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Divergent Paths: An Analysis of the Autonomous Future in McLean County

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An Analysis of the Autonomous Future in McLean County

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Contents

Abstract

Autonomous vehicles (AVs) are expected to arrive on public roads in the mid-term future, but will vary in their uses and level of self-driving capabilities. On the heels of the rise of shared mobility services from transportation network companies like Uber and Lyft, the combination of these technologies has generated the anticipation of a diminishing need for private car ownership. The promises of when AVs will arrive has been somewhat tempered in recent years, allowing the public and stakeholders valuable time to more adequately plan for their arrival. A yet undetermined outcome is the influence these new technologies will have on traveler behavior, which impacts nearly every aspect of transportation planning. This report highlights two divergent paths that the autonomous future is likely to usher in: One scenario is marked by a new mobility ecosystem which enables people and things to move faster, cleaner, cheaper, and safer than today. The other possibility is that the autonomous future is marked by a decrease in overall safety, increased congestion, abandonment of public transport systems, lack of privacy, and transportation deserts. Which of these futures comes to fruition is dependent on various competing forces from public entities and the private sector. This discussion aims to provide a ten-thousand-foot view of the myriad of changes that self-driving vehicles are likely to generate. This report was written for multiple purposes, both for the formal needs of the McLean County Regional Planning Commission (MCRPC), as well as a brief introduction for Bloomington-Normal-McLean County stakeholders to start planning for the autonomous future. The author hopes it will be utilized as a resource for ongoing intergovernmental discussion of smart cities, intelligent transportation systems, and public technology currently being conducted by MCRPC and local governments. In addition, it will serve as a supplement to the 2045 Long Range Metropolitan Transportation Plan for the Bloomington-Normal urbanized area.

Introduction

Autonomous vehicles will change nearly every aspect of our existing surface transportation practices. The ramifications of fully autonomous and connected vehicles stretch far beyond transportation, influencing the designs of our streets, our need for parking, car ownership, urban sprawl, and access, all in as-yet-unknown ways. Innovations in automated and connected vehicle technology will drastically change both the local and federal transportation network. When these vehicles will arrive is currently unknown, but how they will affect communities is becoming clearer. As vehicle manufacturers, technology companies, and public officials begin to grasp how these emerging innovations will affect the built environment, it is crucial that local public stakeholders have a working knowledge of them in order to properly assess and plan for the future.

The purpose of this report is to educate the public and policymakers about the core technologies involved, how far along it is today, and what to expect in the future. The information in this report should allow local stakeholders to properly assess and plan for their respective community's future opportunities and threats. Correspondingly, it aims to provide a snapshot of the contemporary dominant vision of an autonomous future in the hope that a thoughtfully constructed future is not hindered by limited imagination.

The autonomous future will largely be shaped by whether proliferation of shared autonomous mobility (SAM) comes to fruition. Today, there is much conjecture regarding the effect of autonomous vehicles on our transport system. The optimism emanating from the private sector that self-driving cars will usher in uncongested roadways and improvements in safety and efficiency are often tempered by those in the public sector who foresee a ruinous future plagued by induced demand, congestion, and problems of accessibility. Which form of the autonomous future is realized will largely depend on whether public and private stakeholders invest in partnerships, agree on regulations, and collaborate on infrastructure improvements.

To best understand how these changes will affect McLean County, it is crucial to recognize what exactly is meant by the term "autonomous vehicle." The Society of Automotive Engineers (SAE) has standardized a six-level framework (figure 1) which has been incorporated by the USDOT in their planning documents.

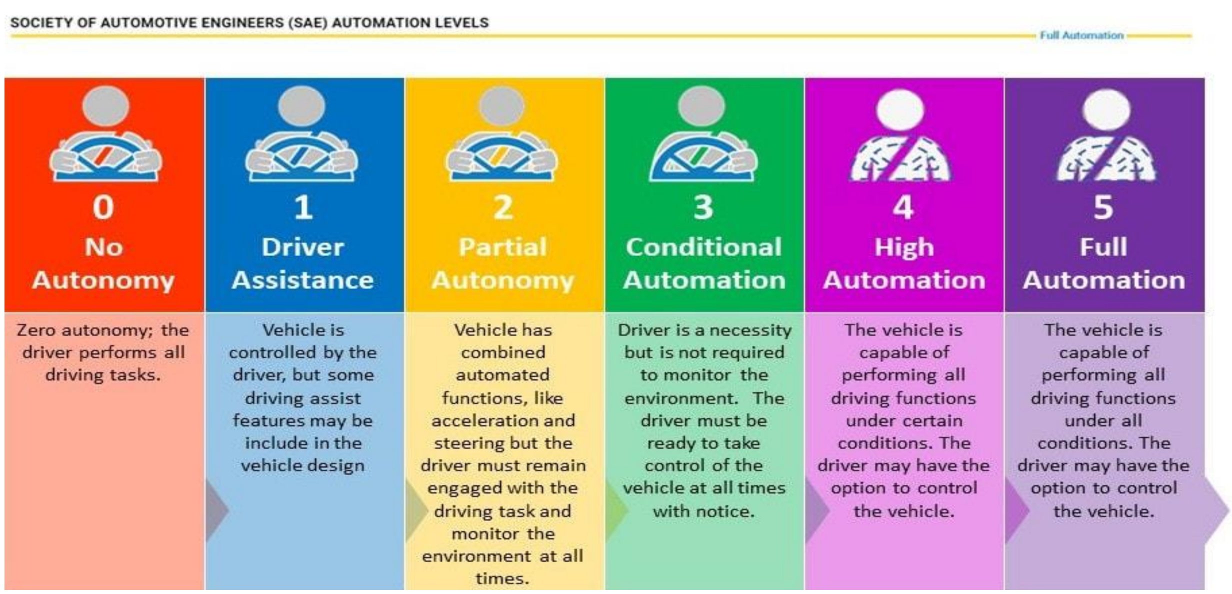

Figure 1

The Time to Plan is Now

Much as transportation network companies like Uber and Lyft arrived on U.S. streets seemingly overnight in the earlier part of the decade, self-driving cars will arrive abruptly; industry experts estimate that multi-passenger autonomous taxis could account for 9% or 500 billion vehicles miles traveled (VMT) across the U.S. by 2030.[1] Yet as of 2019, only 36% of large cities have published plans for self-driving cars in their Long Range Transportation Plans and only 24% "have issued separate strategies for maximizing the possible safety and congestion-easing benefits of self-driving cars."[2] In mid-sized to smaller municipalities, the numbers are even lower. To date, most industry-generated data focuses on large cities; the National League of Cities argues that medium and small sized municipalities should also aim to "envision how autonomous technologies can improve life for residents – by improving mobility, decreasing isolation and increasing the use of public space."[3] Smaller municipalities are more likely to be impacted by amplified safety concerns, congestion, declining revenue, and access to mobility.

EVs: Barriers and Benefits

Industry experts agree that most autonomous vehicles will also be electric vehicles due to ease of integration; it is much simpler to automate an electric vehicle than to automate an internal combustion engine vehicle. Therefore, in order to plan for an autonomous future, action must first be taken to ensure the proliferation of electric vehicles. As of 2019, only 1 out of every 250 cars on the road is a battery electric vehicle (BEV). Electric vehicle sales are, however, growing exponentially. 2018 was a record year for electric vehicle sales, with over 2.2

[1] (Duvall, Hannon, et al., A New Look at Autonomous Vehicle Infrastructure 2019)
[2] (Freemark, Hudson and Zhao 2019)
[3] (Boyer and Townsend 2018)

million sold worldwide. That figure is double the amount of recorded sales in 2017. By 2020 it is projected to that over 4 million will be sold worldwide.[4] By 2021, industry experts project that the current cost-barrier of battery electric vehicles will have eroded, crossing a tipping point for the industry[5].

To some extent, Planning is already underway; In order to prepare for the rise of BEVs, in 2012 the Bloomington-Normal Electric Vehicle Task Force promoted Bloomington-Normal as an "EV Town" which aimed to "provide members of the Bloomington-Normal community with all the information needed to evaluate available electric vehicle technologies."[6] At that time, there were less than forty-thousand EVs on the road nationwide. As numbers increase, there will be new challenges which could impede the growth of BEVs.

Impediments to Adoption

Potential new-car buyers often cite similar concerns when cross-shopping EVs with conventional internal combustion vehicles. The 2018 Deloitte Global Automotive Consumer Survey affirms that customer concerns regarding BEVs echo three major obstacles:

- 26% cite purchase price as their number one impediment to buying an EV.
- 24% cite battery pack range as their number one impediment to buying an EV.
- 22% cite lack of charging infrastructure as their number one impediment to buying an EV.

[4] (Hammond 2019)
[5] (Deloitte 2019)
[6] (EVTown.org 2015)

- Other concerns such as time required to charge, safety concerns, and vehicle type, ranked less than ten percent.[7]

Although more than 80% of all EV charging is done at home, the need for charging infrastructure continues to grow as BEV sales continue to rise.[8] There are currently 39 public charging locations, and a total of 66 charging stations in McLean County.[9] Lack of charging locations continues to be one of the largest perceived obstacles standing in the way of widespread EV adoption.

Over the next decade as EVs become more prevalent, most of these concerns will be solved for by private enterprise as the technology adoption lifecycle moves beyond early adopters and into the early majority phase. Like the smartphone, the other paradigm-shifting technology in the last decade, EV adoption depends on providing a better user experience. Currently, most Americans have yet to understand the full scope of benefits that an EV brings with ownership. The education component combined with a lack of curiosity is the missing piece that currently limits mass EV adoption. When someone buys a gas fueled car today, the operation mimics the same basic formula as it has for the last century. The owner drives until they need more fuel, stop at a fueling station, and in five minutes are on their way again. When someone buys an EV, they must inquire about driving range, battery life, and how to charge, which requires straying from a critical comfort zone. A survey conducted by Ford in 2019 found that “42% of Americans think electric vehicles still require gas to run.”[10]

[7] (Deloitte 2019)
[8] (U.S. Department of Energy n.d.)
[9] (PlugShare 2020)
[10] (Cannis 2019)

According to market research carried out by Ford, ninety-two percent of EV owners will buy another electric car when it comes time to shop for their next vehicle.[11] Once EV proliferation moves beyond the "early adopter" phase, states and local governments will likely need to pass legislation that will ensure EV owners contribute to the maintenance of vehicle infrastructure [e.g. roads, bridges] that are currently supported with a per-gallon fuel surcharge. Currently, twenty-six states impose EV fees.[12] The State of Illinois proposed a $1,000 registration fee on EV owners in early 2019 which was later reduced to $250 after protest from EV owners and stakeholders.

Reducing Impediments

One of the easiest ways for municipalities to encourage EV infrastructure investment is to limit the amount of "soft costs", including expenditures associated with permitting and regulatory delays. When charging infrastructure is bound by the same regulation and review process as other types of development, developers often regard "soft cost" requirements, permits and fees as arbitrary. According to a 2019 report from the Rocky Mountain Institute (RMI), an independent nonprofit with a mission to encourage clean and sustainable energy policy, soft costs often account for three to five times the costs of the physical hardware and software installation.[13] The report also states that "soft costs were also identified as some of the most problematic and unpredictable costs that developers of charging networks encounter, and they are often the reason why a candidate site for a charging station is rejected" (Nedler

[11] (Janczak 2015)
[12] (Harto and Baker-Branstetter 2019)
[13] (Nelder and Rogers 2019)

and Rogers 2019). Charging network operators like Electrify America also bemoan the timeframes and complexity of building codes and permitting in addition to poor communication from utilities. Local governments have tools available to incentivize investment in the installation of EV infrastructure. Municipalities can address costs for charging network developers by considering building and planning procedural adjustments. In particular, The RMI recommends building departments offer a detailed online checklist to identify all required documentation and guide applicants through the permitting process.

Incentives can also be used to address issues of equity in the future transportation landscape. While public-use charging stations are proliferating, more than 80% of EV owners prefer to charge at home.[14] Lack of access to vehicle charging infrastructure is especially problematic for apartment renters. In McLean County, more than 35% of all residents currently rent.[15] Very few, if any local property owners provide EV charging access for their residents. In McLean County, efforts to incentivize local landlords and assist them with permitting and electric grid connection will become a key issue as the transportation landscape moves toward EV proliferation. Nationwide, at least four states and several more municipalities prohibit “unreasonably” denying a tenant’s request to install an EV charger on their properties. For reference, the U.S. Department of Energy Alternative Fuels Data Center has a multitude of resources and case studies from around the country that can be used to facilitate multi-unit dwelling EV ownership among renters.[16]

[14] (U.S. Department of Energy n.d.)
[15] (U.S. Census Bureau 2020)
[16] (U.S. Department of Energy 2020)

In 2018, the International Code Council (ICC) – which provides widely adopted best practices and standards for construction – approved EV charging capabilities for new homes and apartment buildings. The ICC estimates that between today and 2030, there will be a need for 9.6 million new EV charging ports, with at least 80% located in single and multi-family residential buildings. Cost savings average 85% when installation is undertaken during existing construction contrasted with a retrofit.[17] Forward-looking municipalities like Atlanta, Denver, and Seattle, and the State of California already have EV-friendly construction codes in place.

Other Benefits

In the near term, electric vehicles will do little to disrupt the everyday transportation habits of the average American. The average American commutes less than thirty miles round-trip daily, about one-eighth of the range of modern affordable EVs.[18] Furthermore, EVs offer distinct advantages to both the owner and society as a whole. Chief among the benefits for society and individuals are environmental advantages: According to the Union of Concerned Scientists, even when accounting for pollution from battery manufacturing, electric cars generate half the emissions of the average comparable gasoline car over their lifetime.[19] Additionally, the longer the vehicle is in use, the greater the environmental benefit, as much of the pollution is created during battery cell production.

The U.S. Department of Energy sorts vehicle emissions into two general categories: life cycle and direct. Life cycle emissions are notoriously difficult to quantify; they include emissions

[17] (International Code Council 2020)
[18] (U.S. Department of Commerce 2017)
[19] (Nealer, Reichmuth and Annair 2015)

related to fuel and vehicle production, processing, distribution, use, and recycling and disposal. In a traditional gasoline vehicle, emissions are produced when crude oil is extracted, refined, transported, and burned in vehicles. For BEVs, life cycle emissions are lower because electricity power plants are cleaner and more efficient than burning gasoline or diesel. This will only improve as renewable sources of energy become increasingly viable. From a mechanical standpoint, EVs convert about 62% of the electrical energy from the grid to power at the wheels, whereas conventional internal combustion vehicles only convert about 19% of the energy stored in gasoline to power at the wheels.[20] Internal combustion engines like gasoline and diesel vehicles waste a majority of their potential energy on creating wasted heat, whereas EV battery storage is 85-90% efficient.

In contrast with life cycle emissions, direct emissions are traditionally what comes out of a vehicle's tailpipe. These greenhouse gases emit smog-forming pollutants, primarily carbon-dioxide which is a main contributor to global climate change.[21] BEVs have zero direct emissions, which can help improve air quality on a local level and reduce asthma and other air pollution-related illnesses. Another side-benefit of EVs is their inherent lack of noise pollution; studies have shown that the health effects of environmental noise pollution can cause several health issues ranging from stress, cognitive impairment, and fatigue.[22] Because BEVs are whisper quiet, this will greatly reduce road noise, especially near major highways and in congested urban areas.

[20] (U.S. Department of Energy 2020)
[21] (U.S. Department of Energy 2020)
[22] (World Health Organization 2011)

Beyond environmental benefits, operating costs are also compelling; for the owner, the more they drive, the more money they save. In Illinois, the average gasoline price in 2018 was $2.74 per gallon, with the electric equivalent costing $0.70 a gallon. Rural EV drivers save the most on fuel, on average $742 per year with an electric vehicle based on Illinois pricing. Additionally, because EVs have fewer moving parts and do not require regular maintenance, EV owners typically save over $2,000 in maintenance costs over the life of the vehicle.[23]

Where Are We Today?

From EVs to AVs

When Google announced its development of driverless cars in 2009, it seemed to many like science fiction. A decade later, Alphabet, Google's parent company, is just one of many major Silicon Valley powerhouses racing to make autonomous vehicles (AVs) commonplace on public roads. Soon after Google's announcement, major tech firms like Tesla, Uber, Apple, Intel, and NVIDIA, as well as the traditional vehicle manufacturers in Detroit joined the race. Nevertheless, AVs will not arrive as soon as builders once said they would. The first AV planning guide published by the National Association of City Transportation Officials (NACTO) in 2017, has, by their second edition in 2019, been "tempered by recognition of the enormity of the policy foundation that must be laid for us to reach a human-focused autonomous future" (National Association of City Transportation Officials 2019).

From a technology standpoint, todays aspiring AV makers currently utilize either camera-based [vision] technologies alone or in combination with radar, GPS, and currently

[23] (Union of Concerned Scientists 2019)

cost-prohibitive light detection and ranging [LiDAR] systems to traverse public roads. Vehicles continuously scan their environment for obstacles and road signage, while the onboard computer reacts as its programming commands. As of the time this report was written, there are no level three, four or five "fully autonomous" vehicles for sale on the market. There are, however, level "2.5" vehicles for sale which include features that allow them to operate somewhat autonomously in certain scenarios with close supervision by the driver.

Several technology and vehicle manufacturing companies are testing AVs on public roads. Chief among them is Google's Waymo, operating in Phoenix, Arizona which operates a level 4 driverless fleet of modified Chrysler Pacifica minivans. These auto-taxis have traversed more than over 20 million miles and given 100,000 rides since April 2017.[24] [25] Two years after the launch, the company has not revealed how much it will charge customers for each ride, in what conditions they can operate, or how it hopes to pull riders away from other TNCs like Uber and Lyft. In a more speculative direction, Tesla has already sold nearly half a million vehicles with the necessary "full self-driving" computer hardware but has not yet released the software to vehicle owners. More than 1 billion miles have been driven with Tesla's "autopilot" feature engaged, which still requires human drivers to pay attention and intervene when necessary. When not activated, Tesla uses onboard cameras and telemetry to gather data about how human drivers react to certain situations, called "shadow mode." They then use this data about the car's environment and potential autopilot behavior to train a

[24] (Chu 2019)

neural network. This will, Tesla hopes, eventually log enough situational awareness to push a software update that will enable further levels of autonomy than currently possible.

Without human intervention, even the term "driving" has to be redefined: The American National Standards Institute (ANSI) defines driving as consisting of a series of "dynamic driving tasks" when undertaken by an AV.[26] [In several respects, AV driving improves on human performance:] A computer is never distracted, never tired, and never intoxicated behind the wheel. Properly designed AVs will not speed, tailgate, forget to indicate a lane change, nor race other cars. However, some challenges remain: Currently, driving is done by humans who watch the road ahead, maintain the accelerator and brake pedals, and process information about their surroundings without much strain. There will be problems in the software code, and there will be accidents due to yet unforeseen circumstances. There are many small but significant decisions that humans currently make that would fall on the shoulders of a computer. One commonly cited example includes a vehicle with a bike mounted on the back of it, causing the following vehicle's self-driving software to confuse its computer classification as a pedestrian (figure 3).

[26] (Kelechava 2016)

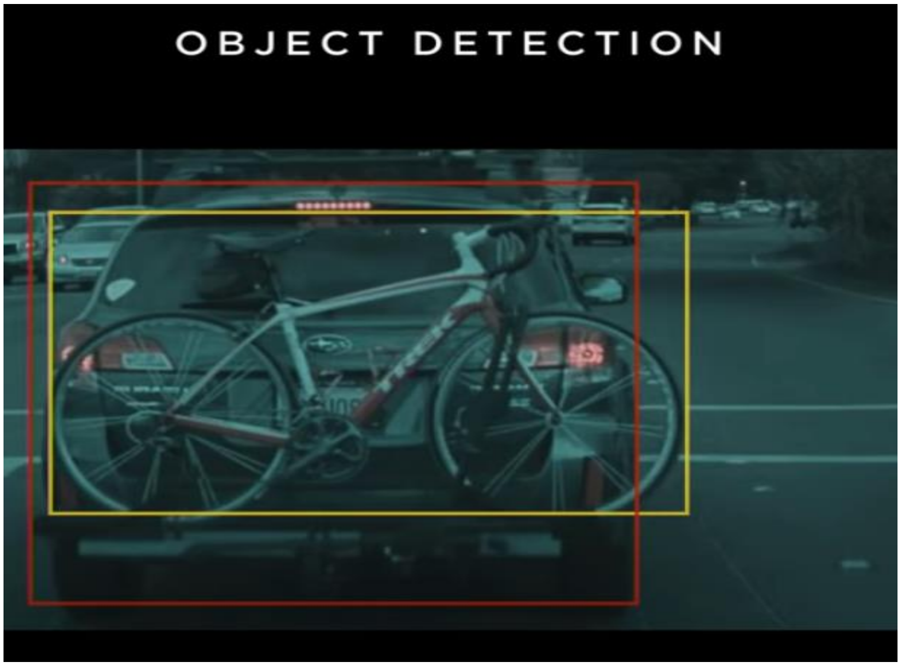

Figure 2 – Source: Tesla Autonomy Day Livestream April 22, 2019 - Timestamp 2:36.34

While the technology is being shaped, society and regulators will have to decide whether AVs need to be “perfect” or simply better than the average human driver. This has regulators and industry experts asking questions about liability: Who will be responsible for these problems when they do occur? The insurance company? The owner? The manufacturer? Currently, in vehicles with Level 3 and below autonomy, the answer is the driver, as they are supposed to be monitoring the road. However, there will inevitably be many cases where the vehicle cannot prevent an impending accident. In one such much publicized case in 2018, a pedestrian was struck and killed by a human-supervised autonomously operating Uber vehicle. This is believed to have been the first pedestrian death resulting from self-driving technology, leaving stakeholders wondering how this investigation would play out. Once the dust settled, prosecutors did not charge Uber with a crime, but the accident raised questions about the comprehensiveness of the federal, state, and local rules governing AV testing and who is liable for potential accidents. The focus on who is responsible for any flaws in engineering and programming will be a key issue for manufacturers, insurers, and regulators to decide.

The In-Between

Between today and the fully autonomous "level 5" future there will likely be a decades long transition period where society, regulators and vehicle makers will determine which aforementioned "version" of the autonomous future will come to fruition. Over the next decade or two, single-family households may transition from owning two vehicles to one; The Victoria Transport Policy Institute contends that in the next decade it will become "cost-effective for a family to give up one of their cars if they're driving it fewer than 10,000 kilometers [6,214 miles] a year."[27] Allstate reports that in 2018, the total cost of car ownership tops $7,300 annually, and predicts that by 2030 driverless ridesharing will cost slightly more than $3,000, saving each car owner up to $4,000 per year.[28]

Currently, AV manufacturers are developing vehicles knowing they will need to share space with traditional vehicles. Of the 38 accidents self-driving vehicles were involved in between 2014 and 2018, 37 of them were caused by other human drivers crashing into the self-driving vehicle. Once SAVs become more than an aberration, self-driving cars might be confined to specific lanes or geofenced areas to get the most benefit the technology can offer. Beyond drivers, cyclists and pedestrians must also be accounted for in this "in-

[27] (Litman 2020)
[28] (The Allstate Corporation 2019)

between" phase. Pedestrians and cyclists must not be separated into walled-off pedestrian zones that further isolate and discourage their travel. Governments at every level will have to provide regulations and guidelines answering these questions as the rollout of AVs comes to fruition.

Answers to these questions could not have higher stakes; today, between ninety-four and ninety-six percent of road accidents are due to human error.[29] In 2016, 37,461 people were killed in crashes on U.S. roadways.[30] This number continues to climb at a rate of between eight and ten percent year over year. If autonomous vehicles were to eliminate these accidents, they would become one of the greatest health achievements of the century, saving over 300,000 American lives per decade,[31] an impact similar to that of mandatory vaccination.[32]

One of the largest impediments to manufacturers hoping to debut the world's first truly autonomous car is the "march of nines"; rare circumstances that a vehicle might encounter while navigating public roads. During an investor presentation in 2019, Tesla CEO Elon Musk noted that at 98% accuracy, autonomous driving is only as good of a driver as a child or someone under the influence of alcohol. The difference between 98% and 99% is exponential; each subsequent decimal point is significantly harder to program than the last. These decimal points take more time to achieve than the first 98%. Each nine manufacturers add after the decimal increases safety by an order of magnitude. Even at 99.999% safe driving, this means an

[29] (U.S. Department of Transportation National Highway Traffic Safety Administration 2017)
[30] ibid
[31] (Bertoncello and Wee 2015)
[32] (Center for Disease Control and Prevention 2014)

AV will crash every 100,000 miles; more than four times worse than a human driver.[33] This raises the question - does the enhanced percentage of successful trips made in conventional situations outweigh the rare failure in a very limited number of circumstances that challenge the AV programming at a fundamental level?

Programmers will also have to use their deep learning algorithms honed over millions of miles to create a set of rules that delves into the philosophical. There are an infinite number of situations in which a computer will have to choose between two or more negative outcomes. Philosophers call this the trolley problem, after a hypothetical example in which a decision to act, or a decision to not act determines the fate of a different victims:

> "An out-of-control trolley is barreling toward five track workers who are trapped on the track ahead of it. If the driver does nothing, the five will be run over and killed. The driver cannot stop the trolley, but he can turn it onto a spur of track to the right, on which there is another trapped track worker who would be run over and killed were he to do so" (Graham 2017).

Because computers would not be making value judgements due to inherent biases or split-second poor decisions, these situations can be morally perilous to program for. For example, what happens if an AVs computer determines that crashing itself is the "best" outcome? This would risk potentially injuring its own passengers in order to avoid harming others.

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[33] (U.S. Department of Transportation 2019)

Therefore, prospective AV builders have turned to their user base to gather data from their respective fleet to develop deep learning algorithms which react similarly to a "good" human driver. Humans are very good at subconsciously contextualizing situations; when a ball rolls into the street, a human knows from experience that a child might follow it. Unless a computer is programmed to do so, it will not. Tesla, for example, has over one-million vehicles on the road which, when operated by a human driver, send vehicle camera footage and telematics data back to Tesla. This data is then mined for driving data and turned into a "deep neural network," a collection of algorithms that recognize patterns, in order to correct any potential corner cases that would render the AV software confused.

Regulatory Environment

Once the technology is ready, multilayered regulatory barriers to implementation remain, extending from municipalities, to states, up to the federal government. Federal regulation begins with Congressional decisions in legislation, followed by actions by the numerous regulatory agencies that codify Congressional intent. As with any regulatory process, the more levels involved, the greater the potential for confusion, and broad assumptions about the relationship between levels of regulation may not be met. With respect to the regulation of autonomous vehicles, regulatory complexity is increased by a rapidly shifting state of the technology and the regulations that respond to it.

The federal government has traditionally assumed responsibility for ensuring safety, the core issue for most federal regulations regarding transportation. This includes standards for the interstate highway network and the structural integrity of bridges and other infrastructure, extensive regulation of specifications for vehicles of all kinds and reflecting all modes, compliance with data collection for travel behavior and traffic volumes, air quality, fuel efficiency, regulation of freight traffic movement and numerous other operating aspects of the national transportation system. States are allowed to control who, or in this case, what, is allowed to drive. In addition, as in Illinois, many states regulate vehicle insurance as a condition of driver licensing and vehicle registration. These requirements sometimes create access barriers to the use of personal vehicles.

During the current period in which the industry's principle actions are development and testing, the USDOT has adopted a noninterventionist approach to oversight of AV technology. Companies are expected to voluntarily adhere to technical and safety standards unless there are applicable local or state regulations. The level of industry compliance required will intensify as autonomous vehicles are an increasing proportion of vehicles on the road.[34]

The USDOT has outlined six major priorities regarding regulation of AVs in the 2018 report *Preparing for the Future of Transportation*.[35]

1. Prioritization of Safety
2. Remaining Technology Neutral
3. Modernization of Regulations
4. Encouragement of Consistent Regulations
5. Proactive Preparation for Automation

[34] The National Highway Traffic Safety Association (NHTSA) has issues a voluntary, twelve-point safety checklist for AV operators.
[35] (U.S. Department of Transportation 2018)

6. Protection and Enhancement of Individual Freedom

Of the smaller counties and municipalities which have already passed AV specific policies have done so to recognize potential economic benefits. These policies are often enacted due to large research institutions asking for permission to start testing on public roads. For example, Johnson County, Iowa is home to the National Advanced Driving Simulator (NADS) at the University of Iowa. The county board of supervisors passed a proclamation that entitled "Encouraging Autonomous Vehicle Testing as a Public Safety and Economic Development Initiative" which granted NADS access to begin testing on public roads.[36] The stated goal is to encourage car manufacturers to conduct testing in the county, brining local economic development investment that otherwise would not be possible without this change in policy.

Nevertheless, policy experts warn that local policymakers must exercise caution when enacting policies that allow AV testing in public roads; Linda Bailey, the executive director of the National Association for City Transportation Officials (NACTO) warns that local leaders and governments need to exercise caution when trying to attract AV pilot program testing:

> "Cities need vehicles to meet a clear minimum standard for safe operations so the full benefits of this new technology are realized on our complex streets. We cannot afford for companies' race-to-market to become a race-to-the-bottom for safety."[37]

[36] (The Johnson County Board of Supervisors 2014)
[37] (Bliss, Fatal Uber Crash Raises Red Flags About Self-Driving Safety 2018)

At minimum, local officials should be aware of restrictions created or under consideration at the state level. Ideally, communities considering testing programs should be involved in the state discussion as much as possible, both to understand the regulatory environment and to provide context for state officials deciding the content of such restrictions.

Economics

One economic impact of removing the human element from driving is the cost savings: McKinsey estimates the overall economic savings of a 90% reduction in auto accidents at over $190 billion per year due to decreases in medical and auto repair costs.[38] Accounting only for improvements to safety, the repurposing of parking into revenue generating businesses could produce economic benefits of some $850 billion. Beyond accident avoidance, increases in productivity while travelling and traffic efficiency due to AVs are estimated to "contribute $1.3 trillion in annual savings to the US economy alone" according to a 2015 report by Morgan Stanley.[39] Some 75 billion total hours Americans currently spend driving each year will be reallocated to business and consumer potential, accounting for an 8% increase in GDP.[40] These technologies will transform the entire economy, beyond the traditional transportation industry. This disruption will affect tax and usage-based revenue, housing, employment, and more. Deloitte Insights concludes their 2015 *Future of Mobility* report with a statement about the profound disruption that AVs will create: "Every aspect of the modern economy based on the assumption of human-driven, personally owned vehicles will be challenged."[41] Entire industries

[38] (Bertoncello and Wee 2015)
[39] (Morgan Stanley 2015)
[40] ibid
[41] (Corwin, et al. 2015)

will rise and fall: insurers, technology firms, vehicle manufacturers, body shops, and cargo shippers. The economics will soon be too compelling for companies to both continue the status quo and remain competitive.

Rural communities have a lot to gain from AVs; beyond the financial savings from reduction in fuel and maintenance costs, rural drives stand to benefit the most from improved safety. Rural drivers also accounted for 46% of all traffic fatalities despite only 19% of the U.S. population living in rural areas.[42] Unfortunately, they are also the *least likely* to realize these benefits due to the extended wait periods of time for a taxi to appear at the desired pickup location. On the favorable side for rural areas, improved ease of movement could lead to population gain from urban areas as people stop prioritizing the convenience of living near employment centers. When economics inputs get cheaper, the net effect is generally more use, not less. If a commute were to include enough time to get ready, watch the morning news while sipping coffee, or take a nap on the way home from the office, living outside of town would likely to become more appealing than it is today. Demand for housing in the suburbs might grow as the inconvenience of commuting evaporates. There is also concern that AVs will foster sprawl by extending currently unappealing commutes into the exurbs and rural areas.

AVs will free up 50 minutes per day for the typical commuter. These travelers can choose to spend their commute either working, relaxing, conversing with fellow riders, or accessing entertainment. In-car entertainment and marketing will become the next frontier for media groups. Industry players are already working on how to monetize the "25th hour;" a term that

[42] Rural/Urban Traffic Accidents NHTSA 2017

refers to the extra hour that users get back while no longer having to drive during a commute. Leading companies in the world are already vying to monetize this newfound free-time. The Consumer Electronics Show in 2019 previewed the visions emerging for the entertainment and activities that can be created during this free time. The German automaker Audi has partnered with Disney to create *Holoride*, a “procedurally generated virtual and augmented reality experience that match[es] the motion and length of each car ride”[43] Intel and Warner Brothers showcased an augmented-reality gadget that will turn your commute into an adventure through Batman’s Gotham City. Visa and SiriusXM have partnered for in-car purchasing of fuel, parking, and coffee via biometric verification and satellite connection.[44] These ventures have the potential to create global digital-media revenues of more than $5 billion per year “for every additional minute people spend on the mobile internet while in a car.”[45] The act of personal transportation will be fundamentally changed when the rider no longer has to pay attention to the road.

Beyond entertainment and in-car shopping, other industries will be impacted too; traditional parts manufacturers will be supplanted by more technology-focused companies which build the software and hardware needed for cars to make decisions. Airlines, specifically short-haul flights will be impacted when AVs make car travel more comfortable and less bothersome than air travel. Fast-food companies will be less successful luring in convenience customers when people input their point A to point B trip, drastically lowering impulse food purchases. These are a few of the industries that will be affected by self-driving cars but will

[43] (Holoride 2020)
[44] (Herman 2020)
[45] (Bertoncello and Wee 2015)

need to tweak their business model to prosper. Insurance companies will likely have to migrate from a personal ownership model to a fleet model. Instead of basing premiums on the judgement of human risk assessment, hardware and software will need to be evaluated in order to accurately assess risk. State Farm has recently been awarded U.S. patents for "Accident Fault Determination for Autonomous Vehicles" and "Autonomous Feature Use Monitoring and Insurance Pricing."[46] If insurance companies are able to accurately price risk associated with AVs, they will thrive in the transition from human to robot drivers.

Other industries will be completely reshaped but will also be afforded significant opportunities by AVs if they are able to successfully make the transition. The ride-hailing explosion ushered-in perhaps the largest shift in transportation habits this century. Unprepared cities saw vehicle miles traveled (VMT) and congestion increase as everyday people eschewed public transit for a door to door, private ride. Studies suggest that ride-hailing draws people away from public transit, with an estimated 49-61% of ride-hailing trips which either wouldn't have been made at all if these services didn't exist, or would have been made by foot, biking or transit.[47] In short, all those trips added cars to the road that otherwise would not have existed. Presently, transportation network companies (TNCs) like Uber and Lyft rely on third-party "contractors" to drive.[48] These contractors are currently responsible for costs associated with fueling, maintaining, and cleaning their own personal vehicles. In the future many TNCs stated vision is to eliminate the human driver altogether. Each company will then be responsible for deploying, maintaining and perhaps even manufacturing their own fleet of vehicles. TNCs have

[46] (Konrardy, et al. 2019)
[47] (Clewlow and Mishra 2017)
[48] (AB-5 Worker status: employees and independent contractors 2019)

years of experience in mapping and user data which may help them become the default AV hailing companies.

AVs and Public Transportation

Public transportation is another industry that will be affected by automation, both fiscally and behaviorally. Currently, there are numerous driverless shuttles on the road, including at the University of Michigan and Heathrow Airport in London.[49] Fixed-route transportation is perhaps the simplest to modify; planned, repetitive tasks are the easiest to automate, and schedules are easy to program. It is becoming clear that AV's will have a significant impact on public transit ridership. The Journal of Transport Reviews found that AVs are mostly found to reduce public transport ridership. Without the cost of human drivers, autonomous ride-hailing services will be able to work around the clock and cut prices significantly. The authors warn that public transport systems will eventually need to themselves become automated to become more reliable. This will allow public transport to be viewed as the nucleus for how the urban population get around.[50] It is crucial is that AVs are shared, work with public transit, and municipalities make the necessary investments in technology and infrastructure. These investments will provide the best possible chance to support a connected, equitable multi-modal transit network.

Public transit agencies might in the future partner with AV ride-hailing companies for first-mile, last-mile solutions in order to get people to and from main transportation hubs. The

[49] (Ultra Global PRT 2011)
[50] (Soteropoulos, Berger and Ciari 2018)

use of AVs as a means for public transport also provides an opportunity to improve mobility for the non-driving population; disabled persons, elderly persons, and even perhaps youth passengers might enjoy expanded opportunities for accessing crucial services, education, and employment. Currently, partnerships with human-driven transportation network companies have already been in at least twenty-seven communities across the United States with mixed results.[51] There exist concerns about data-sharing and how to make these partnerships more equitable from an access standpoint. In one such case, an exurb of Toronto decided to subsidize Uber trips for its residents at a cost of $3 per trip. City officials estimated that building its own bus lines would cost an $270,000 in Canadian dollars for the first year of service for a projected 17,000 riders, or roughly $16 per trip.[52]

The business model of ridesharing often widens the disparity gap that public transit aims to close. Certain populations including disabled people, those without smartphones, and those without a bank card are effectively excluded from using the service. Proponents of transit agency and ride-hailing partnerships argue that because TNCs offer door-to-door service, it can be more equitable by providing residents access to transportation that live beyond walkable distance from public transport. TNCs are already heavily subsidized by shareholders and using public funds to further drive-down costs will likely be untenable in the long term. Eventually, as TNCs are expected to turn a profit by their shareholders, fares will increase and the cities who have chosen to subsidize rides will either have to increase their subsidy to keep pace or go back to the drawing board.

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[51] (Schweiterman, Livingston and Van Der Slot 2018)
[52] (Bliss, Uber Was Supposed To Be Our Public Transit 2019)

Revenue Strategies

Until a standardized platform for tracking and collecting use taxes from personal and SAVs exists, one of the largest impacts that AVs will have on local governments is a gradual decline in revenue. While all city budgets will be impacted, this will be particularly troublesome for small municipalities whose revenues disproportionally derive from traffic fines. In 2018, the City of Chenoa reported Total General Revenues of $1,093,487, with $241,133 [22.1%] of that revenue coming from Police Fines and Services.[53] If AVs are required to follow all traffic and parking rules and regulations, these revenues will dwindle as AV adoption rises and eventually be eliminated entirely. According to one Bureau of Justice survey, more than 85% of all involuntary stops by police were traffic-related.[54] When operating properly, nearly all of these traffic violations will be eliminated by AVs. This, in turn, could also impact staffing levels; as traffic collision rates decline the apparent need for traditional traffic enforcement efforts also decrease. Current staffing levels for first responders could either be reduced by a significant amount or repurposed for other initiatives.

First responders will also need to adapt to the changing landscape in their training protocols. Many fire departments have already been trained on how to deal with an electric vehicle fire, but will require further mechanical and technical training when there is no longer a driver in the car. Currently, AVs on the road like Google's Waymo automatically pull over if it detects a police or emergency vehicle is in the vicinity with flashing lights. The vehicle then can unlock the doors and roll down the windows for its off-location "rider support" team to

[53] (City of Chenoa, Illinois 2018)
[54] (Langton and Durose 2016)

communicate with law enforcement. Owners, riders, and first responders will need to be trained accordingly once a standard protocol for interaction is established.

As mentioned earlier, governments will have to come up with new ways to fund infrastructure improvements necessary to promote and sustain AV proliferation. Today, federal, state, and local governments already struggle with budget shortfalls. The growth of EVs and AVs will likely further increase these shortfalls it not properly planned for. According to the American Society of Civil Engineers, the United States has a backlog of over $836 billion dollars for highway and bridge capital funding.[55] Fuel-tax revenues will diminish as more EVs hit the road, and personal licensing and vehicle registration income will also dwindle as SAVs burgeon. Industry publications suggest public sector officials should face this financial challenge by considering whether new revenue streams would encourage or discourage use of shared autonomous mobility.[56] Some examples of potential revenue streams include:

- Collecting user-fees for AV only lanes on roads and loading locations. Some policy-focused organizations suggest a fee per mile structure, but in practice that will likely be difficult to implement.
- Infrastructure in the form of smart meters that monitor demand and price the curb accordingly. These would also be able to provide data to potential vehicles and municipalities on whether they are occupied or not.
- Creation of pick up and drop off zones to facilitate ease of access to busy urban areas.

[55] (American Society of Civil Engineers 2017)

[56] (Duvall, Hannon, et al., A new look at autonomous-vehicle infrastructure 2019)

- Construction of staging areas in underutilized parking lots where AV fleets can sit idle and charge when dropping-off and picking-up passengers.
- Price vehicles with passengers less than vehicles running errands (AKA "dead-heading" or "zombie miles") at a higher rate to discourage use.

On the positive side, the public sector will also enjoy potential savings from AV proliferation. A few examples include:

- Public-transit driver salary and benefits will be eliminated. Labor and fuel costs account for more than 66% of Connect Transit's FY 2020 operating budget.[57]
- Publicly owned fleets and services like residential waste pickup will be largely automated.

Divergent Futures

Two deviating possibilities are predicted to unfold over the next few decades in transportation; which future becomes a reality will largely depend the approach taken by planning professionals and regulators. The first envisions fleets of autonomous buses navigating effortlessly alongside ridesharing dispatched autonomous taxis. Many Americans will abandon personal vehicle ownership due to the flexibility that shared autonomous vehicles (SAVs) offer without any of the built-in costs of ownership. Streets will be quiet, safe, and accessible to all demographics of the population, and the physical environment will promote pedestrian movement. In this scenario, the benefits of autonomous electric vehicles

[57] (Connect Transit 2018)

will integrate with other modes of transport to form a truly sustainable and equitable transportation system for all users. The creation of "mobility hubs" (figure 3) allows travelers to transfer easily between different transportation modes.[58] Shared transit is perceived as convenient, affordable, and safe.

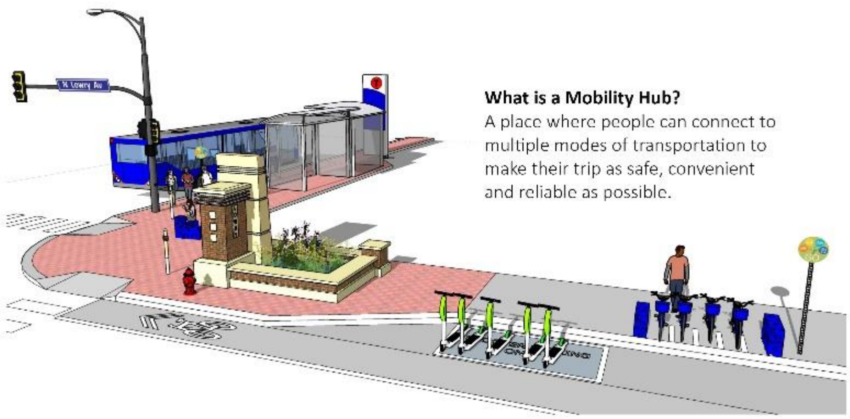

Figure 3

In the second scenario, AVs are purchased primarily for personal use. Those who own their private AV will be dropped off at work by their personal AV. The car then may be "rented out" while they are at work providing an additional source of income. Droves of autonomous vehicles whisk products and deliveries from shops to customers, deliver meals from restaurants, and packages from distribution centers to customers via online purchases. Vehicle miles traveled (VMT) could increase fifty percent.[59] The result is "induced demand" due to newfound ease of use. This "induced demand" phenomenon is not hard to imagine; unoccupied vehicles between trips accumulate unoccupied "zombie miles" which drastically

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[58] Large cities such as Los Angeles, Columbus, and Minneapolis have launched or are planning mobility hubs. See http://www.minneapolismn.gov/publicworks/trans/mobilityhubs

[59] (Harb, Xiao, et al. 2018)

increase congestion and traffic. In a small sample size (n=13) study conducted via U.C. Berkeley, car owners were given a chauffeur for the week in order to simulate a driverless car. The co-author of the study clarifies how this relates to AV technology: “Nearly everything a self-driving car will be able to do for you in the future, a chauffeur can do for you today.”[60] The results of study indicated a staggering 83% increase in VMT, well over the 20-30% predicted by previous studies.[61] The reason for this increase was that the vehicle was able to make trips that would have otherwise not been worth the owner’s time: For example one “owner” sent the car on trips to the various stores to pick up a small item that would have normally waited until the next day. In one case, an elderly couple took a day trip to Napa that would have otherwise been too far for them to drive. Another used the car to get dropped off at work, then sent it back to drop off the kids at school, and later return to the house to avoid parking fees in a downtown area. Futurists and urban planners anticipate that AVs may circle neighborhoods and city blocks while waiting for their owners to finish their coffee to avoid parking restrictions and fees. In this scenario, the potential benefits of autonomous vehicles are suppressed by failures to discourage induced demand and move beyond the conventional status quo of personal, private transportation.

Co-author of the study, Mustapha Harb, seeks to separate VMT into subcategories; “good” and “bad.” An example of “bad” VMT is a trip where the car is not transporting passengers but instead running errands on behalf of people that otherwise would not have driven themselves. Another “bad” example is when a vehicle is replacing more efficient forms

[60] (Harb, Zombie Miles And Napa Weekends: How A Week With Chauffeurs Showed The Major Flaw In Our Self-Driving Car Future 2019)
[61] ibid

public transportation, as one study participant did during their week with a chauffeur, foregoing their normal commute on public transit. "Good" VMT can be found in the form of increasing the mobility of currently underserved groups such as non-drivers, senior citizens, and the disabled. VMT could increase by 14% for these currently underserved groups alone. If minors are assumed to be "non-drivers" but are able to use AVs, this could double that number.[62] It is important to note that any increase in VMT could *add* to the absolute number of crashes and deaths on U.S. roads. Even if AVs could be 80 percent safer than human-driven vehicles, the absolute decrease in number of crashes could be far less than 80 percent due to the increase in total VMT.

Policy Implications

This study sought to show how each divergent path could steer societal norms. Policies should first and foremost discourage zombie miles. What those policies look like is still being debated, but most policy experts agree that the simplest mechanism for letting people decide for themselves which trips are worth making is to simply charge them for it. Some organizations argue the U.S. DOT needs to research different approaches for tracking vehicles on a per-mile (VMT) basis, with various multipliers based on congestion or how many people are in the car.[63] These deterrents should be implemented before the technology becomes public. It will be very difficult to take something away from the public or regulate its use once it becomes a normal aspect of daily life.

[62] (Harper, et al. 2016)
[63] (Lewis and Grossman 2019)

Each of these two divergent futures would require roughly the same technology but would have been planned for and regulated differently. Similarly to how electric vehicles will likely require little direct financial investment by the public sector, autonomous vehicles will also be able to traverse today's roads without large-scale infrastructure change out of necessity; car manufacturers realize that they cannot wait for every road in every jurisdiction to be outfitted with new sensor technology, high-speed connectivity, and clearly marked lanes. Maintaining current streets, including maintaining a state of good repair should be adequate for municipal government infrastructure investments in the near term. Deterioration of roads is a longstanding concern of transportation system users, which will carry over to owners and users of AVs. Without proper lane and traffic markings on public roads, especially during the negotiation of intersections, AVs will be less precise. Governments should consider working to ensure high-accuracy mapping is available to manufactures once a standard format becomes clear.

This does not, however, mean that the current status quo of today's roadways will remain sufficient moving forward. One of the largest transformations to the modern urban fabric will be to parking infrastructure. Researchers at the Massachusetts Institute of Technology (MIT) predict that transition to shared vehicles will decrease parking needs by 70%.[64] Currently, privately owned cars stay parked for 95% of the time.[65] There are currently three parking spots for every vehicle on American roads, with parking often accounting for many times the amount of land dedicated to human uses. In nearby Peoria, "the amount of

[64] (Kondor, et al. 2018)
[65] (Shoup, The High Cost of Free Parking 1995)

land devoted to surface parking in the county actually surpasses the amount of land devoted to buildings."[66] The gradual, sustained transition to shared mobility will require progressively less parking infrastructure. Potentially 50-70% of land occupied by parking spaces today could be repurposed once AVs are commonly in use.[67] In addition, with the decrease in parking space, reports from the American Planning Association encourage zoning which promotes storefronts adjacent to the street, especially in mixed-use developments.[68] This will allow for greater ease of access for passengers being dropped off, and better foot traffic for nearby businesses.[69] On-street parking in residential zoned areas will be greatly reduced or eliminated altogether as AVs will use suburban residential roads for pick-up and drop-off of people.

Long term, municipalities and Metropolitan Planning Organizations must prepare for a fully autonomous world. Public officials should already be considering potential modifications needed to accommodate emerging technologies. AVs will eventually require the ability to utilize sensors, record, and upload information in real-time. Researchers from the University of Texas at Austin are currently working on an artificial intelligence-based "reservation" system (figure 2) which would massively increase safety and efficiency by communicating with vehicles before they reach an intersection.[70]

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[66] (Quednau 2017)
[67] (Skinner and Bidwell 2016)
[68] (Spivak 2018)
[69] (Shoup, Parking is Sexy Now. Thank Donald Shoup 2018)
[70] (Dresner and Stone 2007)

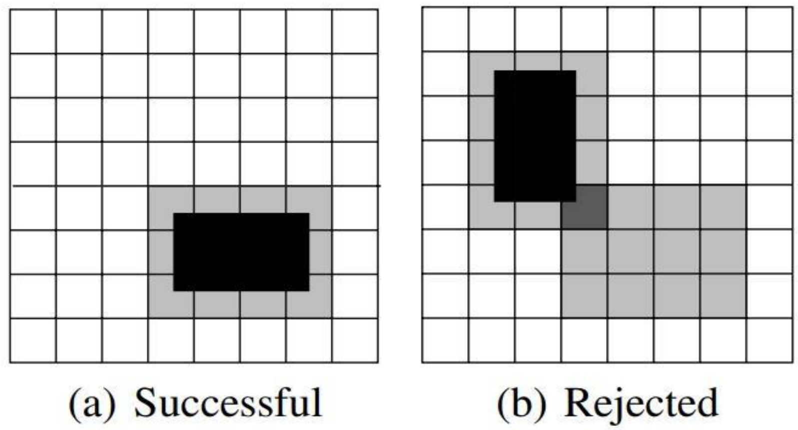

Figure 3

In this figure, each black box represents the vehicle's dimensions and the grey boxes surrounding them represent a buffer zone around the vehicle. This system would predict whether an accident was imminent and communicate with the vehicle accordingly, allowing it to traverse an intersection without slowing down if the computer predicts no imminent crash. Potentially, every signal will require upgrades to include an array of new sensors, each communicating with multiple vehicles and pedestrian traffic in real time.

The intersection pre-registration system hypothesized in figure 2 would require high-speed and extremely low latency communication between each vehicle and each signal. AVs will require high-speed vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) connectivity and sensors. These sensors would relay crucial data to vehicles about speed limits, turning restrictions, traffic ahead, and countless other data points. All that communication largely depends on currently rolling-out access to high-speed, ultrafast 5G wireless networks. Tech giant Intel estimates that autonomous vehicles could generate up to four terabytes of data per day, requiring low-latency wireless connected to fiber networks and data centers.[71] Counties and other governments will have to find funds to finance these potential upgrades in order for AVs to traverse each jurisdiction seamlessly

As AVs become more commonplace, proper planning, funding, and preparation for this new technology becomes imperative. Without the foresight of all stakeholders, the result will be swelling congestion and sprawl, choking municipal budgets, and requiring further expansion of roadways.

Conclusion

After the initial optimistic timelines for AV proliferation came and went, enthusiasm has given way to a more moderated, realistic timeline. The second edition of NACTO's *Blueprint for Autonomous Urbanism* continues to prioritize walking, biking, rolling, and taking transit "while taking advantage of new technologies in order to reduce carbon emissions, decrease traffic fatalities, and increase economic opportunities."[72] All told, self-driving cars have the potential to improve existing transportation and create new economic opportunities, but without proper planning and proactive policy adoption, they also might increase urban sprawl, reduce walkability and choke roads with deadheading, empty cars. All these things could strain public infrastructure in McLean County and place a financial burden on our local governments to maintain our infrastructure with less money coming in through traditional outlets like parking and speeding fines. Autonomous vehicles offer an exceptional opportunity

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[71] (Winter 2017)
[72] (National Association of City Transportation Officials 2019)

to reset our roads and address the fundamental issues facing our streets today; safety, congestion, access, and mobility. Proper planning for automated vehicles will play a key role in making this transition work for everyone.

Autonomous vehicles will drive the most disruptive changes in transportation since the invention of the automobile itself. Which of two "divergent paths" outlined in the report are taken will largely be determined by many of the largest players in the new mobility sphere, including the companies developing new technologies and services, policymakers, and regulators. While private companies might boast altruistic visions of bringing improvements to society at large, government ultimately is responsible for the protection of public safety and well-being by ensuring policy related to the inception of autonomous vehicles is thorough, future-proof and expeditiously adopted.

Self-driving cars will provide both public and private benefits. One of the most difficult aspects of researching for this report was accurately capturing the overlapping interests of varying agents and entities. The private sector, including tech companies, vehicle manufacturers, consulting firms, and financial institutions are interested in the economic opportunities provided by autonomous vehicles. Along with the fiscal impact on municipal budgets, the public sector includes planners and other organizations that are coming to understand the potential impact of AVs on civic well-being, privacy, and quality of life. How might the two be reconciled or prioritized in any given project?

It is wrong to suppose that innovation and regulation are always necessarily opposing forces. Well-implemented regulations could also act as a necessary mechanism for innovating new forms of mobility. Technology and auto manufacturing companies are already inventing new products and services that will soon be on the road. Without clear guidance and standards from a broad spectrum of regulators, these companies risk losing large sums of their investments on endeavors that may not meet standards set at a later date. If the “good” divergent path is to triumph over the next decade or two, congestion, emissions, and issues of access will require cooperation among both private and public entities.

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