A NEW TRANSPORTATION PARADIGM

THAT FACILITATES

HIGH QUALITY CITY LIVING

PRT CONSULTING, INC.
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1340 Deerpath Trl., Suite 200

Franktown., CO 80116 USA

(303) 532-1855

www.prtconsulting.com

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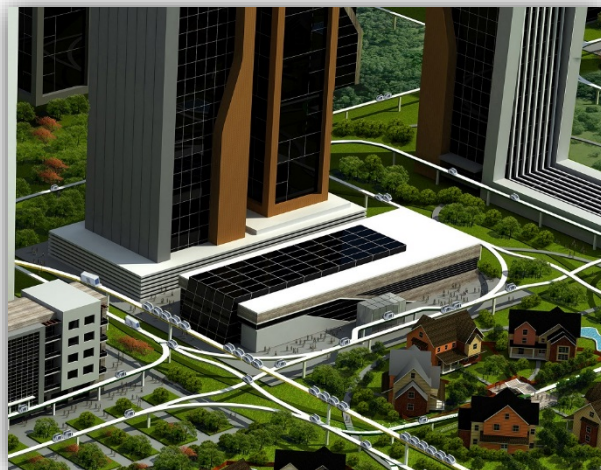
We could reclaim the surface for walking, biking and landscaping. We could live and work in park-like settings.

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 beauty of the SMART system is that it can immediately reduce congestion while being economically self-sustaining from the beginning.
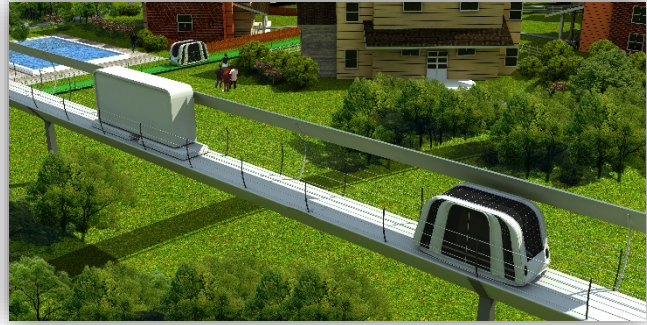
Passengers and freight on one system

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
Mobility	✖	🟠	✔
Logistics	🟠	🟠	✔
Safety	✖	🟠	✔
Security	✖	🟠	✔
Land Use	✖	✖	✔
Walkability	✖	✖	✔
Infrastructure Costs & Funding	✖	🟠	✔
Real Estate Value	✖	🟠	✔
Sustainability	✖	🟠	✔
Likelihood of Success	✖	✔	🟠

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.
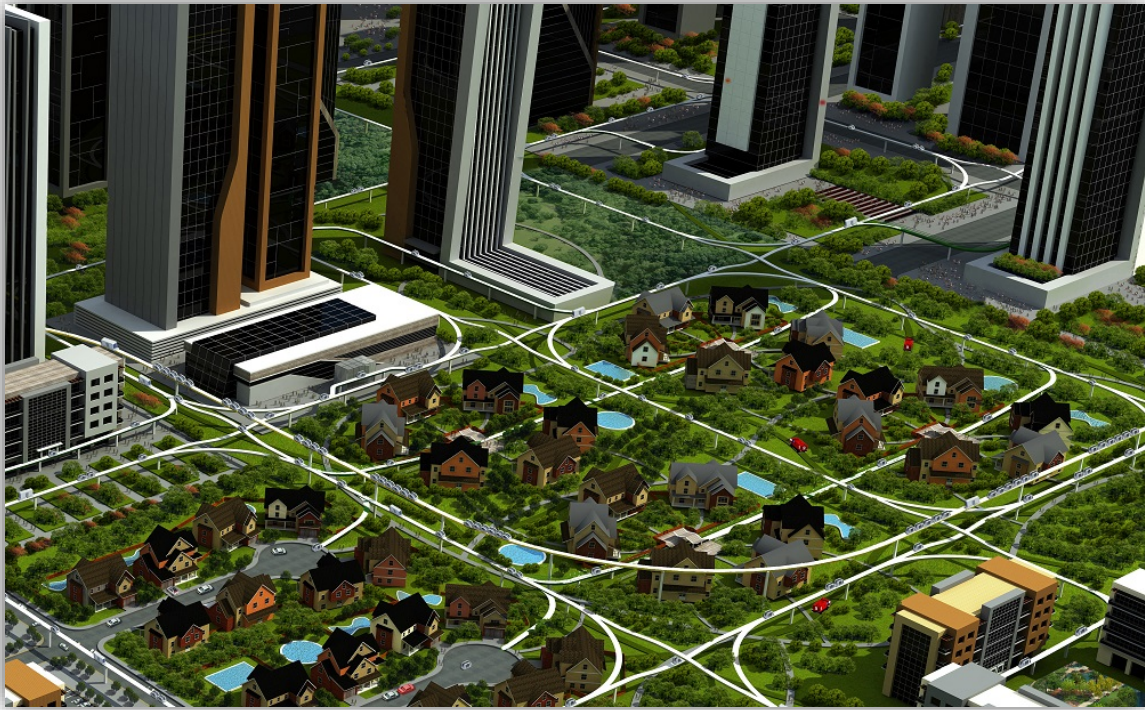
Some cities will become truly great

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
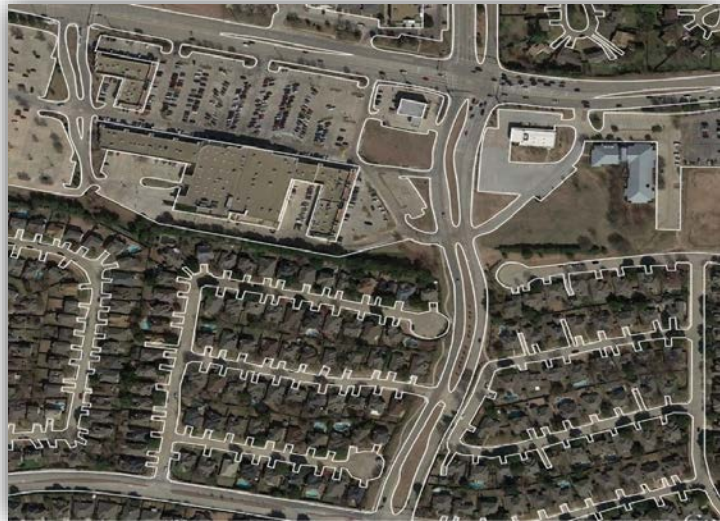
ACCESSIBILITY

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.

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

Pavements dominate land use

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.
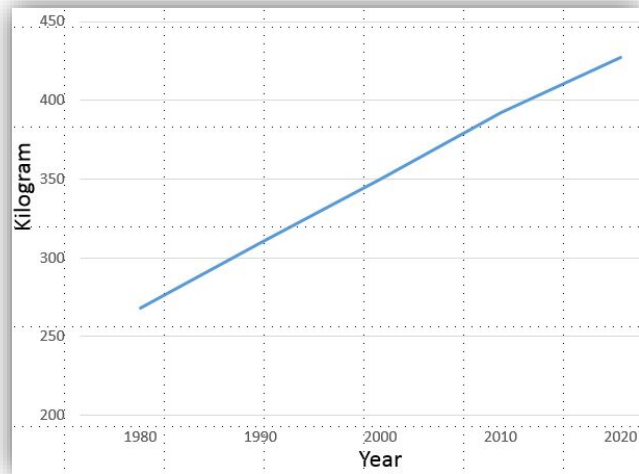
Per capita US paper consumption

Fatal conflict

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.

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.

Modutram, Guadalajara, Mexico

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.

2getthere, Masdar City, UAE

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.

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.
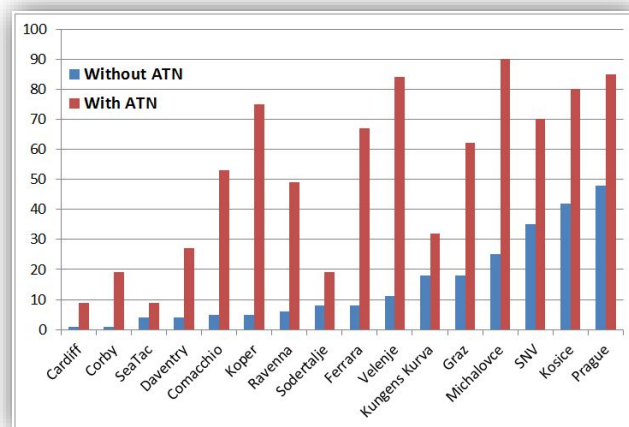

Vehicles can leave the guideway

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

Impact of ATN on transit mode share

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.

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 are designed for three speed categories – low (< 20 mph), intermediate and high (> 60 mph)
- 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

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

- 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.

Adding elevated guideway-like overpasses where driverless cars 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.

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 legacy transit systems.

Rail station connection
Credit: WSP

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 $1.1 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 32 stations. This would increase the area within walking distance eight times at a cost of only $0.8 billion. The improved accessibility could help revitalize the entire neighborhood.
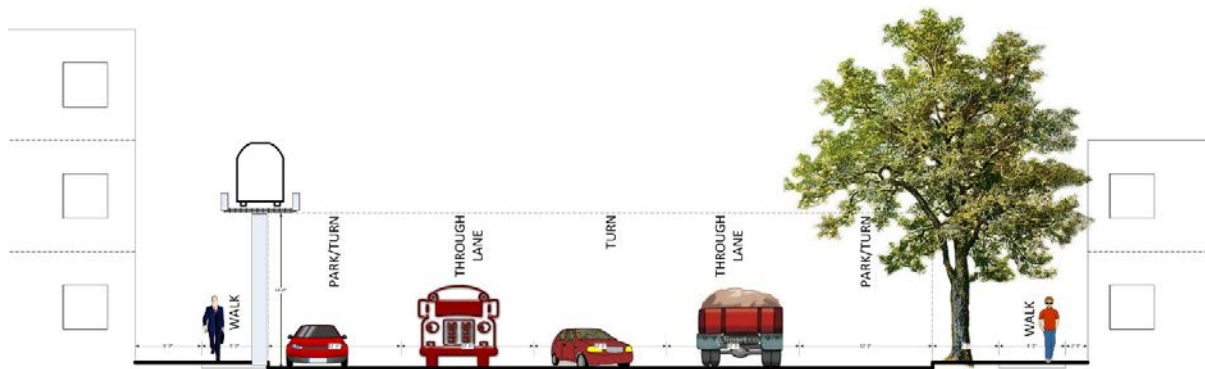
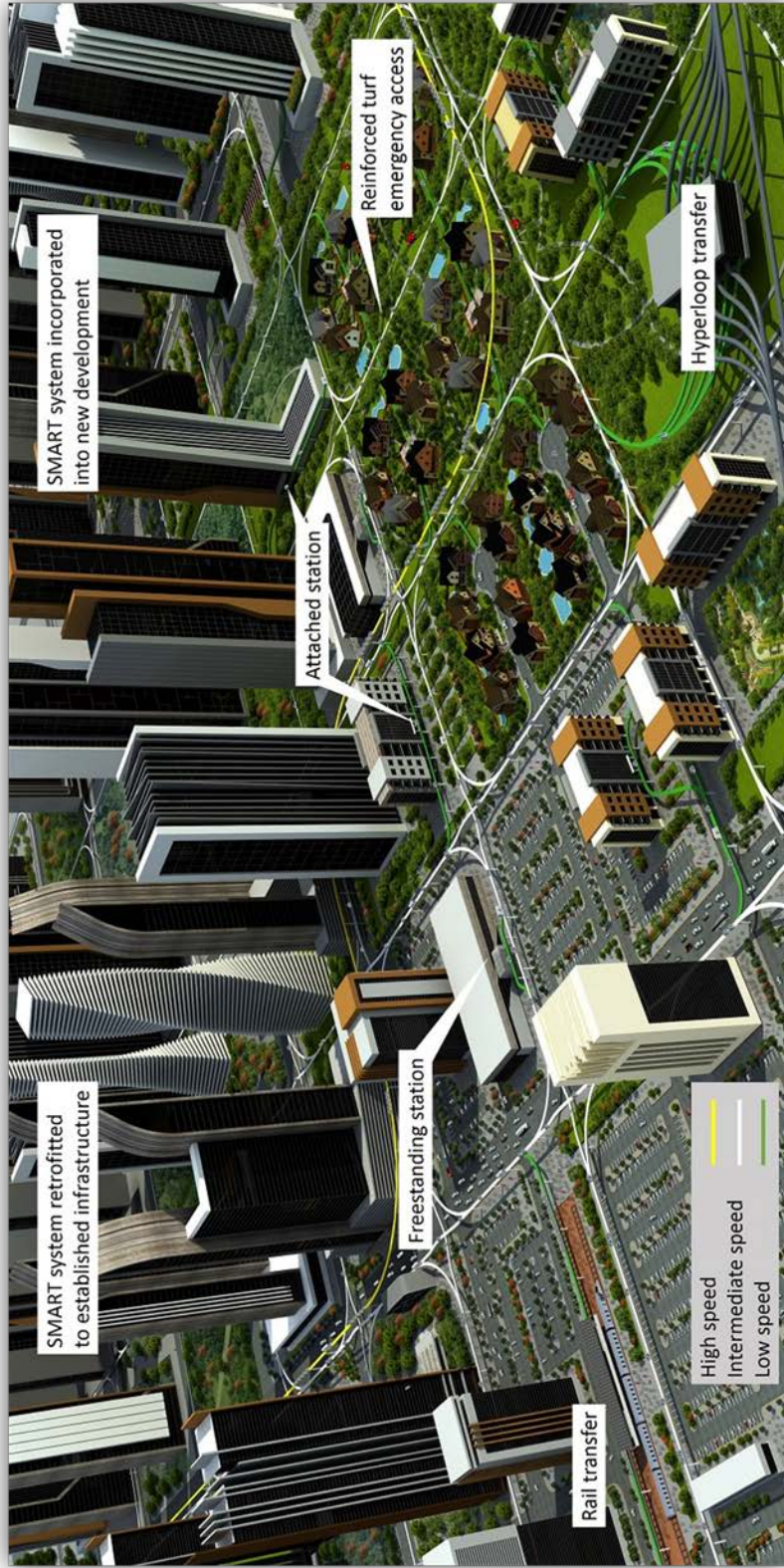Small infrastructure fits in existing ROW

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.

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

Labels on figure:
- SMART system incorporated into new development
- Reinforced turf emergency access
- Hyperloop transfer
- Attached station
- Freestanding station
- SMART system retrofitted to established infrastructure
- Rail transfer
- High speed
- Intermediate speed
- Low speed

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

SMART System

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

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 become 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 ✅

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 🟠

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

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.
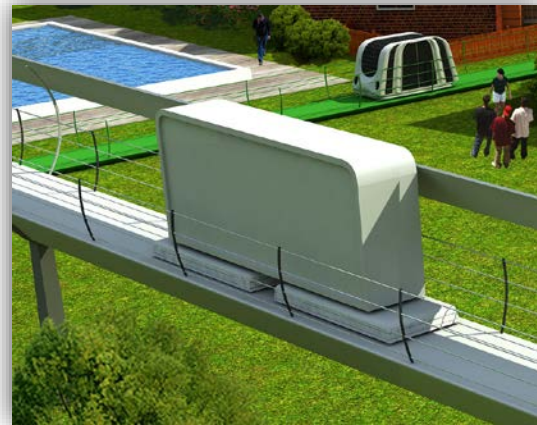
Containerized cargo vehicle

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.

Intermediate 🟡

Reinforced turf emergency access

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.

Interchanges will be small

Good ✅

LAND USE

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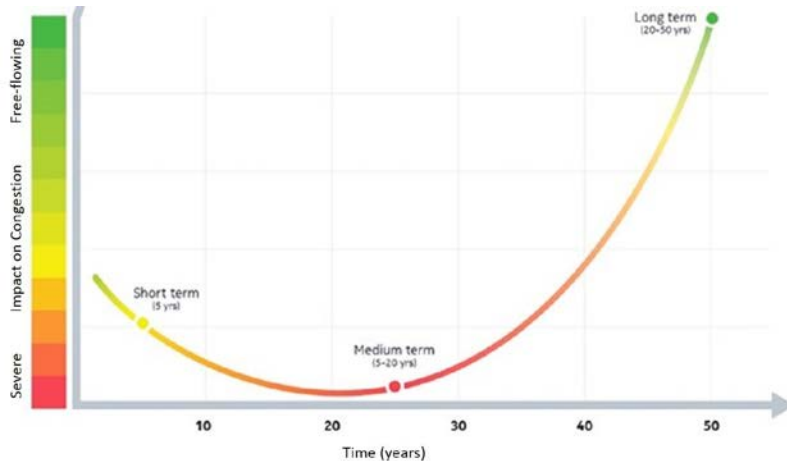
Driverless cars could increase urban congestion
for the next 30 to 40 years
Source: ITS International

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.

	Driverless Car	Retrofit SMART	SMART
Mobility	Poor	Intermediate	Good
Logistics	Intermediate	Intermediate	Good
Safety	Poor	Intermediate	Good
Security	Poor	Intermediate	Good
Land Use	Poor	Poor	Good
Walkability	Poor	Poor	Good
Visual Intrusion			
Infrastructure Costs & Funding	Poor	Intermediate	Good
Real Estate Value	Poor	Intermediate	Good
Sustainability	Poor	Intermediate	Good
Likelihood of Success	Poor	Good	Intermediate

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?