THE FUTURE OF SUSTAINABLE TRANSPORTATION

INTRODUCTION

The transportation industry has long been plagued by a combination of crippling issues: i) infrastructure; ii) traffic congestion; and iii) road safety.

In terms of infrastructure, roads are crumbling, bridges are collapsing, and our transit systems are failing [1-8]. The latest report card from the American Society of Civil Engineers (ASCE) grades our country's infrastructure as a D [9]. Almost a third of our major roads have outlived their functional lifespan and are considered to be in poor condition; more than 70,000 bridges are structurally deficient and in need of replacement; and only a small percentage of our trains are equipped with the safety technology needed to automatically prevent derailments and crashes caused by most human and mechanical errors [4, 8, 9]. Tackling these problems will take more than a new coat of paint, and ASCE warns us that we will need to spend $1.1 trillion more than currently budgeted by 2020 to even keep the transportation system at its current level of performance [9]. In fact, some of the infrastructure still being used along Amtrak's northeast corridor dates back more than 150 years to when Abraham Lincoln was President [10].

At the same time, we continually hear that traffic congestion is bad and getting worse. Although we had a brief respite, somewhat coinciding with the economic downtown, the latest Urban Mobility Report put out by the Texas Transportation Institute says that traffic congestion causes Americans "to waste more than 3 billion gallons of fuel and kept travelers stuck in their cars for nearly 7 billion extra hours – 42 hours per rush-hour commuter" [11]. This problem is not limited to big cities. While average traffic delay doubling for the average US commuter since the early 1980s, it quadrupled for those living in cities with fewer than 500,000 residents over that same time span [11]. This is a problem that supposedly costs Americans more than $186 billion annually [12, 13].

Beyond the infrastructure and congestion crises, transportation also faces significant road safety concerns. Road fatalities in the US went from being almost non-existent at the turn of the twentieth century to being one of the leading causes of death less than a generation later in 1926 [14]. Now, more than 1.2M people worldwide die on the roads each year. In fact, road crashes wipe out more productive years of life than any other disease, including cancer and heart disease combined. These numbers do not even include the other 50 million annual injuries caused by road crashes, nor the human health effects of transportation-related air pollution [15].

These three issues have regularly been labeled a "national embarrassment" and cited as a major vulnerability in the lives of everyday Americans with respect to health, economic well-being, and overall livability [4, 16]. However, these are also problems easily solved if we only had more funding and better technology.

Everything discussed thus far is true – except for the last sentence. We continue to blame our transportation problems on a simple lack of funding while simultaneously believing that these issues would disappear if we threw enough money at them. The evidence, however, refutes this widespread belief. Under the current system, most federal transportation dollars funnel through state departments of transportation. Old and new projects compete over this same pot of money; unfortunately, nobody gets to have a ribbon cutting ceremony for the completion of a maintenance project. Over a recent five-year span, state DOTs spent more than $108 billion on the new construction of just over 1% of our roadway system and $81 billion on the other 99% of roads in need of repair [3]. The bigger problem is that such an approach can exacerbate the problem. With respect to pavement maintenance, a single dollar spent on prevention saves between $4 and $10 on rehabilitation [16]. Another common

assertion is that roads, unlike transit, pay for themselves though user fees; in reality, this is not the case [17, 18]. Summing all the relevant road users fees such the gas tax, tolls, vehicle registration fees, and licensing fees, almost half of our existing roads do not carry enough traffic to pay for their own maintenance (let alone the initial construction costs) [17]. By continually building more roads, the roads we already have become all that much harder to sustain.

With the Highway Trust Fund on the brink of insolvency, the funding problem is certainly challenging. However, this paper is more about the second anticipated panacea: technology. Proponents of autonomous cars, for instance, claim that putting technology in charge of driving – instead of humans – will result in much better efficiency and safety. The National Highway Traffic Safety Administration (NHTSA) says more than 90% of road fatalities are caused, at least in part, to human error. Removing human error, in theory, would have saved almost 34,000 American lives just last alone. Humans also require what is called perception-reaction time. This means giving the car in front of you enough space where if it stopped, you would have enough time to see that happen, hit your own brakes, and stop safely. Connected and/or autonomous cars could reduce these headways, greatly increase the capacity of our existing infrastructure, and supposedly eliminate traffic. Not only will autonomous cars cure our road safety and traffic congestion ailments, but we would also have little need for parking spaces or street signs. This would give us more room for other modes such as walking and biking, more compact development, and/or parks. New Urbanists should love all this. Unfortunately, it is not that simple.

First, I consider the litany of reasons why technology may not be the savior it is being made out to be. After delving into what we might be able to learn from the historical precedence of cities and transportation technology, we then apply this knowledge to lay out a more fundamental vision for the future of sustainable transport.

TECHNOLOGY AS A SAVIOR?

Instead of sitting back and waiting for technology to solve our transportation problems, it is worth thinking through the realities and pretenses of the technological possibilities. This section discusses many of the benefits of autonomous cars in light of the unanswered questions and potential concerns.

Efficiency

The MIT Sensable City Lab recently released a study on the promise of autonomous intersections. Essentially, the idea is that connected and autonomous cars will make traffic lights obsolete. In doing so, traffic capacity would be doubled, and in theory, eliminate traffic delay and queues. In a March 2017 presentation I attended in Sydney, Australia, Sensable City Lab director Carlo Ratti showed an accompanying video depicting a conventional intersection – with queues forming – in contrast to an autonomous intersection with a neverending stream of cars rushing through – and no queues. Ratti called the autonomous intersection the "future of urbanism".

One of the more obvious unanswered questions: where do the pedestrians go?

A second issue: few of the efficiency benefits of autonomous cars can be realized without a fully autonomous system. If the market penetration of autonomous cars is any less than 100% – and there is one guy trying to drive through town the old-fashioned way – intersections such as the one proposed by MIT would not work.

Preferences

If we need full autonomy to find the efficiency benefits, just how difficult would that be to achieve? Expert opinions vary; you typically hear that it would take anywhere from ten years to upwards of forty in order to reach a fully autonomous system. Nevertheless, a recent Business Insider article suggested that highways would be fully autonomous within two years [19]. Obviously, two years is a difficult scenario to realistically fathom. With eight Fast & Furious movies – and counting – having made more than $1.1B, we may not be much closer to full autonomy in forty years either. As Dr. Peter Norton points out, when you type "America's love affair with…" in Google, the first two autofill answers are cars and automobiles. Next on the list is guns. This speaks to the predicament we might end up in where the car debate mirrors the gun debate. While driving is not exactly protected as a Constitutional right, the prevalence of people that love driving or consider it a part of their culture cannot be discounted. You are going to have to pull this *steering wheel* out of my cold, dead hands.

Risk Compensation

Cars are not either autonomous or not. Instead lies a spectrum of autonomy, ranging from level 0 through level 6, with level 6 indicating a completely autonomous car. Many current driver assist technologies – such as lane change assistance or emergency brake assist – fall somewhere in the middle of the spectrum. The intent behind most of these new technologies is to improve safety. The underappreciated problem has to do with risk compensation. Risk compensation refers to the natural human inclination to alter one's behavior depending upon their perception of safety. In other words, when one feels that a situation is dangerous, they are likely to be extra careful. On the other hand, if a situation feels safe, they might become a bit more lackadaisical. When it comes to vehicle technology, for instance, lane change assistance should increase safety when used in addition to traditional behaviors of looking over one's shoulder and/or using mirrors. If a person begins to rely on such a technology exclusively – instead of also going through the conventional routine – then the road safety outcomes are not as clear-cut.

Elements of risk compensation – and unintended safety consequences – have been uncovered in many

areas beyond transportation, including football and auto racing. When Google first let their employees use their autonomous cars for the weekend in 2013, they told the employees that even though the car was autonomous, they needed to be ready to step in at a moment's notice [20]. Google then hid cameras throughout the car to monitor user behaviors and found passengers texting on their phones, applying makeup, and taking naps while the car exceeded speeds of 55 mph. Similar issues will likely crop up for any vehicle technology that sits less than level 6 on the autonomous spectrum. On the road safety front, this again speaks to the need for full autonomy to realize the benefits.

Reliability

Even with the perfect technology, there are many challenges to ensuring adequate dependability. How often does your cell phone not work exactly as you want or as quickly as you would like? Are we willing to accept a similar level of reliability with autonomous vehicles? Since the possible negative ramifications of malfunctioning autonomous cars likely exceeds those of malfunctioning cell phones, we will likely be asking for a higher reliability standard.

The question is whether this is possible. A Tesla driver using autonomous mode on a limited-access highway recently rammed at 65 mph into the back of a firetruck that was stopped in the roadway. Tesla admits that their "Traffic-Aware Cruise Control cannot detect all objects and may not brake/decelerate for stationary vehicles, especially in situations when you are driving over 50 mph (80 km/h) and a vehicle you are following moves out of your driving path and a stationary vehicle or object is in front of you instead" [21]. Luckily, there were no fatalities. Although America has unfortunately become accustomed to tens of thousands of deaths on our roads each year, are we willing to accept them when technology, instead of humans, are to blame? Figuring out the threshold where we would be willing to accept technology-at-fault fatalities is a question that has yet to be answered.

This all does not even begin to get into issues such as rain, snow, or sun glare. It is one thing for an autonomous car to perform admirably in perfect conditions; it will be much more of a challenge to ensure it also does so while dealing with nature-related issues. Dirt build-up can probably be considered more of a maintenance problem, but it is one that could severely impact the capabilities of the sensors on an autonomous car. Will this require legislation forcing autonomous cars to be kept clean?

Ownership Model

There is also the key policy decision regarding the autonomous vehicle ownership. Will they be a shared resource, or will we continue the personal ownership model? If the former, I can get a ride to work, and the car can then continue to be used by others while I am at the office. If the latter, would I park my autonomous vehicle in the central business district all day? Or would it be able to function as a zero-occupancy vehicle? If so, could I have it circle the block by itself a dozen times while I am in a meeting or grabbing dinner? Could I send it home and ask it to pick me up later? Whatever the answer is to such questions, our autonomous future could actually lead to an exponential increase in vehicle miles traveled (VMT) and congestion (despite the increased perception-reaction times and reduced headways).

Induced Demand

Beyond the risk of zero-occupancy vehicles adding VMT to the system, there is also the potential for induced demand. Induced demand refers to the idea that making driving easier or more efficient will lead to more people wanting to drive. For instance when adding new travel lanes to a highway, existing drivers might change their behavior; instead of carpooling or leaving at 5 AM to beat traffic, the newly

widened road entices them to drive by themselves or leave during the peak hour. Those traveling a different route or by another mode might change their behavior and drive the newly widened option. When it comes to added capacity, the principle of induced demand has been shown to undermine the supposed congestion benefits of such an expansion project. Thus, the supposed capacity benefits of smaller headways that should come with autonomous cars may attract more drivers. Additionally, anything that makes the driving experience more attractive can also increase one's willingness to do so. If one can get work done or nap during the drive to work, then longer and longer commutes may become an issue with significant VMT and congestion ramifications.

Is That All?

All of the above barely begins to address the laundry list of potential problems. Not that we want the perfect to be the enemy of the good, but we also have to consider issues such as hackers and autonomous vehicle security. On another note, do we really want two-ton car delivering a two-pound pizza?

Assuming that autonomous vehicle software is programmed to always try to stop for pedestrians and bicyclists that may be in harm's way, then anybody would theoretically be able to walk in traffic like Moses parting the Red Sea. Teenagers bullying autonomous cars could become a viral phenomenon. How might we stop this? The alternative would entail legislating, policing, and punishing such activities. Or it could just mean programming autonomous vehicles not to stop for pedestrians or bicyclists when the car has the right of way. Whatever the case, there is still much to be determined when it comes to technology being the savior of our sustainable transportation problems.

HISTORICAL PRECEDENCE

So what do we do now? How can cities, states, and federal governments begin to prepare for the arrival of autonomous vehicles?

One example that might prove fruitful is looking at what cities did 100 years ago when preparing for and adapting to the new technology at the time: the automobile. When automobiles first came to market, many people saw this technology as a savior to cities. At the time, cities were dirty, unhealthy places filled with horse manure and, in some cases, dead horse carcasses. The clean alternative was considered the automobile [22].

A couple years before his Futurama exhibit at the 1939 World's Fair, Bel Geddes designed a similar utopian vision for a Shell gasoline advertisement in Life Magazine. The advertisement promised to eliminate traffic congestion through three interventions: i) "sidewalks will be elevated – you'll walk and shop ABOVE Main Street, actually cross over it"; ii) "local traffic will use the FULL width of the streets below – no sidewalks, no parked cars"; and iii) "high-speed, long-distance traffic will have its own elevated, one-way lanes, no stop lights or intersections" [23].

Many cities tried to reinvent themselves along these lines in an attempt to best accommodate the automobile and gain a competitive advantage. Some parts of Atlanta, GA, for instance in the downtown area with the network of pedestrian 'gerbil tubes', look to be straight out the Futurama playbook. Did Atlanta solve their congestion problem as Bel Geddes predicted? Unfortunately, the answer is a resounding no. Many cities tried to compete with the suburbs by building freeways and increasing parking supply [24, 25]. While seemingly well intended, what we know now is that most such efforts had the opposite effect. Urban freeways destroyed historic neighborhoods and created barriers between communities [26]. Although the supply of parking spaces went up, population and employment in these cities typically went down [24, 27]. The research even suggests that it was the addition of parking in these cities that led to more driving and not the driving demand leading to increasing the parking supply [28].

The fundamentals of community design also evolved in an attempt to adapt to automobiles. For hundreds of years, if not thousands, compact and connected street networks endured as the foundation upon which our cities were built. However, this approach underwent a major shift over the course of the 20th century [29]. Traditional gridded street layouts gave way to a hierarchical, cul-de-sac approach and increasingly sparser communities focused on vehicular mobility. Unfortunately, a growing body of research shows that people in these new networks drive more and use active transportation less [30, 31]. Moreover, the results suggest that these newer networks turn out to have worse road safety outcomes [32, 33]. People living in these newer networks are also associated with higher levels of obesity, diabetes, and heart disease [34].

At the street level, the streets themselves gradually shifted from being places for kids to play and people to use to a focus on moving cars. Norton's book, *Fighting Traffic,* investigated the history of this evolution from pedestrians being welcome in the street up through the 1920s to them being universally outlawed and condemned under the newly-invented term "jaywalkers" less than a decade later [22]. These sorts of changes were often done in the name of efficiency and safety. In terms of street-level design, these themes led to building and expanding roads to be as forgiving as possible. The clear zone concept, for instance, was in part an outcome of the Congressional road safety hearings held during the 1960s to combat a rapid rise in traffic fatalities and injuries. The hearings were highlighted by two key figures: Ralph Nader, who had just published Unsafe at Any Speed the year before; and Kenneth Stonex, a General Motors engineer [35]. Nader's testimony focused on the need for what can be referred to as a "passive safety paradigm" based on the premise that while crashes are inevitable,

injuries are not [36]. Since humans are apt to make errors, the idea is that we should make sure that cars and roads are designed to protect them [37]. Stonex, who worked at the GM Proving Grounds test track, highlighted three keys to better road safety based on his research: access management; one-way traffic; and fewer roadside obstacles [35]. On the last point, Stonex testified that removing all fixed objects from within 100 feet of the road, such as at the Proving Grounds, would make it "pretty hard to commit suicide on" [35]. Stonex went on to say that:

> "What we must do is to operate the 90% or more of our surface streets just as we do our freeways… [converting] the surface highway and street network to freeway and Proving Ground road and roadside conditions" [35, 36].

Despite existing research at the time suggesting that urban places were safer than rural areas, this quote represents the mindset has guided engineers over the last fifty years [36]. The problem turned out to be that these changes actually led to worse safety outcomes. Noland, for instance, studied 14 years of data from all 50 states and found that these sort of safety 'improvements' resulted in a significant increase in injuries and fatalities [38]. As risk compensation theory suggests, wider and straighter roads – intended to protect drivers from themselves – may actually induce different behaviors in drivers such as speeding and inattention.

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Today, cities and states alike are trying to prepare for the next disruptive transportation technology. The question that continually gets asked: what can we do to make sure we are ready? Despite the uncertainty, transportation agencies are currently working on expanding road capacity to include lanes dedicated to autonomous vehicles in hopes of solving congestion [39]. Elon Musk, on the other hand, is working on the *Stranger Things* version of the Futurama exhibit. Instead of going up, as was the plan with Futurama, he wants to do down. Thus, he founded The Boring Company to first improve tunneling technology and then begin digging tunnels going 10, 20, 30 layers deep. He has already started digging under his SpaceX campus in an effort to eliminate the tiresome Los Angeles traffic.

One problem is that we continue to ask the wrong questions. If the goal is to solve traffic congestion, then bigger highways and tunnels seem like the right solution. If we take a step back and ask what transportation is really for, then we may begin to realize that transportation is about much more than moving people and goods between point A and point B. It is really about helping make sure people can take care of their daily needs, something that we call accessibility. If we ask ourselves how to improve people's access to desired goods, services, and activities, we find a wider range of solutions that values all the ways we can reduce physical travel, but still meet these needs, such as the more accessible land use patterns and modal options found in good urbanism.

The bigger lesson we should draw from is that we should not go about changing our cities to accommodate future technologies. Despite reports to the contrary, the bottom line is that we just don't know what will happen with autonomous vehicles. On one hand, trying to adapt cities to such an uncertain future should give us pause. On the other, the mistakes we made trying to adapt to the automobile over the course of the 20th century should stop us in our tracks because, although hindsight is 20/20, the places we left alone tend to be the ones that are better off now. Nearly every major city has neighborhoods that were built before the advent of street design guidelines and minimum parking requirements. Not only do these neighborhoods continue to thrive in the age of the automobile, they tend to be our most loved places. The same goes for our older cities. So instead of adapting our cities to accommodate these new transportation technologies, we should force these new technologies to adapt to our cities. The real future of sustainable transportation is not that different than it was 20 or 200 years ago. The future of sustainable transportation will always be good urbanism.

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