Autonomous Vehicles and The Social Construction of Safe Roads

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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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A fully autonomous vehicle (AV) future has continued to make strides as more resources flow into the industry following developments in potential safety benefits. According to the United States Department of Transportation (DOT) 94% of serious accidents in 2017 involved driver-related factors (National Highway Traffic Safety Administration, 2018). Later in 2019, the DOT announced $60 million in grants to test AV integration on national roads to gather safety data on what AV's can provide (U.S. Department of Transportation, 2019). Numerous other stakeholders are involved in the rise of AV's, and negotiations between these different groups are shaping current AV development. This paper will outline and analyze the issues related to the push for autonomous vehicles made by the DOT and what it means to have "safe roads" using the framework of Social Construction of Technology (SCOT).

Social Construction of Technology in Automobile Development

SCOT as defined by Pinch and Bijker (Pinch & Bijker, 1984) argues that technology is "embedded in a social context" and that relevant social groups perceive artifacts in different ways that can either support or renounce innovation. The differing perceptions of artifacts leads to conflict between the relevant social groups. Analyzing these conflicts allows users to identify each side's viewpoint and the connections that can be made between perspectives and design features of the technological artifacts.

Social construction of technology has been a part of the American automobile industry from the very beginning. The first cars were unreliable, expensive, and perceived as dangerous compared to the alternatives (bicycle and horse), which led to their lack of initial success. Henry Ford redesigned the manufacturing process using interchangeable parts to keep production prices

low. The roads which were once quietly run by bicycles and pedestrians, quickly became violently controlled by the new cheaper automobile (Smithsonian, 2019). With the initial surge in automobiles, more accidents occured as the roads were not designed to accommodate their size. To make areas better suited for automobiles, lobbyists called for restructuring of entire cities and roads to accommodate for them (Ladd, 2008). With the physical restructuring of cities and roads, a social restructuring also developed as new interactions formed between automobiles and pedestrians. Lobbyists and companies pressed for these large changes by presenting the automobile as part of a "perfect future, delivered by their latest technology" (Zipper, 2021). Integration of current AV technology echoes this same ideal by illustrating a "perfect world" with AV's being a solution to "safer roads."

AV's For Safer Roads?

A "safe road" can be viewed in different ways as actors prioritize varying factors in their pursuit of creating a more "perfect world". One of these definitions is the elimination of any severe incident involving a vehicle. The Vision Zero project uses this definition to guide their goals to ideally reform the road system and related policies to account for human error which could both prevent and eliminate incidents (Vision Zero Network, n.d.). They seek to "prioritize traffic safety as a public health issue" by integrating traffic planners, engineers, policymakers, and public health professionals in the process of infrastructure reformation (Vanterpool, 2019). Others say that the problem is that there are too many cars on the road which leads to higher chances of accidents. This notion is supported by England's implementation of a congestion tax which has led to fewer vehicles on the road, and shown that a 1% reduction in vehicle miles traveled generally results in a 1% drop in crashes (Wilson, 2020). There are also those that believe that the amount of cars on the road is not the issue, but rather the actors who use the

roads. They believe that cars need to become smarter and make up for what humans lack without the need to reform most of the current infrastructure.

AV's are imagined to be one of the solutions to help create "safer roads" by making technology adapt to situations instead of humans. AV manufacturers are proposing an abundance of benefits and solutions to problems in the world today from a fully functioning AV. A major proposed benefit is the reduction of human error and thus accidents by using an onboard system that plans every movement the vehicle makes. Using vehicle to vehicle (V2V) communication AV's can also change routes in real time to quickly optimize fuel efficiency and time spent on the road (Robinson, 2017). AV's can also make informed decisions without communication with other vehicles. Using an array of sensors to provide information on its surroundings, the vehicle can use what it sees in conjunction with algorithms to decide its best course of action (Hyundai, 2018). There are a plethora of ways of designing AV's as technology continues to advance and become better at adapting to numerous situations.

AV's can come in a multitude of different shapes, sizes, and functional capabilities which are all up to the discretion of the manufacturer. However, the DOT and NHTSA have set design guidelines that AV's must follow to be approved for road use. The NHTSA lays out these guidelines for partial driving automation (L2) and conditional driving automation (L3) vehicles (Campbell et al., 2018). L2 automation is the only level legally allowed on US roads as the driver is required to supervise and be ready to take control of the vehicle at all times. NHTSA guidelines are split up into five categories: general design, message characteristics, driver input, visual, auditory, and haptic interfaces. The general design category highlights the need for L2 vehicles to have the ability to signal the transition between automation and user control to help the user maintain focus. The message category highlights the need for effective forms of

communication to drivers that are easy to interpret and can result in quick action. The NHTSA set guidelines for these two sections by referencing the success of General Motors HAVEit project which used detection algorithms to successfully determine driver focus and the use of signals to regain driver attention (Salinger, nd). Driver input is a broad category that NHTSA narrows to focus on control placement and interaction between an interface system. The final sections regarding visual, auditory, and haptic interfaces discuss proper placement of such systems to aid in driving and user engagement. Based on similar restrictions set by the European Union, NHTSA set guildienes for driver input and interfaces so that devices can be controlled while keeping one hand on the wheel, as well as the ability to maintain the same level of control seen in a non autonomous vehicle (Official Journal of the European Union, 2008). This means that much to the dismay of lobbying companies such as GE, steering wheels and other essential control parts must stay in autonomous vehicles (Shepardson, 2019). These broad technological guidelines on how AV's look are generally set by the US DOT; however, state governments and cities still have the power to set their own regulations and testing protocols.

Case Study: Phoenix, Arizona

Arizona is considered one of the hotspots for AV development evidenced by the state's actions to encourage the migration of large automotive companies to the area. Arizona as a state has been one of the most progressive in terms of supporting AV development and testing. In 2021, an executive order was turned into a state law allowing for advanced AV testing and integration onto public roads (ADOT, n.d.). Passing such legislation has encouraged innovation state wide, and in particular has led the city of Phoenix to be a hub of AV innovations. Waymo, a subsidiary of Google's Alphabet Incorporated, has started testing their Waymo One service which is the country's first fully autonomous ride-hailing service that's serving the Metro

Phoenix area. With the actions being taken by the state, and specifically the city of Phoenix, the future of transportation and safe roads shows a clear desire for AV's to be a part of it .

Governor of Arizona Doug Ducey has been a catalyst of AV acceptance in Arizona as first seen in 2015 when he passed an executive order calling on relevant government agencies to support the testing and operation of AV's on public roads. In 2018 he passed another order establishing the Institute of Automated Mobility to help foster a community of research and push AV innovation. Before 2018, AV's had the same registration requirements as any other vehicle, allowing for full freedom of testing and highlighted the government's desire to be an attractive location for AVs (Stern, 2021). Finally in 2021, the culmination of previous executive orders were passed into a singular state law, which officially cemented Ariona's stance on their support of AV's. This law was sponsored by a representative who even said that "industry leaders sought legislation that would allow local governments to adapt to the increasing use of this technology" (Somsan, 2021). The passing of such legislation highlights the influence that the automotive industry has over the state of politics in Arizona, and AV's claiming the space of roads on a local level. The state consistently updating its legislation to adapt and provide favorable guidelines has resulted in AV companies to set up shop and set roots in dictating the future of roads in Arizona.

With the industry ecosystem, favorable legislation, and a government desire to draw in big businesses, many AV companies have flocked to Arizona and the city of Phoenix in particular. Companies such as Waymo, General Motors, Toyota, and others are currently innovating and testing AV technology in the Phoenix area. Beyond the argument that AV's will help reduce user mistakes while driving, large companies are presenting additional reasons as to how they fit into the notion of safe roads. One of these reasons is that autonomous and semi

autonomous vehicles on the road right now are passively making it safer just by being on it. This is because the vehicles are “learning” and adapting to more and more situations which helps feed into the vehicles decision making library (Mantica, 2021). This is also a major reason as to why Phoenix was chosen, as its stable weather patterns and the general spacioness of the city requires AV’s to adapt to fewer variables compared to more dynamic regions (Rubes, 2021). This does require AV’s to be on the road for extended periods of time which can sacrifice potential road safety as the chance of potential incidents increases while the AV is still learning. AV’s will theoretically get better much faster in the static environment, but the limited variability and need to adapt can create a false perception of success and preemptively reshape roads before they are ready. AV companies also have easy and direct access to research support through partnerships with multiple Universities set up by the Institute of Automated Mobility. The partnerships with Universities encourage a pipeline of job-ready workers, and allows companies to invest in training those that can eventually not only help push their current ideas for safe roads, but future ones as well (GPEC, 2019). From the government to the citizens, AV companies are including the population of Arizona to have a stake in the notion of safe roads.

Arizona and the city of Phoenix are an interesting case as the residents have watched and observed the introduction of AV’s onto their roads for the past 6 years. It has been reported that nearly ¾ Phoenix residents support AV’s on the roads even though only 14% have been inside one (Waymo, n.d.). The actions taken by the government are also supported by the people, and thus shows that from the top down Phoenix believes in AV’s in some capacity and the potential they have in being a solution to creating safe roads. However, in light of recent events there have been inklings of resistance from some social groups.

Even though much of legislation is behind the integration of autonomous vehicles into everyday life in Phoenix, other parts of the country have shown pushback from over policies and the integration of AV's on the roads. In 2018, the first AV death was recorded in Arizona when Elain Herzberg was struck by a Uber vehicle. Unfortunately the incident was preventable as there was a human monitor present but was distracted watching TV. Even before the incident, the general U.S. public voiced their concerns with a majority of surveys reporting that people would choose to drive rather than ride autonomously, and that the government must play a large role in regulation and testing (Advocates for Highway and Auto Safety, n.d.). With most AV's still requiring a human driver to be present with the vehicle, there will always be confusion over who is at fault when incidents occur. This public sentiment shows the strong distrust surrounding AV's which has even led to violence through vandalism and even running AV's off the road (Mushkatel, 2020). These actions echo the violence from the first days of the automobile, but this time the new technology is the one under attack. Opposite of the general US population, the local opinion of AV's in Arizona is still very high and the support from the public and government in building supportive infrastructure is evident.

Case Study: New York

New York City (NYC) is a prime example of a more cautious approach to AV testing and implementation onto their roads. In 2021 new regulations have allowed AV's to test on NYC roads. If an AV company wanted to test their design in NYC the company would need to apply for a testing permit, and have a "vehicle operator able and present to assume control of the vehicle in the event of a failure" (NYDOT, 2021). These rules are overall very similar to Phoenix's, but the structure of the regulations around specific testing requirements, as well as the potential legal implications in the result of an accident have left more questions than answers.

Those in favor of AV's are arguing that the way the rules are worded would deter companies from testing in the city due to the legal uncertainty, evidenced by the opposition to how the city wants AV's to be "safer than a human driver" before making it onto the road (Furchgott, 2021). The other side also argues that the wording is an issue, but from a different perspective. Many residents are asking what even rightfully qualifies as a "vehicle operator" and the ethical decisions that must be considered when testing in a densely populated area such as NYC. The legislation of NYC is approaching the idea of AV's as a solution to safe roads cautiously and more slowly than its western counterpart in Phoenix.

The latest rules issued by the NYC DOT offer less guidance on how to meet the city's safety standards than Phoenix's, and are considered to be generally more harsh. New York City's requirements go beyond any that have been enacted before requiring "certification by the developer of the AV that test vehicle(s) will have to operate more safely than a human driver" (Scribner, 2021). This language clearly illustrates NYC's skepticism on current AV status and the opinion on how the roads are still safer when the driver has the control until proven otherwise. However, AV manufacturers still have a say in the policy making process as NYC has allowed them to be a part of the process of defining what exactly does it mean to be "safer than a driver." This policy making process is very different compared to Phoenix as New York is not biasing AV's, but rather allowing discussions to be formed around how AV's will make roads better than they already are.

NYC's style of policy building surrounding conversations around AV's, has encouraged only a select few manufacturers to test in the city. Unlike Phoenix's warm and predictable street patterns, New York's streets are highly varying with many actors sharing the roads that are oftentimes very unpredictable. An increase in pedestrians, bikers, erratic drivers, and varying

levels of connectivity between actors are just a few of the unpredictable characteristics that companies have to take into account when dealing with New York. This unpredictability is one of the reasons that AV companies cite for wanting to come into the city and test their products (Mobileye, 2021). The main argument being if a safe road can be developed in one of the most varying cities in the world, then it can be developed anywhere. However, just like in Phoenix, companies are following the government's lead in terms of the speed of development with NY development progressing slower to ensure more refined products before testing.

Unlike in Phoenix, the high variability of New York and city infrastructure has led to way more discussions and viewpoints on road ownership and usage. In 2021, the U.S. House of Representatives passed the Infrastructure Investment and Jobs Act (IIJA), to invest in the nation's infrastructure with a budget of 1.2 trillion dollars. New York alone already has a budget of 16.8 billion dollars dedicated to transportation infrastructure for 2022 through 2026 to build and repair existing roads (The City of New York, n.d.). Such massive investments in roads show New York's plans of keeping standard cars on the road for the foreseeable future, and accommodating their needs first. New York also has a Connected Vehicle Project sponsored by the USDOT and NYCDOT, whose goal is to install semi autonomous technologies that would communicate with other cars, infrastructure, and passengers while driving. The technology would solely be in conjunction with human drivers, providing them with the information it collects from other vehicles and roads to allow the driver to be more informed and make better decisions (NYC Connected Vehicle Project, 2021). NYC25x25 is a group calling for NYC officials to solve inequitable distribution of public space and the ongoing harm of car traffic to New Yorkers. They see streets as a system of public spaces designed to serve people and breaks from traditional thinking centered on moving and storing cars (Transportation Alternatives, 2021). Autonomous

vehicles can fit into their plan and solution to safe roads as they can reduce the number of driving lanes which could be reallocated for shared spaces. There are many different social groups in NYC beyond AV companies and the government as each are vying for a spot in the creation of safe roads and have their own unique definition of how they want to see a "better world" come to pass.

Discussion

AV development differs drastically state to state as different actors and variables have stake over the creation of safe roads. Social construction of roads has been prevalent since the automobile was first introduced and conflicts of social groups have progressed from past to present. Safe roads are defined differently by those that use the space, and AV's are imagined to create safe roads because of the way they theoretically make decisions in the place of humans. There is currently no coherent vision on AV integration and whether they are safer than human drivers. Instead the notion of AV's and safe roads are a space of conversation around where AV's can fit. The examples of Phoenix and New York both show that AV's are not miraculously going to create safe roads, but a future with AV's as part of making safe roads is in fact possible.

The NHTSA is in charge of setting regulations in regard to the basic requirement of how AV's at a base level look and function. However, as seen in Phoenix and New York states and cities have control over how testing and rollout of vehicles will look like on their streets. Phoenix's legislation has made it clear that AV's are a de facto part of the future and a final solution to solving safe roads. Many companies have responded in kind by setting up in Phoenix and been testing their innovations on their roads. The people and large groups such as Universities have bought into this notion as well as there have been a number of partnerships with companies in order to foster more innovations and progress towards completing AV's. New

York on the other hand is more cautious in how they have been approaching AV integration onto their roads. Even though AV testing has been approved as early as 2017, New York does not seem to preclude or oppose AV's but rather make it so that multiple actors still have ownership over the safe roads. They break open the definition of what a street can be used for through the rise of opposing social groups which AV companies would seemingly rather choose to ignore.

AV development in the United States has been progressing swiftly in more and more areas. Acceptance of AV's varies in different areas and there will always be discussions on how much people are willing to let AV's shake up infrastructure. Technical problems will continuously be prevalent as the sensors involved in providing information will need to be maintained and updated. However, as the technical issues start to lessen the ethical issues will become more prevalent. When met with tough decisions, the algorithms running the vehicle are forced to make hard decisions. The difference between life and death can be dictated by one line of code or one mathematical formula. Every situation is different and currently no combination of sensors and algorithms can make the "right" decision every time. Only through greater advancements in sensors and detection algorithm integration will AV's ever be able to find their place in a safer, more perfect world.

References

ADOT. (n.d.). *Autonomous Vehicles Testing and operating in the state of Arizona*. Autonomous Vehicles Testing and Operating in the State of Arizona. Retrieved April 3, 2022, from https://azdot.gov/motor-vehicles/professional-services/autonomous-vehicles-testing-and-operating-state-arizona

Advocates for Highway and Auto Safety. (n.d.). *Public Opinion Polls Show Skepticism About Autonomous Vehicles*. Advocates for Highway and Auto Safety. Retrieved April 3, 2022, from https://saferoads.org/wp-content/uploads/2018/04/AV-Public-Opinion-Polls-4-26-18.pdf

Campbell, J. L., Brown, J. L., Graving, J. S., Richard, C. M., Lichty, M. G., Bacon, L. P., Morgan, J. F., Li, H., Williams, D. N., & Sanquist, T. (2018, August). *Human Factors Design Guidance for Level 2 And Level 3 Automated Driving Concepts*. National highway Safety Traffic Administration. Retrieved October 16, 2021, from https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/13494_812555_l2l3automationhfguidance.pdf.

Furchgott, R. (2021, December 23). *Public streets are the lab for self-driving experiments*. The New York Times. Retrieved March 3, 2022, from https://www.nytimes.com/2021/12/23/business/tesla-self-driving-regulations.html

Greater Phoenix Economic Council (GPEC). (2019, October 9). *4 reasons why driverless vehicle companies scale in Greater Phoenix*. GPEC. Retrieved March 3, 2022, from https://www.gpec.org/blog/4-reasons-why-driverless-vehicle-companies-scale-in-greater-phoenix/

Hyundai Motor Company. (2018, August 15). *How do self-driving cars work?* Hyundai Newsroom. Retrieved April 6, 2022, from https://www.hyundai.news/eu/articles/stories/how-do-self-driving-cars-work.html

Ladd, B. (2008). *Autophobia*. Autophobia: Love and Hate in the Automotive Age. Retrieved October 16, 2021, from https://press.uchicago.edu/Misc/Chicago/467412.html.

Mantica, G. (2021, July 30). *Self-taught, self-driving cars?* Boston University. Retrieved April 3, 2022, from https://www.bu.edu/articles/2021/self-taught-self-driving-cars/

Mobileye. (2021, July 19). *Why we're testing our autonomous vehicle in New York*. Mobileye. Retrieved March 3, 2022, from https://www.mobileye.com/blog/new-york-city-autonomous-vehicle-testing/

Mushkatel, R. & B. (2020, December 6). *Self-driving cars are being attacked in Phoenix*. Mushkatel, Robbins & Becker. Retrieved March 3, 2022, from https://www.phoenixlawteam.com/blog/driverless-cars-being-attacked/

National Highway Traffic Safety Administration. (2018, October). *TRAFC Safety Acts - Transportation*. Traffic Safety Facts. Retrieved October 16, 2021, from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812580.

New York Department of Transportation (NYDOT). (2021). *New York City Department of Transportation Notice of Adoption*. Autonomous Vehicles. Retrieved March 4, 2022, from https://rules.cityofnewyork.us/wp-content/uploads/2021/08/DOT-Notice-of-Adoption-AV-Rule-FINAL-with-Finding.pdf

NYC Connected Vehicle Project. (2021). *FAQs*. FAQs | NYC Connected Vehicle Project. Retrieved March 3, 2022, from https://cvp.nyc/faqs

Official Journal of the European Union. (2008, December 8). *On safe and efficient in-vehicle information and communication systems: update of the European Statement of Principles on human-machine interface*. EUR-Lex. Retrieved October 16, 2021, from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32008H0653.

Pinch, T. J., & Bijker, W. E. (1984). The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other. *Social Studies of Science*, *14*(3), 399–441. http://www.jstor.org/stable/285355

Robinson, J. (2017, April 25). *4 benefits of autonomous vehicles you may not have considered*. Rarestep Inc. Retrieved October 28, 2021, from https://www.fleetio.com/blog/4-benefits-of-autonomous-vehicles.

Rubes, Hickey, J., Ohn-Bar, E., & Drk. (2021, July 30). *Self-taught, self-driving cars?* Boston University. Retrieved March 3, 2022, from https://www.bu.edu/articles/2021/self-taught-self-driving-cars/

Salinger, J. (n.d.). *Human Factors for Limited-Ability Autonomous Driving Systems*. Transportation Research Board. Retrieved October 16, 2021, from http://onlinepubs.trb.org/onlinepubs/conferences/2012/Automation/presentations/Salinger.pdf.

Scribner, M. (2021, September 29). New York City's misguided automated vehicle rules. Reason Foundation. Retrieved March 3, 2022, from https://reason.org/commentary/new-york-citys-misguided-automated-vehicle-rules/#:~:text=Regulators%20at%20the%20New%20York,automated%20vehicles%20on%20public%20roads.&text=Thus%2C%20in%20order%20to%20test,safer%20than%20a%20human%20driver

Shepardson, D. (2019, May 22). *GM faces pushback on U.S. Self-Driving Vehicle Plan*. Reuters. Retrieved October 16, 2021, from

https://www.reuters.com/article/us-gm-selfdriving/gm-faces-pushback-on-u-s-self-driving-vehicle-plan-idUSKCN1SS2TQ.

Smithsonian. (2019, April 15). *Better roads*. National Museum of American History. Retrieved October 16, 2021, from https://americanhistory.si.edu/america-on-the-move/better-roads.

Somsan, C. (2021, April 15). *Ducey signs autonomous vehicle regs into law*. Ahwatukee Foothills News. Retrieved March 3, 2022, from https://www.ahwatukee.com/news/article_54b522f0-9d58-11eb-8e4e-4bf3992a1400.html

Stern, R. (2021, September 14). *New rules: Arizona will no longer be the Wild West for testing self-driving cars*. Phoenix New Times. Retrieved March 3, 2022, from https://www.phoenixnewtimes.com/news/arizona-governor-doug-ducey-creates-rules-for-self-driving-cars-10191122#:~:text=Under%20the%20new%20order%2C%20companies,ve%20already%20begun%20such%20testing

The City of New York. (n.d.). *The Infrastructure Investment & Jobs Act*. New York City Department of Transportation. Retrieved March 3, 2022, from https://www1.nyc.gov/html/dot/html/home/home.shtml

Transportation Alternatives. (2021). *The Challenge*. NYC 25x25. Retrieved March 3, 2022, from https://nyc25x25.org/25x25report.html

U.S. Department of Transportation. (2019, September 18). *U.S. secretary of Transportation Announces Automated Driving System Demonstration Grant Winners*. U.S. Department of Transportation. Retrieved October 3, 2021, from https://www.transportation.gov/briefing-room/us-secretary-transportation-announces-automated-driving-system-demonstration-grant.

Vanterpool, V. (2019, March 7). *United Nations launches new initiative to reduce road crashes*. Vision Zero Network. Retrieved October 28, 2021, from https://visionzeronetwork.org/united-nations-launches-new-initiative-to-reduce-road-crashes/.

Vision Zero Network. (n.d.). *What is Vision Zero?* Vision Zero Network. Retrieved October 28, 2021, from https://visionzeronetwork.org/about/what-is-vision-zero/.

Waymo. (2019). *Waymo Driver*. Waymo. Retrieved October 28, 2021, from https://waymo.com/waymo-driver/.

Waymo. (n.d.). *Seeing is believing: How phoenix residents feel about self-driving tech*. Let's Talk Autonomous Driving. Retrieved March 3, 2022, from https://ltad.com/news/seeing-is-believing-how-phoenix-residents-feel-about-self-driving-tech.html

Wilson, K. (2020, February 21). *Vision Zero is missing something big: Getting cars off the Road*. Streetsblog USA. Retrieved October 28, 2021, from https://usa.streetsblog.org/2020/02/21/vision-zero-is-missing-something-big-getting-cars-off-the-road/.

Zipper, D. (2021, October 12). *The Dangerous Promise of the Self-Driving Car*. Bloomberg.com. Retrieved October 28, 2021, from https://www.bloomberg.com/news/articles/2021-10-12/the-dangerous-promise-of-the-self-driving-car.