CRAFTING THE FUTURE OF AUTONOMOUS VEHICLES: SELF-DRIVING CART IN A CONTROLLED ENVIRONMENT

THE NEXT INDUSTRIAL REVOLUTION: AUTONOMOUS VEHICLES DISRUPT WORKERS

A Thesis Prospectus
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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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Despite the effort of Elon Musk's promise of fully autonomous vehicles by the end of the 2021, engineers are struggling to implement fully self-driving cars (Korosec, 2021, para. 1-2). To stratify different automation, the Society of Automotive Engineers (SAE) benchmarked progress on human interaction and the variety of situations as in Figure 1 below. The levels of autonomy range from 0 to 5 with the following definitions: for Level 0, "the human driver does all the driving"; for Level 1, "an advanced driver assistance system on the vehicle can sometimes assist the human driver with either steering or braking/accelerating, but not both simultaneously"; for Level 2, "an advanced driver assistance system on the vehicle can itself actually control both steering and braking/accelerating simultaneously under some circumstances"; for Level 3, "an automated driving system on the vehicle can itself perform all aspects of the driving task under some circumstances"; for Level 4, "an automated driving system on the vehicle can itself perform all driving tasks and monitor the driving environment – essentially, do all the driving – in certain circumstances"; for Level 5, "an automated driving system on the vehicle can do all the driving in all circumstances" (National Highway Traffic Safety Administration [NHTSA], n.d., Benefits section).

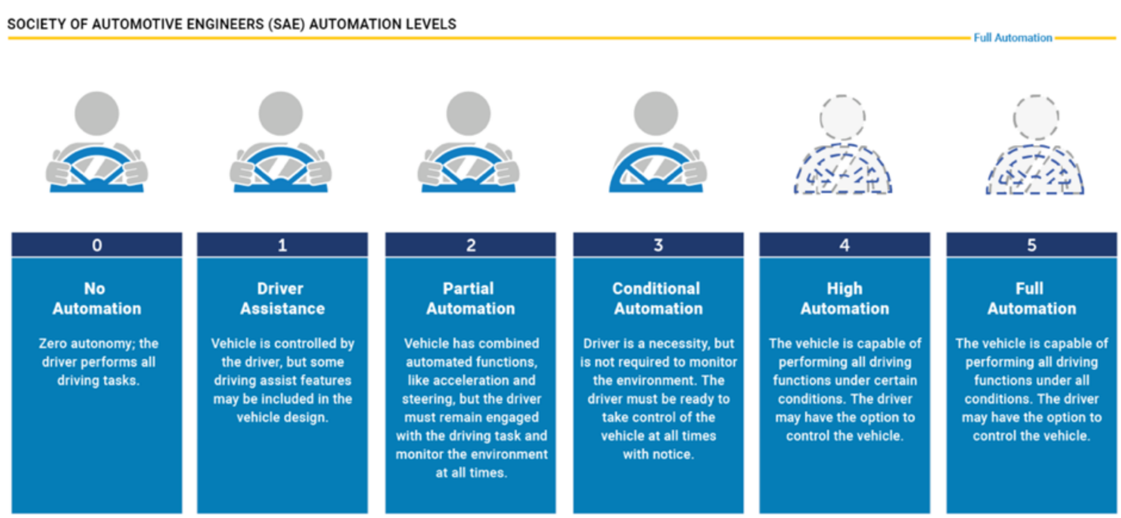

Figure 1: Level of Autonomy from SAE. Industry definition of autonomy from full human control, Level 0, to completely autonomy, Level 5. (NHTSA, n.d., The Road to Full Automation section)

According to these definitions, Tesla's full self-driving package truly operates at a Level 2 autonomy (Korosec, 2021, para. 6). Autonomous vehicles benefit day-to-day life in four ways: road safety, increased profitability for companies, reduction in traffic, and assistance to people with disabilities (NHTSA, n.d., Benefits section). However, these benefits rely on the superior capabilities of computer perception and communication over their human counterpart. Therefore, the technology needs to Level 5 to reap all the rewards.

The technical research will contain two components: create an autonomous follower vehicle and create an autonomous leader vehicle to navigate the University of Virginia's campus. Both vehicles need to rely on environment perception from sensors, like cameras or Lidar, to determine the automation. For distinction, the follower vehicles can rely on another vehicle to determine appropriate motion. However, the leader vehicle must rely solely on detection of the environment to navigate around campus. Both vehicles will attempt to reach Level 3 autonomy without the use of GPS, which is a crucial intermediary step to reach Level 5 autonomy. Closely coupled to the technical topic, the STS project focuses on the societal impacts of autonomous vehicles, specifically the effects of self-driving cars on working-class Americans. The research will investigate impact on the working-class through the lens of economics, individual relationships, and broad societal changes. Figure 2 displays a general timeline for goals for the three components of the project. Our team may elect to modify this Gantt Chart.

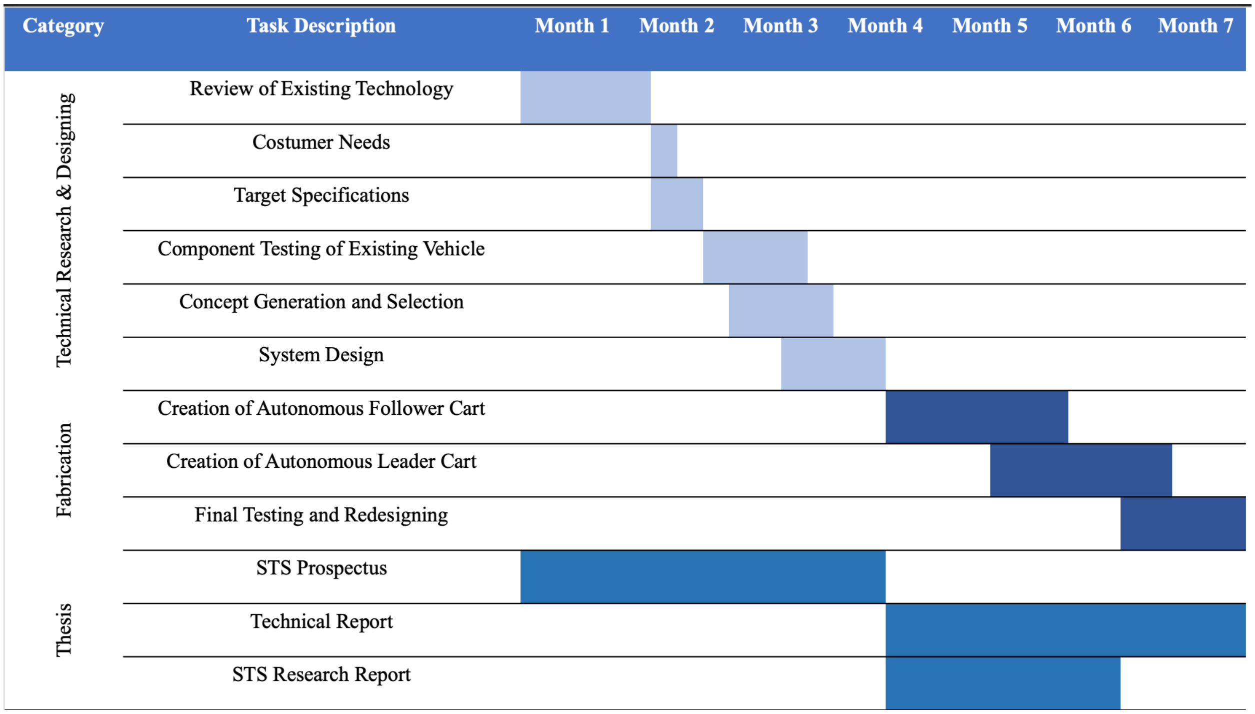

Figure 2: Gantt Chart for Thesis Project. A timeline of crucial steps in reaching our important milestones. The figure groups intermediate steps into three categories: technical research and designing in light blue, cart fabrication in dark blue, and thesis in royal blue. (Rushton, 2021)

CRAFTING THE FUTURE OF AUTONOMOUS VEHICLES: SELF-DRIVING CART IN A CONTROLLED ENVIRONMENT

The need for Level 5 autonomy becomes increasing necessary as companies release Level 3 autonomous vehicles; with less stimulation, the user of the vehicles will become less alert and can cause more accidents (Kannan & Lasky, 2020, p. 6). Waymo leads the self-driving car market with the help of significant funding from Alphabet, the parent company of Google (Courtney, 2021, para. 12). Recognizing the dangers of Level 3 autonomy, Waymo announced, "Waymo's vehicles don't drive themselves. Rather, Waymo is automating the task of driving…Researchers find people consistently overestimate the capabilities of driver-assisted features" (2021, para. 2). With the industry leader recognizing the danger, the need for autonomous vehicles to reach Level 4 and 5 autonomy becomes a primary concern.

Currently, self-driving cars use "geographic information system and global positioning system (GPS)…with the road information…as the source data inputted into the map-matching model, where the intelligent path planning algorithms…are utilized to enable the path planning calculation" (Zhao et al., 2018, p. 4). However, to achieve Level 5 autonomy, these vehicles must navigate every circumstance. Wing et al. determined that "the amount of canopy cover has a significant influence in the determination of horizontal positions by GPS receivers" (2008, p. 171). To operate in all conditions, autonomous vehicles must be able to rely on more than GPS in areas with significant canopy cover, or significant foliage in other words. Canopy cover exists as an example and many other conditions would affect the uses of GPS.

SOFTWARE AND HARDWARE MODIFICATIONS

I will work alongside fellow Mechanical Engineering undergraduate students Gregory Breza, Janani Chander, Sara Khatouri, Zach Kim, and Harjot Singh. Tomonari Furukawa, Professor in the Department of Mechanical Engineering, and graduate student William Smith will oversee the progress of the project. The primary object is to fabricate an autonomous follower cart without GPS. Our team defined a follower cart as a golf cart that can navigate autonomously while directly behind another vehicle. Given the situation, the follower golf cart does not need the capabilities of locating itself in the world but just the environmental sensors to detect the lead vehicle, pedestrians, potential riders, and other objects. As a secondary objective, the team elected to further past team efforts on a fully autonomous leader golf cart. The leader cart will need to detect the environment as the follower cart did, but this cart needs to also be able to locate itself in the world. To achieve this, the leader cart will use Simultaneous Localization And Mapping (SLAM). As the name suggests, SLAM locates the sensor on a three-dimensional field and then maps the information given by the sensor. To implement SLAM, the following four questions must solve: "how to express the environment…; how to get the environment information…; how to express the obtained environment information and refresh the map…; and develop a stable and reliable SLAM" (Zhao et al., 2018, p. 10). To get the environment information, our team will implement two sensors: one Lidar sensor and one stereo camera on the front of the vehicle. For the remaining three questions, our team will utilize the Robotics Operating System (ROS) and its open-source packages. Using ROS, our team already possesses software to generate SLAM from the sensors and control the robot. Our team will need to take careful consideration of pedestrian detection, which generates another level of complexity on top of general location. Figure 3 demonstrates all the levels of complexity in pedestrian detection.

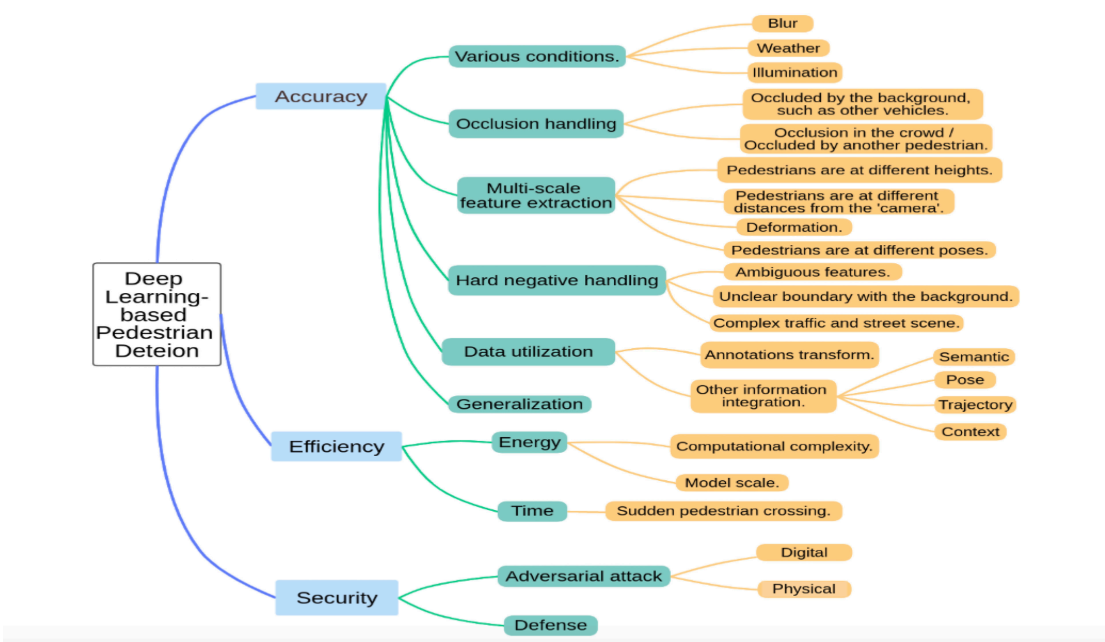

Figure 3. The inherent attributes and major challenges of pedestrian detection. A diagram to show all the critical components to make a successful pedestrian detection system. Each color identifies another layer (Boukerche & Sha, 2021, p. 133).

Although pedestrian detection and general environmental detection possess similar challenges, pedestrian detection presents additional challenges because of human attributes and behavior, such as pedestrian's varying heights, poses, and likelihood to jaywalk as shown in

Figure 3. Therefore, some of the packages may need to be modified to properly address the pedestrian detection. The sensors, ROS, and the subsequential ROS packages will allow for the software portion of the automation, but the mechatronics systems of the golf cart must also be designed to react quickly to pedestrian detection to avoid accidents.

To physically move the golf cart, our team must design three subsystems to modify the two existing carts. The two existing carts will be called Cart 788 for the leader cart and Cart 789 for the follower cart. The three systems are braking, steering, and accelerating. The braking subsystem needs to mimic a foot pressing on the brake pedal. When a foot presses a brake pedal, the pedal moves towards the ground, which moves a connecting bar that pulls on the disk brakes on the wheels. To achieve the same motion of a foot, a linear actuator will be attached the connecting bar to move it into a braking and non-braking position. For the steering subsystem, the motion of the steering wheel being rotated clockwise and counterclockwise must be imitated to achieve turning. When rotated, the wheel rotates a shaft called the steering column. An advanced steering column with a motor will replace the existing steering column to achieve left and right turns. To generate the actual motion of the tires, our team will implement drive by wire. Xiang et al. meticulously explain the technology behind drive by wire systems in their article (2008, p.2-20). Lastly, to mimic acceleration, a signal must be sent to the motor that replicates a foot steeping on the acceleration pedal. Since the foot pressing on the pedal generates an electrical signal to the motor, our team will place an Integrated Circuit (IC) chip before the golf cart motor to accelerate the vehicle. Figure 4 summarizes the previous material in a system diagram.

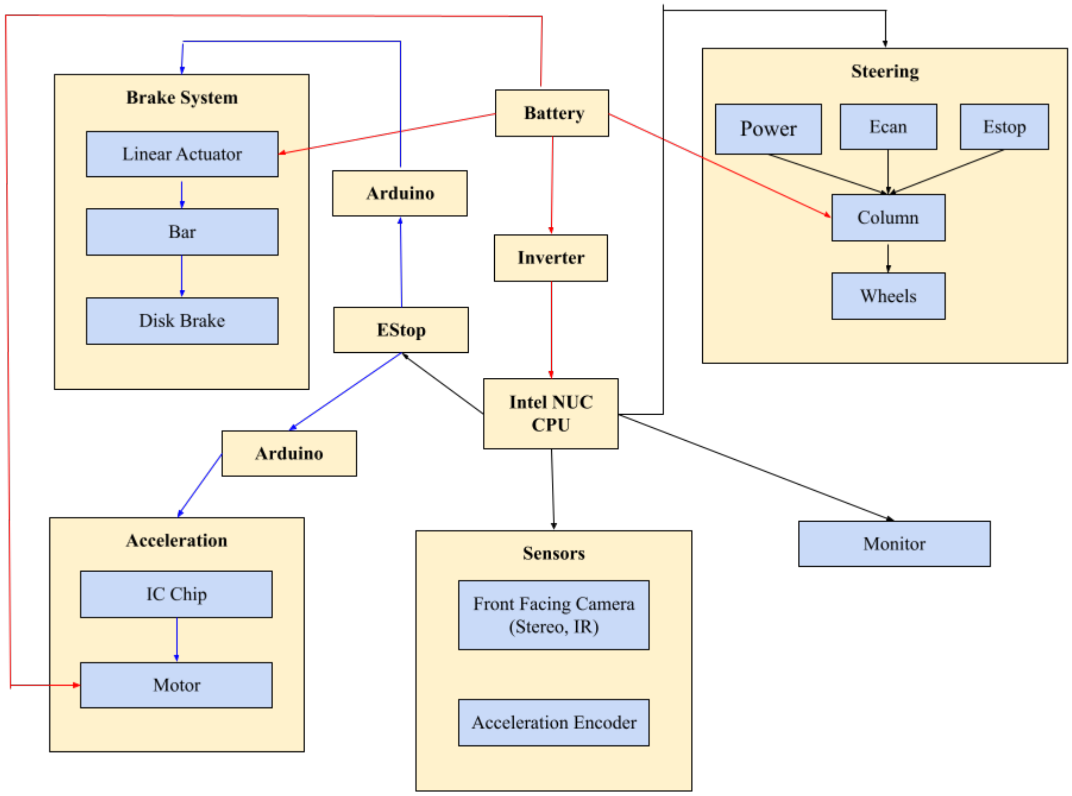

Figure 4. System Diagram for Follower Vehicle. This figure represents a sample system diagram for Cart 789. The yellow boxes represent distinct groups of component(s). The blue parts are interactable components within each group. The red lines depict the power supply. The blue depicts an Arduino connection. The black lines depict general connection (Rushton, 2021).

The primary object of the project is to demonstrate the autonomous capabilities of golf carts without GPS. This will come in two forms: one a follower cart and the other a more advanced leader cart. Our team will modify Cart 789 as described in the system diagram. The findings from Cart 789 will be produced in a scholarly article for the University of Virginia.

THE NEXT INDUSTRIAL REVOLUTION: AUTONOMOUS VEHICLES DISRUPT WORKERS

During the coronavirus pandemic, over eight million workers left their jobs at an unprecedented rate, but companies continued similar levels of production (Lynch, 2021, para. 1). Electronic commerce (E-commerce), one of the major industries affected by the pandemic, coped with a loss of workers by innovating: "the e-commerce boom has fueled orders for…self-driving machines" (Lynch, 2021, para. 8). Whether these self-driving machines are forklifts, trucks, or other machinery, automation spells over eighty-five million lost jobs (Lynch, 2021, para. 26). Although The World Economic Forum forecasts a net gain of twelve million jobs from automation, the ninety-seven million new jobs could be in vastly different industries than lost jobs (Lynch, 2021, para. 26). Experts forecast that the United States trucking industry could implement autonomous trucks by 2027 (Baral, 2021, para. 4). Being the most common jobs in most states, 1.7 million out of the current 3.5 million truckers could lose their job to automation in the next decade (Baral, 2021, para. 6-7).

A job migration of this scope begs the question: how autonomous driving will affect working-class Americans. For the purposes of scope, the STS project will be concentrated on the trucking industry. This job migration can clearly be seen in a purely economic lens, investigating profitability of trucking companies and job relocation. However, that research lacks the broad societal change. Additionally, this project will examine the public's perception to drivers, driver's use of free time, and the engineers' reaction to the change within an industry.

STRUCTURE FOR ANALYZING TRUCKING INDUSTRY

To address each facet of the research, I will use a robust framework. Previously used with medical technology, Hurtado-de-Mendoza et al. altered Actor-Network Theory (ANT) with a secondary Foucauldian view; this dual perspective analyzes the power dynamic from a technology within the proper scope (2015, pg. 330; Latour, 2011). Figure 5 demonstrates the agency within the trucking industry from autonomous vehicles.

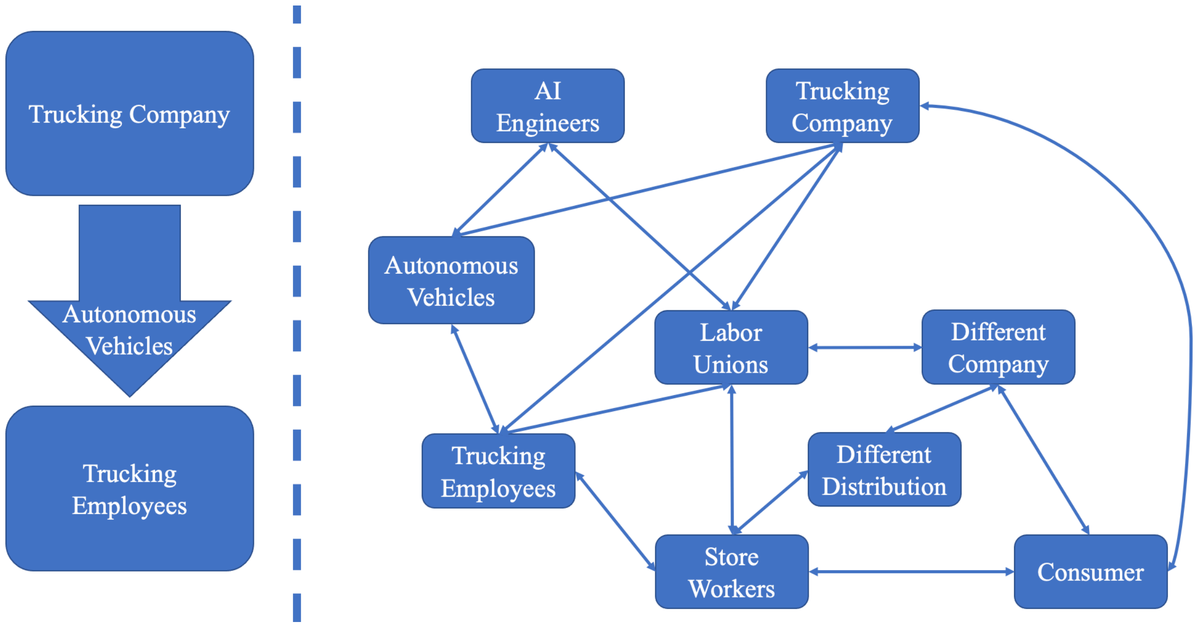

Figure 5: Modified Actor Network Theory for Trucking. The figure shows a framework depicting two ways to view agency with a new technology. The left is a Foucauldian view of power regarding truckers. The right is a traditional ANT for truck drivers (Adapted by Charles Rushton (2021) from Hurtado-de-Mendoza et al. 2015)

Left of the dotted line portrays the purely Foucauldian view of the trucking companies using autonomous technologies to strip truckers of their agency. To some extent, this framework gives insight into the bartering agreement between employer and employee. The employer now has a direct substitute for human labor with self-driving trucks, giving the employer significant leverage when determining wages. This view will assist in the economic portion of the STS research. However, this view fails answer the broad societal views. As shown in the right side of the dotted line, the ANT framework spans across more actors. The agency in this case is dispersed between multiple agents. This framework leads to examine actors and their willingness to engage with truckers post the automation wave.

In addition to this dual framework, the scope of the network needs to be refined further to deliver meaningful results. Figure 6 will show the 4 main relationships of truckers for this research: friends/family, bystanders, employer, and AI designers.

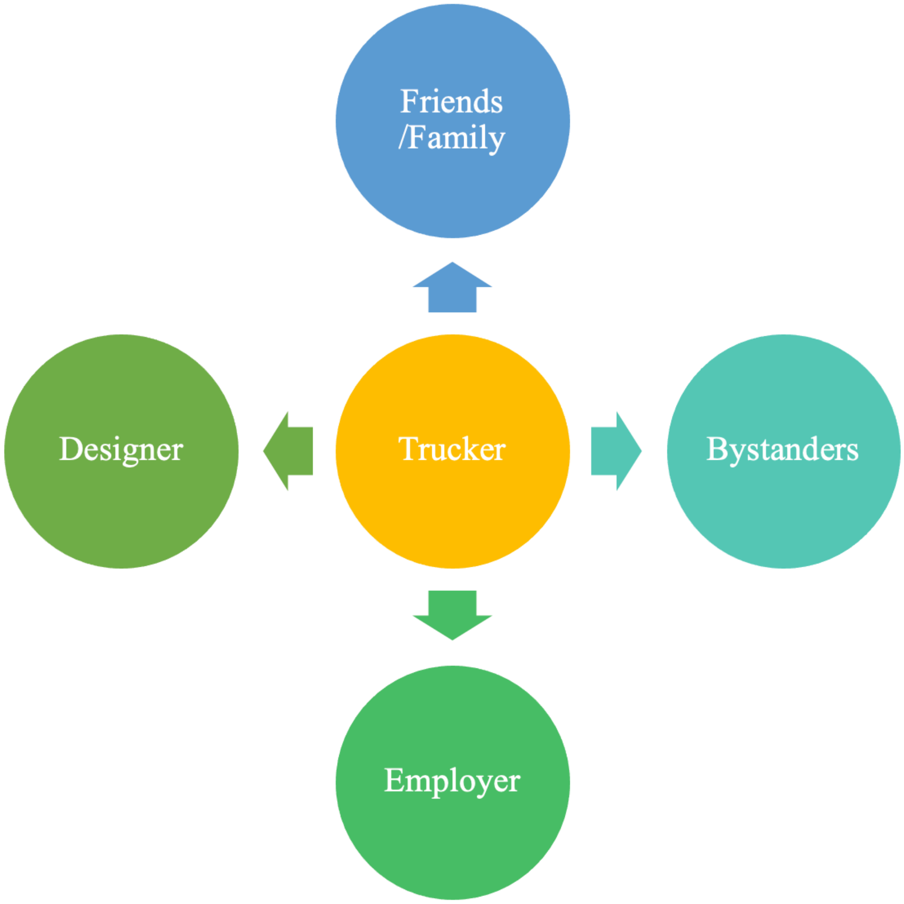

Figure 6: Potentially Affected Social Relationships for Trucker from Autonomous Vehicles. A sample truck driver's network of relationship that could be highly impacted by the introduction of autonomous vehicles. (Rushton, 2021)

STUDY OF TRUCKER'S SOCIAL NETWORK

Each of these relationships requires different questions to determine a possible solution. To determine the relationship between employer and AI designer, the research will rely heavily on the framework in Figure 5 for analysis. Next, for the bystander, I will research how a bystander views the truckers given self-driving trucks. If an autonomous truck creates an accident, bystanders may blame the truck driver. Elish calls this phenomenon the moral crumple zone: "how responsibility for an action may be misattributed to a human actor who had limited control over the behavior of an automated or autonomous system" (2019, p. 41). As more autonomous vehicles become adopted, accidents will occur with vehicles on the roads.

Responsibility remains a huge component of the relationship between truckers and other agents. Elish (2018) applies the moral crumple zone to accidents in the aeronautic and nuclear space (p. 51). Using those examples as a foundation, the STS paper will focus on responsibility in the trucking industry. However, the accidents and responsibility fail to give the complete picture. The perspective of the trucker changes with the adoption of autonomous vehicles without accidents as well. Collingwood (2018) argues that "automation in the trucking industry…will ultimately bring with it a revised identity which, though arguably welcome, is out of keeping with historical and cultural perceptions" (p. 265). Specifically, the cultural perspective is preserving "the last bastion of machismo" in the trucking industry (Collingwood, 2018, p. 260). These two perspectives will allow for an articulate argument for the relationship between trucker and bystander.

For the last relationship, the research will explore the trucker's interactions with friends and family. With the autonomous capabilities taking the wheel, trucker will have an increased amount of free time. However, this newly made time could become more work. Cohen (1987) shows that despite technological advancements in the home, housewives continued to work the same hours from 1960s through the 1980s (p. 58). These housewives continued to accept more responsibilities like using a car to "become her own door-to-door delivery service" (Cohen, 1987, p. 62). With the creation of free time, truck drivers may be asked to burden more responsibilities. Another perspective for trucker is the change in drug use from increased free time. Currently, 30% of trucker drive use amphetamines (American Addiction Center, 2021, Truck Driver, Drug Use & Staying Awake section). With an increase of free time, there is a risk that truck driver increases drug use, especially given that the trucking community will shrink from the adoption of autonomous vehicles. Truckers will not be able to interact with one another as frequently, eroding part of the social support system.

I hope to determine a government or legal structure to maintain or increase the quality of life of truckers. After interviewing crucial stakeholders, Cohen et al. examined the potential government interaction for autonomous vehicles in the United Kingdom. Cohen et al. discovered that "a laissez-faire approach to governance was strongly rejected by almost all of the stakeholders to whom we spoke" (2018, p.269). These authors argue for "at an early stage, coherent visions of desirable future transport and put AVs in their place. Disruptive and utopian claims should be met with [organized], incremental policies" (Cohen et. al, p. 271). I will examine the relationships as well as Cohen et al.'s incremental policy for a recommendation for the trucking industry in America. I will compose this recommendation into a scholarly article.

WHO TAKES THE WHEEL

The technical project allows for an incremental step towards an autonomous world. Developing a vehicle that can navigate without GPS generates technology necessary for Level 5 autonomy. Innovating Cart 788 would allow for more efficient potential student visits of the University of Virginia with a cart tour rather than the traditional walking. A single tour guide could drive a lead cart, and a series of follower cart, full of prospective students, could follow autonomously. However, this innovation reaps benefits and negative consequences. Autonomous vehicles will change the landscape for working-class Americans. Before the full implementation of the technology, policy must be enacted to properly care for key stakeholders. Keeping in mind the user of this technology, our teams hope to create a product, both technical and political, to benefit the maximum number of actors within the network.

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