THE CREATION OF AN AUTONOMOUS SYSTEM TO TRANSPORT STUDENTS

THE UNINTENDED CONSEQUENCES OF AUTONOMOUS VEHICLES

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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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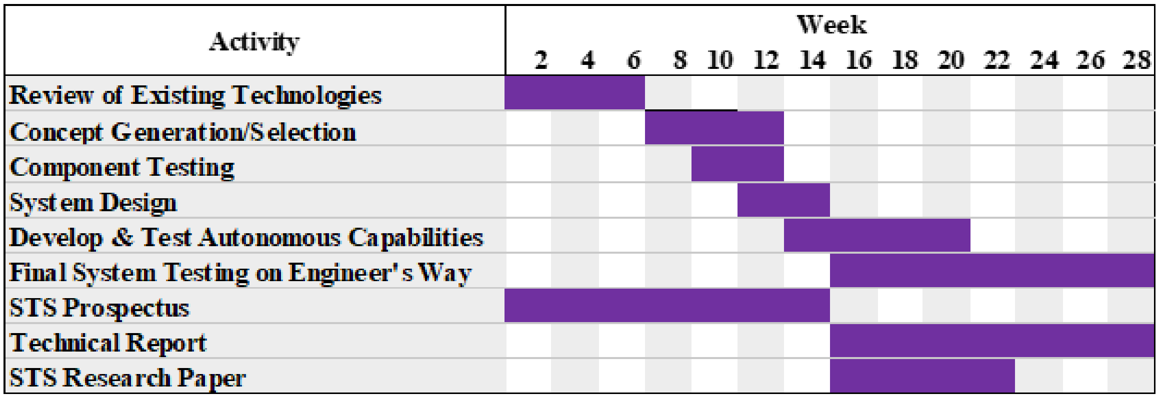
Over the past few years, the technology in automobiles has increased dramatically. The next major innovation in that field is the development of completely autonomous vehicles. The development of this technology will have much greater implications than simply providing people with an effortless way to get from point A to point B. This innovation will cause driving to be much safer than it is today (Karnouskos, 2020), but the benefits do not stop there. There are several social, economic, and environmental impacts that will occur with the popularization of autonomous vehicles. The technical project will discuss the creation of an autonomous vehicle while the tightly coupled STS research will analyze the positive and negative consequences of autonomous vehicles in order to minimize or maximize those consequences. The technical and STS work will be carried out according to the timeline in Figure 1. The majority of the research and planning will occur in the first semester while the technical work will dominate the second semester.

Gantt Chart for Two 14-Week Semesters of Fall 2021 and Spring 2022



Activity	Week 2	4	6	8	10	12	14	16	18	20	22	24	26	28
Review of Existing Technologies	■	■	■											
Concept Generation/Selection				■	■	■								
Component Testing					■	■								
System Design						■	■							
Develop & Test Autonomous Capabilities							■	■	■	■				
Final System Testing on Engineer's Way								■	■	■	■	■	■	■
STS Prospectus	■	■	■	■	■	■	■							
Technical Report								■	■	■	■	■	■	■
STS Research Paper								■	■	■	■			

Figure 1: Gantt chart for Two 14-Week Semesters of Fall 2021 and Spring 2022. The chart was created by the technical project team depicting the planned timeline for work to be completed on the technical project and STS research (Khatouri, 2021).

THE CREATION OF AN AUTONOMOUS SYSTEM TO TRANSPORT STUDENTS

The technical capstone team includes the following students in the Mechanical and Aerospace Engineering (MAE) department: Janani Chander, Zackary Kim, Gregory Breza, Charles Rushton, and Harjot Singh. The project is led by MAE Professor Tomonari Furukawa and assisted by MAE graduate student William Smith. This team is creating an autonomous system that will transport students from one class to the next by developing a two-golf cart leader-follower system.

There are currently multiple methods of transportation between classes. Walking is the most popular method of transportation as it requires no cost, planning, or resources; however, students who have far distances to travel or those who have disabilities or injuries may find it difficult to walk from class to class, so they must either use a personal car or public transportation i.e. busses. Using a personal car to travel from class to class is difficult because the student would need to find a parking space at the destination, which is uncommon on a college campus. This means that the next available option is riding a bus. The difficulty with busses, however, is that they only come at scheduled times and only stop at predetermined stops, so the student is limited in where/when they are able to travel. By creating an autonomous system to transport students from class to class, we will be providing a more reliable transportation method for students who are unable to use walking as their primary transportation method, either due to the distance that they need to travel or due to an injury/disability.

The autonomous system that is being developed for this project will consist of two golf carts; one golf cart will follow the other along the route. We will continue the efforts of last year’s team in making the follower golf cart fully autonomous, and then we will expand on their work by making the leading golf cart autonomous as well. We will be using the Observatory

Mountain Engineering Research Facility (OMERF) laboratory in order to conduct our work. Initial testing will be performed in the OMERF parking lot to determine the current state of the existing golf carts and pinpoint areas that need immediate attention. Once we develop two fully autonomous golf carts, we will then move our testing location to Engineers Way in order to improve the system's interaction with the environment.

We will begin by conducting research of past work on autonomous vehicles and on the efforts of the prior teams that have worked on this project in order to determine the best technologies to use in our system. In the development of this system, there are both hardware and software components that must be considered.

HARDWARE

The main existing hardware components on the golf carts are sensors, potentiometers, motors, and a human machine interface (HMI). Last year's team used a combination of Light Detection and Ranging (LiDAR) and stereo cameras surrounding the golf carts in order to obtain 3D mapping capabilities (Smith, 2021, p. 11). A DC gear motor was used for breaking (Smith, 2021, p. 12). A potentiometer was attached to the golf cart motor in order to encode the exact position (Smith, 2021, p. 13) and a servo motor was used to control the steering system (p. 18). During the concept generation/selection phase, students examined both golf carts to develop a system diagram of each golf cart. The diagram for Cart 788, which will be the "follower" golf cart in the leader-follower system, is shown in Figure 2 on page 4, and the diagram for Cart 789, the "leader" golf cart, is shown in Figure 3 on page 5. During the component testing phase, the 2021-22 team will isolate each of these components in order to determine their functionality and limitations, then discuss the necessary steps to improve upon them in the System Design phase.

Cart 788 System Diagram

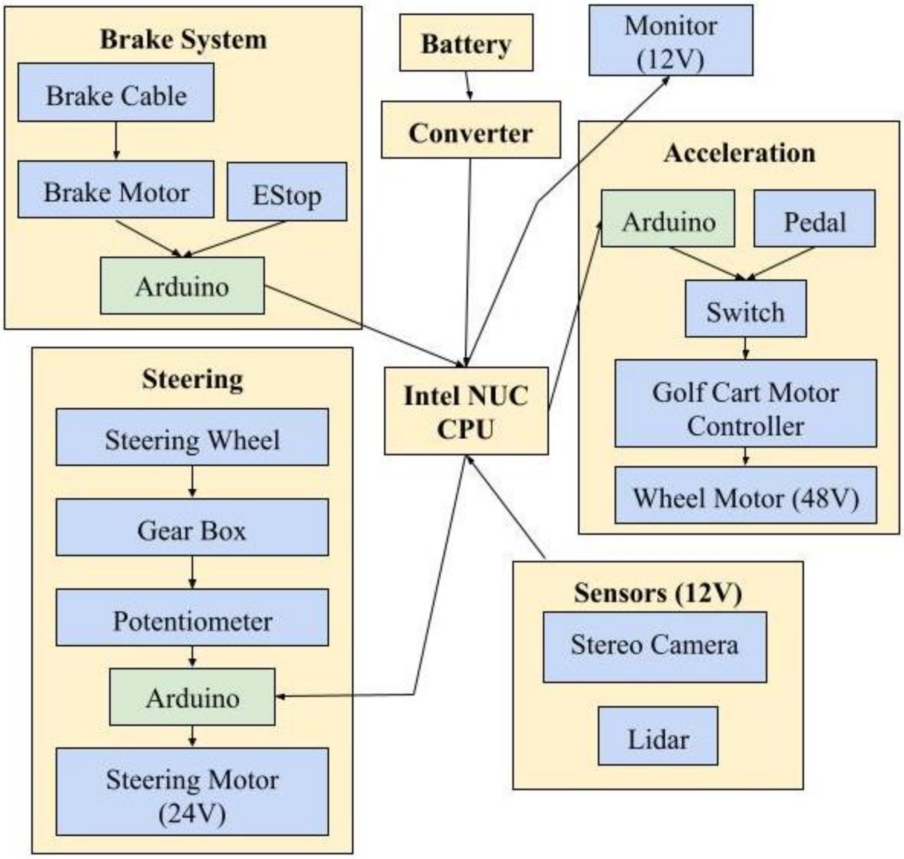


Figure 2: Cart 788 System Diagram. This system diagram depicts the connections between each of the components for the follower golf cart, Cart 788, developed by the 2021 technical project team. (Khatouri, 2021).

Cart 789 System Diagram

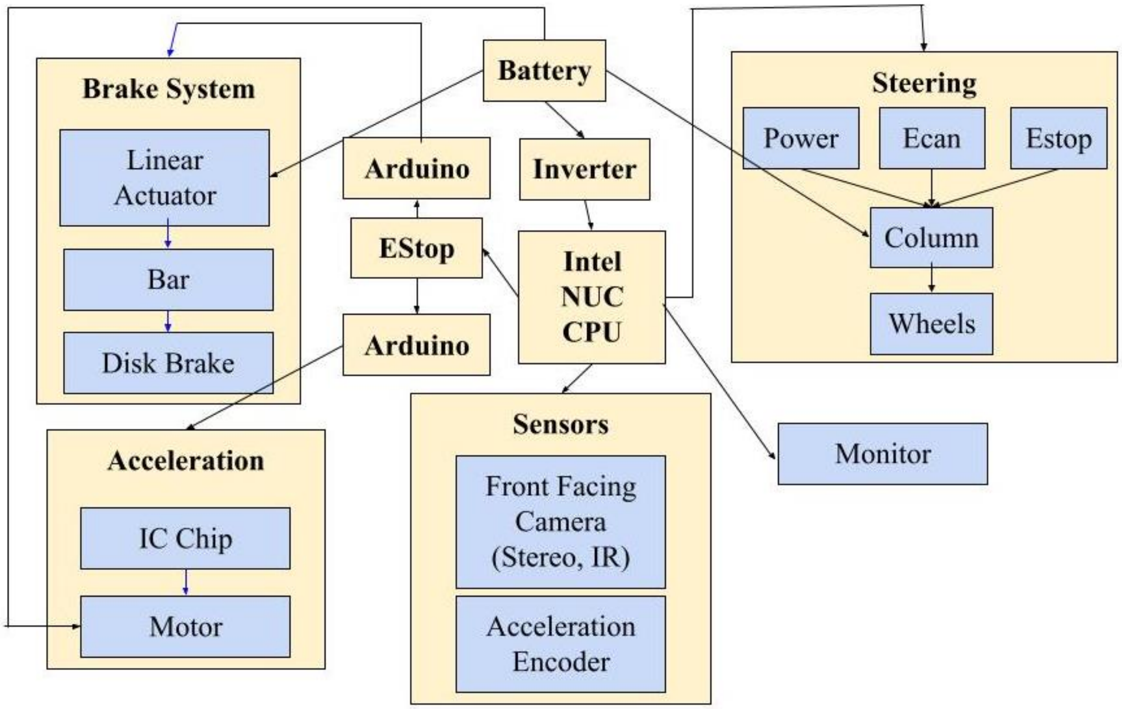


Figure 3: Cart 789 System Diagram. This system diagram depicts the connections between each of the components for the leader golf cart, Cart 789, developed by the 2021 technical project team. (Khatouri, 2021).

SOFTWARE

For the software, the past team used Ubuntu 18.04 as the operating system and installed the Robotics Operating System (ROS), which is a common middleware in the robotics industry (Smith, 2021, p. 21). A graphics processing unit (GPU) was used instead of the central processing unit (CPU) on the computer to enable faster processing of the sensor data (Smith, 2021, p. 22). Real-Time Appearance-Based Mapping (RTAB-Map) was used to develop a point map of the environment (Smith, 2021, p. 22), but in an interview with William Smith it became known that this mapping method did not work. In order to improve upon last year’s capabilities, the 2021-22 team will update the car-following algorithm to use the optimal velocity model, which determines the following vehicle’s motion based on the distance of the current velocity and the optimal velocity (Zhang et al., 2020). The code will also be modified to maximize the capabilities of ROS to accurately navigate the environment using the research of Shimchik et al. (2016).

Our goal in this project is to continue the development of a dual golf cart system that will create a map of the environment and then use that map to autonomously drive students from Engineers Way to the OMERF lab without the use of a GPS. The results of this project and the research that accompanies it will be presented in the form of a technical report.

THE UNINTENDED CONSEQUENCES OF AUTONOMOUS VEHICLES

Currently, there is a major push toward autonomy in the automobile industry. “Almost every major car maker is working on some form of automation” (Waldrop, 2015, p. 20). The immediate goal of the development of autonomous vehicles is to increase efficiency and safety on the road, but the outcomes that follow from the popularization of autonomous vehicles have the potential to have widespread effects on society. It is important to predict these effects in advanced because if there is a potential negative affect, then developers and legislatures would be able to act now to try to minimize that effect. Gaining an understanding of the potential effects would also allow for action to be taken to maximize any potential positive effects. This paper will analyze the potential social, economic, and environmental impacts of autonomous vehicles (AVs) in order to determine the best way to implement this technology to minimize the negative and maximize the positive consequences of its adoption.

SOCIAL

The implementation of AVs has the potential to reduce accidents on the road and increase the efficiency of traffic patterns (Arem et al., 2006, p. 429). This could result in faster and safer commutes for everyone, even those who are not driving an AV. However, not only does AV technology increase efficiency of travel, it could also increase safety on the roads. “The National Highway Traffic Safety Administration (NHTSA) estimates that 94% of road incidents in the United States are caused by human error” (Harrington & Schenck, 2017, p. 3). Switching to automation would eliminate that human error and therefore create safer roads as a result.

However, because of the novelty of AV technology, not everyone is comfortable with the adoption of AVs into society. Chicago legislatures “proposed an ordinance that would ban AVs in Chicago” due to safety concerns (Harrington & Schenck, 2017, p. 3). While this seems counterintuitive due to the fact that AVs would actually create safer roads, the Chicago ban illustrates the hesitancy of society to adopt this new technology. Another popular concern that became prominent with the introduction of AV technology is the ethical concern with the decisions that the AV would have to make in the situation of an imminent crash. Figure 4 depicts three scenarios where the AV would need to make a decision to save someone’s life over another’s. In each of these scenarios, there is unavoidable harm, but the vehicle has options for who and how many people get harmed. These scenarios are just as common with existing manually-driven vehicles, but with the AVs taking the control out of the driver’s hands, concern arises as to how the AV would make these decisions.

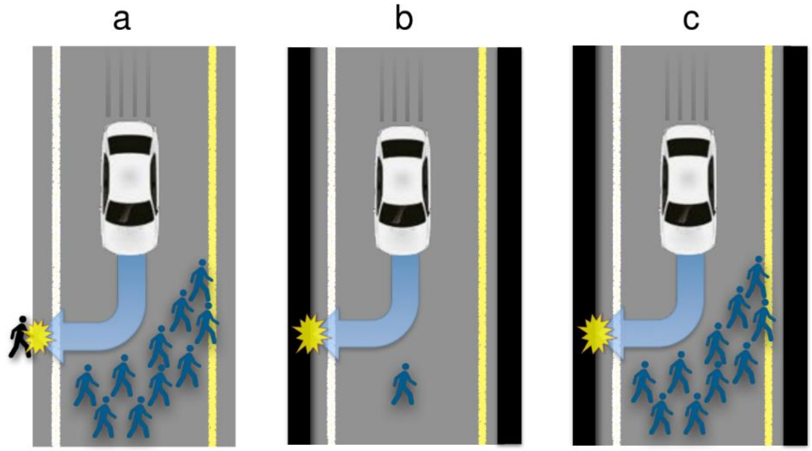


Figure 4: Three traffic situations involving imminent unavoidable harm. The car must decide between (a) killing several pedestrians or one passerby, (b) killing one pedestrian or killing its own passenger, (c) killing several pedestrians or killing its own passenger (Goodall, 2014).

Many people are concerned with whose life the AV would prioritize, which illustrates the discomfort that is caused by an unfamiliar technology. Legislation has the potential to ease people's fears of a new technology because it would ensure that the technology is safely implemented. When Andrews (2004) wrote *Changing Conceptions*, she stated that "regulation with more teeth is necessary to achieve public trust" (Andrews, 2004, p. 128). Learning about the concerns that people have with the AVs will allow for appropriate legislation to be implemented in order to increase public trust of the new technology and therefore be able to reap the benefits of its implementation.

ECONOMIC

The development of autonomous vehicles by rideshare companies such as Uber and Lyft would lead to the popularization of a shared AV system in cities (Harrington & Schenck, 2017, p. 6). According to Tak et al. (2021), the use of shared autonomous vehicles in cities greatly reduces the number of privately owned vehicles. "A shared-vehicle mobility solution can meet the personal mobility needs of the entire population with a fleet whose size is approximately 1/3 of the total number of passenger vehicles currently in operation" (Spieser et. al., 2014, p. 1). In other words, a shared-vehicle mobility solution would lead to a reduction in the cost of maintaining and growing infrastructure because if car sharing becomes the norm, then there would be no more need for cars to sit idly in parking lots, therefore reducing the need for these spaces. This would allow city planners to reallocate these funds elsewhere.

ENVIRONMENTAL

Perhaps the most important factor to consider in the development of AVs is their impact on the environment. However, this is also the factor that is the most unknown. Arthur Harrington & Sarah Schenck, attorneys in the Environmental and Energy Strategies Group at Godfrey & Khan, S.C., detail both the potential negative and positive effects that the popularization of AVs could have on the environment in their article *The Driverless Horseless Carriage: Steering the Anticipated Environmental Impacts of Autonomous Vehicles.* In this article, Harrington & Schenck (2017) use vehicle miles traveled as a metric to determine the environmental impact of AVs – more vehicle miles would result in more emissions, which are harmful to the environment, so the goal is to reduce the total number of vehicle miles traveled (p. 5). Harrington & Schenck (2017) speculate that AVs have the potential to vehicle miles traveled due to the ease of this transportation method causing people to move further away from cities (p. 5); AVs also have the potential to decrease vehicle miles traveled by creating a more efficient transportation system (p. 5). Since the potential effect of AVs on the environment is so ambiguous, more research needs to be done in order to better predict the outcomes of AVs and create legislation that would push the effects in the positive direction.

New technology can have a drastic effect on different social groups, but those social groups also affect the technology itself. The SCOT framework, which is discussed in Johnson's article *Social Construction of Technology*, analyzes this interesting relationship between the developers of a technology and the affected groups. The STS research paper will use the SCOT framework to analyze the effect of autonomous vehicle technology on society. A visual of the interactions between the AV developers and various groups is depicted in Figure 5 below. Research will be conducted with the goal of determining the most probable outcomes of AV technology in order to allow calculated action in the form of legislation to be taken today to either maintain or change those outcomes. This research will be presented in the form of a scholarly article.

SCOT Framework

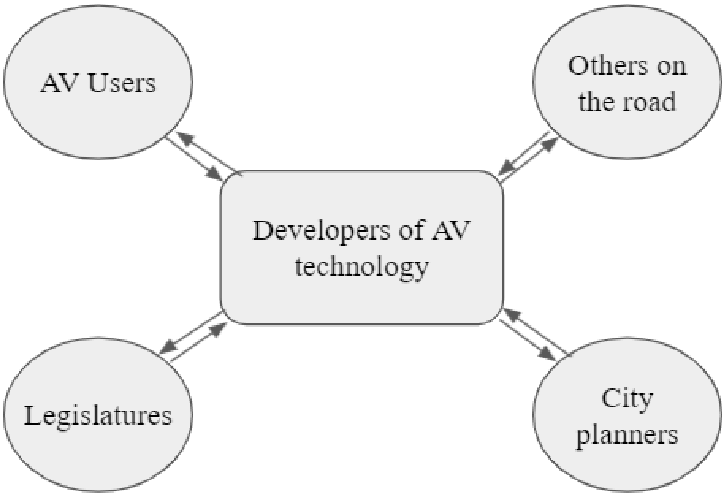


Figure 5: SCOT Framework. This diagram depicts the groups that affect and are affected by the development of AV technology (Khatouri, 2021).

THE PURPOSE OF AUTONOMOUS VEHICLE RESEARCH

Through the research conducted the rest of this semester and next semester, students on the technical project team will create a single autonomous system to transport university students between classes, allowing for a more efficient transportation method for those who are unable to walk. This is a very isolated case of autonomous vehicle technology due to the fact that it will be a single system rather than a network of vehicles; therefore, the development of this technology will not drastically affect many groups outside of the immediate social group. The tightly coupled STS research will analyze the effect of AV technology when implemented on a much larger scale. By scaling the technology, the effects become much larger and more widespread, therefore there is a much greater need to predict those effects in advanced in order to maximize its benefits on society.

REFERENCES

Andrews, L. B. (2004). Changing conceptions. *Living With the Genie: Essays on Technology and the Quest for Human, 41*(08), 105-128. doi:10.5860/choice.41-4617

Arem, B., Driel, C. J., & Visser, R. (2006). The impact of cooperative adaptive cruise control on traffic-flow characteristics. *IEEE Transactions on Intelligent Transportation Systems*, *7*(4), 429–436. https://doi.org/10.1109/tits.2006.884615

Bonnefon, J.-F., Shariff, A., & Rahwan, I. (2016). The social dilemma of Autonomous Vehicles. *Science*, 352(6293), 1573–1576. https://doi.org/10.1126/science.aaf2654

Coste-Maniere, E., & Simmons, R. (2000). Architecture, the backbone of Robotic Systems. *International Conference on Robotics and Automation*. https://doi.org/10.1109/robot.2000.844041

Goodall, N. J. (2014). Machine ethics and automated vehicles. *Road Vehicle Automation*, 93–102. https://doi.org/10.1007/978-3-319-05990-7_9

Harrington, A., & Schenck, S. (2017). The driverless horseless carriage: Steering the anticipated environmental impacts of autonomous vehicles. *Natural Resources & Environment*, *31*(4), 24–27.

Johnson, D. G. (n.d.). Social construction of technology. *Encyclopedia of Science, Technology, and Ethics*, 1791–1794. https://doi.org/https://www.encyclopedia.com/science/encyclopedias-almanacs-transcripts-and-maps/social-construction-technology

Karnouskos, S. (2020). The role of utilitarianism, self-safety, and technology in the acceptance of self-driving cars. *Cognition, Technology & Work.* https://doi.org/10.1007/s10111-020-00649-6

Khatouri, S. (2021). *Gantt Chart for Two 14-Week Semesters of Fall 2021 and Spring 2022.* [Figure 1]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Khatouri, S. (2021). *System Diagram for Cart 788.* [Figure 2]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Khatouri, S. (2021). *System Diagram for Cart 789.* [Figure 3]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Khatouri, S. (2021). *SCOT Framework.* [Figure 5]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Shimchik, I., Sagitov, A., Afanasyev, I., Matsuno, F., & Magid, E. (2016). Golf cart prototype development and navigation simulation using ROS and Gazebo. *MATEC Web of Conferences*, 75, 09005. https://doi.org/10.1051/matecconf/20167509005

Smith, W. (2021, May 14). *Modification of a Golf Cart to Autonomous Campus Vehicle*. Modification of a golf cart to autonomous campus vehicle; social side effects of the development of Autonomous Transportation. Retrieved October 24, 2021, from https://libraetd.lib.virginia.edu/public_view/x346d514t.

Motwani, S., Sharma, T., & Gupta, A. (2021). Ethics in autonomous vehicle software: The dilemmas. *Computer, 54*(8), 46–55. https://doi.org/10.1109/mc.2021.3077576

Skeete, J.-P. (2018). Level 5 autonomy: The new face of disruption in road transport. *Technological Forecasting and Social Change*, *134*, 22–34. https://doi.org/10.1016/j.techfore.2018.05.003

Spieser, K., Treleaven, K., Zhang, R., Frazzoli, E., Morton, D., & Pavone, M. (2014). Toward a systematic approach to the design and evaluation of automated mobility-on-demand systems: A case study in Singapore. *Road Vehicle Automation*, 229–245. https://doi.org/10.1007/978-3-319-05990-7_20

Waldrop, M. M. (2015). Autonomous vehicles: No drivers required. *Nature*, 518(7537), 20–23. https://doi.org/10.1038/518020a

Tak, S., Woo, S., Park, S., & Kim, S. (2021). The city-wide impacts of the interactions between shared autonomous vehicle-based mobility services and the public transportation system. *Sustainability*, *13*(12), 6725. https://doi.org/10.3390/su13126725

Zhang, G., Ma, Q., Pan, D., Zhang, Y., Huang, Q., & Jiang, S. (2020). Study on the integration effect of multiple vehicles' delayed velocities on traffic stability in Intelligent Transportation System Environment. *Engineering Computations*, *38*(2), 929–940. https://doi.org/10.1108/ec-05-2020-0261