are safe – it is the intermediate spacing that is dangerous). This would increase road capacity and thereby reduce congestion. However, forming and breaking up platoons is problematic and platoons on multi-lane roads make lane changing difficult.

Narrower lanes would allow existing pavements to support more lanes and therefore more traffic. Narrow lanes would require all driverless cars to be able to perform to the same standards of lane-keeping and additional lanes would add to the difficulties of lane-changing alluded to above. However, these problems are probably solvable.

Ride sharing could reduce congestion. However, ride sharing has been the holy grail of congestion reduction for decades (this author wrote a graduate paper on the topic in 1982) without having significant impact. It is unclear how removing the driver from the vehicle will make people more willing to share rides than they are now. People do not now share their cars or their taxi rides to any significant extent. Driverless taxis should be cheaper and thus the financial incentive to share will be less.

Driverless cars are likely to increase vehicle miles traveled (VMT) since people may choose to live further from work and to send their cars looking for cheap parking (perhaps even all the way home). A recent study in Sweden found that, only by making the most optimistic assumptions is ridesharing sufficient to offset the additional VMT induced by the driverless fleet.


Other human factors could also adversely affect congestion. For example, knowing that driverless vehicles will be super-cautious, pedestrians may just step in front of them. This type of behavior could lead to a kind of revolution where pedestrians retake the surface and prevent cars from uninterrupted travel between designated crossings.

Constructing overpasses to relieve congestion will be possible. To the extent that driverless cars are fully developed with reliable functionality and meeting standardized requirements, these overpasses may be quite significantly narrower and lighter than overpasses presently constructed for road traffic and could be more like guideways. Nonetheless, they will likely face many of the same hurdles facing present-day road expansion including a significant lack of funding.

Failure to relieve congestion fully implies that driverless car passengers will still get stuck in traffic and, when they do, they will remain as powerless to do anything about it as they are today. Even the fact that they may be able to work, relax or entertain themselves while in traffic could itself exacerbate the situation, since some may choose to no longer avoid the rush hour the way they do now.

The much-touted safety improvements may not be all that significant. There is already an awareness in the industry of how difficult road safety is to achieve. It is being suggested that driverless cars should only be required to be twice as safe as driven cars. This implies that killing 17,500 people on the roads each year is acceptable.

Unintended consequences such as rogue pedestrian behavior or distracted driving may plague the development of driverless cars. Many unknowns remain and many of these relate to how driverless cars will be accepted and used by humans. Driverless cars could suffer the same fate as the paperless office.

Poor 

*RETROFIT SMART SYSTEM:* This scenario combines the SmART system and driverless cars in a way that plays to the strengths and known abilities of both systems. In this regard it is likely to succeed. Perhaps the biggest hurdle to success is the historic slow implementation of ATN systems. Recognition by large engineering, procurement, construction (EPC) companies of the significant profit potential of using ATN to relieve traffic congestion without requiring significant land acquisition could result in rapid ATN deployment beginning soon.

Good 

*SMART SYSTEM:* The technical hurdles are small. Scalability of ATN systems is largely unproven but engineering studies and existing deployments point to it being readily achievable. Because this scenario makes so much sense from an economic standpoint as well as from a quality-of-life standpoint, much of the risk involved can be carried by large developers and EPC companies.

As described above, development of the SmART system is anticipated to begin with retrofitting. Once the initial retrofit applications are seen to work well, developers should see the opportunities for greenfield applications. Once people see how well the greenfield applications work, they will want their own neighborhoods retrofitted.

The biggest hurdle for the SmART system is the inertia of governmental agencies. New rules, regulations, codes and standards will be required. Fortunately, deployment will be incremental over many decades. Hopefully the private sector will not be too hampered by the public sector.

Intermediate 



## CONCLUSIONS

Table 1 summarizes the results of the previous discussion. While one could certainly argue with some of the individual results, the negative scores for driverless cars compared to positive scores for the SmART system are quite overwhelming. This stark difference is surprising in light of the small amount of recognition that this type of solution has historically received. However, it should be pointed out that many futuristic renderings of large cities show elevated guideways of some form or another with the concept being taken to the extreme by The Jetsons. This reveals an instinctual recognition that surface transportation is inadequate for future cities.

**TABLE 1.**

	<b>Driverless Car</b>	<b>Retrofit SmART</b>	<b>SmART</b>
<b>Mobility</b>	✘	●	✔
<b>Logistics</b>	●	●	✔
<b>Safety</b>	✘	●	✔
<b>Security</b>	✘	●	✔
<b>Land Use</b>	✘	✘	✔
<b>Walkability</b>	✘	✘	✔
<b>Visual Intrusion</b>			
<b>Infrastructure Costs &amp; Funding</b>	✘	●	✔
<b>Real Estate Value</b>	✘	●	✔
<b>Sustainability</b>	✘	●	✔
<b>Likelihood of Success</b>	✘	✔	●

Poor ✘ Intermediate ● Good ✔

In fact, as this discussion indicates, our road infrastructure is far from being merely inadequate. It is dangerous, unsustainable and falling apart. It detracts from our general wellbeing and quality of life. We pay a huge price for the questionable quality of mobility it provides.

Better mobility is now available in the form of proven ATN systems that can be further developed to bring all the advantages of the SmART system proposed here. We have the privilege of being able to choose between sitting back and letting market forces bring us the few benefits driverless cars can provide, or moving towards a future that promises great mobility with a markedly improved quality of life. Do we want to settle for more of the same, or do we want the truly high quality-of-life promised by infrastructure-based transportation improvements to our cities?

## APPENDIX B

GREENVILLE, SC PRT STUDY, RIDERSHIP EVALUATION



**TO:** Peter Muller, PRT Consulting

**FROM:** Gina Trimarco, Tran Systems  
Rick Halvorsen, TranSystems

**RE:** Greenville, SC PRT Study  
Ridership Evaluation

**DATE:** April 17, 2014

TranSystems, as subconsultant to PRT Consulting, was asked to generate ridership estimates for the Personal Rapid Transit (PRT) mode alternative and the Bus Rapid Transit (BRT) Main Street alternative proposed to operate between downtown Greenville and the ICAR facility/City of Mauldin. The following provides the background of the analysis and the estimated 2020 ridership.

#### Mode Split

The basic question in estimating the ridership of the proposed transit services is what share of existing travelers in the corridor will be attracted to a new transit service. This has been estimated by reviewing journey to work data contained in the Census Transportation Planning Products. Data was reviewed from both the 2000 and 2010 Census, and the 2006 – 2010 American Community Survey (ACS).<sup>1</sup> The 2010 Census provides population data for the census tracts, but does not include journey to work data. The ACS provides the most current information on the total journeys to work between census tracts, but the small size of the sample means that it does not provide data on the mode used. Therefore, the 2000 Census data was also referenced as it provides more details regarding small groups, such as the mode of transportation used for journeys to work between specific census tracts.

The 2000 Census journey to work data was analyzed to determine the average use of transit for work trips between specific pairs of census tracts with good transit service. Thirty-six of these pairs currently had transit mode shares of 10% or higher (i.e. 10% use transit), with the maximum mode share of 83%. Another 16 census tract pairs had mode splits of between 2% and 9%. Overall, the transit mode share between census tracts where there were any transit riders identified was 12%. While there is a high degree of potential error in some of these results (since they are based on a sample of 1 in 6 census respondents and between 14 and 386 respondents per census pair), this does show that where a reasonable transit alternative is available, many individuals will choose to use it. This analysis will use 12% as the base estimate for the transit mode split of a transit system that has hourly service.

All census tracts along the proposed transit corridor were assessed to determine work travel patterns using the 2006 – 2010 ACS. It was assumed that the journey to work trips made

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<sup>1</sup> Effective with the 2010 Census, the Census Bureau no longer used the long form census survey, which had previously been the source of journey to work and other key transportation data. The Census Bureau has replaced the long form with the American Community Survey, which surveys a small sample of households every year.

within a census tract most likely would not be made on transit due to the short distance that would be traveled, and were not considered in the ridership model. In addition, it was assumed that the BRT Main Street option would not generate additional transit travel within the downtown core. The journey to work trips that were made between census tracts along the corridor were considered as a potential for future transit trips and included in the ridership model.

The census tracts were then examined from a geographical standpoint to determine how close they were to a proposed station; i.e. what percentage was within one half mile of the station. Typically, transit users living within one half mile of a station walk. Those who live beyond one half mile are much more likely to drive to their destination, while only those who are making the longest trips are likely to drive to the station or get dropped off. These percentages were then applied to estimate the portion of the journey to work trips that can reasonably be served by transit, i.e., for which both the origin and the destination of the trip are within one half mile of a station.

### Estimated Ridership

Applying these percentages to the journey to work data along the proposed transit corridor gives an estimate of 964 daily journeys to work that would be served by the proposed PRT service and 585 daily journeys to work that would be served by the proposed BRT service in this corridor. Each journey to work is matched by a second journey from work to home which doubles the potential number of trips. Furthermore, when estimating ridership for most transit services, work trips are assumed to equal about half of the total number of transit trips taken. Thus, after applying Greenville's current journey to work mode split for hourly service of 12%, hourly service along this route would generate an estimated 462 daily passenger trips along the PRT route and 281 daily passenger trips along the BRT route. Considering that Greenville's public transportation system, Greenlink currently operates 11 bus routes across the county with an average daily ridership (NTD 2012) of 2,979, or about 270 daily passenger trips per route, and that these routes would serve relatively high density population and employment centers, these estimates appear to be reasonable.

Greenlink's annual ridership in 2012 was 800,965, or approximately 269 times the reported daily ridership. This factor is used herein for developing estimates of annual ridership for both BRT and PRT.

TCRP<sup>1</sup> indicates that the high quality of BRT service can attract an additional 25% ridership and, since PRT service levels will be as high or higher than BRT, this factor should also be applied to PRT. Since PRT service will be much more frequent and stops more widespread, it is necessary to determine what impact these factors will have on ridership levels. In addition, it is important to understand how ridership will vary with the cost of fares. A web-based transit survey was conducted in the Greenville area in 2013 and ridership coefficients were extracted for each of the above factors. As illustrated in Table 1, the Greenville factors are in line with those reported by the TCRP<sup>2</sup>.

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<sup>2</sup> TCRP Report #118 Bus Rapid Transit Practitioner's Guide



Table I: Mode Choice Coefficients

Variables		Coefficients			
Attribute	Units	TCRP			GVL
		HBW	HBO	NHB	
In-vehicle time	Minutes	-0.020	-0.010	-0.020	-0.015
Out-of-vehicle time	Minutes	-0.040	-0.020	-0.040	-0.030
Fare	Cents	-0.003	-0.0012	-0.015	-0.003

Key: HBW: Trips between home and work  
HBO: Non-work trips beginning or ending at home  
NHB: Trips not beginning or ending at home  
GVL: Greenville travel survey for all trips

The coefficients given above are the change in ridership for every change in attribute. For example, for every one cent increase in fare, the ridership for HBW or GVL would reduce by a factor of 0.003 (if there were 1,000 riders and the fare was raised one cent then the number of riders would reduce to 997 (1,000 – (1,000\*.003)).

The GVL results indicate Greenville residents value in- and out-of-vehicle time about the same as reported by TCRP and fare cost slightly more. These are not surprising results and the TCRP HBW coefficients will be used in this document.

Service frequency has a major impact on ridership. Based on the 0.040 per minute coefficient in Table I, the BRT numbers should then be adjusted up by a factor of 60% to account for a 30 minute service frequency (an average 15 minutes less wait time). Similarly, the PRT numbers should be adjusted up by a factor of 113% to account for a 2.5 minute service frequency.

By comparison, the City of Greenville’s BRT study<sup>3</sup> uses a range of elasticity factors of 0.44 to 0.58, referencing TCRP Report 118. Applying the mid-point arc elasticity formula from the TCRP Report, these elasticities would result in an estimated ridership increase of between 34% and 48% (an average of 41%) as a result of increasing service frequency from hourly to once every 30 minutes.<sup>4</sup> For increasing service frequency from hourly to once every 2.5 minutes, these elasticities would result in estimated ridership increases of 136% to 229% (an average of 182%).

Both of these methods provide similar results. Averaging the two results gives an estimated increase in ridership of 51% for 30 minute service and 135% for 2.5 minute service. Combined with the ridership increase from the higher service quality of BRT and PRT service this results in an estimated increase in ridership, compared with hourly bus service, of 89% for 30 minute BRT service and 253% for 2.5 minute PRT service.

<sup>3</sup> Study Management Plan, City of Greenville Bus Rapid Transit (BRT) and Transit-Oriented Development (TOED) Feasibility Analysis, January 2013

<sup>4</sup> The Study Management Plan, City of Greenville Bus Rapid Transit (BRT) and Transit-Oriented Development (TOED) Feasibility Analysis, January 2013 estimated a much higher ridership for BRT service as it used a different methodology to estimate the impact of changes in frequency instead of the mid-point arc elasticity formula presented in TCRP Report 118.

Population in the Greenville region is expected to increase by 11.2% from 2010 to 2020, while population in the City of Greenville is expected to increase by 11.5% over that same period. Population in the corridor is expected to increase approximately 16%, due to the large Verdae mixed-use development and the fact that much of the corridor is designated Transit-Oriented Development for the future development. Substantial additional employment development is also expected at ICAR, as well as at Mauldin to the south. Ridership for 2020 was estimated by increasing ridership between any two census tracts by the average of the systemwide increase in employment (8.5%) and the anticipated population increase for each originating census tract (from the Greenville-Pickens Area Transportation Study). This method therefore reflects the anticipated large growth in population around Verdae as well as the anticipated slight loss in population in and near the urban core.

Daily ridership in 2020 with the 2.5 minute PRT service is estimated to be 1,898, while daily ridership with the 30 minute BRT service is estimated to be 617. Annual ridership for PRT is estimated as 510,257, while annual ridership for BRT is estimated as 165,834.

According to the ACS, the peak journey to work time in the Greenville area is the 7 'clock hour, when approximately 30% of trips to work are made. Normally the peak travel hour is during the afternoon, when a similar portion of journeys home are made, as well as some non-work trips. The peak hour ridership was therefore estimated as 30% of the return journey to work trips (work to residence) plus 0.5% of the journey to work trips (residence to work) plus 12% of non-work trips.

#### Park and Ride

PRT, with an exclusive right-of-way and a 2.5 minute headway, is potentially a very attractive alternative for park and ride service. The PRT provides a quick service to downtown with no downtown parking issues, while the 2.5 minute headway eliminates concerns over significant wait times when transferring from auto to PRT. The majority of the park and ride ridership would occur at the Verdae and ICAR stations and serve individuals living more than ½ mile from a station, or who are driving into Greenville on Laurens Road from either I-85 or from south of ICAR.

Providing parking at these stations would slightly more than double the trips that PRT could potentially serve. However, because riders do need to transfer from their automobile to a PRT vehicle and wait a few minutes for a vehicle, the mode split for park and ride service is generally about 25% that for individuals who can walk to transit. These two factors would result in park and ride service increasing PRT ridership by just over 25%.

#### Mauldin Extension

An extension to Mauldin would increase the journeys to work served by approximately 17% on both BRT and PRT. Estimated peak hour, daily and annual ridership for both 30 minute BRT and 2.5 minute PRT services are shown in the table below for both the base service and the extended service to Mauldin.

BRT		PRT	
Base	To Mauldin	Base (including Park and Ride)	To Mauldin

2020

Peak Hour	84	98	343	400
Daily	617	722	2,515	2,943
Annual	165,834	194,026	676,252	791,216

## APPENDIX C

### PERSONAL RAPID TRANSIT (PRT) AND CONNECTIVE PARKING INFRASTRUCTURE



September 14, 2016

Councilman Fred Payne  
Greenville County Council  
1907 Bethel Road  
Simpsonville, SC 29681

**Re: Personal Rapid Transit (PRT) and Connective Parking Infrastructure**

Dear Councilman Payne:

It was a pleasure meeting you and the others last week to discuss the interest and the benefits of Personal Rapid Transit (PRT) and connecting a PRT system with supporting parking infrastructure and how this concept might make sense for Downtown Greenville and the Upstate region.

As master planners and experts in parking structure design, my firm has long supported and promoted the idea of placing parking on the periphery and creating more walkable, less congested and safer communities. In fact, even though we design parking for a living - the less parking in the urban core, the better. Over the years, we have seen "if you build it, they will come". Well, with more downtown parking, people will come, bringing more cars to the core, or any other popular destination in the region. So, since I anticipate that the Southeast and in particular, Greenville, will continue to grow and densify, the need for better mobility solutions is quickly approaching. Maybe the best mobility solution is the use of personal rapid transit – something a forward-thinking community like Greenville will use and embrace.

The concept of driverless vehicles is becoming a reality. The technical capability to move people around, in their own "personal" vehicle, is why so many companies are researching, developing and investing in this concept. Firms like Apple, Google, GM, BMW, Mercedes-Benz and others are building on the premise that people love to "multi-task" while moving from one place to another. A great way to stay in touch via our many personal devices and communicate, go online, conduct business, shop, etc., is when one is commuting or driving around town. This certainly seems to be the direction we are heading in this very digital, high-tech world we live in. So, to provide more personal freedom, while providing a comfortable environment, is why so many firms (like those noted previously) are developing some form of driverless, or personal transit vehicles.

So, when you introduced me to the concept of implementing personal rapid transit in Greenville, it seems to make a great deal of sense, especially when one considers the high-tech region Greenville sits in and the many institutions and businesses in the region that cater to the high tech industry. Building a system that complements today's changing lifestyle, through the use of personal rapid transit, may be ideal for those that live, work, learn and play in a progressive city like Greenville. Thus, the PRT concept is very intriguing and something that needs to be taken very seriously. What a great way to differentiate Greenville from all of the cities in the region. What a great way to enhance your City's brand!

We understand that Greenville/Spartanburg International Airport (GSP) is strongly considering the use of a PRT system that will link remote parking lots to the terminal. We applaud their forward thinking and consideration of creating something that is truly very unique in their industry and something that will set GSP apart from other airports, especially airports in the southeast such as ATL, CLT and RDU. What they are contemplating for GSP can certainly be employed in Greenville as it could provide an incredible way to link critical destinations such as the TD Convention Center, the Peace Center, Downtown Offices, the Arts District, Clemson and other popular destinations. Most importantly, I believe the PRT concept is great way to reduce traffic congestion, promote walkability, promote mixed use development and promote sustainable development and green construction, while providing a very "personal" solution that will enhance the mobility experience for individuals, families and friends.

From an economic development perspective, I would anticipate that developers would jump at the opportunity to build mixed use projects at stations or stops along the system, like developers have done in cities like Washington (WMATA). From a larger perspective, the linking of destinations builds community and that reinforces the brand that Greenville has created.

On the front page of the New York Times today, there was an article about the potential success of the new Beltline in Atlanta. Though the Beltline is predominantly a walkable experience, the importance of it to Atlanta, as noted in the article, cannot be overstated as for the first time in the history of the largest city in the Southeast, communities are finally becoming linked together using a common thread, essentially an enhanced sidewalk. Developers are building restaurants, office buildings, apartments and condos along the Beltline, even though it is less than 20% complete. I see PRT as a similar mobility improvement, but one that is more geared towards traveling greater distances than Atlanta's Beltline.

My firm is known for "thinking beyond parking" - the concept of a personal rapid transit is the epitome of this thinking. Parking will still be needed, but if parking is placed on the edges, on sites that are most likely more efficient, then building parking will be much more affordable, while keeping cars out of the core! Parking could be built as larger surface lots (land banked for transit-oriented developments) or multi-level parking structures that don't require as much architecture (and cost) as urban solutions.

I know there are many steps, and probably many hurdles, that must be ahead of you as you continue to discuss, study and evaluate the merits of this idea. But, based on what I have seen and my understanding of your vision, my firm is completely supportive of the idea and stands ready to help in any way that we can to help advance the concept.

Very truly yours,



Michael D. Martindill  
Principal

APPENDIX D

GREENVILLE COUNTY RESOLUTION NO. 1579

**A RESOLUTION**

A RESOLUTION SUPPORTING GREENVILLE COUNTY AS A PILOT SITE IN THE STATE OF SOUTH CAROLINA FOR THE RESEARCH, DEVELOPMENT, TESTING, AND DEPLOYMENT OF MULTIMODAL, INTELLIGENT, AUTOMATED TRANSPORTATION SYSTEMS AND MANAGEMENT TECHNOLOGIES INITIATIVES.

**WHEREAS**, Greenville County Council recognizes that the public, freight, and personal transportation and automotive industries are rapidly and constantly changing with technological advances; and

**WHEREAS**, such technological advances are (a) revolutionizing and improving how people move and how goods and services are delivered, increasing transportation efficiency and vehicle and infrastructure connectivity; (b) improving safety; (c) reducing fuel and energy consumption, air and water pollution, and congestion costs; and (d) saving governments, businesses, and individuals billions of dollars in mobility costs; and

**WHEREAS**, to remain economically competitive, nationally and globally, Greenville County, SC, would be an ideal pilot site for research, development, testing, and deployment of intelligent, automated, and connected vehicles technology due to its wide range of automotive traffic patterns, rural and urban driving situations, and skilled workforce; and

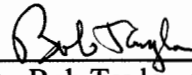
**WHEREAS**, Greenville County, SC, has the intellectual capacity and technical assets to become a leader of the technological advancement of the transportation industry through research universities, innovation centers, corporations and small businesses to create incubators and the jobs associated with them in promoting a proactive, responsive, and inviting setting for the development and deployment of initiatives in the evolving transportation industry;

**NOW THEREFORE BE IT RESOLVED THAT** the Greenville County Council does hereby (a) encourage and support working with federal and state officials, universities, private sector businesses, industries, and non-profit organizations to create a collaborative environment for Greenville County to be a pilot site for research, development, testing, and deployment of emerging and new modes of transportation and mobility technologies; (b) encourage the submission of grant applications to public agencies and private organizations for transportation, mobility services, and energy efficient associated projects and for projects related to the consolidation of such technology interests in Greenville County, SC; (c) encourage public/private partnerships with business, corporations, and/or non-profit organizations; and (d) encourage the establishment of collaborative efforts with the State of South Carolina, other local governments, community leaders, universities, and other organizations to research, design, test, develop, and bring to market such transportation technologies and infrastructure as well as

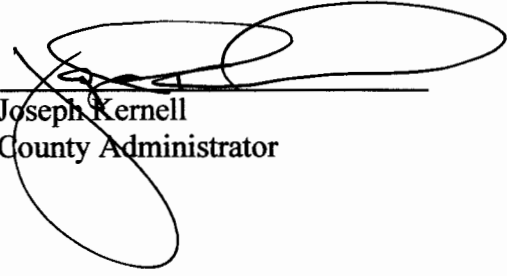


to provide leadership in the development of industry standards and guidance for the creation of federal, state, and local regulations.

**DONE IN REGULAR MEETING THIS 7<sup>th</sup> DAY OF JUNE, 2016.**

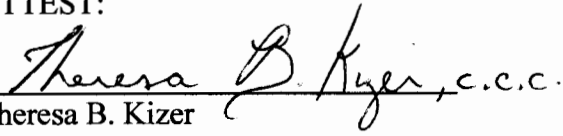


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Dr. Bob Taylor, Chairman  
Greenville County Council



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Joseph Kernell  
County Administrator

ATTEST:



\_\_\_\_\_  
Theresa B. Kizer  
Clerk to Council

## APPENDIX E

### ESTIMATE OF TAX REVENUE GROWTH FOR THE LAURENS ROAD CORRIDOR 2015-2045

# ***Estimate of Tax Revenue Growth for the Laurens Road Corridor 2015-2045***

## **Conducted by:**

Bob Brookover, Ph.D.

Clemson University

Department of Parks, Recreation, and Tourism Management

## **Contact:**

864-656-2231 or [bob@clemson.edu](mailto:bob@clemson.edu)

**Method:**

Greenville County staff developed a map of properties to be included in a multi-county industrial park designation in a corridor along Laurens Rd. That corridor shape was overlaid on Woodruff Rd. and Fairview Rd. to create similar corridors for property tax value increase comparisons for the period from 2004 to 2014 and to use as a basis to project potential future growth in property tax values.

The 10-, 20-, and 30-year increase in property tax values for each corridor was calculated and growth scenarios were created to determine if sufficient additional tax revenues can be generated by properties located in the Laurens Rd. corridor to fund and maintain the proposed Alternative Transportation System. Tax revenue projections were calculated under the assumption that all properties are located outside city limits or with City approval of an MCIP designation.

**From 2004 to 2014 the tax value of properties located:**

- in the Woodruff Rd. corridor increased: 115.0%
- in the Fairview Rd. corridor increased: 98.4%
- in the Laurens Rd. corridor increased: 62.9%

Corridor	2004 Tax Value	2014 Tax Value	Growth
Laurens Road	\$408,408,504	\$665,344,376	62.9%
Fairview Road	\$ 56,453,050	\$113,784,271	98.4%
Woodruff Road	\$211,215,220	\$454,233,246	115.0%



Property Tax Value and Tax Collection Growth Projections for the Laurens Road Corridor  
Proposed Multi-County Park Designation

<b>Assumed Growth Rate</b>	<b>2025 Added Value</b>	<b>2025 Added Tax (in millions)</b>	<b>2035 Added Value</b>	<b>2035 Added Tax (in millions)</b>	<b>2045 Added Value</b>	<b>2045 Added Tax (in millions)</b>
62.90%	\$418,501,612.50	\$7.01	\$681,739,126.77	\$11.42	\$1,110,553,037.51	\$18.60
15.50%	\$103,128,378.28	\$1.73	\$167,996,128.22	\$2.81	\$273,665,692.87	\$4.58
31.40%	\$208,918,134.06	\$3.50	\$340,327,640.39	\$5.70	\$554,393,726.20	\$9.29
80.60%	\$536,267,567.06	\$8.98	\$873,579,866.73	\$14.63	\$1,423,061,602.91	\$23.84
88.90%	\$591,491,150.26	\$9.91	\$963,539,083.78	\$16.14	\$1,569,605,167.48	\$26.29
98.40%	\$654,698,865.98	\$10.97	\$1,066,504,452.69	\$17.86	\$1,737,335,753.43	\$29.10
106.70%	\$709,922,449.19	\$11.89	\$1,156,463,669.73	\$19.37	\$1,883,879,318.00	\$31.56
115%	\$765,146,032.40	\$12.82	\$1,246,422,886.78	\$20.88	\$2,030,422,882.56	\$34.01

62.9% growth rate represents the average growth of the Laurens Rd corridor for 2004-2014.

15.5% growth rate represents the 2004-2014 growth rate for the Laurens Rd corridor decreasing by approximately 75%.

31.4% growth rate represents the 2004-2014 growth rate for the Laurens Rd corridor decreasing by approximately 50%.

80.6% growth rate represents the average of the Laurens Rd and Fairview Rd corridors for 2004-2014.

88.9% growth rate represents the average of the Laurens Rd and Woodruff Rd corridors for 2004-2014.

98.4% growth rate represents the same growth rate as the Fairview Rd corridor for 2004-2014.

106.7% growth rate represents the average of the Woodruff Rd and Fairview Rd corridors for 2004-2014.

115% growth rate represents the same growth rate as the Woodruff Rd corridor for 2004-2014.

Added Tax projection is based on all property being located outside city limits.

*Verdae Development Factor*

An announcement by Verdae Development in 2005 outlined a 20-25 year Master Plan that projected approximately \$2.18 billion in property value upon completion of the plan. Much of this development is occurring the Laurens Road corridor.

According to the developer, in spite of the 2008 recession, they are on target and nearing completion of Phase I and beginning to move into Phase II of the plan. In addition, the developer indicated that any transportation improvements in the area will have a direct impact on the Verdae Development.