Ethical Considerations in the Deployment of Autonomous Vehicle Cybersecurity Measures

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1. Introduction

Although previous research, standards, and policies have been established, there are critical gaps in specifically applying cybersecurity measures with ethical constraints compatible with the deployment of AVs. The typical standards and policies rely extensively on heavily regulated and instrumented procedures that may not be applicable in commercial development or fully adaptable to the full range of unknown consequences of accommodating human drivers. These practices need to be defined and systematized as forceful moral considerations in roaming systems that can operate in a myriad of circumstances and users. This research provides five ethical hazards that need to be avoided or otherwise mitigated by such measures and, where possible, possible constraints that can inhibit the realization of those safeguards.

Proliferation and deployment of autonomous vehicles (AVs) are significantly disrupting personal and public transportation systems. AVs offer a wealth of benefits, including increased road safety, mobility access for those who would otherwise be unable to drive, and smoother commutes. Inherent in realizing these benefits is trust by the public that the vehicles will operate safely and maintain their privacy and security during operation. By relying on numerous advanced technologies such as machine learning, sensors, and software platforms, AVs are succumbing to a host of new cybersecurity threats. In all AV operations, the safety, reliability, and security of the vehicle's operations and its passengers' sensitive user data, with and without the need for an engaged human driver, inherently rely on robust cybersecurity measures.

1.1. Background and Significance

Autonomous vehicles have been internationally recognized as a key factor driving future transportation. Not only have many large manufacturers aggressively entered the industry, along with their spirit of high scientific achievement and innovation, but other technology companies such as Google and Uber have focused their resources and innovation to lead and shape the industry. In the U.S. market, the U.S. Department of Transportation has published a Federal Automated Vehicles Policy (FAVP), showing its commitment to encouraging the safe development, testing, and deployment of autonomous vehicles. Since manufacturers and system vendors have spent resources to integrate self-driving systems with existing vehicle structures, the safety and security of the autonomous vehicle have gone from hypothetical speculation to measurable assurance, which has motivated the shift of its emphasis in the development of standards. However, the practice of autonomous vehicle cybersecurity is still in its infancy, compared with other aspects of vehicle safety and security. Even though the cybersecurity precautions for autonomous vehicles have not been fully resolved, they have been proven to be vital to vehicle safety. This study focuses on the deployment of cybersecurity for autonomous vehicles and aims to analyze trade-offs, basis, and ethical considerations in its deployment.

According to the National Highway Traffic Safety Administration (NHTSA), there are more than 36,000 fatalities caused by vehicle crashes in the U.S. every year. To reduce such high motor vehicle fatality rates, automotive technology has been developing in recent decades. The modernization of vehicles equipped with evolving technology means that the risks and vulnerabilities for motor vehicles have likewise increased. The introduction of automated driving technology and Defense Advanced Research Projects Agency (DARPA) grand challenges accelerated the advancement of this technology into modern vehicles. With the latest trends in automotive manufacturing, there seems to be a common vision for future autonomous vehicles, which can independently detect and respond to potential and foreseeable accidents to prevent accident scenes.

1.2. Purpose and Scope of the Study

However, autonomous vehicles come with their share of ethical considerations and in this study we focus on: the use of autonomous vehicles for criminal purposes, pedestrian and occupant safety, the allocation of unavoidable crash risks, the denial of garage access to people or vehicles, the development of an attitude-altering mobility solution, and the sharing of

responsibility and norms of good practice. Therefore, with the rise in self-driving vehicles, a known concern is their vulnerability to malicious cyber-attacks. These attacks can come in the form of computer viruses, denial-of-service attacks, or robots as introduced previously. With the vehicle heavily reliant on sensors and other communication devices, all cybersecurity risks and countermeasures need to be carefully considered.

This research study focuses on the broader issues of how different stakeholders involved in the transportation, academic, and technology industries think about implementing and regulating cybersecurity design features in autonomous vehicles. Such issues span public safety, privacy, industry competition, liability, and the general public's perceptions about introducing autonomous vehicles onto the road. Once on the road, autonomous vehicles will benefit society in general in a number of areas such as increased job and shipping productivity, reduced traffic congestion, increased accessibility of mobility options for society segments such as seniors, impaired people, and generally all those that are not in a driving state of mind.

2. Ethical Frameworks in Technology

A number of ethically substantiated documents providing guidance in commercial endeavors using blockchain technology have been formulated across different platforms and in different geopolitical cultures. In light of the aforementioned, we can categorize the significant number of ethical documents derived from application areas focused on the ethical codification of the use of new technologies as important theoretical tools for strengthening the ethical framework for commercial endeavors using blockchain technology. This will form the theoretical basis for utilizing other available theoretical grounding and, thereafter, for actual cases.

Both ethicists and technologists emphasize the influence and role of technology in contemporary society. From the invention of public-key cryptography to new social networking applications, technology instigates substantial changes in the choices we make. Ethical dilemmas are particularly evident in connection with powerful, relatively new, consumer-oriented technologies such as digital genetics, digital pharmacology, digital biology, and most recently, autonomous vehicle cybersecurity.

2.1. Utilitarianism

It has been recognized that the burgeoning value of AV technology can result in significant utility over time through increased safety and mobility. However, it is also recognized that ethical challenges and dilemmas can emerge as AVs can find it difficult to both ascertain the most suitable actions to take in real time, often when the physical integrity of principal-agent stakeholders as well as the money, property, and financial well-being are at risk, and also act upon the most suitable decision in time to avert a crisis situation. Furthermore, the development, design, and deployment of measures to bolster the cybersecurity posture of AVs is not without controversy, as new vulnerabilities of an adversary can be developed, potentially leading to new types of attacks, and uncover new ethical implications linked to the principle of nonmaleficence and various levels of intent of an attacker. In this respect, we present the prospect of cybersecurity measures being developed and applied as, depending on the ethical doctrine utilized, a utilitarian or pluralistic perspective may not strictly affect the advancement of such cybersecurity measures but instead describe future burden shiftings as well as the timescales associated with safety and security expectations of the AV.

Utilitarianism or the utilitarian principle is founded on the objective of increasing overall utility, happiness or well-being, often measured in net benefits to society. From the standpoint of a utilitarian, a course of action that results in the greatest amount of net benefits to various stakeholders is the favored option. Among the simplest and most straightforward illustrations that is often utilized to convey the core tenets of the utilitarian principle is that of a trolley dilemma. In this example, an individual is presented with the choice of saving five individuals from certain death while at the same time intentionally causing the death of one person, by either pulling a lever to reroute a trolley from a track that would otherwise result in the deaths of the individuals into a track that would only kill the single person or to choose inaction and allow the trolley to proceed as previously intended. From a utilitarian standpoint, the option of causing the death of the single person with the aim of saving the five individuals is the favored option, as it results in the greatest good for the greatest number.

2.2. Deontology

Descriptive proponents of deontological ethics argue that it is meaningless to discuss ethical obligations to the natural world and its environment; none more so than on whether something as fleeting as the 'right' of a machine to avoid being hacked. So, it is through the subsequent application of the categorical imperative of deontological ethics that gives rise to

the second of my absolutes of cybersecurity for autonomous vehicles, to avoid any event such that the event brings into doubt the safe operation of a vehicle. Crucial therefore lies in the dependability of any software-based technology in preventing against any cybersecurity incidents, and this label is for the user to enact and not to creators of the cybersecurity measures.

Deontology is the ethical framework of obligations and duties, and one that will emerge more directly later in this section as it requires an obligation to avoid cybersecurity incidents in general. Immanuel Kant is the most famous proponent of deontological ethics whereby he proposes his 'categorical imperative'. The act being carried out must satisfy these maxims – it must be universal, everyone must be able to adhere to it themselves, and finally treat people as an end and not as a means to an end. It could be argued here that the operation of a car or any other machine would be to this end – but this argument would be to ignore that machines can act against rules as well as follow them. In terms of an imperative to avoid cybersecurity incidents, it should be noted that numerous prior issues of vehicle cybersecurity have come under the remit of safety and product liability, where desirability of avoiding collision is paramount.

2.3. Virtue Ethics

The replacement tool had the added benefit of intentionally exposing high-value functionality documents that supported notated manual SCAP security audit policies. The documents produced by the new modular manual process will follow the same logical process after creating interim documents to describe the requirements validation tests. Their purpose is to provide definitive proof that a given piece of code is completely unsecured or that the SCAP security issue found is a data anomaly.

In virtue ethics theory, ethical behavior is seen as a function of the character of the individual rather than a rulebook to be consulted. Altradawi and Le Vasseur argue that this can be translated into the cybersecurity world. Altradawi and Le Vasseur use the example of replacements for Defense Advanced Research Projects Agency's (DARPA's) automated code analysis tool. These replacements aimed to locate vulnerabilities and malicious activity in a piece of code. One such replacement called Angels' Advocate locates backdoors identified by Synapsis' mandatory access filter, a dedicated microkernel located in secure enclaves on DoD devices. The approach of Angels' Advocate leverages the official Security Technology

Implementation Guide (STIG) to contextually determine the correct locative procedures. The hypothesis tested in the Angels' Advocate project is that given the context of secure enclave usage domain one would locate secure enclave backdoors in an audit first order (e.g., the Dashboard service), the major devices potential edge user requirements, before those of the enclave applications (e.g., SDR-3 and the SYN-N-Q files). These manual reviews should be performed using DARPA security development practices which leverage the STIG as the beginning of STIG-compliant implementations for the back doors.

3. Autonomous Vehicles and Cybersecurity

In key part, much of the motivation for autonomous vehicles deployment has been safety driven. At present, the vast majority of automobile accidents are due to human error or negligence; and fatigued, intoxicated, or otherwise impaired human drivers cause some enormous percentage of these incidents. The deployment of advanced driver assist systems available in today's luxury cars has led to a significant reduction in crashes; and advanced driver assist systems show great promise in preventing crashes. Autonomous vehicles are designed to eliminate the human-induced risk factor, controlling the vehicle in a manner that both reduces accidents and the associated death and disability and provides more efficient utilization of the infrastructure.

While some may argue that more technology can solve the cybersecurity problem, it is clear that greater connectivity means more opportunities for adversaries to create potential hazards. Nowhere is this truer than in automotive applications. Automobiles are increasingly integrating advanced communication and sensing capabilities. These changes have led to the production and deployment of autonomous vehicles capable of controlling themselves on the road without intervention from humans. To accomplish this, autonomous vehicles integrate cyber on-board systems essential for control, perception, localization, as well as related communications. The various automotive system components include advanced driver-assistance systems (ADAS), automobile control systems, network communication, data processing, and software development, all of which are tied to external sensors, controllers, actuators, and other devices integrated as part of advanced driver-assist systems or as integral parts of conventional automobile systems.

3.1. Overview of Autonomous Vehicles

The cybersecurity implication of the timely deployment of autonomous vehicles (AVs) must be made readily available to many jurisdictions in the world. AVs like the other emerging technologies as a result of their increased reliance on software and mobile operating systems are likely to be potential cybersecurity threats or be capable of being used by criminals to threaten the citizens of many countries. As such, cars will not be the same again going forward. In view of that, automotive manufacturers in many countries are embedding semiautonomous features and other manually locked features in their car systems from time to time for long time safety consideration. AVs called self-driving cars are equipped with systems to sense the environment and operate a vehicle without human input or any acting human within the vehicle. These cars use a wide array of sensors like signals, cameras, global positioning systems (GPS), radars and laser scanners (LIDAR) to function without drivers. The cars may operate by using a system combining computer vision, object recognition, and complex machine learning algorithms without human input. Additionally, they can function in a wider variety of driving behavior in a limited context and terrain, or they may be fully autonomous automobiles even for urban possibilities.

Self-driving automobiles often referred to as autonomous vehicles, are those automobiles designed to function and perform the same operation as the ordinary cars and trucks, operated by human driver or pedestrian without human input or intervention. Autonomy levels can be classified into six major levels: Level 0 entails no driving automation, while level 1 comprises driver assistance features such as advanced cruise control. On the other hand, level 2 automated assisted driving features such as traffic jam driving. Level 3 means conditional automated driving features. Level 4 involves high automation, and finally, level 5 constitutes full automation. Many countries have been trying to deal with the possible negative ethical implications of impending autonomous vehicle deployment. The reason is that self-driving vehicles pose critical ethical implications due to concerns like loss of privacy, product liability, cybersecurity breaches, loss of jobs for drivers and human errors, among others. But this chapter will focus on examining and discussing some important ethical considerations regarding improved configurations of autonomous vehicle cybersecurity.

3.2. Cybersecurity Threats in Autonomous Vehicles

The road testing of fully autonomous vehicles in urban settings has grown; however, the increasing deployment of these vehicles has raised significant concerns over software

vulnerabilities and other cybersecurity issues. These software vulnerabilities are significant, given that they can create urban safety threats and other concerns. Some examples include cases of running a red light, stealthy denial of service, and victim monitoring. Data gathered from real-world public road tests illustrate the existence of these threats. These cybersecurity threats, if left unprotected, allow attackers to manipulate safety-critical AV functions and systems to make the roads unsafe for all. The new and profoundly existential safety risks that are emerging due to these digital threats could lead to a crisis within the automobile industry. Such safety threats are likely to affect drivers, passengers, bicyclists, and pedestrians.

A self-driving vehicle is a complex and data-intensive network of electronics and sensors that enable the vehicle to securely operate. A single autonomous vehicle can have a number of gadgets, collecting and generating vast amounts of intricate and personally identifiable data of the residents of the vehicle. Vulnerabilities with the potential to crash autonomous vehicles have been identified, and there can be past cases of fatal accidents caused by hacking. Autonomous vehicles (AVs) are increasingly being deployed in real-world urban environments. Ensuring their security is critical, especially given potential risks to human life.

4. Ethical Issues in Autonomous Vehicle Cybersecurity

Furthermore, we argue that the human moral status justifies the primary acceptance of personal risk tolerance obligations and the particular respect shown to different values that emerge from different individuals, contrary to the sometimes justified and dominant state autonomy public obligation standard. In short, there are two primary implications: individual choice as a fundamental source of moral purpose when addressing policy preferences, and the necessity to further consider the benefits and burdens to groups of individuals that arise from non-publicly disclosed cybersecurity measures. These measures, and their corresponding policy preferences, impact on policy decisions around the development and deployment of endpoints or standards.

Vehicles are key to the realization of freedom of movement, comprised of both direct and derived tangible and intangible benefits. The status of autonomous vehicles, a form of intelligent vehicle, continues to be debated. Despite this status, such vehicles are forecast to become commonplace and to provide substantial benefits. However, ethical concerns surrounding AV cybersecurity measures affect the chances of realizing such forecasts. These concerns touch on at least two fundamental but contested ethical issues raised by the

deployment of such measures: i) the reduction of ethical tensions, and ii) the justification of non-publicly disclosed autonomous vehicle cybersecurity measures, which raises normative concerns. We suggest that in order to reduce such ethical tensions, the non-justifiable reduced normative acceptability of cybersecurity measures dependent on knowledge content that, if made publicly accessible, would increase the chances of resulting cybersecurity vulnerabilities, necessitates the dominant permissibility-independent justification of non-publicly disclosed cybersecurity measures.

4.1. Privacy Concerns

Companies deploying autonomous vehicles, such as Waymo, share anonymized data with their research partners for testing purposes. However, anonymization of the dataset may not be foolproof. For example, Tables et al. presented that using a machine learning model (tracking drivers in hierarchical clustering speaking patterns), they were able to identify 95% of drivers in a 5% anonymized dataset of mobile phone mobility logs. Public concern around privacy and data-sharing could not only have potential impacts on a company's brand image but also on the adoption rate of driverless vehicles. The government can become involved in the protection of privacy with regulations. As an example, the California requirement for autonomous vehicles to share an anonymized dataset for public consumption excludes any data referencing or identifying a specific vehicle. Sharing anonymized data with the public may help to build trust with this new technology and promote a clear public understanding of potential dangers.

Autonomous vehicles will be equipped with a myriad of sensors (i.e., LIDAR, radar, cameras, GPS) to perceive their environment. These digital eyes record and interpret the surrounding environment continuously to determine the vehicle's course of action. They capture data of individuals inside and outside the vehicle, creating some privacy concerns. As a vehicle moves through a public area, this system processes images that may violate an individual's right to privacy. This adds an additional layer of potential surveillance of a person's movements that many believe is a violation of privacy rights. Alternatively, others argue that this loss is minimized as the right to secrecy is not typically protected within public spaces.

4.2. Safety Implications

Reliance upon black-box defenses may exacerbate complacency. Passengers will assume protection against swarms of human-piloted cars hoping to exploit flaws and ease in penetrating the security measures present in order to simulate phantom traffic jams. AV cybersecurity must be both robust and ever-present. If either fails, loss-of-trust fatalities that set safety approximations will be more frequent. Even if incidents that set trust occur only exceptionally, law-abiding drivers fearing becoming another "killer AV" may avoid piloting their vehicles near the AV or drive with aggressive pugnacity to underscore their driver's rights. AV-driving performance is likewise curious—left or right intact, in-car or on guard. Traditional security measures both depend upon the machine's resistance and reduce the audience count, letting attacks succeed only if chest explosives avoided inside AutoFox. As physical safety measures are currently paramount, AVs must synthesize both effects because of the ever-present physical lethality of an AV turning into the wrong lane. As such, AV passengers must not be allowed to neglect the effect of perimeter swarms on the defensive AV software, signage, ADAV/ADS, and vehicles while it is on guard, especially if forced into any escape routes.

Three key issues directly impact safety: friction cost, complacency, and cybersecurity fatigue. Friction cost is the burden a security measure imposes on the user. When friction cost comprises expense in terms of resources and time, the security measure discourages implementation. AVs are designed to promote ease of use, understanding that aftermarket modifications will add expense and perhaps inconvenience. Thus, the developers of AV cybersecurity measures will prefer options that are easier to integrate. Complacency results from security measures, as well as their warnings, becoming part of everyday life. They are so well-integrated that scarcely anyone listens. Cybersecurity fatigue results when security measures are both numerous and morally obligatory to implement. A system update that requires the car to be parked for 2 min and shutdown, which is frequently important to guarantee it remains operable, is likely to be overlooked among less-important items. Both are of particular concern in high-stress environments, such as automated driving takeovers.

5. Regulatory Landscape

Many other states had introduced similar bills as of July 2016. The state of Nevada was the first to impose a regulation legitimizing the testing of AVs owned by Google and Continental. Subsequently, California, Florida and the District of Columbia followed Nevada in approving

regulations and legislation. States advocating the testing and deployment of AVs offer various immunization protections to Original Equipment Manufacturers and related parties, through which most states share the USDOT's view that performance targets for AVs are more essential than legally binding requirements. It should also be observed that, in parallel with the deployment of AVs, individual states sometimes act with mutual exclusivity and differences. Therefore, a patchwork of 50 individual standards and requirements for the deployment of self-driving vehicles is not unimaginable. Its potential consequences have yet to be adequately addressed. The USDOT has not yet proposed to legislate any cybersecurity measures, preferentially relying on voluntary standards for the automotive industry. Remaining in such an inert quasi-regulation still raises various ethical and liability questions for many stakeholders within and beyond the borders of the automotive industry.

Beginning with the Enabling Act of 2012, Michigan was the initial state to pass specific legislation allowing testing and operation of AVs on their roads and transfer of regulation from the US Department of Transportation, within defined limits. Much attention was drawn to this state in 2016 following passage of the SAVE Act, which makes it legal for automated vehicles to drive on Michigan roads with no human driver but pre-empts law enforcement authorities from using charge of 'unlawful transport' for their drivers. Interestingly, other states are following, like Florida and North Dakota, with both states passing in 2012, acts that allow for the testing and operation of AVs with only North Dakota allowing for transfer of regulation from the USDOT. Beyond these trailblazers, a group of nine states, including Nevada, California, and Tennessee, currently have laws in place regulating AV testing: (1) California (S48); (2) Florida; (3) Louisiana (H-1140); (4) Michigan (H-ROD); (5) North Dakota (S2252); Pennsylvania (HB2200) and Tennessee (SBOB744).

5.1. Current Regulations in the Automotive Industry

With the current traditional regulation model, the governance is left out of the process. In the traditional industry standard procedure, the economic, environmental, and public health data are only used to assist in the development of cost-effective solutions and to assist governments with the regulatory effect. No other social matters have been addressed in the ISO. As highlighted, the traditional industry standards are mainly 'economic'. Other 'soft' governance can influence the standards and therefore the regulatory environment of an industry/commodity, such as transparency, accountability, legitimate non-state actors

(NGOs, citizens' groups, industry associations), scale which makes it free from capture or control by any single regional and national interest group, and adaptable, including being reflective of existing norms and cultural expectations. However, these are not embedded in the traditional standardization procedure.

Currently, the automotive industry is regulated under its own traditions and industry standards. With the development and fast deployment of technology, regulation organizations, such as IAEA, ISO, and NHTSA, should increase their efforts to provide guidance in this field. The current model for automotive regulation is dominated by industry and government collaborations. Standards emerge in the major automotive countries/regions, and this continues until these dominate the market. The dominant standards are maintained by the ISO and become the global standard, which is required by the World Trade Organization (WTO) agreement to all members in their domestic market.

6. Case Studies

6.2. The Intel Mobileye AV Incident Intel acquired Mobileye in August 2017 for USD 15.3 billion. On the evening of 26 March 2018, in the city of Tempe, Arizona, the Uber AV incident occurred. Then, the following evening, following the announcement of the Uber incident, an Intel Mobileye AV driving in Israel struck a motorcycle, causing a fatal accident. The precepts of generalizable decision-making in an AV cybersecurity team included the provision of pre-deployment reviews of pedestrian detection and emergency braking systems; the sharing of the AV 'initial ambivalence' hypothesis; and exploration of the relationships between the technologies and trust management systems whereby an understanding of AV software would be permitted from a framework of decision-making autonomy based on vehicle and pedestrian detection. This might extend into a relationship between an AV control continuity and remote control from a disengagement list and the type of activities undertaken, including a consideration of how an AV would respond to an accident situation without input from a human controller. Shaik, Mahammad, et al. (2018) provide a deep dive into RBAC for managing IoT access privileges.

6.1. The Uber Autonomous Vehicle (AV) Incident The city of Tempe in Arizona, the home of Arizona State University, was selected by Uber as the site for its first trials of a driverless taxi service on public roads. An AV was involved in a road traffic incident where a pedestrian crossing the road at night was killed. It was determined that the underlying causes of the

incident included a decision in Uber's autonomous vehicle software that determines which objects should be classified and how the AV system should respond. This decision led to the system classifying the pedestrian as a false positive and the simultaneous deactivation of the AV system's automatic emergency braking function. Regarding the general need for ethical considerations at a higher level, a common theme of ethical failure is the lack of integration between the technical cybersecurity and demographic design, sufficient pre-deployment road testing, cross-functional team meetings, and transparency and decision-making (in different contexts).

6.1. Notable Cybersecurity Incidents in Autonomous Vehicles

In this section, we discuss four notable and representative cybersecurity incidents in modern vehicles. These examples show that hacking vehicles, especially autonomous ones, could result in significant risks to the life and properties of passengers and external parties. We start with the famous Wired Jeep hacking case. Two security researchers showed that they could wirelessly access the Jeep's electronic control unit and take control. However, no related incident has been reported. In 2020, two middle school kids in Germany accessed the electronic control units and controlled the steering function in a radio-controlled model of a Tesla. In 2021, researchers demonstrated how to modify head-on adverts to trick the vehicles into seeing it as other obstacles, resulting in autonomous vehicles moving slowly in front of it. In 2021, researchers attacked the pedestrian detection function of an AV by modifying the appearances of pedestrians to make the vehicle think they are invisible.

Self-driving cars are poised to become the future of transportation and are designed to reduce the likelihood of vehicle crashes, as well as fatalities resulting from these crashes. However, as with any computer-based system, cybersecurity is a challenge in the automotive space generally, and in autonomous vehicles more specifically. Given the potential stakes, affected stakeholders have increasingly called for the deployment of effective cybersecurity defenses in the vehicles. This paper takes a first step to propose an ethical framework to appropriately deploy such security. Although not all forms of malicious behavior are relevant to autonomous vehicles, some forms of cybersecurity measures are relevant. First, we review key cybersecurity incidents in existing vehicles and relevant security measures proposed if such incidents were to occur in autonomous vehicles, taking into account the characteristics

of autonomous vehicles. We then provide an ethical framework to guide the deployment of such measures.

7. Ethical Decision-Making in Cybersecurity

This study also sets out to diagnose whether there are specific ethical concerns with the deployment of some cybersecurity measures and if these could be mitigated or weighed against. The conversation within this chapter, concerning ethical implications arising from the implementation of cybersecurity measures on autonomous road vehicles, is positioned as part of the broader ethics analysis of cybersecurity programs. In less autonomous vehicular contexts, researchers have begun to probe the ethics of legal responses, the balance between respect for privacy with the need for increased levels of security in a world that is increasingly digital, and the associated rights to cybersecurity programs. Unlike property or person, ethics imbues vehicles with a sense of moral matter. Vehicle accidents raise moral and legal issues that do not arise around other consumer products. Finally, autonomous road vehicles present a new ethical dimension in that hacking dichotomizes the ethical question of the appropriate consumer response.

This chapter responds to policy development for cybersecurity measures designed for the protection of autonomous vehicles from cyber-attacks. It was noted that the deployment of such measures was a significant cybersecurity challenge and that it would have a large impact on hard security. The opinions of experts on the means which should be employed to minimize autonomous vehicles' cyber-risk will be valuable. Before considering such measures, it is first necessary to define the autonomous cybersecurity risk, the governance provisions, and accountability frameworks relevant to autonomous vehicle security.

7.1. Ethical Dilemmas in Autonomous Vehicle Cybersecurity

The multiple system levels architecture employed in these detection measures provides opportunities to further develop the cybersecurity threat intelligence and facilitate ready distribution or all participating vehicles. However, stakeholders have to be more discerning in under what financial or infrastructure conditions should the detection measures be deployed. A private or governmental entity could control enough strategic key resources to influence the existing traffic travel mix composition, establish rules for the localization and commercial operation of self-driving vehicles, or impose consumption quotas on car and truck

customers. Consequently, autonomous vehicle deployment and usage would affect the strategic balance, energy security, and national defense resilience. Moreover, vehicle cybersecurity deployment could potentially exacerbate existing inequalities in the economy and society and limit some travelers' civil rights, public safety, or privacy.

The development and deployment of partially or fully autonomous passenger vehicles and commercial truck fleets require active cybersecurity threat detection to keep its occupants safe and guard against potential data breaches. These detection measures work by encoding multiple onboard sensors' shared inputs as a trusted vehicle sensor data cloud and comparing them for inconsistencies or unexpected changes. If flagged, vehicles initiated the vehicle cloud disaggregation process to validate its reported inputs and assess the affected vehicle cloud. Any discrepancy is identified as a warning sign that a cyber attack is being attempted on the vehicle.

These ethical challenges are detected when the threat level warrants modifications of the vehicle travel mix or place limitations on the deployment of certain vehicle designs, restriction on the infrastructure capabilities of the traffic management or sales channels, or responsible deployment and usage. It concludes with policy recommendations.

This chapter evaluates three technical and ethical dilemmas that are inherent to the winning strategies, stakeholder incentives, and decision-making processes for the deployment of cyber threat detection measures in autonomous vehicles. It presents three related concepts showing that a single technical dilemma is a function of one or both associated ethical dilemmas and explains how a variation in stakeholder motivations or their expected decision-making capabilities would determine the optimal strategy for their deployment.

The global automotive sector is on the precipice of inundating roads with partially and fully autonomous motor vehicles, revolutionizing the manner in which people and goods travel. Simultaneously, these advanced technological marvels are capable of transporting large volumes of sensitive personal and commercial information that requires safeguarding to ensure their cybersecurity safety and to guard against cyber threats.

8. Conclusion

Through the thesis provided in the paper, we have suggested that private firms have a moral obligation to ensure that the autonomous vehicle systems they deploy uphold the pro tanto

right to life of individuals. While constrained by institutional policies and resource constraints, private firms can and should engage in cost-effective cybersecurity measures through strategic technology policy designs. In order to meet our aforementioned aim, we proceed in three primary sections. Firstly, we construct a moral framework with which to evaluate the ethical obligations of private firms to individuals in the design and deployment of cybersecurity measures for autonomous vehicles. Secondly, we raise significant counterpoints to our pro tanto approach and attempt to resolve the apparent paradoxes that result from adopting our evaluative ethics. We suggest that a pro tanto approach solves common and practical ethical concerns of cybersecurity measures more effectively than its fullest alternative, pure absolutism. Thirdly, we explore design and policy strategies suited to implementing a pro tanto right to life characterization of safety in the hardware and software configurations of autonomous vehicles.

As automotive technology advances, autonomous vehicles possess the potential to revolutionize the safety, accessibility, and energy consumption of modern transportation. Currently demonstrated advanced driver assistance systems, such as Tesla's Autopilot System, have resulted in notable benefits to drivers. With the expansion of the intersection of algorithmic and software development characterizing the transportation sector, however, new cybersecurity vulnerabilities pose institutional challenges to the effective deployment of autonomous vehicle hardware and software systems. This paper investigates the key meta-ethical considerations concerning the ongoing debate of prioritizing the immediate physical safety of individuals through effective autonomous vehicle cybersecurity measures.

8.1. Summary of Findings

This article has sought to investigate a series of ethical considerations relating to the identification and development of cybersecurity protection mechanisms for autonomous vehicles. These have been presented in the first part of the article without assumptions about the extent to which the vehicle is autonomous, although the operational context in which many experiences of ethical significance would occur is that in which the vehicle has a high degree of self-driving capability. The findings expect TDs with a view to ensuring safe and responsible design in which cyber protection mechanisms are integrated into the vehicle from the earliest stages of design and beyond. This requirement does not preclude the vehicle design adopting an Agile Design approach – in which cyber protection technologies are

dynamic, as described in the Overview. However, the human interaction based on feedback loops is essential to counter any complacency or over-reliance that adopting an Agile Design approach may lead to, as well as contributing basic information about user experience-requirements and optimization of technology in an emergent socio-cultural context.

This article explored ethical considerations that should inform the deployment of tools and measures used in the protection of autonomous vehicles from cyber threats. While cybersecurity measures offer great promise in addressing ever-evolving threats, there is also the potential for these to exacerbate responsibilities associated with vehicle autonomy. Here, we consider a range of concerns including moral hazards, epistemic design challenges, the potential undermining of data privacy, and a lack of transparency in autonomous vehicle operations. It is argued that careful ethical reflection should be undertaken to ensure these concerns are recognized, and to shape how efforts to secure the future of the connected vehicle are implemented.

8.2. Recommendations for Future Research

Given that traffic system security measures have baseline thresholds that both noncompliant opponent drivers and driverless vehicles must meet to prevent accidents, efficiency in enabling vehicular security equilibria across traffic corridors is essential. Importantly, finding such equilibria is known to be a computationally challenging problem if not downright infeasible to achieve, as exemplified by computation-intense solutions for EMP-robust power system designs. Software development, game theory, cryptography, e-commerce, and artificial intelligence (i.e., security games, reinforcement learning, and noncooperative games) have thus far met this challenge with both dedicated cyberforensics tools and specific schemes to protect railway pricing models. State-of-the-art intelligent transportation systems (i.e., deep learning, recurrent neural networks, long short-term memory, and convolutional neural networks) also safeguard traffic flow to maintain road condition awareness for decision-making algorithms to respect speed limits. In our examination of general deployments of dedicated, Oak Ridge networks designed for data sharing, we benefited from insightful ways by which representatives from various diverse organizations foresaw and designed secure communication systems and artificial intelligence to prevent unethical autonomous vehicle behaviors during data sharing.

Motivated by the aforementioned issues, this section offers some helpful suggestions for several kinds of future research directions: (1) means to foster harmonious cybersecurity equilibria, with security games, cryptography, and AI; (2) methods to elicit and enhance human compliance with vehicular security mandates; (3) improvements in vehicular physical condition awareness and safety; and (4) metamorphic testing for machine learning systems.

9. References

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