The Competing Place of Public Transportation and Autonomous Vehicles in Traffic Mitigation in the United States

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by

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Traffic poses a variety of chronic ailments to drivers such as time lost for productivity and leisure, increased spending and pollution due to fuel use, higher chances of collisions, and blocking emergency services (Rettallack, 2019). The combination of these issues cost the United States economy nearly $87 billion in 2018, according to the World Economic Forum (2019). Additionally, there were 117 motor vehicle deaths per day on average in 2022, which has not risen or fallen significantly over the past 30 years (NHTSA, 2022). Autonomous vehicle companies claim that in the future, their technology will reduce traffic congestion, decrease collision rates, and provide more mobility options for the elderly and disabled. Companies that produce autonomous vehicles (AVs) have all offered services in the United States. None of said companies have achieved full autonomy, so the term "autonomous" is a misnomer. AVs are also known as robotic cars, driverless vehicles, or self-driving cars, but for the purpose of simplicity this essay will use "autonomous vehicles" to refer to cars that have features that employ driver support and automated driving. Public transportation, specifically buses and subways, share a lot of the same benefits as those proposed by AVs, such as decreased traffic, decreased collisions, and mobility for the disabled and elderly. Despite public transportation systems existing in nearly every city in the US, AVs have caused a disruption in the mobility market in urban planning, labor, and infrastructure. The expected cost of a transition to an AV country including necessary infrastructure such as charging, maintenance, and storage facilities would cost $80 billion, while according to the American Society of Civil Engineers the U.S. has a backlog of $836 billion in projects that need funding. Meanwhile, transportation is overwhelmingly underfunded and many projects are in need of modernization and repairs. The competition over a shared market between public transportation and AVs in alleviating traffic congestion in the United States is examined under the context of car-dependency. Though AVs have a place in the

ride-share market, their use should be limited while public transportation should be expanded. Additionally, the use of lower Level AV features can be utilized in the realm of public transportation.

Review of Research

Though studies have attempted to analyze whether autonomous vehicles will actually reduce traffic significantly, findings are often inconclusive. Additionally, the analysis and comparison of autonomous vehicles to public transportation is limited. Often there are comparisons of each to private vehicles, which allows human-driven private vehicles to act as a 'control' variable in this paper. Additionally, the state of American infrastructure and its history is well-documented so the sources of traffic congestion are also well-understood. Many existing studies in transportation make use of simulations to control certain traffic variables to study a specific issue, which may be difficult in measuring real-world scenarios in which the contributing factors in a given traffic scenario may be difficult to quantify. These studies are used to measure traffic flow (vehicles/hour), vehicle density (vehicles/km), and mean speed (km/hour). However, these simulations may be more limited when analyzing smaller and more complex traffic situations such as those on dense city streets, and often do not take into account pedestrians or cyclists, who are the most vulnerable to injury from traffic incidents.

Traffic Congestion

Traffic is mostly known as a nuisance, but it also affects a variety of issues ranging from public health to the economy. Traffic congestion is caused by a greater number of vehicles than the road can allow to flow, and is initiated by three common incidents recognized by the Federal

Highway Administration: bottlenecking, traffic accidents, and poor weather (FHA, 2020). These factors cause slow speeds, longer average trip times, and an increased number of cars on the road. Additionally, congestion can increase the risk of accidents, as accidents have a direct relationship with the amount of congestion on the road (Martin, 2002). As traffic is a source of accidents, traffic by extension can cause physical and emotional injury, and incur costs to those in the accident. These accidents during high congestion can further slow down traffic, making paramount reducing the number of accidents in decreasing traffic. While in traffic, cars are running and using fuel, lowering cars' miles-per-gallon and producing pollution that affects both people and the environment. It is well-documented that children living in close proximity to high levels of traffic are at a higher risk for developing asthma, such as in a study that analyzed 41 studies done on the effects of traffic-related air pollution (TRAP) on childhood asthma and found a statistically significant association. The noise pollution caused by traffic congestion is also a public health matter, with high noise exposure strongly indicated to cause cardiovascular diseases, adverse birth outcomes, respiratory diseases, and type 2 diabetes (Recio, 2016).

The United States has a unique relationship with traffic, as with the American suburbs surrounding cities that became very prevalent in the 1950's. These suburbs reinforced car-dependent landscape after World War 2, "In 1956, President Dwight Eisenhower signed the Federal Aid Highway Act, which dedicated twenty-five billion dollars to build more than forty thousand miles of limited-access roadways across the country. Although transit's decline began decades before the federal government constructed new highways in the postwar era, the interstate program—which funded 90 percent of urban expressway costs—demonstrated the federal government's enthusiasm for automobility. By the 1950s, the United States had become "car country," according to Christopher Wells." (Young, 2015). The highways built because of

the Federal Aid Highway Act encouraged suburban expansion along the roads, making the highways into routes to work. As single-family households moved to the suburbs, a work commute en masse ensued coupled with decreased transit ridership, funding, and investment making car dependency endemic, a trend that continues into the 21st century. As the suburbs became more popular, development companies began marketing and mass-producing suburban homes in large developments with no essential amenities, such as hospitals or grocery stores, within walking or biking distance. Greater car-dependency also increased the number of vehicles on the road, creating traffic congestion.

Autonomous Vehicles

The definition of an autonomous vehicle is broad at this time because many different companies are in different stages of development. AVs use a series of cameras and LiDar and other sensors to generate a local model of the vehicle and the environment, then the model to plan a path and execute the control system to move the car. There are six levels of autonomy as defined by the Society of Automotive Engineers (SAE) from zero to five, where Level 0 features "are limited to providing warnings and momentary assistance" to drivers (2021) while Level 5 is defined as full autonomy and the ability to drive under any conditions. More details about each level can be found in Figure 1, which is a graphic made by SAE to define the levels as well as their similarities. Companies such as Honda, Mercedes-Benz, BMW, and Nuro have all produced AVs for purchase by consumers but the most advanced vehicles available are at Level 3 with very few at Level 4, both of which may require some driver intervention or specific conditions to function. Waymo (a subsidiary of Alphabet Inc., the parent company of Google) and Cruise (a

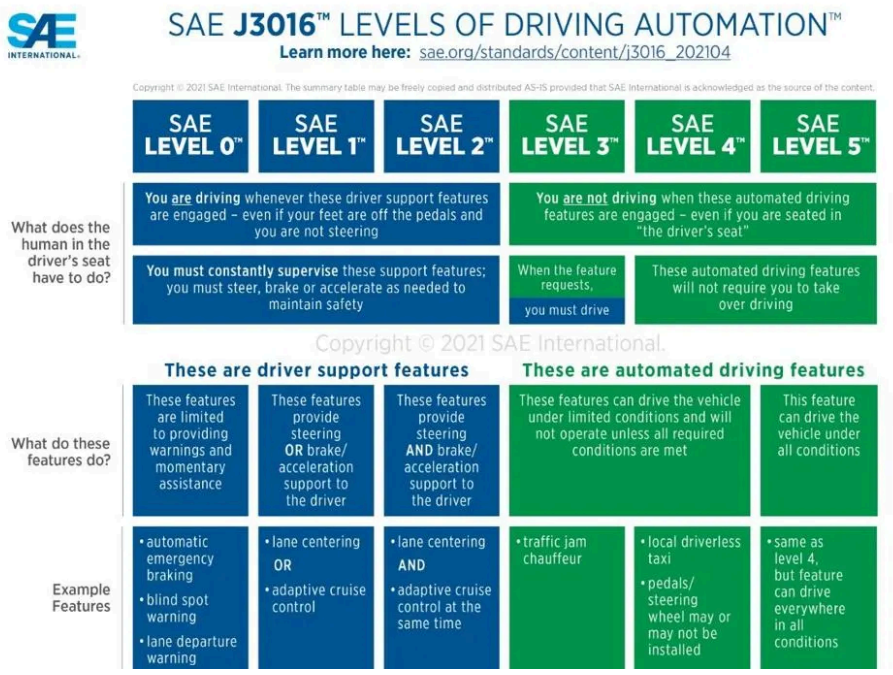

Figure 1: The SAE levels of autonomous driving with each of their features and similarities across other levels. (SAE, 2021)

subsidiary of General Motors) have offered services in the United States, mainly "robotaxis" or driverless taxis that operate at a Level 4. Many of these companies are large and well-established in the existing automobile and technology industry, giving them the resources and networks of their parent companies. For example, the Google headquarters is in the San Francisco Bay Area, and Waymo robotaxis operated extensively in the city of San Francisco until recently.

One of the claims made by AV companies is that they remove the human factor of risky driving. The Waymo technology page of their website echoes this sentiment as they write, "Informed by unmatched experience and designed with safety at its heart, the Waymo Driver is our autonomous driving technology that never gets drunk, tired, or distracted." (Waymo, 2023). Distracted and drunk driving are in fact a major cause of fatal accidents, the National Highway Safety Administration reports that risky driving such as drunk driving, distracted driving, and not

using a seatbelt made up 45% of all fatal crashes in 2020 (2022), so access to AVs could mitigate this risk. Limiting the number of accidents on the road is important to the traffic problem, as accidents are a factor in the severity of traffic. Another method of traffic alleviation through AVs is vehicle-to-vehicle communication, which allows vehicles to communicate information with each other such as speed, position, and sensor data. For example, in 2015 Uber's former CEO Travis Kalanick claimed that, eventually, a city-wide algorithmic traffic management system, such as smart intersections, could be used to reduce congestion (Kiss, 2015). Kalanick also claimed that if every car in San Francisco was an autonomous Uber, car ownership and, consequently, traffic congestion would be reduced.

Regulations over AVs have left policymakers grappling with the challenges of integrating this disruptive and evolving technology into existing transportation frameworks. At the federal level, agencies such as the National Highway Traffic Safety Administration (NHTSA), who typically regulates the hardware components of vehicles, are currently engaged in crafting regulations and guidelines, including the use of the SAE's Levels. The NHTSA also provides oversight by requiring AV companies to submit a safety assessment before testing or deployment in public, but allows the states to form their own laws regarding testing permissions and accident liability. States have taken varied approaches to AV regulation, with some states, such as California and Arizona where Waymo and Cruise among others have been in service, that have written in-depth testing and deployment regulations, while others await federal guidance. In 2023, California, a hub for AV companies, the California Public Utilities Commision (CPUC) approved permits for Waymo and Cruise to begin fared passenger service without a safety driver present with Commissioner John Reynolds saying, "While we do not yet have the data to judge AVs against the standard human drivers are setting, I do believe in the potential of this

technology to increase safety on the roadway,". Though California is hopeful in its position as a trailblazer, it is unclear whether the more cohesive state and federal regulations will be stricter in the future or California has already put its citizens at risks that will in hindsight have been unacceptable. There are already mounting complaints from San Francisco residents about the robotaxis, especially from the fire department, who filed over 50 reports of "autonomous vehicle incidents" (Eskenazi, 2023). X (formerly known as Twitter) user @stanleycandles posted a 2023 video of a Cruise vehicle blocking an intersection where fire department vehicles were trying to get through with the caption "Unbelievable, another Cruise impeding emergency responders at a fire in the inner sunset! Did anyone ask the residents if we wanted them to beta test in our city?".

The data for AVs is limited at this time because there have been far fewer events to analyze therefore it is hard to prove or disprove the claims that AV people have made (rewrite). Because of this, there is debate over the relative safety and traffic mitigation ability of AVs compared to privately driven vehicles. While proponents of AVs point to the promise of reduced accidents in comparison to human drivers, empirical evidence to support this claim remains limited. Due to the mandatory reporting of accidents involving AVs and the underreporting in human driving accidents, mainly in low-damage accidents, it may appear that AVs have a greater accident rate especially when it comes to fender-benders. The increase in accidents at low speeds can partially be attributed to vehicles driven by humans rear-ending AVs at stoplights due to drivers' unfamiliarity with the behavior of AVs (Petrovic, 2020). However, In the case of the claim of reduced traffic in the case of an AV majority, the technology necessary for V2V communication and the number of AVs have been limited and therefore, measuring the degree of traffic reduction requires simulation data to be able to predict levels of traffic congestion. In a simulation of Budapest, the percentage of AVs of the total number of cars and traffic density

were varied and the traffic flow rate was measured. This resulted in a direct relationship between the maximum flow rate and the ratio of AVs, a 16% increase in maximum flow rate at 100% AVs as compared to 0% AVs, and higher flow rates achieved at a given density as the AV ratio increases. As AV companies continue to test and are required to document accidents, more studies should use this type of data to gain a clearer picture of the relationship between autonomous driving and traffic congestion.

Public Transportation

Public transportation is made up of an array of mobility services and infrastructure designed to facilitate the movement of people within and between urban, suburban, and rural areas. Traditional modes of public transit, such as buses, trains, and subways, use fixed routes on schedules to connect neighborhoods, residences, business hubs, and shopping centers. In recent years, public transportation has expanded to include innovative solutions such as on-demand transit, which has experienced tremendous growth since 2020, and micromobility options, such as shared bicycles and electric scooters that provide short-distance transportation. On-demand transit services are characterized by flexible routing and scheduling in rural areas with too little demand for a bus. Together, these diverse elements of public transportation contribute to a comprehensive and inclusive mobility ecosystem that serves the diverse needs of communities while mitigating the impacts of traffic congestion.

The effects of increased public transportation on traffic congestion and accidents have been well documented. In an analysis of the safety of buses and cars in Montreal, it was observed that not only are occupants far less likely to be injured in an accident, but also pedestrians and cyclists were much safer. “Overall, for all ten routes, the ratio between car and

bus occupant injury rates is 3.7 (95% CI [3.4, 4.0]). The rates of pedestrian and cyclist injuries per hundred million passenger-kilometers are also significantly greater for car travel than that for bus travel: 4.1 (95% CI [3.5, 4.9]) times greater for pedestrian injuries; 5.3 (95% CI [3.8, 7.6]) times greater for cyclist injuries." (Morency, 2018). This safety difference may appear that buses are by definition safer, but the difference may be caused by the lower speeds of buses traveling in urban areas as compared to cars that on average drive at higher speeds, as higher speeds are associated with more accidents and more fatal accidents (Morency, 2018). Despite this, buses that travel at high speeds such as on highways pose another benefit to the traffic problem in their ability to increase the traffic flow of a highway by increasing the density of people while maintaining the number of vehicles over some distance, as displayed in Figure 2. Further, public transportation's ability to reduce traffic congestion in its degree of operation has been documented in the case of the Los Angeles subway strikes in 2003. In an analysis of the increase in traffic congestion during the strikes, which lasted 35 days (CNN, 2003), highway delays increased by 47% and even stranded some commuters, especially those with low incomes who did not own a private vehicle (Anderson, 2014). Public transportation is a catalyst in reducing public transportation in a very significant way, while also empowering people with a lack of resources.

Despite the benefits that public transportation brings to the public health and economic problem of traffic congestion, the American public transportation system has been chronically neglected, is massively underfunded, and is in poor condition. The American Society of Civil Engineers releases a "Report Card" every four years grading the US on its infrastructure and its

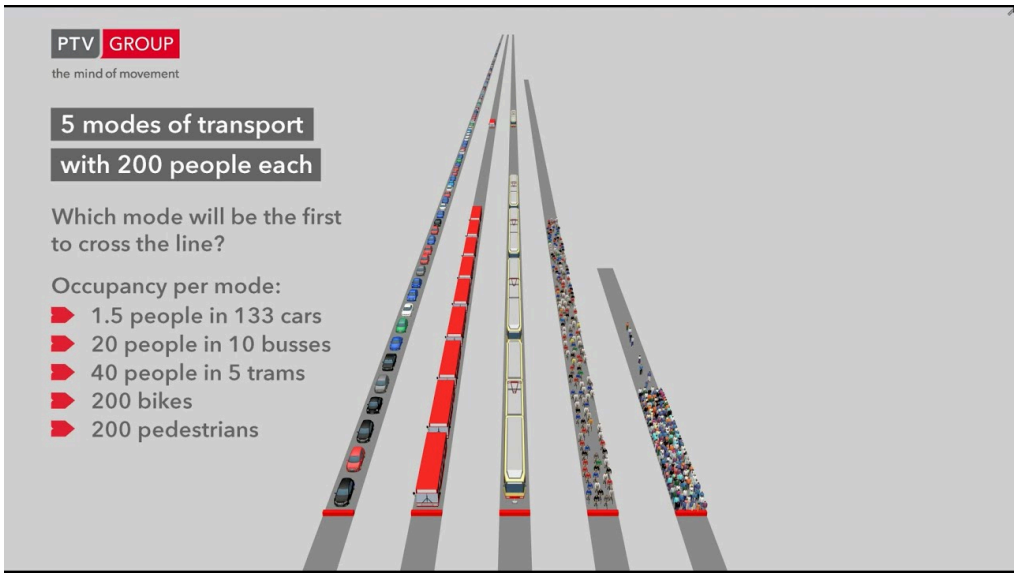

Figure 2: A visualization of the density of various modes of transportation and their ability to travel cohesively together (PTV Group, 2016).

efficiency and condition. The overall grade was a C- in 2021, with transit receiving a D- because, "Unfortunately, 45% of Americans have no access to transit. Meanwhile, much of the existing system is aging, and transit agencies often lack sufficient funds to keep their existing systems in good working order… Currently, there is a $176 billion transit backlog, a deficit that is expected to grow to more than $270 billion through 2029." (ASCE, 2021). Similarly, the World Economic Forum put out a Global Competitiveness report of all nations where the US ranked second overall but twelfth when it came to transportation infrastructure, behind nations such as Japan, Germany, and the United Kingdom (Schwab, 2019).

A Social Welfare Analysis

The dilemma of the expansion of AV or public transportation infrastructure may also be a dilemma of traffic diminishment by means of privatization or democratization. In a poll done in 2012 by the National Resources Defense Council (NRDC), it was observed that a majority of Americans support the expansion of public transportation, "63 percent (more than three in five

Americans) would rather address traffic by improving public transportation (42 percent) or developing communities where people do not have to drive as much (21 percent) – as opposed to building new roads, an approach preferred by only one in five Americans (20 percent)" (Perks, 2012). On the other hand, people are wary of riding in an AV with 63% of Americans saying that they would not want to ride in an AV if they were given the opportunity (Pew Research Center, 2022). As policymakers navigate regulation as well as the opinions of the people that they represent, it is also important to represent those who are most vulnerable in the future of transportation, which are the low-income, disabled, and elderly Americans who are hurt by car-dependency. The effects of lower mobility from a system that lacks other methods besides cars is compounded on vulnerable Americans who do not have access to cars and have reduced access to essential amenities, own poor quality vehicles that have more maintenance costs, and spend more time on trips in order to avoid costs such as tolls or parking (Chevallier, 2016). These issues further reduce the quality of life and reinforce low-income status by providing barriers to maintaining wealth.

Conclusion

A transformation of the current system of transportation must be made to relegate car-dependency and its subsequent effect of traffic congestion among many other afflictions to Americans. This transformation will include the repurposing of highways, parking lots, and roads that are hostile to pedestrians and cyclists. Public transportation has the ability to fit into many of these places and reduce traffic congestion in doing so. Replacing highways with regularly-run high-speed rail both reduces congestion and gets people to their destinations more quickly.

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