Code of Ethics for Autonomous Vehicles

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Abstract
This case study focuses on autonomous vehicles and the ethical and sustainable considerations surrounding them. Autonomous vehicles have potential to greatly impact a variety of areas of daily life in a large scale, such as public health and privacy. It is important to address the concerns of autonomous vehicles before they are completely introduced to market. Proactive planning of how autonomous vehicles should be designed will be useful for creating a smoother timeline of achieving valuable implementations of the technology. For these reasons, the uncertain future of autonomous vehicles should be guided towards ethical and sustainable outcomes with a code of ethics. This paper therefore proposes a possible code of ethics, guided by a literature review on autonomous vehicles and a historic case analysis. The developed code is justified through findings from the literature and considering how it is applicable to a real-world event and the future of transportation.

Keywords: Autonomous; Vehicle; Transport; Ethics; Sustainability.

1. Introduction
Many countries are embracing autonomous vehicle (AV) technology with testing facilities and law changes supporting the future of the transport solution [1, p. 48]. AVs may help many areas of our world, such as road safety, interconnectivity, and the environment [1]. The degree of autonomy in vehicles can vary, but this case study will focus on those that are fully independent, with performance meeting that of a human driver in every scenario. For such a transformational technology, a code of ethics (COE) will be helpful in guiding AV advancements towards outcomes that are beneficial for our societies. In this study, the current trends, debates, and a real-world case will be analysed to propose a COE.

To ensure the COE is appropriate, areas that AVs impact are investigated. This includes public health which is naturally affected by today's transportation solutions. With AVs being a type of transport, they also affect the same areas of public health. The overall outcome of AVs being beneficial or detrimental to public health is likely determined by how it is implemented [1]. Cybersecurity and privacy are also concerned with AVs, given the highly digital and technological nature of the vehicles [2]. Maintaining privacy while embracing AVs is also of serious importance in this digital age [3]. Another ethical concern of AVs is how they act in moral dilemmas [4]. Analysing these topics will provide a strong foundation of knowledge for developing a COE.

A historic case involving AVs will also be explored while considering the proposed COE to assess its appropriateness and applicability.

1.1 Objective
The objective of this paper is for individuals interested in autonomous vehicles to learn about the current trends and debates. It is also aimed that they learn about how AVs can be developed for ethical and sustainable solutions through proposing and justifying a COE.

2 Literature Review

2.1 Impact on Public Health

Transportation is a key factor in societal public health and sustainability. It is a critical contributor to traffic safety, air pollution emissions, stress, energy consumption, climate change, and many more [5]. As the technology has applications on such a large scale, the magnitude of its potential impact is drastic [6]. While AVs are generally predicted to have a beneficial impact [7], they may be detrimental to public health, depending on how the technology is implemented [5, p. 18.12].

Smart mobility is a transportation concept that aims to benefit public health through utilising the Internet of Things and smart technology like AVs [8, p. 2]. The objectives of smart mobility are reducing pollution, reducing traffic congestion, increasing people safety, improving travel speed, and reducing travel costs [9, pp. 15, 16]. An implementation of AVs that contributes to smart mobility are shared autonomous vehicles (SAVs) [10, p. 343]. SAVs are a shift from the current trend of privately owning and using vehicles. SAVs focus on shared usage which includes vehicle sharing, ridesharing, and on-demand services which presents transport as a commodity and the concept of "mobility-as-a-service" [5, p. 18.2]. The nature of sharing vehicles is the key component in benefiting public health, and it can be done very effectively with AVs. SAVs could help minimise the number of vehicles on the road [11, p. 10], helping meet the goals of smart mobility better than when compared with private transport. Dense cities are where a rethought transportation system primarily using SAVs would excel. Fleets of vehicles intelligently designed to support urban mobility as optimally as possible would benefit public health [11, p. 8] [10, p. 343].

Implementations of AVs that negatively affect public health and sustainability are ones that encourage private vehicle ownership. AVs enhance transport overall with improved reliability, comfort, safety, and reducing the perceived value of time [1, p. 50]. This could allow tolerance of longer commuting times and lead to a more dispersed population, increasing urban sprawl [5, pp. 18.5, 18.8]. Therefore, if private transportation becomes more desirable through AVs, the consequential negative impacts on public health issues are then exacerbated.

2.2 Privacy and Cybersecurity

With AVs supporting self-driving and smart mobility, they require a far greater amount of technology than standard vehicles. This extra technology is needed for controlling the electronics, the self-driving components, and wider vehicle networking [2]. AVs often feature LIDAR sensors, video cameras, GPSs, RADAR sensors, central computers, and ultrasonic sensors [2, pp. 2, 3]. A feature of AVs that allow them to contribute to smart mobility is their wider vehicle networking. This covers communication between AVs and other vehicles, infrastructure, and the cloud, collectively referred to as "vehicle-to-everything" (V2X) [12, p. 1860].

The technology and connectivity of AVs also provides the opportunity for collection of enormous amounts of data. It is estimated that 1 gigabyte of data is collected by autonomous vehicles every second [3, p. 35]. When this data can be associated with people, the details of its storage, usage, access, and security becomes a great concern, especially given the human right of privacy [13]. Extensive tracking will generate vast amounts of data which may be subject to unethical or malicious usage [3, pp. 35 - 39]. Current location, past travel patterns, and predicted future travel plans are just the beginning of what can be obtained from AV data collection [1, p. 60] [3, pp. 36, 37] [14, p. 113]. Misuse of personal data may seriously contribute to voiding one's privacy. Data privacy is thus an important consideration when it comes to the ethics of AVs. Current trends show privacy being protected through new and existing laws and recommendations on privacy principles [1, pp. 59, 60] [14, pp. 113 - 115]. One such example is the EU's General Data Protection Regulation, designed to protect user privacy [15]. Though not specific to AVs, these are still applicable and affective [14, p. 119].

Transport presents considerable danger within communities, meaning the security and associated safety of AVs is very important. An analysis of 151 papers from 2008 to 2019 was conducted in [2] to review the attacks and defences relevant to AVs. Papers on attacks targeting technology identified above were included, revealing details of the cyberattacks being researched. It showed how AVs are vulnerable in a great number of ways. These cyberattacks could leak sensitive personal information, gain vehicle control, and manipulate the vehicle [2, pp. 5 - 11]. Defensive techniques have been studied to combat cyberattacks as AVs have shown their networking, protocols, and technology to be insecure [2, p. 21]. Intricate systems and methods have been developed to improve AVs security as shown by the literature reviewed in [2, pp. 14 - 21]. Recent research proposes the use of artificial intelligence and deep learning in cybersecurity systems for more affective results [2, p. 21]. As cyberattacks evolve, defensive security systems need to be continually developed and maintained as well. Security-by-design and privacy-by-design are being called for to be integral parts of AVs' design processes [2, p. 17]. Ethical development of AVs keeps our digital world more secure and private.

2.3 Moral Decision-Making

The key purpose of AVs is to support travel under the sole guidance of computer systems, eliminating the need for human control. The technology needs to be capable of responding to our extremely dynamic and unpredictable roads. With vehicles presenting considerable risk to the public by nature, the design of AVs carries serious ethical and moral responsibilities. AVs will encounter situations where they must choose between two evils, weighing up the self-interest of the AV user against the good of the public [16, p. 94]. Examples of simple situations where AVs are involved in causing unavoidable harm are illustrated in figure [4, p. Fig. 1]

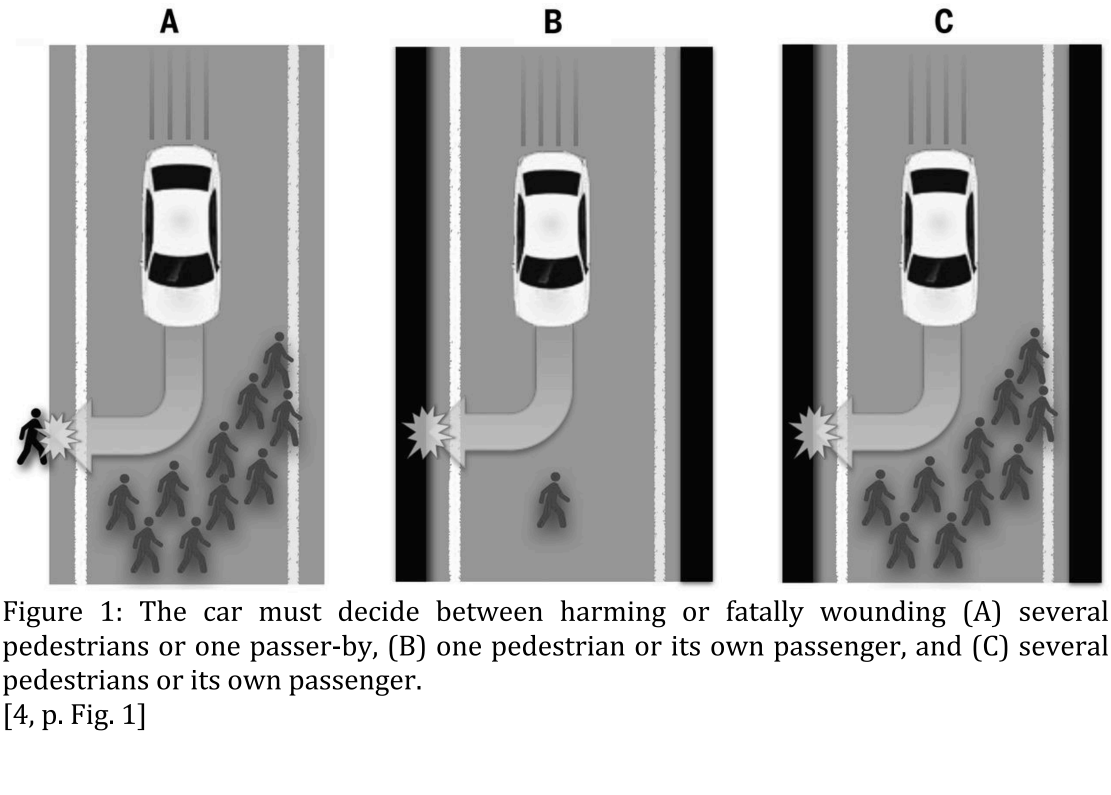

Figure 1: The car must decide between harming or fatally wounding (A) several pedestrians or one passer-by, (B) one pedestrian or its own passenger, and (C) several pedestrians or its own passenger.
[4, p. Fig. 1]

Multiple studies were carried out in [4] to understand people's sentiments towards moral choices involving autonomous vehicles. Patterns across the different studies commonly showed people to be in favour of utilitarian ethical frameworks. They preferred self-sacrificing vehicles with the intention of saving others and doing the least harm for everyone. However, they did not want to be a passenger in, nor purchase one themselves. A suggested solution from the study for this case was regulation, where behaviour leading to the best global outcome is enforced [4]. It is apparent that consumers, manufacturers, and the government may influence how AVs handle moral dilemmas.

Situations of imminent harm and AVs in the real world are not as simple as those shown in [4, p. Fig. 1]. The range and complexity of social dilemmas concerning AVs is vast given their dynamic environment. AVs will need to consider more factors during its decision-making process, such as the uncertainty of events and probability of harm.

The method of decision-making in AV systems is also of great importance. Every detail of the decision-making process should be considered as if it were intentionally designed. As AVs offer the opportunity for consistent, pre-emptive decision making in social dilemmas, developed systems should be under great scrutiny. For example, how much information should an AV consider when it makes decisions? Examples in [4, p. Fig. 1] only consider who the victim will be and how many are involved, but AVs could also consider qualities like age and who is at fault. If AVs are to consider more information, what is the hierarchy of factors in decision making and at what point is information not considered? While a morally perfect decision-making system in AVs is impossible, they should be carefully thought out, so that developed systems are intentionally designed and justified.

3 Proposed Code of Ethics/Sustainability

3.1 Sustainable Solutions Principle

AVs are a promising component of the future of transport, which is an area that impacts many issues as raised in the literature. Therefore, we should be working towards sustainable solutions such as SAVs which support our environment, the economy, and our social wellbeing. Reaching these optimal solutions will occur from developing and improving AV technology over time. With this in mind, the goal of this COE principle is to propel AV technology forward, improving feasibility of sustainable AV solutions.

3.2 Smart Mobility Principle

Smart mobility is one of the key ways that AVs can benefit public health. Efforts should be made to pursue transportation solutions that improve our societies, especially in regard to AVs considering their contribution to smart mobility. Companies developing AVs should strive to create technology that can support smart mobility, and this principle aims to encourage them to do so.

3.3 User Privacy Protection Principle

AV systems should respect the human right of privacy. Enormous amounts of user information can be collected through AVs, so it is essential that they handle data in an ethical manner. Companies developing AVs, regulating bodies, and individuals who use them should have an interest in ensuring that the right to privacy is respected. The aim of this principle is to motivate these parties to encourage ethical AV solutions that protect user privacy, perhaps through methods like privacy-by-design as suggested in the literature.

3.4 Secure Systems Principle

Safety of AVs are one of the most important qualities for the passengers, surrounding pedestrians, vehicles, and infrastructure. Cybersecurity is a key contributor to the safety of AVs, so effective methods for ensuring system security is essential for AVs. The goal of the principle is to encourage processes such as the one suggested in the literature; security-by-design.

3.5 Intentional Design Principle

The inclusion of this principle is due to the moral and ethical dilemmas that AVs will face. There are no simple approaches to deciding how autonomous systems should make decisions, but it is important to ensure that the quality and integrity of these methods are upheld. Doing so would result in AVs that are designed with every detail being clearly justified. An independent panel of researchers should be responsible for monitoring the design justifications and ethical research into autonomous decision making within AV companies. The panel does not need to prescribe towards a certain ethical framework, but they should have the power to monitor the ethical considerations and processes of AV companies. This principle encourages that quality standards are met for the ethical decision-making systems within AVs.

3.7 Maximised Transparency Principle

For a radical change such as SAVs to be adopted in our societies, it will require confidence from all stakeholders involved. Important questions will need answering, and those are highly likely to concern topics raised in the literature. Companies developing AVs will help their transportation solutions gain traction if those they affect are supportive of them.

4 Case Study

In 2017, for the first time in recorded history, a pedestrian was killed by an autonomous vehicle [17]. The high-profile event saw global news coverage and a publicised investigation. The AV was operated by Uber and was travelling at 60 kilometres per hour when it struck Elaine Herzberg who was walking across a four-lane motorway.

The police report determined that there were faults on the pedestrian's and driver's sides, with Herzberg being criticised for jaywalking across a motorway. The distracted driver, whose responsibility it was to monitor the AV, was criticised for not overriding control and stopping the vehicle. However, the software enabling the vehicle's autonomy and "steering two tonnes of metal" was also critically at fault [17, p. 2].

It was concluded that the AV had detected Herzberg 5.6 seconds before the crash but did not recognise her as a pedestrian because the system did not understand jaywalking. The AV required crosswalks to acknowledge pedestrians [18, p. 16]. As the car essentially ignored Herzberg, it continued as planned, consequently colliding with her. The gross naive oversight that pedestrians only exist on crosswalks should have been caught early in development, but Uber's "cheap and quick" approach to testing likely inhibited this [17, p. 2]. Their software was determined to be fairly unintelligent, contrasting Uber's claims [17, p. 3]. Additionally, engineers from competing company Waymo, testified that Herzberg's death would have been preventable had the AV been using Waymo technology [19, p. 140]. This further demonstrates how Uber's AV systems were unsuitable for deployment on public roads.

4.1 Relevance of the COE to the Case Study

The death of an individual is an indicator of how great of an effect AVs can have on public health. In this case, shortcomings in AV software killed a pedestrian. Autonomous transport solutions need to be safer than Uber's AVs, and the COE may help achieve this.

While the tragic event highlights the harm that AVs can cause to public health, the AV in question was contributing to Uber's efforts in achieving smart mobility. Self-driving vehicles and ride sharing platforms can support each other in providing SAV solutions. The COE includes principles for inspiring sustainable transportation and progressing towards smart mobility. Here, they are relevant with SAVs being more sustainable than private transportation and Uber's efforts in working towards smart mobility.

The COE calls for intentional design, encouraging that AVs are heavily scrutinised with every detail needing justification. The fatality demonstrates how naïve assumptions and careless software development can have such a drastic impact. The outcome could have been prevented had Uber recognised the need for a more versatile pedestrian recognition system. The case acts as evidence for the importance of designing with intention under the proposed COE.

Transparency concerning Uber's AV decision making and awareness could have prompted them to operate at a higher standard. Assuming that pedestrians are only ever present at crosswalks is extremely naïve and would have been noted by a review panel for improvement. Transparency on Uber's general AV operations may have also restricted their ability to test their vehicles on public roads, or for individuals to sign up for the role of drivers. The COE's principle of transparency would have likely helped in this case.

5 Conclusion and Recommendations

AVs are very likely to play an important role in the future of transport. However, the outcomes that they cause in contexts like public health, cybersecurity, privacy, and morality are uncertain. The present literature review provided insight into how AVs may impact these areas with the extent being seen in the tragic case of Uber's AV. To help achieve transportation solutions powered by AVs that are ethical and sustainable, a COE has been proposed. It is recommended that companies developing AVs follow the principles. Security and privacy by design approaches, high levels of scrutiny for every design decision, and increased transparency should be implemented. Findings from research into the ethical and sustainable issues of AVs and the historic case analysis shows the need for a code of ethics in the context of autonomous vehicles.

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