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# ECO-CITY OR AUTOMOTIVE CITY? POLICIES AND PLANS FOR AUTONOMOUS VEHICLES

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**Abstract:** This paper identifies a sometimes over-optimistic trend in thinking about a future with autonomous vehicles (AVs). These are often depicted as robot-chauffeured cars providing low-cost, effortless mobility, powered by renewable energy, and driving safely down narrow lanes surrounded by ample space for cyclists and pedestrians. There are potential dangers in this uncritical approach: the ease and lower costs associated with AVs may result in an increase in the distance travelled by low-occupancy vehicles, exacerbating urban sprawl, encouraging further car-dependence, crowding out public transport, cycling and walking, and potentially even increasing emissions. Moreover, widespread benefits of narrow roadways are unlikely to arise until manually controlled cars are phased out – improbable for decades, if ever – and there are complex issues arising over the transition between these two phases. In light of these risks, this paper advocates a careful use of planning and public policy. It envisions a more sustainable trajectory through the continued prioritisation of compact, mixed-use and walkable neighbourhoods and the promotion of active and public transport. The role of AVs in this future is characterised by responsible use and ride sharing, which may be achieved through policies such as road user charges, infrastructure restrictions and transportation demand management. Although this paper is written from a US perspective, its fundamental arguments apply to many cities and countries around the world. The opinions expressed in this paper are those of the author.

**Keywords**: autonomous vehicles, sustainable city, eco-city, compact city, ride sharing, Smart Growth, New Urbanism.

## 1. Introduction

Autonomous vehicles (AVs) create concern as well as excitement. Pessimistically speaking, the convenience of door-to-door robot chauffeuring could motivate more people to become even less careful about where they live and work, accelerating the sprawl that already consumes more than one million acres of farmland, habitat and countryside every year in the USA alone. Likewise, if AV ride hailing becomes as cheap as advocates predict, and if Americans continue their low ride-sharing behaviour, the inevitable outcome will be greater vehicle miles travelled (VMT) and its related impacts of congestion, pollution, pedestrian hazards, bicycle conflicts, decline in urban liveability and failure to meet targets for reducing climate changing emissions.

Conversely, under an optimistic scenario, many advocates envision that fully-occupied AVs of every size and shape could serve passengers located too far from public transit hubs to walk or bike. Rather than using these smaller AVs to access distant destinations, passengers would share rides to the closest transit hub and transfer to whatever public transportation option is most effective for long-haul travel or for reaching urban centres and other higher density areas. If the passengers cannot walk or bike to their final destinations, other appropriately sized AVs will take them this so-called last mile. These shared autonomous vehicles (SAVs) would consequently improve mobility for all and reduce travel costs without creating a destructive increase in VMT.

Depictions of this positive AV future often show roadways with expansive areas for pedestrians, bicyclists, greenspace and urban amenities.[1] Articles and presentations likewise note that AVs could reduce the need for parking spaces and would consequently allow developments to achieve the higher densities needed to support diverse, mixed use neighbourhoods where housing, worksites, retail, recreation and nature can easily be reached on foot, by bike or on public transit. Many of these visions are consistent with one of the primary components of eco-cities: 'access by proximity' … creating places where people can live most of their everyday lives in one place rather than constantly needing to go somewhere else.

It is somewhat comforting to know that many if not most observers want and expect AVs to improve cities. However, in the first section of this paper, I argue that good urban outcomes will not happen without active avoidance of the potential potholes in the road to utopia. In the second section, I propose that cities harness this enthusiasm to achieve rational land use patterns rather than simply apply an AV band aid on the sprawl generated by a century of car dependency. And lastly, I highlight three implementation measures that could help nudge cities in the direction of a truly sustainable future. Although this paper is written from a US perspective, its fundamental arguments apply to many cities and countries around the world.

[1] For example, the graphic on page 16 of a Florida Department of Transportation report depicts roadway configurations that are improved by AVs but still dominated by motor vehicles: http://www.automatedfl.com/wp-content/uploads/2015/06/Envisioning-Floridas-Future-Final-Report-BDV30-TWO-934-10.pdf.

## 2. Autonomous vehicle reality check

Before launching visioning and planning exercises, industry, business and municipal organizations as well as the general public should ideally understand the potential for AVs to create good and bad outcomes. The three examples below illustrate why governments need to guide deployment and use AVs to build better cities.

### *2.1. Car sharing is not ride sharing*

Car sharing and ride sharing are two different things. Yet these terms are often used interchangeably, which is not helpful for understanding the potential impact of AVs (Glus, Rothman & Iocabucci 2015). Here, car sharing simply means that a single vehicle is used by passengers who are not necessarily traveling in the vehicle together at the same time. An increasingly popular form of car sharing is ride hailing, which is the on-demand summoning of a vehicle from a taxi service, a transportation network company (TNC) like Uber, Lyft or a public mobility agency. On the other hand, ride sharing here means services in which unrelated individuals or parties pay separately to ride in the same vehicle at the same time. Ride sharing increases riders per vehicle and reduces vehicle miles travelled (VMT), thereby lowering energy use, greenhouse gas emissions, and the need to keep pedestrians and bicycles out of harm's way. In contrast, ride hailing and car sharing without ride sharing does not reduce VMT, congestion, traffic hazards or climate-changing pollution. It merely replaces a privately-owned vehicle with a ride-hailed vehicle.

That said, cities could benefit from increased use of car sharing and ride hailing alone. By eliminating drivers, trips on ride-hailed AVs are expected to become so cheap that more and more people will forego owning their own vehicles in favour of using these on-demand services. As mentioned above, this would reduce the number of families currently burdened with the cost of owning, registering, insuring, maintaining, parking and fuelling their privately-owned cars.

AV advocates also assert that the increased use of AVs will reduce the number of vehicles needed to maintain mobility because ride-hailed AVs can theoretically be in service nearly all the time. If that occurs, urban space could be shifted from housing idle cars to creating room for people. Some of this benefit seems likely to occur. But if unlimited numbers of AVs are available for private purchase, there is no assurance that individuals will not buy far too many of these vehicles (UITP 2017). A glut of privately-owned AVs is a distinct possibility considering that potential buyers are already being told that they will be able to more than offset the cost of their AVs by sending them out to work for them through ride-hailing services (Neiger 2017; Twidell 2017). If there are more AVs than needed to meet demand, some will become just as idle as their conventional counterparts. These unused/underused AVs will need to be parked, thereby reducing the urban space that could have been transformed for human use. Even worse, owners could keep their superfluous robot-piloted AVs out on the street competing for fares in an overcrowded market. Under this scenario, AVs cruising for passengers could increase rather than decrease VMT, congestion, fuel consumption and urban quality of life.

In short, we must increase ride sharing as well as vehicle sharing. In *Three Revolutions in Urban Transportation*, Dr Lewis Fulton and his research team from University of California Davis put it this way: “Taxi services or transportation network companies (TNCs) that are not shared do not reduce trips” (Fulton et al. 2017: 5). The UC Davis report warns that AVs, even assuming electrification, could drastically increase congestion and urban sprawl while causing us to miss our climate change goals unless we achieve a corresponding increase in shared mobility, transit usage and active mobility (walking and cycling).

AVs will likely induce more travel because of their ability to reduce time and money costs. As documented by the UC Davis study, the negative impact of this increase in travel cannot be offset merely by assuming that all AVs are electric vehicles. In fact, without increasing active transport (walking and bicycling) and shared mobility, including the use of public transportation, electrified AVs could substantially increase congestion and sprawl while also making it less likely that we will reach climate change goals.

To prove that point, the UC Davis team analysed a ‘2Revolutions’, or ‘2R’ scenario, which assumes that cars will continue to be primarily privately owned and that electrified AVs dominate vehicle fleets world wide by 2050. The assumption of electrification mitigates but cannot assure a total offset of the emissions generated by an estimated 15 to 20 percent increase in vehicle travel induced by AVs. Other observers estimate that AVs will induce slightly higher increases in demand (Fagnant & Kockelman 2013). And some researchers warn that AVs could create a quadrupling or quintupling of traffic demand (Notaro 2017).

The sustainability of the UC Davis 2R scenario depends largely on the extent to which electrical generation becomes completely carbon free around the world by 2050. Without complete de-carbonisation of all electrical generation worldwide, the 2R scenario may generate more CO2 than the targets needed to limit temperature increases to 2 degrees centigrade or less. The authors do not attempt to quantify other R2 impacts but note qualitatively that the continuation of private car ownership and suboptimal ride sharing would likely increase congestion and degrade urban liveability.

Fulton et al. (2017) team compared its 2R scenario and a business as usual (BAU) scenario with a ‘3R’ scenario involving AV technology and electrification plus a significant shift in mobility patterns generated by maximizing shared trips. In addition to the “three revolutions” of AV, EV and ride sharing, the 3R scenario assumed a multi-modal strategy with active mobility supported by improved pedestrian and bicycling infrastructure. The 3R scenario also promotes the creation of greater opportunities for shared rides using public transportation vehicles of all sizes ranging from on-demand shuttles and larger buses to rail service.

Their analysis concluded that the 3R scenario could produce an efficient, globally-applicable transportation approach featuring low traffic, low fuel consumption and low climate-changing GHG emissions. Specifically the authors estimated that the 3R scenario's combination of on-demand service, ride sharing and active transportation could cut VMT by more than 50 percent and reduce the size of the worldwide car fleet almost 75 percent by 2050 compared with the BAU scenario. These findings are consistent with results generated by other studies including one that estimated a 50 percent increase in public transportation mode share and a 90 percent reduction in the total vehicle fleet using simulated combinations of AVs and transit in Lisbon, Portugal (ITF 2015).

The UC Davis study's 3R scenario would also significantly reduce congestion and parking demand, consequently freeing more urban land for walking, bicycling, open space and enjoyment by people rather than vehicles. Importantly, the study estimated that the 3R scenario could produce a very low CO2 world by 2050, with energy use and CO2 emissions less than one third of the BAU scenario and roughly one half of the 2R scenario.

### *2.2. Benefits resulting from an all-AV fleet will not arrive for decades (if ever)*

As argued above, cities will benefit if people increase ride sharing and per-vehicle occupancy rather than simply swapping their cars for AVs. Consequently, the first order of business would logically be the development of policies and regulations aimed at boosting ride sharing. After all, why would we immediately leap to the task of facilitating a transportation revolution before knowing whether or not we were making things better or worse for cities?

Yet, the excitement generated by robot-cars seems to have scrambled our priorities. Many urban planners have become so infatuated with AVs that they have lost sight of their primary mission to help make great communities. Instead, they seem to see their jobs as orchestrating public acceptance and widespread deployment of a technology that many of them admit could accelerate VMT, congestion, climate changing emissions and the further decline of the cities they are tasked with protecting.

Presentations and articles about AVs typically devote one or two sentences to possible negative consequences before describing how the roadways of the future will look once humans are no longer behind the wheel. For example, we are often told that more right of way will become available for wider sidewalks, bike lanes and green space because travel lanes will be skinnier thanks to the greater steering abilities of AVs. Likewise, if all vehicles were robot controlled, they would be able to communicate with each other and the infrastructure, thereby reducing the need for signage and traffic signalisation as well as increasing the throughput of each lane and intersection (Chapin et. al. 2016).

However, these designs will not be possible unless and until all vehicles are piloted by robots (Crute 2017). We cannot shrink lanes, discard traffic signs and eliminate intersection signalisation while conventional cars are still on the road. Even promoters admit that AVs and human drivers will be sharing our roadways for decades. And some observers question whether we will ever reach a future with only robots at the wheel. If a segment of the population refuses to surrender control of HDVs even decades from now, some AV benefits might never materialise, including the narrower lanes that we are promised will return more of the public right of way to the public.

Some AV advocates dismiss this possibility, claiming that the economic benefits of on-demand electrified AVs will be so overwhelming that no one will be able to resist handing over their cars keys once they see how cheap it is to travel using on-demand AVs. It does seem likely that many, perhaps most people will become the rational economic decision makers envisioned by these futurists. But it seems improbable that every single person will make this transformation in their behavioural DNA. For every low-priced, fuel saving car, there are just as many gas guzzling muscle cars, pick-up trucks and sport utility vehicles driven by people who complain about every increase in gas prices but refuse to change their buying or driving habits in order to save money. TV and print ads for luxury and performance cars might mention cost savings but the images are selling power, speed, success and personal identity. AV proponents are claiming that these emotional appeals will disappear as all humans evolve into rational economic decision makers.

In addition to ignoring price cues, many drivers also have travel behaviours that seem intractable. They rarely start journeys early enough to reach their destinations on time without ignoring traffic laws and speed limits. Even when they are not under any time constraints, they still drive like they think they are at the Daytona Speedway or starring in a heist movie. These are the people who AV advocates claim will voluntarily submit to sitting in cautious AVs which presumably will be programmed to obey speed limits and all other rules of the road.

More likely, there will be more rather than less reckless driving as human drivers get frustrated behind cautious AVs that observe speed limits and slow down or stop for no apparent reason. In testing on city streets, AVs have been involved in twice the number of accidents per mile as HDVs (Schoettle and Sivak, 2014). Typically, the AVs are not at fault, leading to speculation that humans are having trouble adapting to AV behaviors. These accidents are occurring during a testing phase in which humans are in the driver's seat of the AV, ready to take control of the vehicle if necessary. In the future, when no human is behind the wheel, or rather when there is no steering wheel, it seems possible that AV-HDV conflict will grow worse, ranging from pranking of AVs to outright hostility. It will not reduce road rage if human drivers see that the AV causing them to stop, slow down and make them late for an appointment has no human passengers but is a robot possibly just roaming around looking for parking or for a rider.

Some observers acknowledge that there will be holdouts – people who will not voluntarily give up driving regardless of how easy, cheap or rational AVs might prove to be. In what might be called the nuclear option, these observers float the idea that government may have to prohibit people from driving (Thackrey 2016). The ban-human-driving forces will base their arguments on accident statistics which presumably will show that robots are better drivers than humans *on average*. But there will still be lots of examples documenting that AVs are not flawless, like the Florida man who was beheaded in 2016 when his semi-autonomous car failed to detect a truck. Over time, the holdouts will have many more horrific anecdotes to use as counter arguments to data on overall AV safety records. Will politicians have the spine to take away everyone's car keys? It won't be easy, particularly at a time, presumably decades from now, when robots will already have replaced humans in many workplaces and other aspects of everyday life. It is not too far-fetched to imagine a segment of society claiming a constitutional right to continue driving with the kind of fervour currently displayed by gun right extremists: "You can have my car keys when you pry them out of my cold, dead hands."

Consequently, it seems logical to set aside those urban benefits that AVs are forecast to deliver but that actually cannot occur as long as human drivers and robots share the road. Instead of dreaming about roadway designs that might or might not materialise for several decades, we should focus on the immediate future. Yes, that joyless plea is a deliberate attempt to tamp down the unbridled enthusiasm and get a rational grip on the real prospects for AV deployment. Overly optimistic speculation only gives cover to elected officials who would love a good excuse to defund and possibly dismantle public transportation systems. Ironically, these officials might repeat some of the hyperbolic rhetoric from the urban planning profession to justify these decisions.

It is less glamorous than spinning out visions of ultra-efficient automated travel, but the task immediately at hand requires AVs to contribute to the functioning rather than the dismantling of multi-modal mobility networks. We cannot absolutely assure this outcome unless AVs are publically owned and/or operated within the coordination of a public mobility agency; an option that appears at odds with the current attraction to disrupting traditional safeguards including governmental regulations. Consequently, I concur with the widespread recommendations to use price cues as a way of motivating ride sharing and generating the revenue needed to build a 21st century mobility network. In addition to roadway user charges that simply track a vehicle's total mileage, the UC Davis team and many others recommend charges that encourage travellers to transfer to public transit and other appropriately sized vehicles for longer trips. In addition, the UC Davis researchers and many others envision user fees that reward ride sharing and discourage longer trips in low-occupancy vehicles, perhaps using these proceeds to subsidize desirable ride-sharing behaviours. These ideas are explored in greater detail in the third section further below.

### *2.3. Trading crowded parking garages for crowded roadways*

As mentioned, AVs are likely to radically reduce the cost of taxi and other ride-hailing services like Lyft and Uber and cause vehicle per person ownership rates to decline, as many families get rid of one or all of their personally-owned cars. This will relieve many people of the cost of buying, registering, insuring, repairing and fuelling the family fleet, a burden that now represents an obscene portion of the typical household budget. And at a macro level, a smaller worldwide fleet will require fewer materials and less energy devoted to vehicle manufacturing. This could represent a huge leap for efficiency since the average car is in use only 5 percent of the time (The Economist, 2017). Instead of having a billion or so cars parked 95 percent of the time, we might ultimately have a significantly smaller fleet with many of these vehicles on the road almost around the clock.

AVs are likely to reduce the vast number of cars inefficiently sitting in garages and parking lots. But unless per-vehicle occupancy increases, we will still have too many cars on the road generating too much traffic, noise, safety hazards and greenhouse gas emissions. This obvious point is often overlooked in all the excitement about AVs. The fact that cars are parked 95 percent of time is incredibly wasteful. But the impact on our roadways is the same regardless of whether a solo passenger is driving his or her personal automobile or riding alone in a ride-hailed AV.

Most experts predict that AVs will increase VMT primarily because AV TNCs are expected to significantly reduce travel costs (Grabar 2016). Reduced travel cost should increase mobility options for currently underserved communities including the poor and elderly. But in addition to those potentially beneficial outcomes, travel demand will also increase simply because of basic economics: as cost declines, demand rises. In addition, VMT will increase because many AVs will be traveling without any human passengers (Fagnant & Kockelman 2013). In some cases, zero-occupant travel will reflect legitimate repositioning rather than abuses like sending AVs to circle the block during lunch. But nevertheless, VMT will increase unless vehicle-occupancy increases as well.

Ideally, people will use AV TNC services to get to and from transit centres where they can transfer to the higher-capacity vehicles that are best suited for urban centres and other areas. Pessimists worry that people will simply ride solo in their low-cost AVs for the entire trip into downtown areas or across the region. Optimists assume that people will need no encouragement to use AVs responsibly. But if AV TNC travel becomes as cheap as its promoters claim, travel costs will become less rather than more effective in single-handedly supporting the fully-functional multi-modal transportation systems needed for a liveable and sustainable city. Most middle-class Americans have not changed their ride-sharing behaviour at current travel costs. Consequently, it seems unlikely that the cost reductions possible via ride-hailed AVs would be any more effective in getting Americans to use AVs only for first-mile/last-mile trips or to improve their ride-sharing behaviour (Litman 2017).

What would motivate responsible urban travel? Public ownership would help ensure that AVs contribute to community wellbeing and support a healthy multi-modal transportation system (Tiell 2013). But I have not found any proposals to regulate even zero-occupant AVs to ensure that they are serving a legitimate mobility purpose instead of just using public rights of way to find cheap parking or, worse yet, avoiding parking entirely. In other words, reducing parked vehicles is not progress unless the number of vehicles on our roadways is also reduced.

The section above and the implementation section below recommend dealing with this issue through user charges on VMT and longer trips in low-occupancy vehicles. In addition, I advocate that cities restrict infrastructure built to accommodate AVs to vehicles that comply with ride-sharing protocols. For example, it is common to see AV enthusiasts recommending the conversion of parking lanes to pick-up/drop-off lanes for AV passengers. As an aside, I predict that these pick-up/drop-off lanes will be fought by abutting businesses unless and until AVs outnumber HDVs; in other words, a long time. But, beyond that hurdle, if there are no restrictions on who can use these pick-up/drop-off lanes, cities will be missing an opportunity to motivate desirable ride-sharing behaviour. Specifically, without rules, these lanes could serve solo-occupant and even zero-occupant vehicles as well as vehicles that are achieving ride-sharing goals and therefore reducing rather than increasing VMT impacts. Yes, it will require enforcement to ensure that only ride-shared vehicles are using pick-up/drop-off lanes. But such restrictions are not materially different from our current prohibitions limiting the use of bus stops to public vehicles.

Many urban planners are already working on how to turbo charge AV deployment without stopping to consider what public policies need to be adopted to reduce the potential for negative outcomes. For example, some engineering firms are urging cities to prepare for right-of-way configurations that would only be feasible when absolutely no humans remain behind the wheel. While it is likely that some production AVs will hit the streets in a matter of years, robots will pilot only a fraction of the vehicles on our roads for decades. As already noted, there are also some sceptics who doubt that everyone will ultimately hand over their car keys voluntarily. Consequently, it seems logical to focus on the road directly ahead of us rather than promoting roadway designs that may not make sense until the middle or the end of the 21st century, if ever. Furthermore, any proposals to build infrastructure for AVs should be evaluated by the criteria adopted in the policies and plans covered in the next section. This scrutiny will reduce the chances of creating unintended consequences by building infrastructure that undermines rather than supports community goals.

**3. Planning for urban eco-villages**

Streets in the US and many other countries are typically dominated by multiple travel lanes filled with low-occupancy, privately-owned cars and flanked by parked cars, leaving pedestrians to hug the margins of the public right of way and forcing bicyclists to ride in traffic or abandon the road entirely. The future roadway envisioned by AV enthusiasts is a vast improvement over the current reality, with bicyclists on separated paths and pedestrians strolling on wide sidewalks. But even in this envisioned future, the right-of-way is still devoted primarily to motor vehicles (e.g. Chapin 2016). Many of the vehicles depicted in these drawings are typically fully-occupied transit and quasi-transit trains, buses, and TNC-operated AVs, all presumably electrically-powered by a fully decarbonised generation system. If these visions materialise and get VMT sufficiently under control, we would have a much better chance of meeting our targets for GHG emission reductions as analysed by the UC Davis team.

Despite being much better than our current roadways, motor vehicles still dominate the envisioned rights-of-way in most depictions of a future AV world, exposing a land use pattern that is still less than ideal. These configurations devote slightly more roadway width to bikeways and sidewalks, but the bicyclists and pedestrians in these drawings still have to cross multiple motor vehicle lanes to cross streets. Some advocates claim that these street crossings will be perfectly safe since robots will be more respectful of pedestrians and bicyclists than human drivers. Other observers warn that bicyclists may have to wear special signalling devices that allow AVs to predict their trajectories and that crossing signals with heavy enforcement will be needed to keep streams of pedestrians from bringing entire platoons of AVs to a dead stop.

In addition to the continuation of conflicts with pedestrians and bicyclists, the sheer predominance of motor vehicles in depictions of future roadways perpetuates the assumption that urban design must facilitate the longer trips that cannot be accomplished by active transportation. These designs reinforce the notion that public space should primarily be devoted to getting people from one part of the city to another rather than providing for people to use and enjoy the public space itself. In my opinion, an ideal city of the future would reduce longer trips by building compact, mixed-use neighbourhoods where homes, work, shopping, entertainment and even nature can be easily reached on foot or by bicycle. In this future, the emphasis would shift from ‘going places’ to ‘being places’ in every sense of the word ‘being’.

Even though these ‘being places’ should have enough density to support food stores, workplaces, schools and other everyday needs, I refer to them as eco-villages because they occupy a geographic area small enough to be walkable. One or more eco-villages can be connected by active mobility corridors, transit and other shared-ride vehicles, thereby creating the urban form of an eco-city.

Eco-city urban form is consistent with Smart Growth, New Urbanist and good planning principles in general. In my opinion, we should use AVs to pursue the compact, mixed use, transit oriented goals that seemed to be gaining traction just as AV euphoria burst on the scene. As documented by the UC Davis researchers, compact urban form is one of the factors needed to achieve the increased ride sharing and reduced VMT necessary for the world to keep GHG emissions within the targets identified to address climate change.

The existence of climate change denial suggests the need to promote eco-villages by demonstrating near-term, direct benefits to individuals in addition to severe weather events, sea level rise, loss of biodiversity and other longer-term, impersonal impacts. Consequently, this paper advocates that public officials and private non-profit organisations use the excitement surrounding AV deployment to launch city plan updates beginning with a visioning process in which participants express their urban design preferences. These exercises are likely to reveal that many if not most people would prefer to live in places where they can walk or bike without the unpleasantness and hazard of sharing public space with motor vehicles.

A visioning event can compare two or more scenarios of the future at one or more public workshops ideally well attended by participants who are representative of the community. Scenario A could include any of a number of cross sections and artist renderings currently being used to depict roadways in a long-term future when presumably AVs are no longer sharing the roadway with human drivers.

The visioning workshop participants would then be asked to compare Scenario A with Scenario B featuring an eco-village form in which the public right of way is devoted almost entirely to people walking, bicycling, sitting at outdoor cafes or just relaxing in greenery. The Scenario B illustration would depict greenways allowing people to access other neighbourhoods and even the countryside on pedestrian/bicycle paths ideally following stream corridors and other natural features that support biodiversity while also keeping people in touch with nature. The Scenario B drawing might also include a transit hub, acknowledging that there will still be a need to access destinations that cannot be located in every eco-village such as museums, theatres, parks, major employers, hospitals, public offices and other activity centres. However, in the Scenario B illustration, motor vehicles occupy a small fraction of public space, in contrast with the Scenario A drawing, in which pedestrian and bicycle infrastructure is still dwarfed by motor vehicles.

My guess is that most people would choose Scenario B. Sceptics will likely say that such a comparison is unfair, because Scenario B may be preferable but is nevertheless unachievable or at least unrealistic. How can we possibly turn travel-obsessed, car-dependent cities into networks of eco-villages? My response would be that cities need to create one eco-village at a time. Admittedly, it will take a long time to transform cities shaped by the ubiquitous, private automobile. But, as argued above, the conversion to an all-AV fleet will also take time and might never be fully realised.

To demonstrate that Scenario B is attainable as well as desirable, visioning processes can document how some cities have already achieved notable success in building eco-villages. Many good examples have been identified by the European Green Capitals and European Greenleaf programs, annual competitions conducted by the European Commission (European Commission, 2017; Pruetz, 2016). Many Americans admire the compact, sustainable structure of certain European cities but assume that these successes cannot be achieved in the US. Common wisdom holds that these European cities evolved before the automobile and consequently they only had to retain their compact form to achieve walkability and bike friendliness. That is true to an extent. But European cities had to choose whether or not to surrender to the personal-automobile onslaught throughout the past century and many took an entirely different path from their North American counterparts.

A century ago, cities like Hamburg, Copenhagen, Helsinki and Oslo envisioned green networks to achieve multiple objectives: preserving stream corridors and flood ways, protecting habitat, putting all residents close to nature and green space and creating pleasant corridors where people could walk or bike to most everyday destinations without having to contend with the hazards, noise and pollution of cars. Unfortunately, The Great Depression and two world wars slowed implementation for decades. But, in recent years, several European cities have doubled down on their commitment to build cities for people rather than cars.

Copenhagen, for example, made a U-turn in the 1970s after realising that accommodating cars only induces more traffic. The Danish capital converted car lanes and parking to cycle tracks and prioritised active mobility to the extent that by 2014, 62 percent of city residents biked to work. Despite likely pressure from car owners and car makers, Copenhagen invested in compact communities accessible on foot, by bike or on public transportation which partly explains why this city is poised to become the world's first carbon neutral capital by 2025 (Pruetz, 2016).

Visioning workshops can explore how some of these cities developed specific eco-villages. For example, Stockholm adopted a detailed plan to transform a highly-polluted industrial area into Hammarby Sjöstad, a state-of-the-art eco-village aimed at cutting environmental impacts in half by incorporating closed-loop energy, waste and water systems. Light rail, bus and ferry lines as well as pedestrian trails and cycle tracks make it possible for the inhabitants of this eco-village to live car-free. In fact, 80 percent of Hammarby residents walk, bike or use public transportation. Fingers of greenspace reach into every part of Hammarby and link to a nearby nature reserve using a landscaped viaduct called an 'ecoduct'. Hammarby has also become an economic development tool, attracting 10,000 visitors each year plus serving as a calling card for the architects, contractors and technicians who built this eco-village (Pruetz, 2016).

Freiburg, Germany, transformed an abandoned military base into the Vauban eco-village. Residents with cars can drive on the traffic-calmed street of Vauban to pick up/drop off passengers and packages, but parking is confined to the perimeter of the district. That arrangement makes Vauban Germany's largest, modern car-free development. Instead of owning cars, residents here are encouraged to walk, bike and use public transit. As a result, less than one percent of Vauban residents own cars. It helps that a high-frequency tram line directly links Vauban with downtown Freiburg, which has been a pedestrian zone since 1973. In addition, Freiburg built Rieselfeld, a third eco-district with a population of 10,000, and connected it with a direct tram line to downtown, providing a fledging example of how eco-villages can be joined by active transportation and transit to create the foundations for a future eco-city (Pruetz, 2016).

Several European cities have converted portions of their centres into pedestrian zones, largely because these areas can usually accommodate the density needed to support a mixed-use, walkable environment. In 2007, Ljubljana, Slovenia, declared its city centre as an ecological zone closed to motor vehicles with the exception of early-morning deliveries and by 2013 had expanded the car-free zone to more than 30 streets. Ljubljana also transformed the river within this zone by the removal of extraneous pavement and the installation of four new pedestrian bridges allowing people to reach as well as cross the water. In addition to improvements in water quality, air quality, safety and reduction of greenhouse gas emissions, establishment of the ecological zone substantially reduced noise levels, creating a large peaceful environment for living, working and relaxing in the heart of the city (Pruetz, 2016).

Admittedly, building better cities does take time and effort. And Americans are impatient. But we should not accept the idea that AVs offer a fast and easy way to tolerate the urban structure formed by one hundred years of land use mistakes. Manufacturers have good reason to claim that AVs will be in dealership showrooms as soon as 2018. These corporations are trying to outpace each other in a race to dominate what they see as a multi-trillion-dollar market. But even the most aggressive projections estimate that it will take decades for AVs to constitute more than half of the vehicles on our roadways. As noted above, there are good reasons to believe that an all-AV fleet will never materialise unless governments prohibit driving while human. Consequently, we have the time to do this right. We should recommit to building compact, mixed use neighbourhoods that use AVs to support rather than degrade a multi-modal mobility system featuring walking, bicycling and mass transit.

## 4. Future transport policies to support eco-city plans

The visioning process and subsequent planning outlined above can help cities seize opportunities to build eco-villages. But these plans can also provide the policy support that cities need to adopt road user charges, ride-sharing programs and infrastructure requirements needed to control VMT, sprawl, congestion, pedestrian hazards, bicycle conflicts and GHG emissions.

### *4.1. Road user charges*

Once a plan is adopted, cities can more readily identify how to transform the vision for a future city into reality. Many observers either assume (or hope) that the benefits from AVs will be gained with minimal or no governmental intervention. But no city would adopt a land use plan without following up with action to implement that plan. As argued above, these plans should aim to increase ride sharing so that the low cost of AV mobility does not generate increased VMT and its associated impacts. Roadway user charges appear to be the implementation measure most likely to motivate increased ride sharing without placing undue restrictions on future mobility options.

The mobility strategy proposed in the UC Davis study envisions AVs supplementing rather than replacing other modes of transportation. For example, people who live in compact mixed-use neighbourhoods would walk or bike to public transportation hubs while those who live farther away would use AVs for first-mile/last-mile trips in order to transfer to higher-occupancy vehicles that are best suited for reaching denser destinations. To achieve best outcomes for mobility and urban liveability, people would not remain in low-occupancy AVs to travel longer distances.

Alternatives to the UC Davis vision have also been proposed. For example, AVs could pick up people at various locations and then form platoons resembling trains that possibly operate on infrastructure devoted exclusively to AVs (Calthorpe and Walters, 2017). As a plus, this option might attract riders who resist changing vehicles in mid trip regardless of the efficiency of the transfer. As a disadvantage, the exclusive AV infrastructure might have to displace whatever is currently within the right of way. It seems ill advised to replace conventional heavy rail, light rail or trolleys. And if transportation planners try to displace conventional traffic lanes they will likely run into the backlash that bedevils road diets and other attempts to remove car lanes.

In addition, unless they are restricted to separate infrastructure, highly-efficient, interconnected AV platoons could be stymied by pedestrians and cyclists, travelling via the active transportation modes needed in sustainable cities. Since AVs dutifully stop when they detect obstructions, some futurists predict that pedestrians will habitually cross in front of them unless police departments ramp up enforcement to prevent them doing so. Co-existence with bicycles is also uncertain since current AV technology can spot only 74 percent of cyclists and can successfully predict which way bicycles are facing only 59 percent of the time. These conflicts suggest the need for separate AV infrastructure. But, as one author notes, separate infrastructure built to facilitate individual, high-speed vehicles sounds suspiciously like today's urban freeway, a land use as well as transportation mistake that places the speed and convenience of cars above all other urban values (Laker 2017). Before going down that road again, we should remind ourselves how limited-access highways created physical barriers for other travel modes, isolated neighbourhoods, degraded the environment and were ultimately proven to be a monumentally bad idea for cities. It is probably premature to try to sort this all out now. But the point here is that an optimal multi-modal transportation system will not evolve unless AV deployment follows a coordinated plan backed by governmental regulations.

To fully realise their potential benefits for cities and the planet, Fulton et al. (2017) recommend that private AV ownership be discouraged or restricted. In addition, the authors urge governments to adopt user fees that encourage reduced VMT and increased vehicle occupancy. Other studies echo this call for road user charges as a way of discouraging harmful use of AVs (e.g. Hutchinson 2016).

Optimistically speaking, many states have tested or are testing road user charges because gas taxes are simply not keeping pace with infrastructure funding needs (Kirk and Levinson, 2016).

Consequently, we are likely to see more road user charges becoming a reality despite political pushback. But states will first have to take the step of adopting mileage-based charges before tackling the more complicated concept of congestion fees for dense urban areas. After that, cities may be able to explore the UC Davis study's even more contentious proposal to use vehicle-occupancy charges as a way of discouraging solo ridership. Ultimately, cities might impose a 'zombie tax' on zero-occupant vehicles that are not operating within the coordination of a public mobility agency. Even though road user charges are materialising at a slower pace than AVs, these pricing mechanisms may be our best strategy for encouraging a beneficial outcome for cities.

Road user fees, like most other regulations, have never been popular in the US. Plans and governmental intervention will be even more difficult to adopt if they are seen as an impediment to disrupters like AVs. Disruption has become such a buzzword that cities themselves are promoting it regardless of whether or not the things being disrupted are beneficial, like a multi-modal transportation network that facilitates active transportation and mass transit.

The disruption mantra suggests that government should get out of the way so that the private sector can give people what they want. Believers in a completely unfettered free market might argue that individually-owned and operated cars dominate US cities and US city planning because Americans love their cars and that society is simply responding to the will of the people. But this argument ignores how public policy made individual cars practically indispensable for many Americans. Gas tax revenues are much lower than in most other industrialised countries and fail to address the fact that car exhaust treats the atmosphere like an open sewer. Federal, state and local governments fund the expansion of roads while letting public transportation deteriorate. Lending practices and tax deductions on mortgages motivate people to buy homes in suburban subdivisions with few options for walking, bicycling or public transportation. After our cities were built around cars, auto-dependency became a self-fulfilling prophesy. Is it really the will of the market if, in many parts of most US cities, there are no other reasonable alternatives to car ownership?

Many advocates claim that AVs will succeed where HDVs failed. Some of these advocates assume that the technology itself will benefit cities. Other promoters understand that ride-sharing is the real key to a positive urban transformation but they assume that AVs will accomplish ride sharing without any governmental intervention such as user fees (Chase 2016; DuPuis, Martin & Rainwater 2015). This paper argues the opposite position: public policy is essential to assuring that the future will not simply be a car culture on steroids (Circella, Ganson & Rodier 2017; Lubell 2016).

Roadway user fees based solely on miles travelled, as described above, will discourage many owners from harmful behaviours such as sending their AVs home midday, using AVs to run errands for them or letting their AVs circle the block while they go shopping or attend a meeting. Even more AV owners would be hesitant to misuse their AVs if the fees increase as the number of passengers decreases and might avoid abusive behaviours altogether if the fees increase even more for mileage in zero-occupancy mode. It must be acknowledged that some people are largely impervious to such price cues. Nevertheless, the right suite of user charges should be able to change the travel behaviour of average travellers.

### *4.2. Transportation demand management*

The adoption of AV ride sharing or car sharing will likely reduce parking demand since fewer people will be driving and parking their personal vehicles. A reduced need for parking will benefit cities by allowing space in a development to be devoted to living, work and other human activities rather than places for cars to sit idle for hours. This will generate a corresponding increase in usable density which in turn will have positive impacts on the diversity and activity of neighbourhoods. Clearly, developers will also benefit by being able to achieve the maximum densities found in zoning codes that are often not physically or monetarily attainable because of parking requirements.

By adopting and following a plan as proposed above, cities will be more likely to adopt measures that implement several community goals rather than focusing on mobility. For example, the reduction of parking requirements could create an opportunity for cities to adopt Transportation Demand Management (TDM) programs capable of controlling VMT by enhancing ride sharing. Successful TDM programs will help achieve the passenger occupancy ratios needed to keep the increased travel demand induced by cheap AV car sharing/ride hailing from generating unacceptable increases in VMT. If VMT can be controlled, cities can prevent the benefit of reduced parking on private property from simply being cancelled out by increased congestion of the public right of way. Using TDM mitigation measures, developers promote greater occupancy of appropriately sized vehicles by contributing to transit infrastructure, fare subsidies, employee commuting pools and other techniques. Many cities have used TDM for decades. But TDM requirements might become more common and perhaps more aggressive if adopted in conjunction with the reduction/elimination of parking requirements. By routine monitoring of travel behaviour, the TDM requirements imposed on a development might be relaxed or even removed if ride sharing targets are continuously achieved. By offering the possibility of relief, developers may become more engaged in promoting the infrastructure and price mechanisms needed to control VMT.

### *4.3. Infrastructure restrictions that favour ride sharing*

The first section of this paper advocated restricting the use of future infrastructure to vehicles that comply with ridesharing protocols using the example of the conversion of parking lanes to pick-up/drop-off lanes. As another example, many AV enthusiasts are excited by the ability of AVs to follow a straight line and suggest that cities should plan to reconfigure roadways with narrower travel lanes. If and when all vehicles are autonomous, these lane diets will be possible, consequently liberating more space for bike paths, sidewalks and other forms of public space. However, in the near-term future, when humans and robots share our roadways, human drivers will have to be prohibited from these skinny travel lanes. If cities shoulder the cost and political headaches of creating AV-only lanes, I believe they should also require the AVs using those lanes to comply with the ride-sharing programs adopted as part of the general plan updates previously outlined.

Hypothetically, a city ride-sharing program might restrict AV-only lanes to public vehicles and private TNCs that follow the pricing policies based on ride-sharing: 1) low or no charge for a shared ride on a route that maximises vehicle occupancy by taking passengers to and from mobility hubs for transfer to appropriately sized vehicles; 2) higher charges for passengers who choose to pay more to avoid transfers with the revenues used to subsidise ride sharing infrastructure and behaviour.

This approach to using infrastructure to achieve policy goals makes inherent sense. Furthermore, it may also be politically necessary because human drivers will protest the elimination of HDV lanes. The restrictions placed on these AV-only lanes will not necessarily end public opposition. However, it should give officials the ability to overcome these objections by demonstrating that the AV-only lanes are implementing the ride-sharing goals of the updated city plan.

**5. Conclusion**

With production models of AVs scheduled to roll out in 2018, local governments should not wait to develop policies and plans capable of minimizing the potential for negative urban outcomes and harnessing AV enthusiasm for the re-imagination of cities as liveable, sustainable places. Although action is needed at the municipal level, the significant impact of AV deployment also requires close cooperation between cities to exchange knowledge and coordinate policy responsiveness.

The paper should be referenced as follows:

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