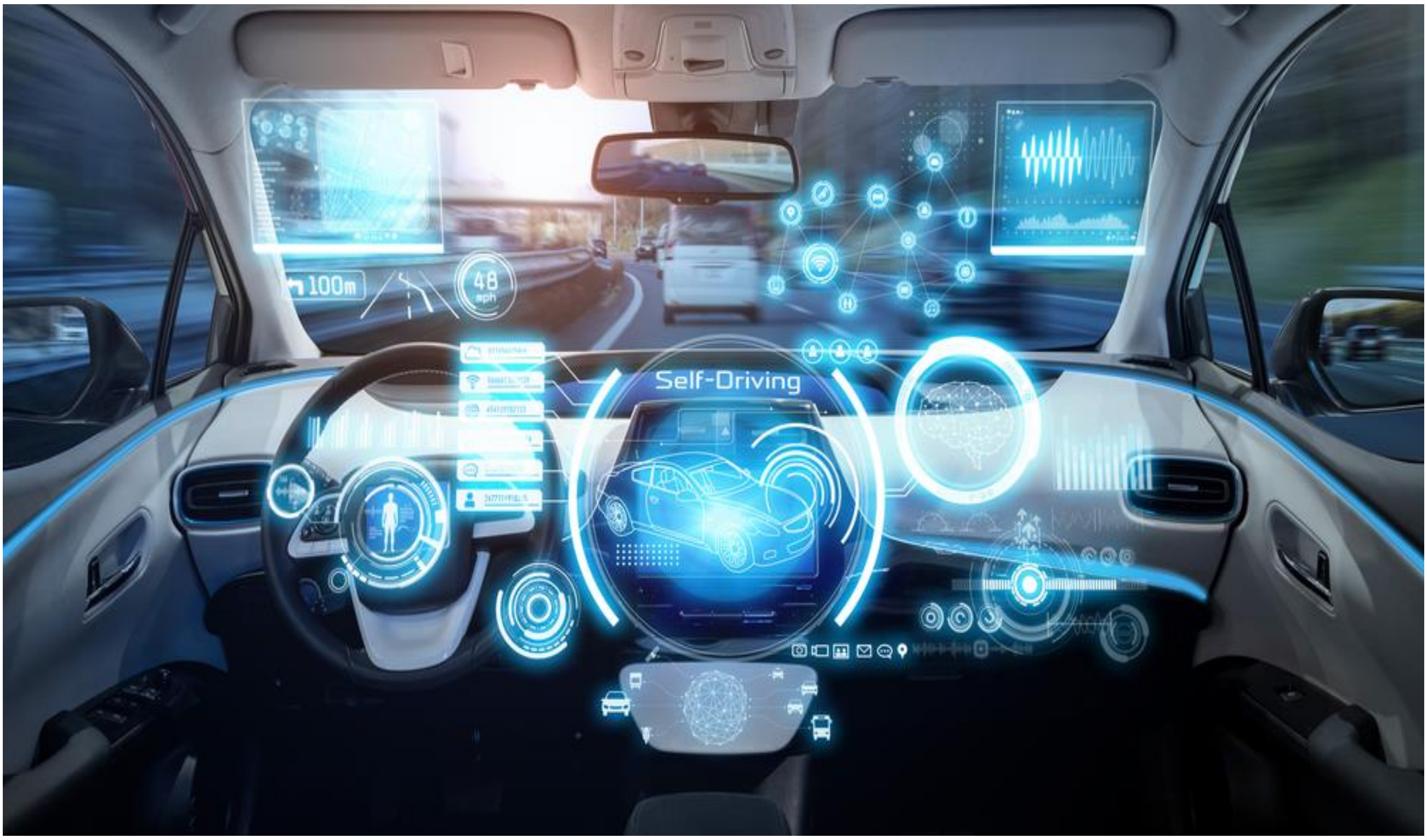
Driverless Cars Implications: A Literature Review



Moayad Shammut

School of People, Environment and Planning

Massey University

2020

Acknowledgment

I would like to express my gratitude to the Transportation Group of Engineering New Zealand for providing funding for this research through the Tertiary Study Grant 2019. I am also grateful for the insightful feedback from my supervisors, Dr Imran Muhammad and Dr Faraz Hasan, that has substantially improved the quality of this project. The useful comments from Dr Paul Perry on an earlier version of this report has helped me refine my thinking, for which many thanks.

How to Cite This Document

This report is part of a PhD thesis on the safety perceptions of AVs in New Zealand from social, political, technological and economic perspectives. You are welcome to share ideas and excerpts from this report provided that the author[1] is given attribution. Please cite this document as: Shammut, M. (2020). *Driverless Cars Implications: A Literature Review.* Massey University.

[1] Contact Email: M.Shammut@Massey.ac.nz

Table of Contents

Executive Summary

- Automated driving was envisioned 100 years ago. Promoting safer and faster travel were amongst the main drivers for the development of autonomous vehicles (AVs) since the 1920s. It was believed that developing automated driving would solve road safety issues created by the elimination of human error. The car industry played a huge role in the dissemination of this narrative, which led to the hyping the expectations of AVs as early as 1920s. However, the complexity of implementing AVs was a barrier to their development and deployment. The review of the literature in this report revealed that implementing AVs is a complex issue that needs to overcome several barriers not only in the technological aspect, but also in its social, planning, and business aspects as summarised in Table 3.

- One factor that influences the large-scale adoption is consumer attitudes towards the AVs technology. Highly-educated, employed, young male individuals were found the most optimistic about AVs safety in 51 countries around the world (Moody et al., 2019). Developing countries in Asia seemed more optimistic about AVs safety as they have higher car crash rates compared to Western European countries. Optimistic perceptions about AVs safety in developing countries may minimise the disparity in road safety around the world. The public in the developed world raised concerns regarding AVs' potential technical failures, interaction with conventional cars, and there use as a mode of public transport. Addressing these safety concerns may increase their market penetration rate, thus may increase the degree of market penetration together with the wider and deeper levels of consumer acceptance that may flow from this.

- For AVs to address the associated safety risks, the public would need to accept mass deployment and AVs would need to be trailed in real-world environments. This would enable AVs to learn more from the real-world driving experience, enhance its performance, and help evaluate safety regulations and policies. In response, some national governments (UK and US) have refrained from imposing strict measures on AVs testing requirements with the purpose of promoting AVs development. Some governments adopt a "prevention-oriented strategy" in which they require the AV to have a driver while conducting on-road testing, whereas a "control-oriented strategy" is adopted by others, which requires developing plans for mitigating crashes while testing AVs. In NZ, the driving law is unique as there is no requirement for a driver to be present in the vehicle, which suggests having fewer legislative barriers to adopting AVs compared with other countries that require a driver in vehicles.

- Resolving the technological risks of AVs will likely result in a large-scale adoption that would create a significant economic impact. The latest statistics for the total economic costs of car crashes amount to NZ$6 billion and $836 billion annually in NZ and the US, respectively (MoT, 2020b; NHTSA, 2017). The opportunity for AVs to improve safety could result in cost savings ranging from $355-$488 billion in the US, depending on their market penetration rate (Fagnant & Kockelman, 2015). Reducing congestion may result in annual savings of approximately $447 billion in the US alone (Clements & Kockelman, 2017). AVs would also create new job opportunities for manufacturers, software sectors, research industries, and AVs start-up companies. The trucking industries may gain up to $500 billion by 2050 from driver elimination in the US (Clements & Kockelman, 2017). By contrast, the "driver elimination" narrative is a threat to bus, taxi, and truck drivers, who account for at least 10 million people in the US alone (Bureau of Labor Statistics, 2019). Substantial reduction in car crashes might be perceived as a concern for the repair and maintenance businesses as well as insurance agencies as safety improvements could result in huge revenue losses. Governments have not yet established any strategies regarding how to manage the industrial risks that threatens people's jobs. Although retraining displaced workers is one potential solution, it might create a skills mismatch and be limited to those who are well educated.

- Finally, AVs are promising technologies that could possibly address road transport problems and also change cities' landscapes, economies, and the way people live their lives. However, safety risks of AVs remain a barrier to adopting them widely. The arguments narrated today about the positive impacts of AVs (particularly improving safety) are 100 years old, and planners are currently adopting a "wait and watch" approach (Milakis, 2019), which indicates the necessity to conduct further research in this area. This report reviews the wider benefits and implications of AVs in various dimensions. It also highlights the complexity of implementing AVs and demonstrates that the issue of their safety is not merely a technological one. Investigating and resolving the safety risks of AVs is expected to result in a largescale adoption and greater benefits.

Abbreviations and Acronyms

ACC	Adaptive Cruise Control.
ADAS	Advanced Driver Assistance Systems.
AHS	Automated Highway Systems.
AI	artificial intelligence
AVs	Autonomous Vehicles.
CAVs	Connected Autonomous Vehicles.
CO_2	Carbon Dioxide.
DSRC	Dedicated Short-Range Communications.
GDPR	General Data Protection Regulation.
GHG	Green House Gas Emissions.
GM	General Motors.
ITS	Intelligent Transport Systems.
MaaS	Mobility as a Service.
MoT	Ministry of Transport in New Zealand.
NOx	Nitrogen Oxides.
PM	Particulate Matter Emissions.
RSUs	Infrastructure Road-Side Units.
SAVs	Shared Autonomous Vehicles.
V2I	Vehicle-to-Infrastructure Communication.
V2V	Vehicle-to-Vehicle Communication.
V2X	Vehicle-to-Everything Communication.
VANET	Vehicular Ad hoc Network.
VCCW	Vector-based Cooperative Collision Warning system.
VMT	Vehicle Miles Travelled.

Introduction

Road transport has been associated with increased levels of congestion, road traffic accidents, air pollution, and social inequalities (Banister, 2019; Goetz, 2019). About 1.3 million people around the world face death every year in traffic collisions, half of whom are aged between 15-44 years old (WHO, 2018). It is estimated that road crashes will cost the world economy about $2 trillion between 2015-2030 (Chen et al., 2019). Adding to these concerns is the issue of Greenhouse Gas (GHG) emissions from road transport that has increased by 85% from 1990 to 2016 (Hasan et al., 2019), whereas congestions costs over $305 billion annually in the US (Gong et al., 2020). This has resulted in health, environmental and economic crises.

To tackle these pressing issues, smart infrastructures and technology-led measures have been implemented such as deploying intelligent transport systems (ITS) and Information Communication Technologies (ICT) as well as adopting electric vehicles (Makarova et al., 2018**;** Graham-Rowe et al., 2012; Park et al., 2012). Despite implementing these technological measures, road transport challenges still remain, so that ever more advanced technologies are required. The persistent desire to address road transportation problems has led to the search for a "magic bullet" that could potentially solve all those problems (Goetz, 2019). In this context, the "magic bullet" refers to driverless cars. Driverless cars, popularly known as autonomous vehicles (AVs), are "disruptive technologies" capable of executing all critical driving tasks with little or no intervention from a human driver. AVs have become a vigorously growing area of popularity in the field of transport planning and policy. In recent years, the positive impacts of AVs have been widely recognised by many countries, and the UK has allocated about £100 million towards AV research with the stated ambition to be at the forefront of their development (House of Lords, 2017).

AVs are often seen as a technological saviour that could drastically disrupt mobilities, cities, and economies (Clements & Kockelman, 2017; Zakharenko, 2016). Advocates of this innovative technology argue that the deployment of AVs could potentially improve safety, relieve congestion, reduce parking demand, promote shared mobility, increase fuel efficiency, lower air pollution, innovate businesses and advance intelligent infrastructure and economies (Milakis et al., 2017; Fagnant & Kockelman, 2015). It is estimated that AVs may cause an annual positive economic impact of $1.2 trillion globally when adopted widely (Clements & Kockelman, 2017). Many of the aforementioned benefits mentioned above may be achieved more widely and more effectively when AVs are both shared and connected. The term shared AVs (SAVs) is used when they are integrated into the public transport systems and act as a Mobility as a Service (MaaS). The term connected AVs (CAVs) is used when AVs move in platoons as one entity.

In NZ, road accidents claimed over 350 lives in 2019 alone (Ministry of Transport, 2020a) and total annual economic cost of all vehicle crashes was over NZ$5.5 billion in 2017 (Ministry of Transport, 2020b). It is believed that the adoption of AVs might contribute to reducing the number of crash fatalities (AIFNZ, 2018) given the commitment of NZ government to achieve a 'Vison Zero' target, which emphasises "no loss of life on the roads is acceptable" (Ministry of Transport, 2019b). Therefore, the aim of this report is to explore the implications of AVs for the society, planning and policy, technology, and the economy.

This report is structured as follows: Section 1 provides a historic overview of AVs spanning the past 100 years. Section 2 compares and contrasts the social perception and attitudes towards AVs in the developed and developing countries. Section 3 sheds light on the implications of AVs from planning and policy perspectives covering areas in transport, land use, and the environment. Section 4 presents the technological risks associated with AVs and highlights some of the national governments' strategies to address and control these risks. Section 5 discusses the economic implications of AVs for employment, businesses and the wider economy. Finally, Section 6 concludes the report and provides directions for future research.

1. Driverless Cars: A Historical Overview

Automated driving was originally envisioned in the 1920's (Faisal et al, 2019) despite its being presented today as a mobility of the future (Zakharenko, 2016). As early as 1921, a remotely radio-controlled vehicle was produced in the US followed by another radio-controlled vehicle trialled on New York's public streets in 1925 as illustrated in Fig 1 (Jensen, 2018). During the 1920's, car accidents were responsible for the deaths of about 200,000 people across the world (Norton, 2008). Thus, it was imagined that AVs would improve safety by presumably eliminating the driver error, as Illing (1930, p. 38) describes "[t]he most wonderful thing about it was that the car (…) behaved as if it had learnt all possible traffic rules by heart" (cited in Kröger, 2016, p. 45).

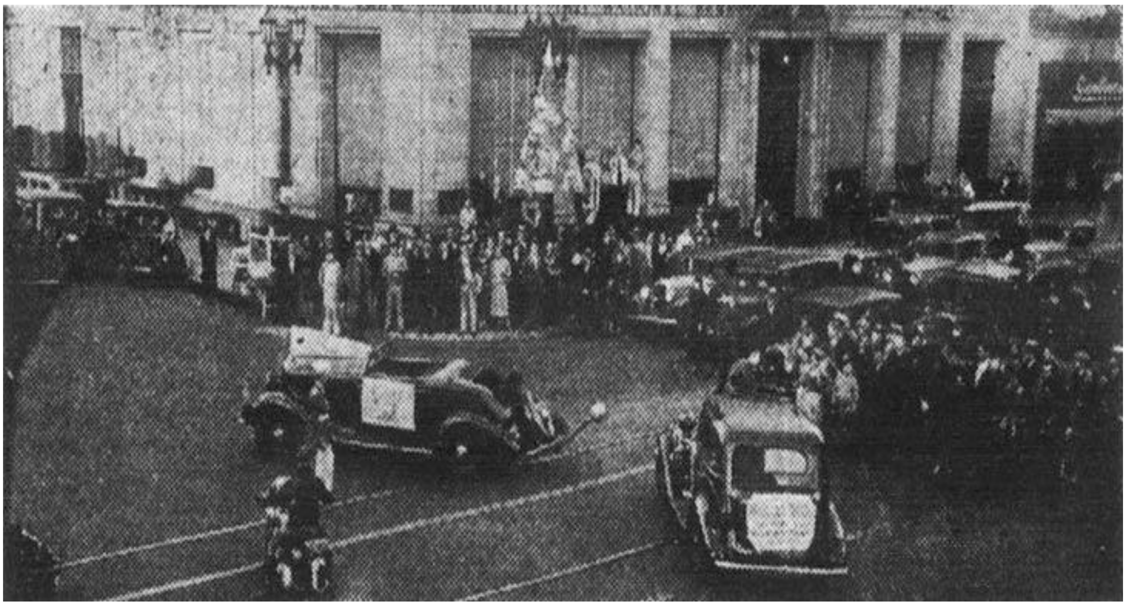


Figure 1: Remote-controlled vehicles in USA, 1930s. (Copyright: Kröger, 2016, p. 44).

The automobile industry was heavily involved in the AV discourse to the point of promoting overly high expectations (Goetz, 2019). In 1935, General Motors (GM) produced an educational film about road safety named 'The Safest Place'. The vision promoted in their film was that human drivers were the only responsible cause for accidents. However, there was barely any reference to how safe this technology might be (Kröger, 2016). This suggests that the automobile industry at that time did not realise the importance of conducting research on the safety of this technology nor did they acknowledge the complexity of this radical change in automobility systems (Siegel, 2005). In 1939, GM invited people from the general public to the New York World's Fair to share with them the vision of building new 'automated highway systems' (AHS) designed for cars to be self-driving by 1960 (Fig 2)

(Wetmore, 2003). Following this Futurama exhibit, an industrial designer at GM named Bel Geddes published his book "Magic Motorways" (Geddes, 1940), where he promotes his vision of using technology to improve safety and alleviate congestion. Further benefits of AVs were also recognised as Keller (1935, p. 1470) describes, "young people found the driverless car admirable for petting. The blind for the first time were safe. Parents found they could more safely send their children to school in the new car than in the old cars with a chauffeur." (cited in Kröger, 2016, p.45).

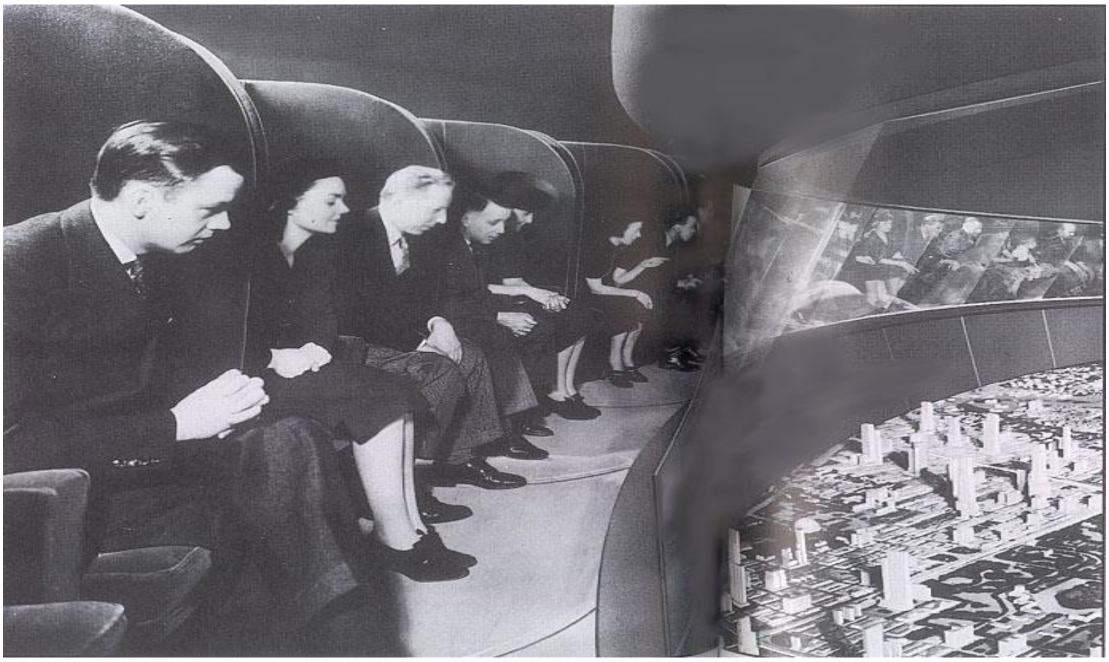
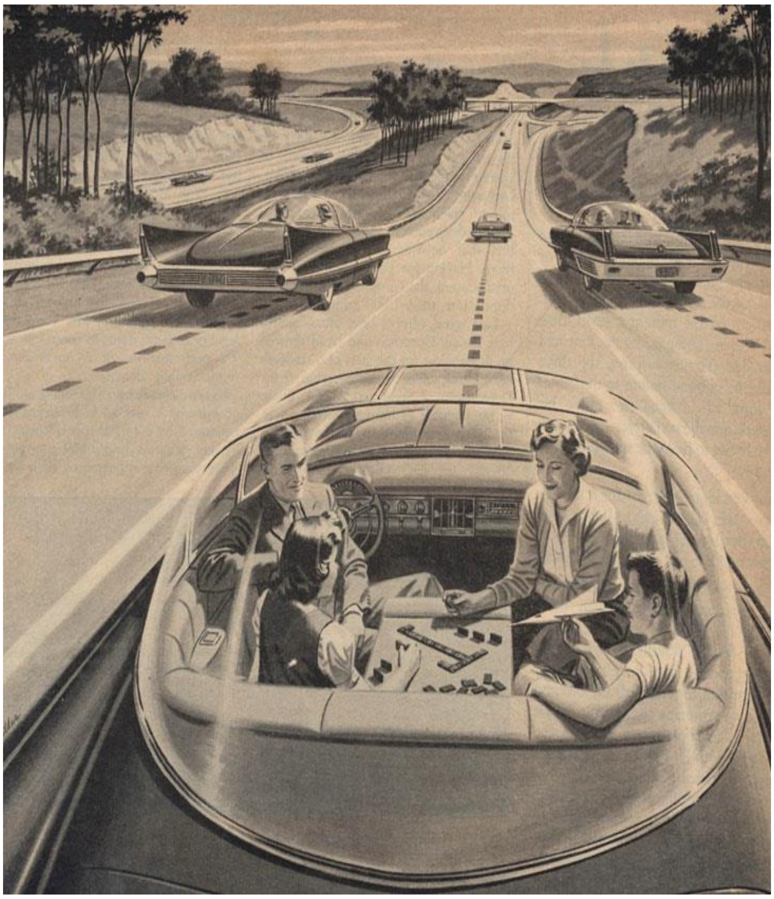


Figure 2: The New York World's Fair, 1939 (Source: Wetmore, 2003, p. 4).

In 1940's, the car industry was focussing on developing new technologies for army vehicles and highway infrastructure, which subsequently introduced the radar technology (Jenson, 2018). In the late 1950's, new car gadgets were developed such as sensors, cruise control, and automatic transmissions (Kröger, 2016). Fig 3 shows how AVs were envisioned in the 1953-1956. The consistent advertising and promotion of automated driving has had a cultural impact which reverberates down to the present time. The car industry's portrayal and projection of the driverless car at this time seems to have placed a greater emphasis on its potential in respect of its narrower safety aspects than as a truly feasible technology with significant implications for its broader mobility and societal outcomes. For AVs to operate properly, there was a need for the development of machine learning, the internet, 3D sensors, GPS, and intelligent infrastructure and networks, none of which were available at that time (Guerra, 2015).



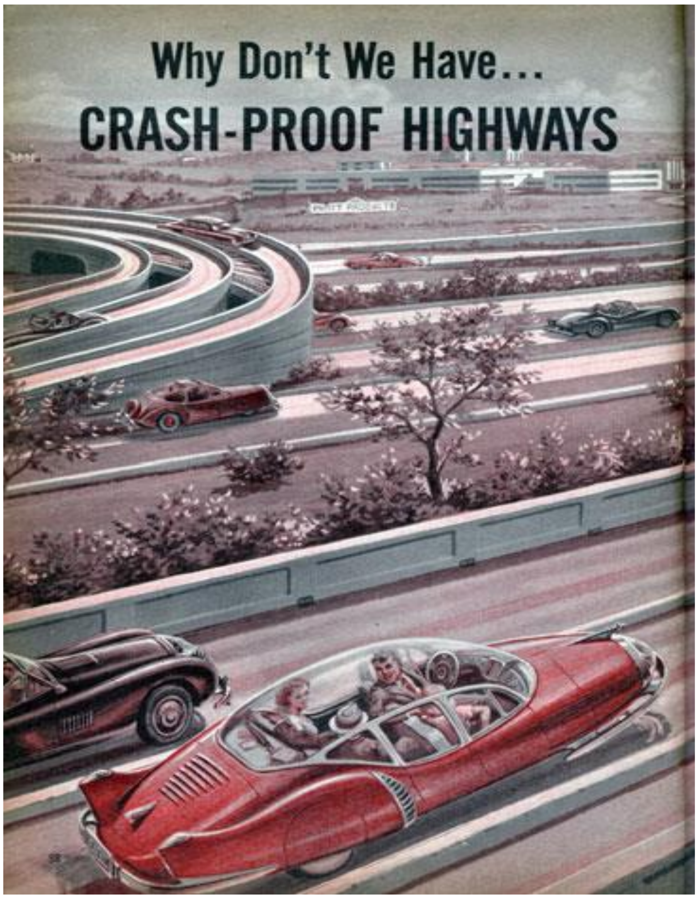


Figure 3: Detailed illustration of an AV in 1953 and 1956. (Source: Kröger, 2016).

Moving forward to the 1960's, technological innovation reached a milestone when the Transport and Road Research Laboratory in the UK tested a *Citroen* car that could communicate with implanted magnetic cables on the street (Bimbraw, 2015). In 1977, Japan presented a vision-based autonomous car that had a top speed of 30 Km/hr and was guided by two TV cameras and a small computer (Masaki, 1992). Several countries continued to test automated driving during the 1990's such as Germany, France and the US (Franke et al., 1997; Wenger, 2005; Kröger, 2016). In 1991, the US supported advancing the AV technology. The US Congress passed an Intelligent Vehicle-Highway Systems Act that required the Secretary of Transport to (1) start a research program on AHS for evaluation and testing; (2) develop an AHS and a prototype vehicle that could be developed into a full AV in the future; and (3) to have the first fully AHS ready by 1997 (Transportation and Public Works, 1991). Despite this legislation, automated driving was still not possible by 1997.

Over the past 100 years, the world was regularly promised automated vehicles. However, these efforts failed to become a reality due to the complexity of implementation (Wetmore, 2003). Firstly, it costed about $100,000 per mile to build

AHS, which was perceived as too high an economic burden (Wetmore, 2003). Building new highways also required buying private property, which delayed the progress of construction for years (Mohl, 2004). Secondly, AV demonstrations during 1970s-1990s drove in a controlled environment and pre-determined routes (Dickmanns, 2015). At that time, the technology was not sufficiently advanced as AVs did not have 3D-detection capability, which made them unready to perform in cities where normally would expect to encounter cars and other obstacles. Thirdly, the overly promoted public expectations by the car industries, the media, and sometimes government officials who made it seem simple to implement AVs (Wetmore, 2013). GM designers also publicized that the safety issues can be resolved by the mere intervention of car manufacturers and road builders. To this day, scholars still argue about the lack of proper planning for AVs (Porter et al., 2018; Legacy et al, 2019) and planners are currently adopting a "watch and wait" approach although the technology has advanced substantially (Goetz, 2019). Reflecting on the AV history of the past 100 years was essential because it reminds us of the repeated visions that are presented to us today regarding how AVs will solve transport problems such as road traffic accidents and congestion (Wetmore, 2019; Goetz, 2019).

Technological advancement in various sectors continued to grow. The development of technologies such as the internet, GPS, machine learning and LiDAR paved the way to trigger the AV discourse again. Consequently, Google was the first company to introduce a self-driving taxi project known as Waymo in 2009 (Jensen, 2018). It is predicted that AVs will form a proportion of 1 in every 4 conventional vehicles by 2030 (Jensen, 2018; Litman, 2020). As this innovative technology continues to progress, vehicles will have different levels of automation and control systems, thus they will become more sophisticated (Jensen, 2018). A taxonomy of the automation levels that a vehicle can have is detailed in Table 1. Describing the different AV's levels of automation is important to:

- Enable clearer arguments in academic research regarding implications of each automation level.
- Discuss this topic with insurance companies and stakeholders more accurately and clearly.
- Provide a guideline for governments when conducting on-road trials for AVs.
- Accurately delineate which level of automation is being discussed in this report.

Table 1: The classification of automation systems (Source: adapted from NHTSA, 2013; SAE J3016, 2018).

Level of automation	Vehicle Capability	Driver Responsibility	Example Features
No Automation Level 0	No authority to control driving primary functions such as braking and steering.	Always required to engage in full control over the vehicle.	Blind spot monitoring, hazard lights, and collision warnings.
Driver Assistance Level 1	Has control only over an individual primary function such as braking or steering.	Responsible for controlling the rest of driving tasks with expectations to immediately take full control over the vehicle when necessary.	Cruise control, lane centring, parking assistance, and automatic braking.
Partial Automation Level 2	Able to control more than one primary function	Driver can take foot and hands off the pedals and steering simultaneously but requires driver to be ready to resume driving on short notice.	Traffic-jam assistance such as keeping the vehicle on lane while cruise controlling at the same time.
Conditional Automation Level 3	Can control all safety-critical functions under certain conditions but also recognises their potential limitations	Might be required to physically engage in driving in certain occasions, with expectations to respond appropriately to a request to intervene.	Highway patrol.
High Automation Level 4	Capable of taking over the entire driving dynamics under certain conditions	No requirement for engagement	Local self-driving taxi.
Full Automation Level 5	Able to perform the entire safety-critical driving tasks under any situation encountered.	No driver required	Full end-to-end trips.

Driverless cars are attained at level 5 “full automation”, whereas vehicles with lower levels of automation can be called autonomous vehicles. Thus, a driverless car is more advanced than an autonomous one. However, in this report, the terms “driverless cars” and “AVs” will be used interchangeably for convenience. The term “AVs” will mostly be referring to Level 4-5 automation unless otherwise stated. The next section critically reviews the literature on the potential ripple-effect implications of AVs.

2. Driverless Cars: A Social Perspective

This section explores public attitudes towards AVs around the globe. It compares and contrasts the public perception of driverless cars in both the developed and developing countries.

2.1 Perceived Safety

The way the public perceives the safety of AVs will likely have a substantial impact on their acceptance. As such, numerous studies have focused on the safety perception of AVs (Moody et al., 2020; Montoro et al., 2019; Bansal & Kockelman, 2018; Dixit et al., 2019; Schoettle & Sivak 2014a; 2014b). Using a structural equation model, Montoro et al. (2019) found that the perceived safety of AVs is significantly linked to increasing their acceptance level in Spain. It was also found that Spanish residents showed high levels of perceived safety for AVs (Moody et al., 2020).

Moody et al. (2020) surveyed 41,932 participants to explore the safety perception of AVs in 51 countries around the world. The results showed that younger males were the main demographic that reported the highest favourable perception of AV safety across all countries. Their findings also revealed that developed countries were the least optimistic about AV safety as compared to developing countries, as illustrated in Fig 4. Countries like Canada and respondents in Western Europe showed low levels of perceived safety. Those findings are in line with Piao et al. (2016) as they also found that only 25% of French respondents felt that AVs would be safer than human driving. In their study (Piao et al., 2016), the highest concern was pointed in the direction of AV's system failure.

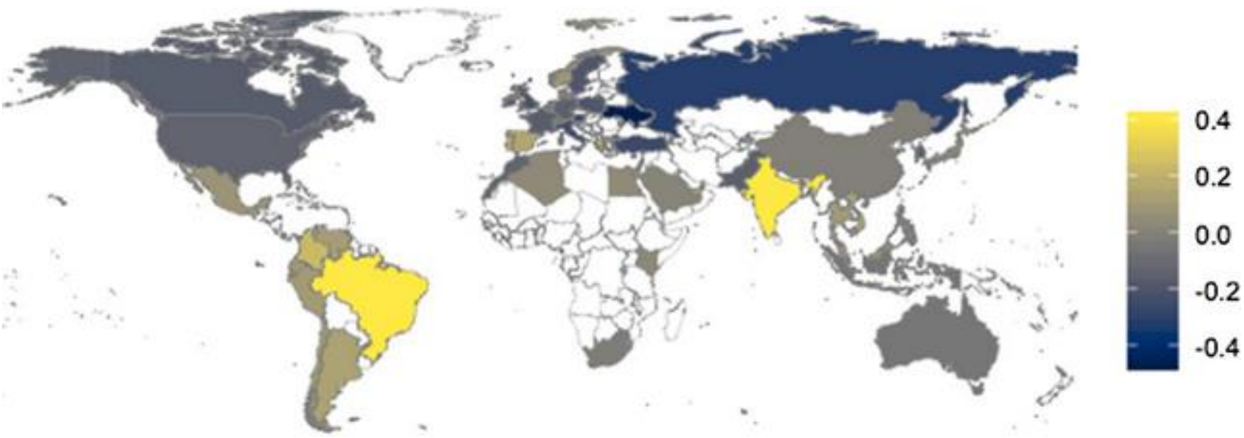


Figure 4: Perception levels of AV safety across the globe (Source: Moody et al., 2020).

Schoettle and Sivak (2014a) explored public opinion towards AV safety in the US, UK, Australia and Japan. The results revealed that about 62% and 53% of respondents in the US and Australia were concerned about driving Level-3, whereas in the UK and Japan about half of the respondents raised safety concerns about AVs in general (Schoettle & Sivak, 2014b). US respondents were more concerned about issues related to safety, such as AVs interaction with conventional cars. Other respondents were afraid that the general behaviour of AV driving would be different from human driving, whilst others raised concerns regarding data privacy and liability issues. On the other hand, UK respondents appeared less likely to be concerned about AVs interaction with cyclists and pedestrians as well as the vehicle's cybersecurity.

while the developed world tends to show high levels of concern regarding perceived AVs safety, the developing world seems to have less concern for safety issues. In China for instance, less than half of the participants (49%) declared having safety concerns about riding in Level-3 AVs (Schoettle & Sivak, 2014b). Work by Moody et al. (2020) also revealed that developing countries in Latin America, such as Brazil, Colombia, and Argentina, were more optimistic about AV safety as compared to developed countries such as Canada, Sweden, Austria, and the US.

Asian countries also tend to show high levels of perceived safety. According to Moody et al. (2020), countries such as the UAE, Thailand and India have a high perception of AV safety. The differences in perceived safety between the developed and developing countries is explained by Moody et al. (2020) who point out that countries with higher car crash rates seem more sensitised of AVs as a safety product. As such, reports from the World Health Organization (WHO, 2015) show that developing countries have higher fatal crash rates than developed countries, thus they are more optimistic about AV safety.

2.2 Perceptions about Automated Public Transport

When researchers (Schoettle & Sivak, 2014b) asked participants from the US, UK, Australia and Japan about their concern levels if AVs served as public transportation, the results showed a similar trend for all the countries. About two thirds (75%) of respondents from the US, UK, Australia, and Japan reported concerns for using AVs as public transport mainly due to potential system failure in AVs. Similarly, a French case study reported about 60% of respondents raised safety concerns for using AVs as public transport (e.g. busses) (Piao et al., 2016).

People in developing countries also appear to have high levels of concern regarding using AVs as public transit. For instance, slightly less than 90% of Chinese respondents were concerned about riding in automated public transportation (Schoettle & Sivak, 2014b). Generally, riding in automated public transportation (e.g. busses) raises safety concerns for both developing and developed countries. Montoro et al. (2019, p. 867) argue that these concerns are related to cybersecurity issues as well as system error and instability, which may cause AV users to "think twice before jumping into a mode of transport that substantially reduces the driver's operability, and consequently, their sense of power and control."

2.3 Attitudes towards AVs

Developed countries have different attitudes to driverless cars. For instance, about 65% of respondents in Australia and the UK showed positive attitudes to AVs (Schoettle & Sivak, 2014a), whereas only about 40% of Japanese respondents showed positive attitudes towards AVs (40%) (Schoettle & Sivak, 2014b). In France, Piao et al. (2016) revealed that participants who had higher education levels were more likely to express greater positive attitudes to AVs (71% of respondents) as compared to those with lower education. This view is also in line with Pettigrew et al. (2019) who argue that potential AV users with higher education level tend to show more interest in riding in AVs. By contrast, developing countries often seem to have higher levels of awareness of the AV technology when compared with the developed world. For instance, 87% and 74% of respondents from China and India had heard of AVs before participating in the survey as compared to 66% and 61% of respondents from the UK and Australia (Schoettle & Sivak, 2014b). Moody et al. (2020) found that some developing countries such as China, India, Southeast Asia and the UAE seem more aware of AV technology as compared to developed countries such as Canada, Germany, the UK, Austria and the Netherlands that had moderate awareness levels. Fig 5 illustrates this global comparison.

Awareness levels about AVs might influence the public attitudes towards AVs. For instance, China and India both showed extremely high levels of positive attitudes towards AVs (87% and 84% respectively) due to having high levels of AV awareness. By contrast, the same study indicates that Japan had a lower awareness of AVs and showed lower positive attitudes (43%) (Schoettle & Sivak, 2014b).

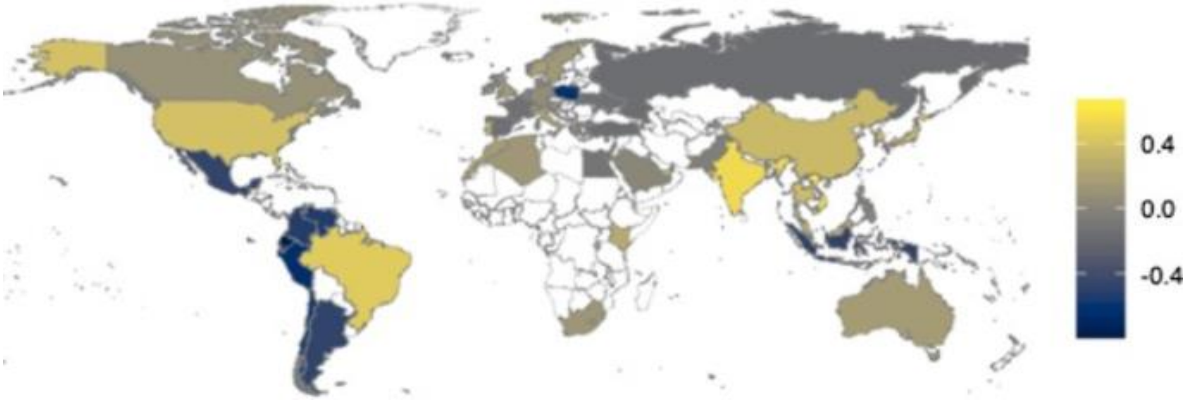


Figure 5: AVs awareness by country (Source: Moody et al., 2020)

It appears that countries that perceive AVs as a safe technology tend to have high awareness and positive attitudes levels towards AVs. As such, Moody et al. (2020) indicated that developing countries in Asia, along with Brazil, had high levels of AV awareness and perceived safety. In contrast, the rest of Latin America, Turkey, Russia and Ukraine showed moderately below-average levels of AV awareness and low levels of perceived safety.

2.4 Summary

This section highlighted attitudes to AVs by comparing and contrasting countries from the developed and developing world. Understanding the perspective of society with respect to AVs is an important factor in determining the likely success of this technology in terms of adoption rates. As such, when a population shows a high level of acceptance towards AVs, this may help increase their uptake. Once they are widely adopted, significant economic benefits may be attained. In New Zealand, no empirical investigations to gauge public attitudes towards AVs were found. Further research can be conducted to address this gap in practice, helping to pave the way for planners to shape the AV future in ways that meet public expectations and needs with less uncertainty. The next section of this literature review discusses the potential implications of AVs on the planning sector.

3. Driverless Cars: A Planning and Policy Perspective

This section discusses the AV impacts from the planning and policy perspectives, which covers areas in transport planning such as congestion, safety, and shared mobility. It also sheds light on land use planning regarding how AVs might affect parking demand and design, as well as urban sprawl. Lastly, implications on emissions, air pollution and environmental planning are also presented.

3.1 Transport Planning

3.1.1 Congestion

3.1.1.1 Roadway Capacity

AVs could potentially reduce congestion by enhancing roadway capacity and traffic flow. Increasing road capacity can be achieved by minimising the distance between AVs via the concept of platooning. Elbert et al. (2020, p. 206) describe platooning as a group of vehicles "that circulate in a coordinated fashion, cooperating and constantly communicating with each other through WIFI and other technologies." Fig 6 below illustrates how AVs in red are moving safely in platoons by minimising the distance between each other. Despite this, the capacity of the roadway may be reduced when bigger vehicles such as busses and lorries are included in the platoons (Michael et al., 1998).

Figure 6: Vehicles platooning (Source: Schindler, Dariani, Rondinone, & Walter, 2018).

Simulation studies show that AV platooning can increase road efficiency by 100%, emphasising that the gap between vehicles will be significantly reduced (Imura et al., 2015; Clement, Taylor, & Yue, 2004) have used simulation to estimate how AVs might impact congestion. However, these studies assumed that (1) AVs were error free, (2) there would be a market penetration of 100%, and (3) that road users (e.g. pedestrians and cyclists) were excluded from the simulation, all of which do not reflect a real-world environment (Milakis et al., 2017; Kalra, 2017).

Another way that AVs may reduce congestion is by improving safety and eliminating driver error (Fagnant and Kockelman, 2015). Since car crashes contribute (in partial sense) to 25% of the congestion in the US, reducing these accidents would help minimise congestion (ibid). On the other hand, Carbaugh, Godbole and Sengupta (1998) reported that rear-end crashes in platoons are more probable as road capacity increases. It is noteworthy that congestion might be increased in some instances due to induced demand on AVs (Kane & Whitehead, 2017). Shared AVs might be programmed to keep cruising while empty to find the next customer (Lim & Taeihagh, 2018), which could worsen congestion.

3.1.1.2 Intersection Capacity

A group of studies (Monteil et al., 2014; Wang et al., 2016; Xie et al., 2016; Yang et al., 2013; Zhou et al., 2016; Grumert et al., 2015) point out that vehicular communication (vehicle to vehicle and infrastructure), and adaptive cruise control (ACC) technologies would increase the platoon length and improve the traffic flow. For example, AVs can better utilise the green light time at an intersection to avoid delays compared to a human driver, which will enhance intersection capacity. However, work by Shladover et al. (2012) showed that ACC technologies are less likely to impact traffic flow significantly. This is because AV drivers may feel more comfortable to adjust the ACC settings at a gap length similar to the gap distances used when driving conventional cars. Dresner and Stone (2008) argue that improving intersection capacity would be an ambitious achievement unless 95% of the vehicles are autonomous. Additionally, relying on technologies such as traffic apps used in smartphones may lead to traffic chaos and increased congestion (Macfarlane, 2019). Overall, Milakis et al. (2017) conclude that the long-term implications of AVs on congestion are uncertain due to several unknown parameters. These include the travel demand, vehicle's automation level, and the market penetration rate.

3.2.1 Safety

3.2.1.1 Human Error

It is claimed that human error contributes to about 90% of all car accidents. In the US (Moody, Bailey, and Zhao, 2020; NHTSA, 2018). Fagnant and Kockelman (2015) assert that AVs could improve safety by removing the 90% of crashes caused by human driver error. Human driving errors include the effects of drinking, drugs, fatigue and distraction as well as carelessness (e.g. using mobile phones while driving), speeding and running red lights (Zakharenko, 2016; Fagnant & Kockelman, 2015). It is assumed that AVs will not make these errors and will be programmed to obey road speed limits and traffic lights. Simulation modelling by Morando et al. (2018) revealed that AVs have the potential to reduce collisions by 30% to 65% for roundabouts. For signalised intersections, the simulation showed that AV penetration rates of 50% and 100% could minimise the number of collisions by 20% and 65% respectively. However, AVs were involved in several fatal car crashes in recent years (Banks et al., 2018; Elliott et al., 2019), which suggests that "the elimination of human error does not imply the elimination of machine error" due to technical errors and potential cyberattacks (Taeihagh & Lim, 2019, p. 107). Some studies found that AVs have higher accident rates in comparison to conventional cars. For example, Schoettle and Sivak (2015) found that AVs have higher crash rate per million miles travelled compared to conventional cars, whereas Favarò et al. (2017) reported that connected AVs are 10 times more likely to be involved in an accident compared with conventional cars. When interpreting these findings, it is important to acknowledge that distance accumulated by AVs is still relatively low compared with conventional cars. Also, the severity of AVs crash-related injuries has been lower than for conventional cars, and AVs might not have been at fault in all crashes in which they were involved (Schoettle & Sivak, 2015).

3.2.1.2 Liability

The liability issues of AVs are considered a challenge to their effective regulation. Although AVs could potentially increase safety, Pinto (2012) concludes that AVs may have technical issues and software bugs that could compromise their safety, leading to traffic accidents. In such scenarios, the liability for AV accidents is considered a policy concern that needs addressing (Li et al., 2019; Fagnant & Kockelman, 2015). The involvement of various parties in the AV system can be problematic in terms of determining the liability of accidents (Dahiyat, 2018). Parties involved in liability range from software programmers, car manufacturers and owners, to service providers (e.g. V2I and V2X communications), highlighting the complexity of deciding who is at fault in the event of an accident (Collingwood, 2017).

Dahiyat (2018) argues that making a pre-judgment that a certain party would be held fully accountable for crashes may make other parties hesitant to follow legal rules, knowing that someone else may be held liable for those accidents. By contrast, the Department for Transport (DfT, 2015) in the UK asserts that eliminating full liability from car manufacturers, as an example, might discourage them from producing the safest AV possible.

Taeihagh and Lim (2019) point out that it is still unclear how the liability will be apportioned between the parties involved in accidents, as there is no legal framework to outline this issue. This highlights the need to develop a national liability framework that outlines how governments would equally and justly hold accountable the parties involved in an AV accident. In NZ, the Ministry of Transport (MoT) (2019a) declared that AV liability is considered one of the major challenges to regulating them for testing, "Autonomous vehicles could raise issues about who is at fault if they were to crash." Similarly, the South Korean and Chinese governments are currently adopting the "no-response" strategy regarding liability regulations (Taeihagh & Lim, 2019). Therefore, drafting a legal framework for liability at an early stage is crucial so that technology evolvement and liability legislation can develop together in a balanced fashion.

3.2.1.3 Public Ethics

AVs may raise ethical concerns with regards to "crash algorithm" settings. Dahiyat (2018) notes that AV systems cannot maintain a consistent level of accuracy, intelligence and sophistication at all times. As such, in an unavoidable car crash scenario, how would an AV behave? Fig 7 below illustrates this situation by showing a possible scenario where an AV is travelling at a high speed but cannot stop in time to avoid the accident. The car will have to choose between either saving the passenger or the pedestrian, which is also known as the "trolley problem" (Bonnefon, Shariff, & Rahwan, 2019; Foot, 1967).

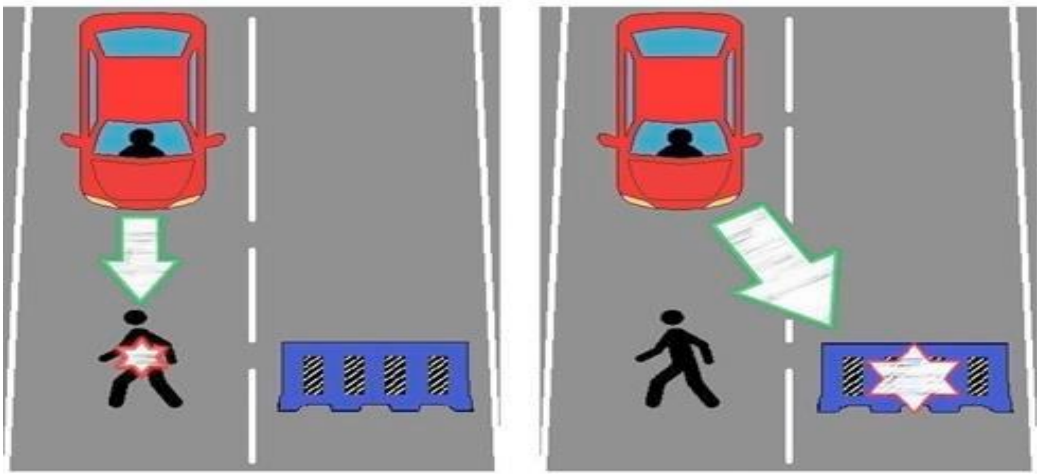


Figure 7: AV's choices between saving the pedestrian or the passenger (Source: Pickering et al., 2019).

Situations where AV's are required to make "life or death" decisions render the technology highly problematic from an ethical perspective (Pickering et al., 2019). As such, would an AV decide who to crash based on people's age, gender, occupation, and ethnic background? For instance, would AVs rather crash homeless individuals to save doctors and teachers? Would AVs risk older people to save younger ones? Would they crash into an animal instead of a human? (Coca-Vila, 2018). Since AVs Will effectively either themselves be data rich sources of information or have access to such data, these massive datasets will contain very detailed information about users that would enable AVs to make these decisions. While researchers (Fagnant and Kockelman, 2015) raise questions regarding the authority of AV programmers and owners to adjust those "crash algorithm" settings, Fleetwood (2017) responds that there is no current legal framework that defines who can design and modify those settings. This situation raises serious concerns regarding the public ethics of AVs (Taeihagh & Lim, 2019). A summary of the ethical issues and the proposed solution are summarised in **Appendix 1**.

3.2.3 Shared Mobility

3.2.3.1 AVs Ownership

The likelihood that AVs to reduce car ownership is uncertain. Fagnant and Kockelman (2016; 2014) suggest that about 11 conventional cars would be replaced by one SAV. Both studies suggest that SAVs will be significant substitute for conventional cars, implying lower levels of car ownership. In addition, using an agent-based simulation approach, several researchers have estimated that SAVs would replace 10-14 conventional vehicles (Boesch et al., 2016; Zhang et al., 2015). By contrast, a Texas case study revealed that 61% of respondents declared that accessing or owning an AV would not change the number of their household vehicles, whereas 16% stated that they would increase the number of AVs owned (Zmud et al., 2016). Lavieri and Bhat (2019) also found that commuters in Texas would be willing to share an AV ride with strangers for commute trips only, but less likely to do so on leisure trips. Research by Sener et al. (2019) found that the social status of individuals is a significant factor in influencing their intention to own AVs in the US, whereas Lee et al. (2019) revealed that a feeling of AV ownership was essential in Korea. These studies suggest that customers may not be willing to share an AV despite the popular assumptions about AVs reducing car ownership.

People dispositions towards AVs ownership (e.g. shared or owned) is clearly a key determinant in understanding the effects of AVs in terms of reducing congestion, emissions, etc. On the one hand, AVs replacing many conventional vehicles is more likely to happen in a context where, (1) the society is more open to sharing AVs rather than owning them, and (2) there is a high market penetration rate of 'Level-5' AVs. On the other hand, society with a "car culture" might lead to more private adoption of AVs. In the second case scenario, the benefits of AVs such as reducing emissions and congestion as well as improving safety and health, may not be realised. For simplicity, this argument is summarised as an illustration in **Appendix 2.**

3.2.3.2 Public Transport Integration

The impact of AVs on the public transport use and whether AVs can become part of public transport is still uncertain. Fernandes and Nunes (2015) indicate that the platooning of AVs can outperform the capacity of public transport in terms of the number of people transported, whereas Clements and Kockelman (2017) assert that AVs could replace trains since they can provide easier and higher accessibility for mass transportation. However, Currie (2018) argues that SAVs cannot provide high rates of shared "occupancy" as compared to public transit. Currie (2018) shows that 34% of Uber cars drive on roads while empty. Estimates from the Transportation Authority in San Francisco to show that Uber cars have on average occupancy of 1.7 including the driver (SFCTA. 2017), which amounts to having 0.7 of a passenger in each trip. Therefore, for better utilisation of mass transportation, it is shared "occupancy" that must be sought (e.g. trains, busses) rather than shared "vehicles". As such, trains can carry over 2,000 people on board, while busses can transport 50 passengers per trip as compared to almost one passenger on average using Uber car services. Currie (2018) concludes that SAVs cannot provide high rates of shared "occupancy" as compared to public transit.

There is limited research on the impact of AVs on public transport use. One Australian study showed that about half of current public transport users would be replaced by AVs deployment Booth et al. (2019). It might be recommended that AVs could be integrated into the wider public transport system by serving as mobility-as-a-service (MaaS) in order to reap the benefits of both public transport and AV systems (Legacy et al., 2018). This suggests that advocating that AV's be utilised as public transport is based on assumptions that AVs are likely to be shared and hence both would reduce private vehicle traffic.

3.2.3.3 Public Health

SAVs can have a positive impact on public health for the disabled and elderly. Wide deployment of SAVs can increase accessibility and enhance the social interaction experience, which would provide more freedom for the disabled and improve the mental health of the elderly (Pettigrew et al., 2019; Bennett et al., 2019). AVs may also have assistive technologies with minimal complexity that could resolve some of the difficulties faced by mentally disabled individuals when using conventional public transport systems (Bennett et al., 2019). However, older people might be less likely to accept new technologies, suggesting that health benefits for using AVs may not be optimally realised (Piao et al., 2016; Lee & Coughlin, 2015). Privately owned AVs will be expensive to buy and thus might be a barrier to access the advantages that come from their use or adoption (Clements & Kockelman, 2017). Policy development in this area is described as being in its infancy (Pettigrew et al., Norman, 2019). This is due to the lack of relevant datasets required for appropriate decision-making, and because the implications of AVs on public health is considered an under researched area (Curl & Fitt, 2019; Milakis et al., 2017). Thus, more research is still being conducted to explore how the implications of AVs on public health can be governed (Fitt et al., 2018).

3.2 Land Use Planning

3.2.1 Parking

3.2.1.1 Parking Demand

AVs are predicted to lead to less parking demand. Less parking demand suggests that valuable land that has been used for carparks could be reclaimed and used for more creative and sustainable alternatives (Zhang et al., 2015). A group of simulation studies (Fagnant and Kockelman, 2014, 2016; Boesch et al., 2016; Chen et al., 2016; Zhang et al., 2015) found that the demand on parking can be minimised by 70% to 90% when conventional cars are replaced by 30% - 40% AVs, stressing that the public's willingness to share AVs will contribute significantly to parking demand reductions. However, some studies found that consumers might not feel comfortable sharing AV rides (i.e. using SAVs), suggesting that parking demand might not drop significantly. Zhang and Wang (2019) also assert that privately owned AVs might not reduce parking demand substantially because they will still require a space to park.

3.2.1.2 Parking Design

AVs may substantially reduce car-parking sizes. Researchers (Chester et al., 2015) highlight that about 15% of the land in Los Angeles County is devoted to automobile storage, whereas half of the land in Downtown Buffalo, NY is devoted to parking (Zakharenko, 2016). However, to the make the best use of land, AVs can help in reducing carpark spaces as illustrated in Fig 8.

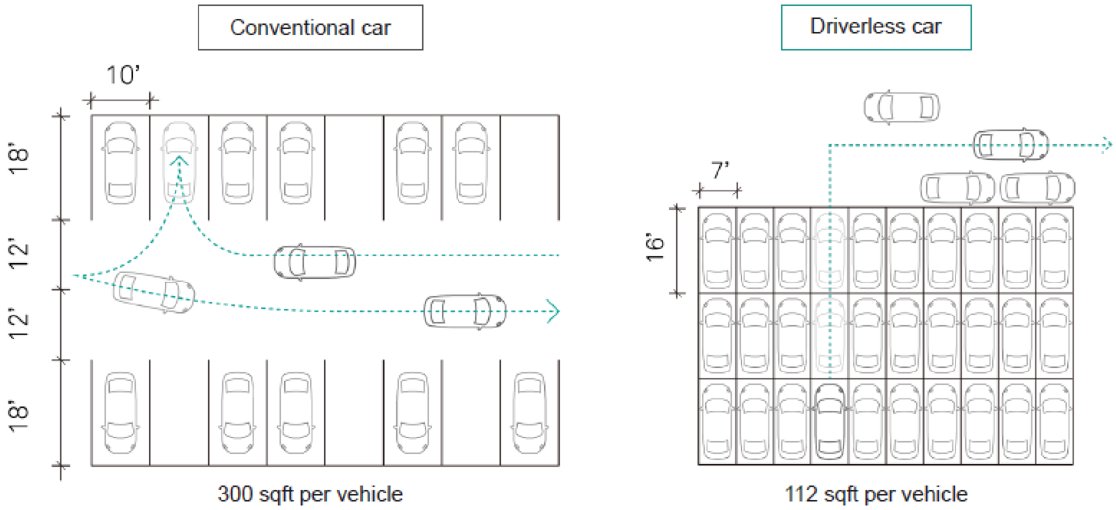


Figure 8: Size of carparks for conventional cars vs driverless cars. (Source: Chen, 2018).

When the AV drops off the vehicle owner at their destination, it will have the option to keep empty cruising or stop in a designated carpark (Bischoff et al., 2019). Since AVs can be 'driverless', this means that AV owners do not have to be physically present in the carpark. This would help in reducing the size of the parking lane since the space required to open the vehicle's doors will no longer be needed (Nourinejad et al., 2018**).** Fig 8 shows how AVs can be stacked closely to each other using multiple rows, thus reducing the parking space substantially. Research by Nourinejad et al. (2018) reported that AVs could reduce parking spaces by 62% on average. However, some cities such as Toronto enforce restrictions on the dimensions of carparks as well as their orientation (Valverde, 2009). This suggests that there might be future policy challenges to changing/reducing carpark sizes. It is speculated that there would be a substantial proportion of AVs in a city's vehicle mix, before special AV carparks could be justified.

3.2.2 Urban Sprawl

Another implication for land use is the potential to create urban sprawl (Clements & Kockelman, 2017). This scenario is likely to happen if AVs increase accessibility and cause more road expansion, leading people to seek cheaper housing on the outskirts of cities. By contrast, there is speculation that AVs could cause a movement towards cities especially when the positive implications of AVs are noticed, making cities more attractive to move into, thus reducing urban sprawl. The positive implications of SAVs on cities entails reducing congestion and the demand for dedicated parking zones. This would result in creating more productive and sustainable facilities such as public squares, green infrastructure, dedicated cycling and walking lanes which encourage active travelling and improve the quality of life (Porter et al., 2018).

3.3 Environmental Planning

3.3.1 Fuel Efficiency and Energy Consumption

Studies show that CAVs may increase fuel savings. Work by Khondaker and Kattan (2015) reported that AVs may increase fuel savings by 15%. However, fuel savings will be much lower if the AV market penetration rate was less than 100% (Larsen et al., 2019). Eco-driving can also contribute to fuel consumption savings for different levels of AV automation (Stephens et al., 2016; Anderson et al., 2014; Brown, Gonder, & Repac, 2014), as AVs can achieve better fuel economy in a given situation through a smooth style of driving compared to that of a person.

AVs may lower energy consumption in the short-term while the long-term impacts could be uncertain. Wadud, MacKenzie, and Leiby (2016) found that AVs are estimated to lower energy intensity by up to 20% if deployed globally due to vehicle platooning. However, Ross and Guhathakurta (2017) argue that AVs that function as MaaS would increase the number of trips and VMT, resulting in greater energy consumption.

3.3.2 Air Pollution and Emissions

AVs may contribute to a reduction in air pollution. Advanced driver assistance systems (ADAS) and adaptive cruise control (ACC) systems may reduce emissions due to their ability to reduce the change of lane movements as well as controlling the acceleration and braking of the vehicle (Wang et al., 2014). Some studies (Wang, Chen, Ouyang, & Li, 2015; Grumert & Tapani, 2012) reported that AV deployment can possibly reduce nitrogen oxide (NOx) levels due to applying systems such as variable speed limits and platooning. Research by Jones and Leibowicz (2019) revealed that carbon dioxide (CO2) emissions savings can also be attained with wide deployment of AVs due to zero emission capability. However, non-exhaust emissions might easily be overlooked as contributory variables to air pollution even if AVs were electric. There will still be a chance of emitting particulate matter (PM) concentrations that originate from non-exhaust emissions, such as brakes and tire-wear (Shammut et al., 2019; Ketzel et al., 2007).

Fully automated AVs could potentially lower GHG emissions although the long-term implications could be uncertain. A case study in NY City investigated GHG emissions for electric self-driving taxis with and without a driver using a multiphysics energy model (Zhang et al., 2019). The study revealed that AVs without a driver showed about 7% reduction in GHG emissions compared to the ones that had a driver. The authors concluded that higher levels of vehicle automation could potentially lower GHG emissions. A recent study conducted in China revealed that substantial reductions in GHG emissions will not be achieved before 2050 due to low levels of AV market penetration (Liu et al., 2019). These researchers further argue that estimating the long-term impact of AVs on GHG emissions is highly uncertain because AVs ownership and VMT are currently unknown. They concluded that these unknowns affect the results validity and urged further research be conducted in this area.

3.4 Summary

This section has reviewed the literature regarding the impact of AVs on transport, land use and environmental planning. It appears that the estimated impacts of AVs for the long term would be highly uncertain (Milakis, 2019). This uncertainty in part hinges on the market penetration rate of AVs in the future, the percentage of AVs becoming shared or self-owned, and resolving existing challenges such as safety risks, liability, and ethical issues. The next section of this report will explore AVs implications from a technological perspective.

4. Driverless Cars: A Technological Perspective

While AVs are likely to have many benefits, there are concerns regarding the associated risks and unintended consequences of this smart technology. These risks include safety, intelligent infrastructure and cybersecurity, data privacy, and surveillance. Governments' response, strategies and best practices to these risks will be presented.

4.1 Safety

The degree of safety that AVs provide is a high priority topic (Elliot et al., 2019). Many researchers (Naranjo et al., 2016; Lin et al., 2014) assert that AVs can improve safety using the advanced driver assistance systems (ADAS). These systems cover lane centring and assisting, collision warning and avoidance, as well as intersection assistance (Luo et al., 2016; Liebner et al., 2013). Despite this, Dalal and Triggs (2005) state that it would be more complicated for AVs to recognise pedestrians, cyclists, or any other objects on the road compared to a human driver. Fagnant and Kockelman (2015) further argue that adverse weather conditions such as ice, snow, rain and fog may affect AVs' sensor on public roads, 'recognition, which gives the human driver an advantage over AVs in these situations. With the introduction of AVs on public roads, some were involved in a number of fatal incidents. For instance, two autonomous Tesla vehicles were responsible for the death of the drivers in the US (Parkinson et al., 2017; BBC, 2019; Favarò, et al., 2017), and an autonomous Uber car killed a pedestrian in Arizona, US (Elliot et al., 2019), which forced Uber to suspend their AV testing program in Arizona, San Francisco, Pittsburgh and Toronto after receiving a letter from Governor Doug Ducey (Elliot et al., 2019; Griggs & Wakabayashi, 2018). Governor Ducey sent a letter to Uber's CEO stating that "Improving public safety has always been the emphasis of Arizona's approach to autonomous vehicle testing, and my expectation is that public safety is also the top priority for all who operate this technology in the state of Arizona" (Hensley, 2018). Given the concerns regarding accidents and the use of AVs, it is crucial that their safety performance continues to improve. Scholars (Bansal et al., 2016; Kalra, 2017) argue that AVs' performance can improve when driving in a real-world environment that would enable developers to monitor, evaluate, and enhance the AV system (Kalra & Paddock, 2016). Driving in diverse, real-world environments would also improve the state of art of AVs safety, since machine learning algorithms in AVs can learn from previous mistakes and share it with other AVs to avoid similar errors, thus improving their overall safety performance (Kalra, 2017). Kalra and Paddock (2016) stress that real-world driving for AVs will also help in evaluating safety regulations and policies, although assessing the performance of AVs will require millions of miles driven to statistically justify any improvements. This suggests AVs will need to continue driving on public roads.

In terms of governing real-world driving experience, countries like the UK, US and Australia are adopting a "light control-oriented strategy" (Taeihagh & Lim, 2019), with the purpose of giving enough space for innovation, meaning that they are currently not imposing stringent regulations on AVs safety. In contrast to the "race for innovation" approach, the EU focuses more on protecting AV's users from the technological risks. While the EU legally permits AV testing, the testing should be restricted to private streets, pre-defined routes, and very slow speed limits (Taeihagh & Lim, 2019). The Japanese and Singaporean government have taken steps to amend their laws to ensure the safety of AV testing in 2017. In Japan, the government is adopting a "prevention-oriented strategy" in which they require the AV to have a driver while conducting on-road testing to minimise the risks from technological errors (Taeihagh & Lim, 2019). The driver should obtain license and police approval, and always be vigilant to necessity to activate the braking system. In Singapore, the new amendments to the Road Traffic Act (RTA) enables the Minister for Transport to make new rules on AV testing, acquire data from the trials, and establish standards for AV designs, which demonstrates a "control-oriented strategy" (Taeihagh & Lim, 2019). Before AV testing, the vehicle must pass safety assessments and plans for crash mitigation must be developed.

In NZ, the MoT does not have any specific legislative requirements or the requirement to use specified roads for AV testing (Ministry of Transport, 2019b). AVs are only allowed to be tested on public roads if the safety of all people is guaranteed (e.g. employees, drivers, etc.), and the test-bed is performed on a closed road. Prior the performance of any tests, the testing organisation should submit a 'Safety Management Plan' to NZ Transport Agency (NZTA) to ensure all safety procedures are met and any hazards or risks are identified. According to the Land Transport Act 1988 (New Zealand Legislation, 2019), NZ police have authority to stop AV testing on public roads at any time if safety requirements were perceived to have been breached. This suggests that the early testing and deployment of AVs in NZ will be subject to safety procedures, and also shows how "New Zealand is unique […] it does not have any explicit legal requirement for a driver to be present in a moving vehicle" compared with other countries (Costantini et al., 2020).

4.2 Intelligent Infrastructure

Intelligent infrastructure is vital for enhancing the quality of AVs operation in terms of road safety, traffic flow, and customer convenience. Intelligent Transport Systems (ITSs) enable AVs to communicate with one another, and with their surroundings via communications known as V2V, V2I and V2X (Hasan et al., 2018; Fang et al., 2017) as shown in Fig 9.

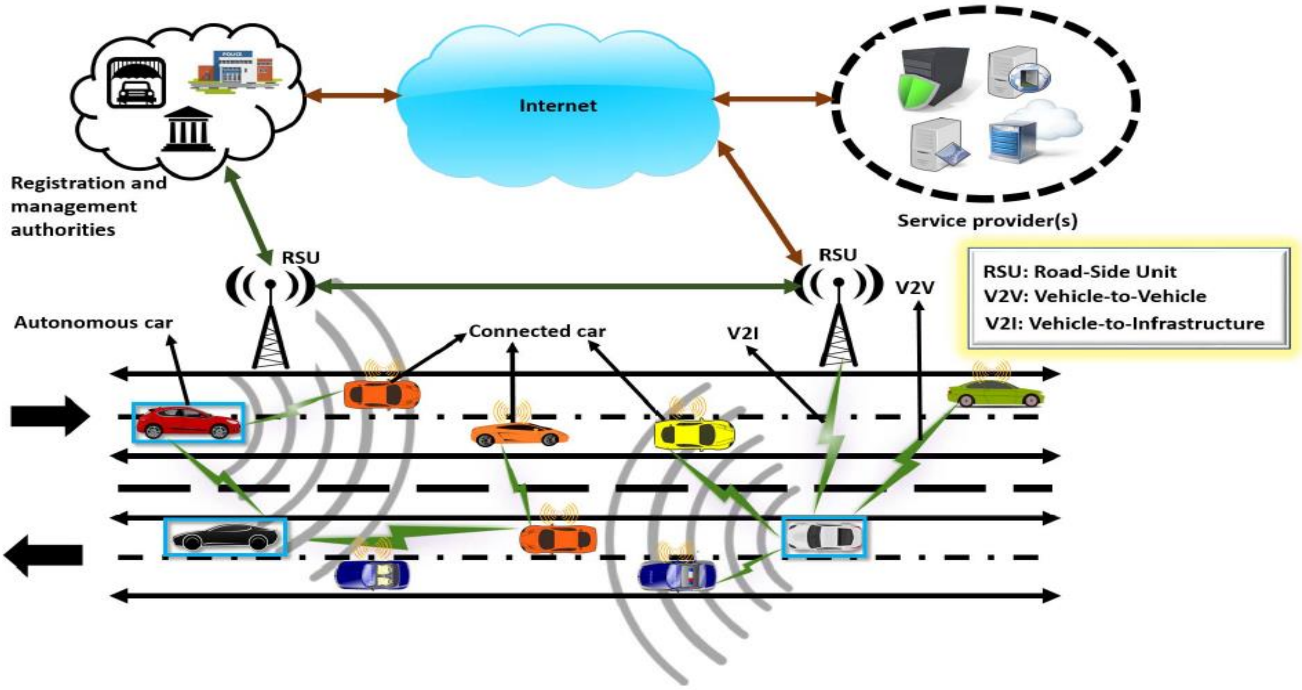


Figure 9: Communication networks for AVs (Source: Hussain and Zeadally, 2019).

Vehicle to vehicle (V2V) communication is when two vehicles transmit signals to each other via routing algorithms to pass periodic information through the Vehicular Ad hoc Network (VANET) (Hasan et al., 2018). V2V networks can transfer real-time traffic data by sending collision warnings through a vector-based cooperative collision warning system (VCCW), which may improve both traffic safety and flow (Elliott et al., 2019). On the other hand, vehicle-to-infrastructure (V2I) communication can provide a higher prevention rate of car crashes than V2V communication by an estimated 12% (Yang, Fei and Dang, 2017). The role of infrastructure roadside units (RSUs) is to enable exchanging traffic-related data, search for available carpark spaces in airports, and circulate notifications about nearby fuel stations and restaurants to enhance the user experience (Hasan et al., 2018). AVs will also be able to communicate with other objects such as mobile phones and pedestrians via communications known as vehicle-to-everything (V2X). It is claimed that V2X may potentially reduce road accidents by up to 80% since it collects data from other vehicles, pedestrians and infrastructure units (Abboud et al., 2016). V2X rely on wireless technologies such as cellular networks and dedicated short-range communications (DSRC) (Elliot et al., 2019). Despite the possible advantages that ITS may present, a group of studies (Linkov et al., 2019; Elliot et al., 2019; Lim and Taeihagh, 2018; Parkinson et al., 2017; Petit and Shladover, 2015) have highlighted the limitations of these systems. These limitations include: (1) the possibility to hacking AVs through V2V, V2I, and other wireless communication networks; (2) the lack of government funding for ITS development and deployment; and (3) the challenge in equipping every vehicle on the road with the special communication devices to make ITS work successfully (Hasan et al., 2018; Shladover, 2018).

4.3 Privacy

AVs rely on collecting data extensively to ensure the high safety operation of the vehicles and optimise the traffic flow (Taeihagh & Lim, 2019). However, sharing, storing, and processing the data collected by AVs is potentially considered a major privacy concern (Fafoutellis and Mantouka, 2019). AVs could collect data about the users' travel behaviours, travel time, location of work and home, mobile phone numbers, areas of interest and other personal information, which may jeopardise the privacy of the users (Hussain and Zeadally, 2019; Fafoutellis and Mantouka, 2019). This sensitive data could be shared with vehicular networks (for targeted advertisements) and other external organisations, such as insurance companies and law firms (Schoonmaker, 2016). Another emerging privacy concern is in the realm of surveillance. AVs will be able to collect location-based data as well as audio and video recordings of the passengers, which enables governments to conduct remote surveillance of the users (Taeihagh & Lim, 2019). For instance, China has announced its intention to launch a "Social Credit System" in 2020 that allows the government to monitor people's social and political behaviours (Lim and Taeihagh, 2018), by which AVs deployment may facilitate the achievement of that goal. It is noteworthy that both the incidence and opportunities for surveillance are less prevalent when individuals own the AV.

Governments' response to the data privacy issues vary across the world. In South Korea and the US for instance, the governments have begun enacting legislations on data privacy for both conventional and autonomous vehicles. In South Korea, the Vehicle Management Act (MVMA, 2016) emphasises that an approval must be obtained from the Minister of Land, Infrastructure, and Transport prior to using the collected data so as to ensure the privacy of AV's owners. Similarly, in the US, a new Spy Car Act (SCA, 2017) states that manufacturers must seek consent from the vehicles' owners before using their data for advertising and marketing. All vehicle owners will have the ability to stop data collection, except the data necessary for accident investigations.

In the EU, the ITS Action Plan (EP, 2009) recognises the urgency to protect personal privacy. The EU has also updated the Data Protection Directive 95/46/EC of 1995 through the new EU General Data Protection Regulation (EU GDPR), which took effect in May 2018. The updated GDPR regulations are more stringent in terms of strengthening the requirement for customers' consent and increasing penalties for violations by up to 4% of companies' global revenue (Taeihagh & Lim, 2019), and the European Commission has already fined Google on many occasions, which shows their commitment to controlling privacy risks (Eben, 2018). The GDPR regulations apply to all companies in the world as long as they process data of EU citizens, extending the privacy control beyond geographical boundaries of the EU. However, having excessive regulation on data privacy and usage may disadvantage car manufacturers in the EU and may hinder AVs deployment.

In the UK, the Privacy Architecture framework (DfT, 2017a) states that AV users should have the ability to delete any "sensitive data" and ensure that personal information is "properly managed" in terms of how the data is stored and used. However, no definitions were provided regarding what is considered "sensitive data" or "proper management" of personal information. This suggests that the UK government is aware of the privacy risks posed by AVs but is not enforcing stringent legislations that would hinder AVs deployment as the UK government aspires to be a world-leader in AV research and development (Taeihagh & Lim, 2019).

The Australian's National Transport Commission (NTC) recommends adopting a "privacy by design" approach and, "whenever possible", not generate personal information about individuals (Daly, 2017). The phrase "whenever possible" indicates that these are only rhetorical overtures and do not reflect strong legislation to mitigate AV privacy concerns. In New Zealand, the new Privacy Bill has replaced the Privacy Act of 1993 (New Zealand Parliament, 2019). By introducing new offences and higher fines, the new Privacy Bill legislation is seen as having EU adequacy status (Costantini et al., 2020), although it has dissimilarities to the GDPR. For instance, there are fewer restrictions on consents, no restrictions for AV decision making tools, and no guidelines regarding the management and ownership of AVs' data (Costantini et al., 2020).

4.4 Security

Security of the AV system is vital for social stability and safety (Lim & Taeihagh, 2018). According to Hussain and Zeadally (2019), the sophisticated technology that is used in AVs can contribute to increasing security. As such, AV owners will be able to register their biometrics with the car. This enables the vehicle to recognise the authentic owners of the car by voice, fingerprints and retina detection, which prevents people from stealing it. In contrast, AVs might be subjected to cybersecurity threats (Lee, 2017). Those threats involve jamming the V2V, V2I, and V2X signals for the purpose of stealing the car or harming the passengers (Amoozadeh et al., 2015; Lim and Taeihagh, 2018). In the US for instance, Schellekens (2016) reported that two hackers succeeded in gaining access to a car's engine and brakes in 2015 using mobile wireless networks. Gerdes et al. (2013) clarify that manipulating the speed and motion of connected autonomous vehicles (CAVs) by hacking the vehicles' network system is also possible. Hackers can also modify maps and sensors in AVs to block reception of necessary information and inject fake messages (Parkinson et al., 2017). To overcome these cybersecurity risks, Katrakazas et al. (2020) recommend monitoring and conducting analysis of diagnostic for the data collected by AVs to reach a level where the AV can predict a threat and react in milliseconds. Using machines learning and artificial intelligence (AI) techniques along with 5G data networks might provide AVs with the computing power to detect the threats before they occur and eventually prevent the attack (Katrakazas et al., 2020).

Governments' guidelines on cybersecurity best practices vary widely around the world. In the US for instance, the government has established a new department to research the safety and security of "electronic vehicle systems" and has set up the Electronics Council to enhance research collaboration on cybersecurity matters (NHTSA, 2018). The NHTSA has made non-mandatory recommendations to software companies and car manufacturers that AV systems should be designed in line with international standards such as the SAE, NHTSA, and the Automotive Information Sharing and Analysis Centre (ISAC) (NHTSA, 2017). In addition, the Spy Car Act requires AVs to have the ability to detect, prevent, and report any cyberattack that attempts to take control of the vehicle and its data (SCA, 2017). These guidelines demonstrate the US government efforts to both gain and raise awareness regarding cybersecurity risks for software companies and car manufacturers (Taeihagh & Lim, 2019).

The EU has also taken steps to manage cybersecurity risks. EU-wide legislation was published for the first time on cybersecurity in 2016 (EC, 2016). In the same year, a best practices guideline for cybersecurity issues was released by the EU Agency for Network and Information Security (ENISA, 2017), which shows the EU commitment to manage and increase awareness on cybersecurity risks. In the UK, although the government has not enacted any new legislation on cybersecurity, they have made efforts to raise awareness of cybersecurity risks related to AVs. It has established the National Cybersecurity Strategy (2016-2021) aimed at strengthening the UK's position as a world leader in this field by 2021 (Cabinet Office, 2016).

In Japan, the government has not taken any steps to amend its existing Road Traffic Act (RTA) nor it has established any guidelines on cybersecurity issues (Taeihagh & Lim, 2019), which suggest adopting a "no-response" strategy. The Japanese government has yet exhibited any heightened awareness or increased sensitivity or anxiety in respect of cybersecurity risks. In New Zealand, the MoT has established an AV Programme that listed cybersecurity as an area that needs further research (Ministry of Transport, 2019c). The NZ MoT may monitor international developments and adopt relevant strategies in the future regarding controlling and managing cybersecurity risks (Costantini et al., 2020). A timeline of further strategies for privacy and cybersecurity across the world are contained in **Appendix 3**.

4.5 Summary

This section has presented the associated risks with AVs and highlighted some of the strategies and best practices adopted by different countries to mitigate these risks. Some countries have stringent legislation with a view to controlling the technological risks associated AVs that might lead to hampering their deployment, whereas other countries such as the US and UK tend to focus more on giving space for innovation and progress. The next section of this literature review discusses the potential economic implications of AVs as well as their likely impact on employment and businesses.

5. Driverless Cars: An Economic Perspective

As various industries invest heavily in AVs in order to facilitate their development, this will have a series of economic implications. Such implications range from the possibilities for economic growth, the creation of new job opportunities, shifting roles in the workplace in parallel with the risk of a diminution in certain job profiles. Not only are AVs predicted to impact the transport sector, but they may also "change the landscape of almost every industry" (Clements & Kockelman, 2017, p. 113). This section sheds light on the impact of driverless cars on employment, businesses, and the wider economy.

5.1 Impact on Employment

5.1.1 Job Opportunities

The development and deployment of AVs may provide new job opportunities in many sectors. For instance, more positions may "open up" for researchers to conduct further research in the realm of AVs. A good example of this is when the UK government established the Centre for Connected Autonomous Vehicles (CCAV) and announced the allocation of £100 million research funding focusing solely on the AV technology (House of Lords, 2017). New jobs might also be created in the engineering, planning and software sectors (Milakis et al., 2017). Cruise, an AV start-up, has provided about 2,000 job opportunities for AI engineers since its opening in 2017 (IEEE, 2019). A report commissioned by the Australia and New Zealand Driverless Vehicle Initiative (ADVI) estimates that AVs deployment would possibly create over 2000 annual jobs in Australia (Haratsis et al., 2018). Consulting companies such as ATKINS estimate that about 320,000 jobs might be created by AVs development and deployment by 2030 in the UK only (Somashekar, 2020).

Despite the aforementioned areas of job creation that AVs will offer, it appears as if these new opportunities would be available to those groups of people who are skilled and educated, not necessarily those who will lose their jobs as drivers (see Table 2 for emerging job opportunities and skills requirement). Low-skilled and less educated individuals would seem to have much less chances of keeping their current jobs (Taeihagh & Lim, 2019), although there might be some jobs that still require essential human involvement. For instance, Deming and Kahn (2018) state that employees who have developed non-routine and social skills will be more likely to retain their jobs since these positions are presently more difficult to automate. It is noteworthy that the overall effect of AVs on employment will vary greatly depending on the region of AV deployment and the market penetration rate (Milakis et al., 2017).

Table 2: AV emerging job opportunities and the corresponding skill requirements (Source: Somashekar, 2020; Cutean, 2017).

No.	Occupation	Skills Required
1	AV machine learning specialist	Experience in programming software (Python, JavaScript, etc.).
2	AV driving algorithms and deep learning	Experience in advanced statistical analysis and design optimization.
3	AV application engineer	Experience in C programming and MATLAB.
4	Robotics software engineer	Knowledge of Java spring framework.
5	AV lab manager	experience in messaging protocols (AMQP, DDS, MQTT).
6	AV software research scientist	Experience with embedded software and automotive systems (Brakes/Powertrain).
7	AV platform system engineer	Cloud services and software development.
8	AV driving test	Expert in vehicle communication network protocols.
9	Transport modelling engineer	Knowledge of vehicle dynamics modelling and CarSim software.
10	Repair technician	Expertise on the design, test, validation, and development of solutions for wireless power.

5.1.2 Job Losses

Although AVs are anticipated to result in job creation in some sectors, a growing body of the literature indicates that the deployment of AVs might present a threat to jobs and employment. Low-skilled individuals, along with those having manual jobs, will be the most affected by this technological advancement (Frey & Osborne, 2017). Such people would include taxi, bus, and truck drivers (Alonso Raposo et al., 2018). To highlight this in numbers, the latest statistics of the American Trucking Association reported that there are around 3.5 million truck drivers in the US. These estimations would even increase to about 8 million people if other job positions in the trucking business were included (American Trucking Association, 2018). In the

US alone, bus and taxi drivers are reported to account for about 505,000 and 208,000 drivers in 2018, respectively (Bureau of Labor Statistics, 2019). In NZ, truck drivers are estimated to number over 25,000 and 27,000 drivers by 2023 and 2028 respectively (MBIE, 2020), these jobs may be threatened by the large-scale deployment of AV technology.

A report published by the US Department of Commerce (Beede, Powers, & Ingram, 2017) revealed that one in nine employees are working in jobs that will be threatened by the deployment of driverless cars. Forecasting models developed by Arinze et al. (2016) suggest that by 2050, AVs will eliminate about 4.35 million workers from their jobs in the US. Even the profession of attorneys might be negatively impacted by the fewer accidents caused by cars. In the US, there are more than 1.2 million attorneys, 75,000 of which specialise in personal injuries. Clements and Kockelman (2017) report that about $3 billion in revenue could be lost from personal claim lawsuits due to reduced road injuries, which provides real challenges to some attorneys. Furthermore, estimates of Frey and Osborne (2017) show that 47% of all US employment is at high risk of replacement as automation increases, whereas estimates by Arntz et al. (2016) suggest that only about 10% of US employment would be at risk.

The threat to employment posed by the adoption of AVs is acknowledged by few governments around the world but strategies to address them are yet to be formulated. The Singaporean government has announced its intention to set up programmes aimed at retraining future displaced workers to help them gain new skills and obtain higher valued jobs. In the US and Australia, the governments there also recognise the potential negative impacts of AVs on employment and strongly recommend transitioning the workforce as quickly as possible (Taeihagh & Lim, 2019). Trucking industries, for instance, may redistribute the roles of drivers to other technical departments to minimise the percentages of job losses. Yet, the job-shifting prospect can be daunting, and people may feel insecure that their new job since they may fear losing their jobs yet again by the emergence of more qualified individuals (Salmon, 2019, p. 118).

5.2 Impact on Businesses

5.2.1 Industrial Growth

From a company owner's perspective, it is preferable to hire robots rather than human beings since the former provide a higher level of work efficiency at a reduced cost in terms of wages and attendant cost (Kencebay, 2019). In that sense, companies might consider AVs as an economically efficient alternative to a human driver. For instance, Clements and Kockelman, (2017) argue that trucking industries may gain up to $500 billion by 2050 from the elimination of human drivers. Autonomous taxis also seem to be a promising business, given that the drivers' associated costs will be eliminated (Hussain and Zeadally, 2019). However, for fully automated taxis to operate on today's road network, capital investment for the infrastructure will be needed (Nikitas et al., 2017).

According to Clements and Kockelman (2017), automated vehicles open more doors for technology firms to flourish by developing vehicle's software and hardware. As such, the software will make up about 40% of the AV's value (Jonas et al., 2014). In terms of the hardware, it is reported that the LIDAR alone costs about $75,000 (Hussain & Zeadally, 2019), whereas the AVs would cost about $100,000 per vehicle (Fagnant & Kockelman, 2015). It is projected that the AV industry would make about $556 billion in revenue by 2026 (Porter et al., 2018). However, less profit would be made if AVs were to be shared rather than self-owned, which will be highly dependent on how countries promote AVs.

With reference to privatising SAVs, Riggs (2019) highlights potential consequences if SAVs were to be dominated by private companies. As such, he indicates that users' private data held by private companies might be sold to other beneficiaries (e.g. restaurants, motels and malls) who would be interested in making targeted sales and advertisements using AV communication networks. Moreover, private companies might use their SAVs as a "profitmaking" tool rather than a "service" tool. This can be done by purposely targeting high-income neighbourhoods instead of low-income ones, which may also increase social inequality.

In New Zealand, a report commissioned by Business NZ and MoT estimates that ITS products such as AVs and drones may generate as much as NZ$2 billion annually by 2050 (BusinessNZ, 2018). The economic modelling in the same report shows that more than NZ$750 million of yearly turnover could be made by ITS companies for exporting their technologies from NZ, which reflects the opportunity for AVs to generate and expand businesses.

5.2.2 Business Loss

Since 90% of car crashes are claimed to be caused by human error (Haboucha et al., 2017), advocates of AVs assume that this innovative technology would largely eliminate car collisions (Morando et al., 2018). Reducing car accident rates will potentially create a huge economic (and social) benefit. For instance, car accidents in the US involved $30 billion in repairs according to 2013 estimates (Fagnant and Kockelman, 2015). Assuming the AV deployment would only reduce 50% of collisions (instead of 90% from the elimination of human error), this means that the repair industry would lose about $15 billion in revenue according to Clements and Kockelman (2017). This also assumes another cause of crashes will not replace "human error", such as "technological" or "programming" errors in AVs. Reducing the predominant cause of accidents is not necessarily the same as reducing the rate of accidents.

The success of AVs in reducing both congestion and crashes will negatively affect the automobile repair and maintenance businesses. In 2019, car accidents in the US generated about $123 billion in revenue for the repair and maintenance industry (García, 2020). The repair and maintenance industry could lose about $31 billion and $62 billion annually in revenue if we assume AVs would reduce car crashes by 25% and 50% respectively. While some opportunities for repair shops might arise in cases of technical malfunction, collision or cyberattack (Clements & Kockelman, 2017), this might result in a skills mismatch as workers need to upgrade their digital skills and expertise (Somashekar, 2020). Another industry that would be negatively affected by reduced crashes is insurance agencies. In the US, the earnings of insurance companies nett about $180 billion yearly (Desouza et al., 2015). If AVs led to both increased safety and less car ownership, this would minimise the revenues generated from vehicle insurance by nearly 60% (Clements & Kockelman, 2017).

Traffic police and governments will accrue lower revenue from speeding tickets and traffic violations, since AVs would offer higher levels of traffic obedience. Statistics from the National Motorists Association show that the annual revenue from traffic fines are about $8 to $15 billion (National Motorists Association, 2007). In New York City alone, the annual revenue generated from traffic violations was $993 million in 2016 (Murphy, 2017). The New Zealand government also earned around NZ$44 million in 2018 from speed camera fines (Hunt and Kenny, 2019). Such huge revenue losses from traffic fines can be expected as AVs become widely adopted (Clements & Kockelman, 2017).

Electric autonomous vehicles (EAVs) are expected to generate a massive economic shockwave for the fuel industries, particularly when they come to be widely deployed (Porter et al., 2018) since EAVs will reduce fuel dependency. Similarly, it could also be anticipated that governments may lose a huge share of revenue from fuel taxes. Across the EU for instance, the loss of revenues in fuel taxes is estimated at €800 billion due to the wide electrification of vehicles (Lindberg, & Fridstrøm, 2015). The Australian and NZ governments make about AUS$20 billion and NZ$1.1 billion in revenue from fuel taxes annually (Budget, 2019; StatsNZ, 2019). Thus, as a consequence of ubiquitous EAVs, national governments worldwide will experience a loss of revenue from the loss of revenue generated by fuel taxes (Porter et al., 2018). However, if AVs were not fully electric, then this would actually increase fuel consumption, and hence increase tax revenue relative to non-fully electric AVs. According to Clements and Kockelman (2017), AVs would travel further to increase accessibility, subsequently, will increase fuel consumption by 5%, which is equivalent to of $14 billion of annual revenues. Another business that might perish is valet parking, although it is not likely to be a big loss of jobs. There will be no need to hire people to park driverless cars as AVs can park themselves. This becomes more probable when AVs become widely adopted.

5.3 Impact on the Economy

5.3.1 Improved Safety

The current impact of car crashes on the economy is significant. As such, the Ministry of Transport (2020b) in NZ reported that the total annual economic cost of all vehicle crashes was NZ$5.6 billion in 2017. Similarly, a report published by NHTSA (2017) revealed that the annual traffic accidents costs in the US amount to $242 billion. When the value of other economic impacts was included (e.g. quality of life lost, productivity, etc.) the comprehensive cost was estimated at $836 billion. Since AVs are anticipated to lead to fewer car crashes (Fagnant & Kockelman, 2015), this could possibly result in savings of $488 billion by reducing the numbers killed and seriously injured individuals in the US (Clements & Kockelman, 2017). Furthermore, estimates by Fagnant and Kockelman (2015) show that the comprehensive cost savings due to improved road safety in the US could be about $18 billion and $355 billion assuming a 10% and 90% AV market penetration, respectively. This shows the significant economic savings that AVs can bring about by improving road safety, particularly when widely adopted.

5.3.2 Congestion and Productivity

Congestion-related costs are significant. Annual congestion costs in the UK and US are estimated to be £30 billion and $120 billion, respectively (Lim & Taeihagh, 2018; West, 2016), whereas about NZ$1.3 billion is the cost of congestion in Auckland (NZIER, 2017). AVs are predicted to result in cost savings of 66% by reducing congestion (Fagnant & Kockelman, 2015). The narrative of AVs ability to reduce congestion implies that productivity will be increased. As such, assuming a 90% AV market penetration, about 2.8 billion unproductive hours could be saved in daily commutes, which equates to savings of $447 billion annually in the US and $5.5 trillion across the globe (Clements & Kockelman, 2017). However, we argue that it cannot be assumed that the saved time would be used productively as commuters might choose to sleep longer, for instance, or have a more leisurely breakfast. Lim and Taeihagh (2018) also report that cyberattacks on AVs might amount to $3 trillion in lost productivity, which would be regarded as a significant burden for businesses. It is noteworthy that those cost savings may only be realised in the event that AVs so actually succeed in minimising congestion (Maciejewski & Bischoff, 2018; Shladover et al., 2012).

5.3.3 Land Use and Parking Spaces

Excessive land allocated to parking spaces may result in less economic activity (Zakharenko, 2016). As an example, consider Buffalo New York, which devotes about half of its downtown land to parking, and there are over 710 million parking spaces in the US (Clements & Kockelman, 2017; Zakharenko, 2016). Since SAVs can potentially reduce the demand for parking spaces and demand (Hawkins & Nurul Habib, 2019; Zhang et al., 2015), this space can be alternatively replaced with commercial buildings to attract economic activity and increase productivity.

Chester et al. (2015) found that the cost of building 25 underground parking spaces for every new 100-unit building is about $1 million in the US. In addition, Clements and Kockelman (2017) point out that the total land dedicated to parking spaces is valued at $4.5 trillion, with an average property value of $6,300 for each parking space. These researchers suggest that if SAVs succeed in achieving a 1% reduction in parking spaces per year, $45 billion in land value can be reclaimed annually. Therefore, money recovered from reduced parking spaces can be invested for other purposes.

5.4 Summary

This section has highlighted the possible implications of AVs on employment, businesses and the wider economy in the private and public sectors. Overall, the higher AV’s penetration rate, the greater the economic impact will be, which is potentially estimated at $1.2 trillion (Clements & Kockelman, 2017; Fagnant & Kockelman, 2015). These economic benefits come from productivity gains, a reduction in collisions, and other economy-wide savings, whilst also acknowledging the possible negative economic effects.

6. Conclusions and Future Work

The previous sections clearly show that safe travel was one of the main drivers for the development of AVs since the 1920s. It was believed that developing automated driving would solve road safety issues created by the elimination of human error. The car industry played a huge role in the dissemination of this narrative, which led to the hyping the expectations of AVs as early as 1920s. However, our review of the literature revealed that implementing AVs is a complex issue that needs to overcome several barriers not only in the technological aspect, but also in its social, planning, and business aspects as discussed in the previous sections (see Table 3).

Road accidents will cost the global economy about $1.8 trillion between 2015-2030 (Chen et al., 2019). Therefore, AVs are presented as a safer option for future travel by offering the "technical-fix" needed to minimize road crashes, thus saving the lives of individuals and impacting positively on the world economy. For AVs to improve safety significantly there must be a large-scale adoption of Level-5 automation. One factor that influences the large-scale adoption is consumer attitudes towards this technology. By exploring the public attitudes towards AVs in 51 countries around the world, Moody et al. (2019) found that highly-educated, employed, young male individuals are the most optimistic about AVs safety. Developing countries in Asia seemed more optimistic about AVs safety as they have higher car crash rates compared to Western European countries. Optimistic perceptions about AVs safety in developing countries may minimise the disparity in road safety around the world. The public in the developed world such as Canada, Australia, the US, and Western Europe raised concerns regarding AVs' potential technical failures, interaction with conventional cars, and there use as a mode of public transport (Moody et al., 2020; Piao et al., 2016). This indicates the importance of investigating the social perceptions of AVs safety since that may influence their acceptance rates and sales (Montoro et al., 2019). Addressing these safety concerns may increase their market penetration rate, thus may increase the degree of market penetration together with the wider and deeper levels of consumer acceptance that may flow from this.

For AVs to address the associated safety risks, the public would need to accept mass deployment and AVs would need to be trailed in real-world environments (Taeihagh & Lim, 2019; Bansal, Kockelman, & Singh, 2016; Kalra, 2017). This would enable AVs to learn more from the real-world driving experience, enhance its performance, and help evaluate safety regulations and policies. In response, some national governments (UK and US) have refrained from imposing strict measures on

AVs testing requirements with the purpose of promoting AVs development. Japan is adopting a "prevention-oriented strategy" in which they require the AV to have a driver while conducting on-road testing, whereas a "control-oriented strategy" is adopted in Singapore, which requires developing plans for mitigating crashes while testing AVs (Taeihagh & Lim, 2019). In NZ, driving law is unique as there is no requirement for a driver to be present in the vehicle, which suggests having fewer legislative barriers to adopting AVs compared with other countries that require a driver in vehicles.

While it is essential for AVs to drive in real-world environments to enhance their performance, previous experiences of AVs operating on roads caused several crashes. During 2009-2015 alone, Google's AVs were involved in 11 crashes (Kalra & Paddock, 2016), which raises policy concerns regarding the liability for accidents (Li et al., 2019). Many governments including those in China and South Korea have displayed a "no-response strategy" regarding liability regulations (Taeihagh & Lim, 2019). A further public policy challenge concerns the ethics of the AVs system as to who is authorized to adjust the "crash algorithm" settings in an inevitable car crash. This is related to the "life or death" events in which AVs would decide who to crash based on people's age, gender, occupation, and ethnic background, etc. (Pickering et al., 2019). While there is still no legal framework that addresses the issues of liability and public ethics, further research is being conducted.

AV's communication and infrastructure networks are associated with data privacy risks and vulnerable to cybersecurity attacks. Personal data could be accessed to be used for advertising, location tracking, and surveillance (Lim and Taeihagh, 2018), whereas cyberattacks may manipulate AVs speeds, jam their signals, block important notifications, and steal the vehicles (Amoozadeh et al., 2015). Responses to managing privacy and cybersecurity risks vary across countries. Most EU countries have adopted a controlled strategy to protect the data of EU citizens even if the company is located outside the EU boundaries, which might lead to disadvantage AV manufacturers. US and Singapore have also enacted new guidelines on data privacy, whereas the UK and Australia have only made general privacy recommendations. Regarding cybersecurity, most governments have enacted strategies to manage cybersecurity risks that are not specific to AVs, but encompass all technological systems, whilst some governments are still gaining awareness about AV cybersecurity risks (Taeihagh & Lim, 2019).

Resolving the technological risks of AVs will likely result in a large-scale adoption that would create a significant economic impact. The latest statistics for the total economic costs of car crashes amount to NZ$5 billion and $836 billion annually in NZ and the US, respectively (NHTSA, 2017; MoT, 2019). The opportunity for AVs to improve safety could result in cost savings ranging from $355-$488 billion in the US, depending on their market penetration rate (Fagnant & Kockelman, 2015). Furthermore, reducing congestion may result in annual savings of approximately $447 billion in the US alone (Clements & Kockelman, 2017). If AVs could reduce parking spaces by only 1%, this may also result in reclaiming about $45 billion in land value in the US. AVs would also create new job opportunities for manufacturers, software sectors, research industries, and AVs start-up companies, employing artificial intelligence engineers to address potential safety issues (Milakis et al., 2017; IEEE, 2019). Because AVs safety relies on the elimination of human driver error, the trucking industries may gain up to $500 billion by 2050 from driver elimination in the US (Clements & Kockelman, 2017). By contrast, the "driver elimination" narrative is a threat to bus, taxi, and truck drivers, who account for at least 10 million people in the US alone (Bureau of Labor Statistics, 2019; American Trucking Association, 2018). Substantial reduction in car crashes might be perceived as a concern for the repair and maintenance businesses as well as insurance agencies as safety improvements could result in huge revenue losses, whereas other businesses such as car manufacturers, software and hardware developers are expected to flourish. Governments have not yet established any strategies regarding how to manage the industrial risks that threatens people's jobs. Although retraining displaced workers is one potential solution, it might create a skills mismatch and be limited to those who are well educated.

Finally, AVs are promising technologies that could possibly address road transport problems and also change cities' landscapes, economies, and the way people live their lives. However, safety risks of AVs remain a barrier to adopting them widely. The arguments narrated today about the impacts of AVs on improving safety are 100 years old, and planners are currently "paralyzed" by adopting a "wait and watch" approach (Legacy et al., 2019; Goetz, 2019; Milakis, 2019), which indicates the necessity to conduct further research in this area. This section highlighted the complexity of implementing AVs and demonstrated that the issue of their safety is not merely a technological one. Investigating and resolving safety issues of AVs is expected to result in a largescale adoption and greater benefits. To the best of our knowledge, no research has been undertaken into the safety aspect of AVs holistically yet. Therefore, our future research aims to investigate the safety perceptions of AVs in the social, political, technical and business aspects that may influence their future adoption in NZ. AVs research NZ is still in its infancy, while Auckland has been listed as a "preparing city" for AV deployment (Faisal et al., 2019). Auckland Transport have explicitly highlighted their commitment to develop a "Connected and Autonomous Vehicle Strategy" with a focus on safety (AT, 2016, p. 17), and this highlights the salience of our future research for NZ cities. Using the "mobilities concept" as a conceptual framework, future work will focus on the complexities and interrelationships between social, political, technical, and economic dimensions that underpin the deployment of safer AVs in NZ.

Table 3: Summary of AVs implications (Source: Author).

Aspect	Theme	Sub-theme	Comments	Source
Society	Perception	Awareness	(±) Awareness levels vary significantly worldwide.	(Moody et al., 2020; Piao et al., 2016; Schoettle & Sivak, 2014).
		Safety	(-) High levels of concern in developed countries compared with developing countries.	
		Public Transport	(-) High levels of concern about using AVs as public transport in both developed and developing countries.	
Planning and Policy	Transport Planning	Safety	(+) Increased safety through the removal of human error factors (effects of drinking, drugs, distraction). (-) Challenges to regulating AVs because they have been involved in fatal crashes. (?) Uncertainty regarding how the liability will be apportioned among the parties involved. (-) Major ethical concerns regarding how crash algorithm settings will be programmed.	(Elliott et al., 2019; Taeihagh & Lim, 2019; Milakis et al., 2017; Fagnant & Kockelman, 2016; 2015; 2014).
		Congestion	(+) Reduced congestion through platooning, enhancing road capacity and traffic flow. (-) Increased congestion arising from induced AV demand. Shared AVs might be programmed to keep cruising while empty to find their next customer. (?) Uncertain long-term implications because of unknown travel demand and AV market penetration rate.	
		Shared Mobility	(?) Uncertainty regarding whether AVs will be shared or personally owned. (?) Uncertainty regarding whether SAVs will be integrated with public transport. (+) Improved utilisation for public health services.	
	Land Use	Parking	(+) Increased land space caused by less parking demand. (?) Uncertain impact on urban sprawl.	(Fagnant & Kockelman, 2016; 2014;
	Environmental Planning	Fuel Efficiency	(+) Improved fuel efficiency through efficient 'braking control' technologies.	(Fagnant & Kockelman, 2014; Milakis et al., 2017; Wadud
		Emissions and Air Pollution	(+) Lower nitrogen oxide and carbon dioxide emissions through shared travel and electrification.	

		Energy Consumption	(?) Uncertainty about the long-term effects of AV ownership and vehicle miles travelled.	et al., 2016).
Technology	Technological Advancements	Safety	(+) Improved safety through AV's built-in technologies (ADAS) (-) Technology limitations can cause crashes. AV sensor recognition is negatively affected in adverse weather conditions (snow, fog, rain).	(Elliott et al., 2019; Hussain & Zeadally, 2019; Lim & Taeihagh, 2018; Fagnant & Kockelman, 2015).
		Intelligent Infrastructure (ITS)	(+) Improved safety and congestion through V2V, V2I, and V2X communications. ITS provides real-time traffic data, collision warnings, and periodic safety information. (-) ITS networks might be hacked into through vehicular communications and wireless networks.	
		Privacy	(-) AVs store personal data in the form of audio and video recordings. (-) Sensitive collected data will be shared with vehicular networks and other external organisations like traffic management, insurance companies, law firms, and commercial services. (?) It remains unknown who would control the collection, collect, storage, and access to data in AV systems.	
		Security	(+) Increased car security through biometric registration. (-) Exposure to cybersecurity threats that can manipulate the speed of AVs, hack into the car's system, and modify maps and sensors to block the reception of necessary information.	
Economy	Impact	Employment	(-) Job losses, especially for drivers. (+) Job opportunities in the research, planning, and software sectors.	(Clements & Kockelman, 2017; Milakis et al., 2017; Fagnant & Kockelman, 2015; Lim & Taeihagh, 2018).
		Businesses	(-) Significant losses for the repair, maintenance, traffic police, and fuel industries. (+) Highly profitable for car manufacturers, software developers, trucking businesses, and AV data operators.	
		Wider Economy	(+) Massive annual savings in the US resulting from improved safety (\$488b), congestion (\$447b), and reclaiming parking spaces (\$45b). (-) Lost productivity from cyberattacks on AVs might amount to \$3 trillion.	

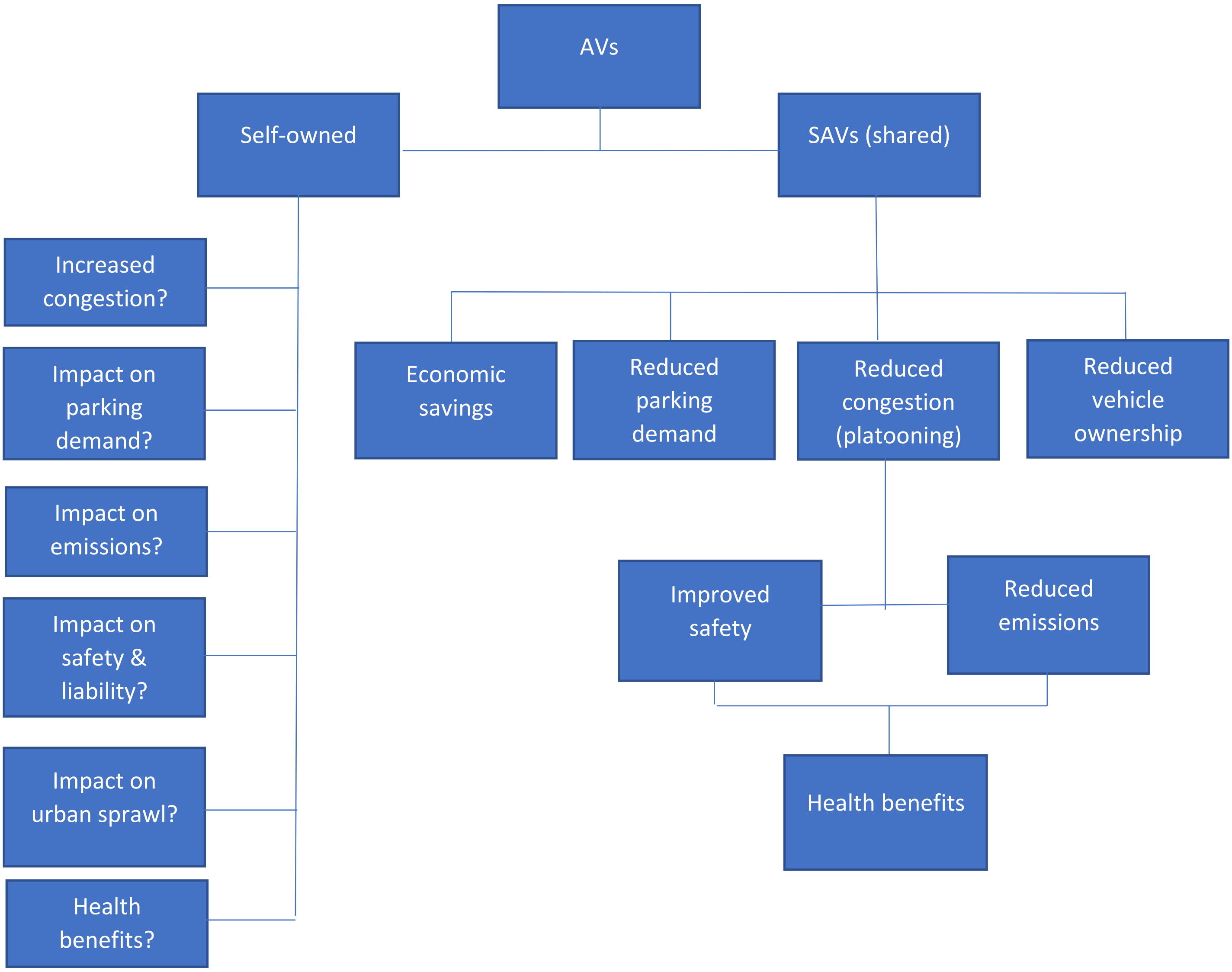
Note: (+), positive impacts; (-), negative impacts; (?), uncertain impacts.

7. Appendices

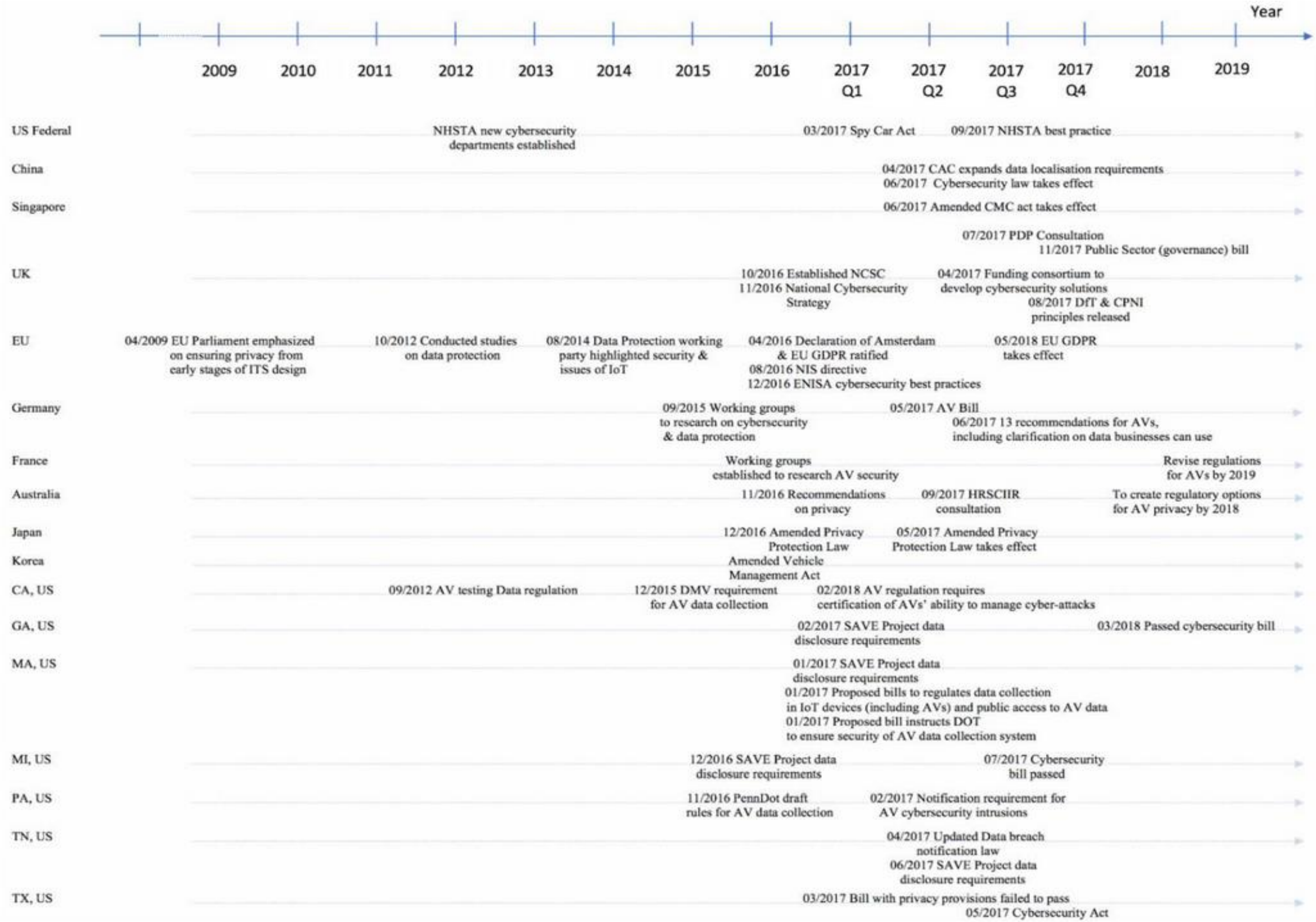
Appendix 1: Summary of AV's ethical issues and the proposed solutions (Source: Lim & Taeihagh, 2019).

	Ethical Issues	Proposed Solutions/Steps Taken
Bias	*Sources of bias in AV algorithms* • Statistical bias and including personal characteristics in the data. • Manufacturers and programmers can program algorithms to favour AV users' safety to boost profits. • Large-scale replication of algorithmic preferences in AVs can perpetuate systemic discrimination. *Challenges of detecting and correcting bias:* • Algorithmic opacity masks decision-making logic. • Data-driven and unpredictable nature of ML-based decisions makes it difficult to predict bias. • Humans are excessively trusting of algorithmic decisions due to "automation bias". • Difficult to prove discriminatory intent in algorithms.	*Proposed solutions* • Modify the data, algorithm and output to offset bias. • Measure and test for data bias, and identify the affected individuals. • Clarify the standards to evaluate bias in algorithms. • Increase transparency via traceability and interpretability. *Steps taken* • AI guidelines that emphasise on fairness, transparency and accountability—Japan, Singapore. • Creating design and testing methods to mitigate bias and discrimination from AI—South Korea, UK. • Prohibiting the use of sensitive personal data in automated decisions and mandating a right to explanation—EU GDPR.
Ethics	*Thought experiments—The Trolley Problem* • Assumptions do not hold in actual driving scenarios. • Participants' ethical reasoning may be inconsistent. • Aggregating single trolley scenarios may create discriminatory patterns. *Top-down approach* *(i) Utilitarianism* • Collective harm minimisation can penalise certain groups of individuals more than others. • Risk of computational errors and issues with mathematically defining algorithmic preferences. *(ii) Deontology* • Rule conflicts, failure to cover all driving scenarios, and path dependencies create safety risks. • Difficult to explicitly program ambiguous rules. *Bottom-up approach* • Difficult to specify a self-learning system's higher level goals and to ensure it expands its set of choices. • The system can override its ethical rules. • The system's decision-making is more opaque.	*Proposed solutions* • Combine utilitarian and deontological ethics in the top-down approach. *Steps taken* • AI guidelines and committees to examine discrimination —Japan, Singapore, China, South Korea. • Ethical rules for AVs—Germany: Promotes utilitarian ethics of damage minimisation but prohibits discrimination based on personal characteristics; Decisions for unavoidable accidents should not be programmed but independently assessed; Standards for self-learning processes should be developed and AVs' programming should be disclosed to the public; Prohibits use of self-learning systems for safety-critical functions unless proven sufficiently reliable.
Perverse incentives	• Manufacturers can design algorithms to favour passenger safety and tailor driving behaviour based on district affluence to reduce liability claims. • Manufacturers' differentiation of algorithms can reduce road coordination and create safety risks. • The incentives of other AV stakeholders in the supply chain can interact systemically and create safety risks.	*Proposed solutions* • Greater data sharing, collaboration and standardisation of algorithms among AV developers to improve coordination of AVs on roads.

Appendix 2: AVs implications when shared vs. self-owned (Source: Author).



Appendix 3: Timeline for privacy and cybersecurity strategies related to AVs (Source: Lim & Taeihagh, 2018).



Reference List

- Abbas, H., O'Kelly, M., Rodionova, A., & Mangharam, R. (2019). Safe at Any Speed: A Simulation-Based Test Harness for Autonomous Vehicles. In *Cyber Physical Systems. Design, Modeling, and Evaluation*. Springer International Publishing.
- Abboud, K., Omar, H. A., & Zhuang, W. (2016). Interworking of DSRC and Cellular Network Technologies for V2X Communications: A Survey. *IEEE Transactions on Vehicular Technology*, *65*(12), 9457–9470. https://doi.org/10.1109/TVT.2016.2591558
- AIFNZ. (2018). *Artificial Intelligence: Shaping a Future New Zealand*. Artificial Intelligence Forum New Zealand. https://www.mbie.govt.nz/dmsdocument/5754-artificial-intelligence-shaping-a-future-new-zealand-pdf
- Alonso Raposo, M., Grosso, M., Després, J., Galassi, C., Krasenbrink, A., Krause, J., Levati, L., Mourtzouchou, A., Ciuffo, B., Thiel, C., Saveyn, B., & Fernández Macías, E (2018). *An analysis of possible socio-economic effects of a Cooperative, Connected and Automated Mobility (CCAM) in Europe effects of automated driving on the economy, employment and skills.* Joint Research Centre. dx.doi.org/10.2760/777
- American Trucking Association. (2018). *Reports, Trends & Statistics*. American Trucking Associations. https://www.trucking.org/News_and_Information_Reports_Industry_Data.aspx
- Amoozadeh, M., Raghuramu, A., Chuah, C., Ghosal, D., Zhang, H. M., Rowe, J., & Levitt, K. (2015). Security vulnerabilities of connected vehicle streams and their impact on cooperative driving. *IEEE Communications Magazine*, *53*(6), 126–132. https://doi.org/10.1109/MCOM.2015.7120028
- Anderson, J. M., Nidhi, K., Stanley, K. D., Sorensen, P., Samaras, C., & Oluwatola, O. A. (2014). *Autonomous Vehicle Technology: A Guide for Policymakers*. Rand Corporation.
- Arinze, B., Ndubizu, G., & Sylla, C. (2016). Forecasting the impact of self-driving vehicles on us employment in the road transportation industry using the technology diffusion model. *Proceedings for the Northeast Region Decision Sciences Institute (NEDSI)*, 1–6.
- Arntz, M., Gregory, T., & Zierahn, U. (2016). *The Risk of Automation for Jobs in OECD Countries*. (189). https://doi.org/10.1787/5jlz9h56dvq7-en
- Auckland Transport. (2016). *Auckland Transport Technology Strategy*. Auckland Transport. https://at.govt.nz/media/1964578/at-digital-strategy.pdf
- Ayele, W. Y., & Akram, I. (2020). Identifying Emerging Trends and Temporal Patterns About Self-driving Cars in Scientific Literature. In *Advances in Computer Vision* (pp. 355–372). Springer International Publishing. https://doi.org/10.1007/978-3-030-17798-0_29

- Banister, D. (2019). The climate crisis and transport. *Transport Reviews*, *39*(5), 565–568. https://doi.org/10.1080/01441647.2019.1637113
- Banks, V. A., Plant, K. L., & Stanton, N. A. (2018). Driver error or designer error: Using the Perceptual Cycle Model to explore the circumstances surrounding the fatal Tesla crash on 7th May 2016. *Safety Science*, *108*, 278–285. https://doi.org/10.1016/j.ssci.2017.12.023
- Bansal, P., Kockelman, K. M., & Singh, A. (2016). Assessing public opinions of and interest in new vehicle technologies: An Austin perspective. *Transportation Research Part C: Emerging Technologies*, *67*, 1–14. https://doi.org/10.1016/j.trc.2016.01.019
- BBC. (2019). *Tesla Autopilot engaged during fatal crash*. BBC News. https://www.bbc.com/news/technology-48308852
- Beede, D. N., Powers, R., & Ingram, C. (2017). *The Employment Impact of Autonomous Vehicles*. U.S. Department of Commerce. https://papers.ssrn.com/abstract=3022818
- Bennett, R., Vijaygopal, R., & Kottasz, R. (2019). Willingness of people with mental health disabilities to travel in driverless vehicles. *Journal of Transport & Health*, *12*, 1–12. https://doi.org/10.1016/j.jth.2018.11.005
- Bimbraw, K. (2015). Autonomous cars: Past, present and future a review of the developments in the last century, the present scenario and the expected future of autonomous vehicle technology. In *12th international conference on informatics in control, automation and robotics (ICINCO)*. IEEE.
- Bischoff, J., Maciejewski, M., Schlenther, T., & Nagel, K. (2019). Autonomous Vehicles and their Impact on Parking Search. *IEEE Intelligent Transportation Systems Magazine*, *11*(4), 19–27. https://doi.org/10.1109/MITS.2018.2876566
- Boesch, P. M., Ciari, F., & Axhausen, K. W. (2016). Autonomous Vehicle Fleet Sizes Required to Serve Different Levels of Demand. *Transportation Research Record*, *2542*(1), 111–119. https://doi.org/10.3141/2542-13
- Bonnefon, J.-F., Shariff, A., & Rahwan, I. (2019). The Trolley, The Bull Bar, and Why Engineers Should Care about the Ethics of Autonomous Cars. *Proceedings of the IEEE*, *107*(3), 502–504. https://doi.org/10.1109/JPROC.2019.2897447
- Booth, L., Norman, R., & Pettigrew, S. (2019). The potential implications of autonomous vehicles for active transport. *Journal of Transport & Health*, *15*, 100623. https://doi.org/10.1016/j.jth.2019.100623
- Brown, A., Gonder, J., & Repac, B. (2014). An Analysis of Possible Energy Impacts of Automated Vehicles. In G. Meyer & S. Beiker (Eds.), *Road Vehicle Automation* (pp. 137–153). https://doi.org/10.1007/978-3-319-05990-7_13
- Budget (2019). *Budget Overview*. Australian Treasury Budget 2019-20. https://budget.gov.au/2019-20/content/overview.htm
- Bureau of Labor Statistics. (2019). *Occupational Employment Statistics. Data tables for the overview of May 2018 occupational employment and wages*. U.S. Bureau of Labor Statistics. https://www.bls.gov/oes/2018/may/featured_data.htm#transportation1

- BusinessNZ (2018). *Unlocking commercial opportunities from intelligent transport systems*. The Intelligent Transport Advisory Group. https://www.transport.govt.nz/assets/Uploads/Our-Work/Documents/608887f8ad/Deloitte-Access-Economics-ITS-Final-Report-24-January-2018.pdf
- Cabinet Office (2016). *National Cybersecurity Strategy 2016–2021*. HM Government United Kingdom. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/567242/national_cyber_security_strategy_2016.pdf
- Carbaugh, J., Godbole, D. N., & Sengupta, R. (1998). Safety and capacity analysis of automated and manual highway systems. *Transportation Research Part C: Emerging Technologies*, *6*(1), 69–99. https://doi.org/10.1016/S0968-090X(98)00009-6
- Chen, F., Balieu, R., & Kringos, N. (2016). Potential Influences on Long-Term Service Performance of Road Infrastructure by Automated Vehicles. *Transportation Research Record: Journal of the Transportation Research Board*, *2550*(1), 72–79. https://doi.org/10.3141/2550-10
- Chen, S., Kuhn, M., Prettner, K., & Bloom, D. E. (2019). The global macroeconomic burden of road injuries: Estimates and projections for 166 countries. *The Lancet Planetary Health*, *3*(9), e390–e398. https://doi.org/10.1016/S2542-5196(19)30170-6
- Chester, M., Fraser, A., Matute, J., Flower, C., & Pendyala, R. (2015). Parking Infrastructure: A Constraint on or Opportunity for Urban Redevelopment? A Study of Los Angeles County Parking Supply and Growth. *Journal of the American Planning Association*, *81*(4), 268–286. https://doi.org/10.1080/01944363.2015.1092879
- Clements, L. M., & Kockelman, K. M. (2017). Economic Effects of Automated Vehicles. *Transportation Research Record: Journal of the Transportation Research Board*, *2606*(1), 106–114. https://doi.org/10.3141/2606-14
- Coca-Vila, I. (2018). Self-Driving Cars in Dilemmatic Situations: An Approach Based on the Theory of Justification in Criminal Law. *Criminal Law and Philosophy*, *12*(1), 59–82. https://doi.org/10.1007/s11572-017-9411-3
- Cohen, T., Stilgoe, J., Stares, S., Akyelken, N., Cavoli, C., Day, J., Dickinson, J., Fors, V., Hopkins, D., Lyons, G., Marres, N., Newman, J., Reardon, L., Sipe, N., Tennant, C., Wadud, Z., & Wigley, E. (2020). A constructive role for social science in the development of automated vehicles. *Transportation Research Interdisciplinary Perspectives*, *6*, 100133. https://doi.org/10.1016/j.trip.2020.100133
- Collingwood, L. (2017). Privacy implications and liability issues of autonomous vehicles. *Information & Communications Technology Law*, *26*(1), 32–45. https://doi.org/10.1080/13600834.2017.1269871
- Costantini, F., Thomopoulos, N., Steibel, F., Curl, A., Lugano, G., & Kováčiková, T. (2020). Chapter Eight - Autonomous vehicles in a GDPR era: An international comparison. In *Advances in Transport Policy and Planning* (pp. 191–213). Academic Press. https://doi.org/10.1016/bs.atpp.2020.02.005

- Curl, A., & Fitt, H. (2019). Will driverless cars be good for us? Now is the time for public health to act together with urban and transport planning. *Journal of Global Health*, *9*(2), 1–3. https://doi.org/10.7189/jogh.09.020303
- Currie, G. (2018). Lies, Damned Lies, AVs, Shared Mobility, and Urban Transit Futures. *Journal of Public Transportation*, *21*(1), 19–30. https://doi.org/10.5038/2375-0901.21.1.3
- Cutean, A. (2018). *Autonomous vehicles and the future of work in Canada*. Information and Communications Technology Council.
- Dahiyat, E. A. R. (2018). From Science Fiction to Reality: How will the law adapt to Self-Driving Vehicles? *Journal of Arts and Humanities*, *7*(9), 34–43. https://doi.org/10.18533/journal.v7i9.1497
- Dalal, N., & Triggs, B. (2005). Histograms of oriented gradients for human detection. *2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, *1*, 886–893. https://doi.org/10.1109/CVPR.2005.177
- Daly, A. (2017). Privacy in automation: An appraisal of the emerging Australian approach. *Computer Law & Security Review*, *33*(6), 836–846. https://doi.org/10.1016/j.clsr.2017.05.009
- Deming, D., & Kahn, L. B. (2018). Skill Requirements across Firms and Labor Markets: Evidence from Job Postings for Professionals. *Journal of Labor Economics*, *36*(S1), S337–S369. https://doi.org/10.1086/694106
- Desouza, K. C., Swindell, D., Smith, K. L., Sutherland, A., Fedorschak, K., & Coronel, C. (2015). *Local government 2035: Strategic trends and implications of new technologies*. The Brookings Institution.
- DfT. (2015). *The pathway to driverless cars: A code of practice for testing.* Department for Transport https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/446316/pathway-driverless-cars.pdf
- DfT. (2017a). The key principles of vehicle cyber security for connected and automated vehicles. Department for Transport. https://www.gov.uk/government/publications/principles-of-cyber-security-for-connected-and-automated-vehicles/the-key-principles-of-vehicle-cyber-security-for-connected-and-automated-vehicles
- Dickmanns, E. (2015). *Robotics History: Narratives and Networks Oral Histories: Ernst Dickmanns*. IEEE.tv
- Dixit, V., Xiong, Z., Jian, S., & Saxena, N. (2019). Risk of automated driving: Implications on safety acceptability and productivity. *Accident Analysis & Prevention*, *125*, 257–266. https://doi.org/10.1016/j.aap.2019.02.005
- Dolowitz, D. P., & Marsh, D. (2000). Learning from Abroad: The Role of Policy Transfer in Contemporary Policy-Making. *Governance*, *13*(1), 5–23. https://doi.org/10.1111/0952-1895.00121
- Dresner, K., & Stone, P. (2008). A Multiagent Approach to Autonomous Intersection Management. *Journal of Artificial Intelligence Research*, *31*, 591–656. https://doi.org/10.1613/jair.2502

- Duncan, T., Scott, D. G., & Baum, T. (2013). The mobilities of hospitality work: an exploration of issues and debates. *Annals of Tourism Research*, *41*, 1–19. https://doi.org/10.1016/j.annals.2012.10.004
- Eben, M. (2018). Fining Google: A missed opportunity for legal certainty? *European Competition Journal*, *14*(1), 129–151. https://doi.org/10.1080/17441056.2018.1460973
- EC. (2017). *The Directive on Security of Network and Information Systems (NIS Directive).* European Commission. https://ec.europa.eu/digital-single-market/en/network-and-information-security-nis-directive
- Elbert, R., Friedrich, C., Pfohl, H.-C., & Boltze, M. (2019). *Urban Freight Transportation Systems*. Elsevier.
- Elliott, D., Keen, W., & Miao, L. (2019). Recent advances in connected and automated vehicles. *Journal of Traffic and Transportation Engineering*, *6*(2), 109–131. https://doi.org/10.1016/j.jtte.2018.09.005
- ENISA. (2017). *Cybersecurity and Resilience of Smart Cars*. European Union Agency for Cybersecurity.
- EP. (2009). *The Intelligent Transport Systems Action Plan*. European Parliament. http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P6-TA-2009-0308+0+DOC+XML+V0//EN
- Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice*, *77*, 167–181. https://doi.org/10.1016/j.tra.2015.04.003
- Fagnant, D. J., & Kockelman, K. M. (2014). The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. *Transportation Research Part C: Emerging Technologies*, *40*, 1–13. https://doi.org/10.1016/j.trc.2013.12.001
- Fagnant, D. J., & Kockelman, K. M. (2016). Dynamic ride-sharing and fleet sizing for a system of shared autonomous vehicles in Austin, Texas. *Transportation*, *45*(1), 143–158. https://doi.org/10.1007/s11116-016-9729-z
- Faisal, A., Yigitcanlar, T., Kamruzzaman, M., & Currie, G. (2019). Understanding autonomous vehicles: A systematic literature review on capability, impact, planning and policy. *Journal of Transport and Land Use*, *12*(1). https://doi.org/10.5198/jtlu.2019.1405
- Fang, J., Xu, R., Yang, Y., et al., 2017. Introduction and simulation of dedicated short-range communication. In: 2017 IEEE 5th International Symposium on Electromagnetic Compatibility, Beijing, 2017. https://ieeexplore.ieee.org/abstract/document/8260392
- Favarò, F. M., Nader, N., Eurich, S. O., Tripp, M., & Varadaraju, N. (2017). Examining accident reports involving autonomous vehicles in California. *PLOS ONE*, *12*(9), e0184952. https://doi.org/10.1371/journal.pone.0184952
- Fernandes, P., & Nunes, U. (2015). Multiplatooning Leaders Positioning and Cooperative Behavior Algorithms of Communicant Automated Vehicles for High

Traffic Capacity. *IEEE Transactions on Intelligent Transportation Systems*, *16*(3), 1172–1187. https://doi.org/10.1109/TITS.2014.2352858

- Fitt, H. (2017). Do social meanings matter? How and how much social meanings influence everyday transport practices? *New Zealand Geographer*, *73*(3), 181–191. https://doi.org/10.1111/nzg.12158
- Fitt, H. (2018). Habitus and the loser cruiser: How low status deters bus use in a geographically limited field. *Journal of Transport Geography*, *70*, 228–233. https://doi.org/10.1016/j.jtrangeo.2018.06.011
- Fitt, H., Curl, A., Dionisio-McHugh, R., Fletcher, A., Frame, B., & Ahuriri-Driscoll, A. (2018). *Think Piece: Autonomous vehicles and future urban environments: Exploring implications for wellbeing in an ageing society*. University of Canterbury https://ir.canterbury.ac.nz/handle/10092/15403
- Fleetwood, J. (2017). Public Health, Ethics, and Autonomous Vehicles. *American Journal of Public Health*, *107*(4), 532–537. https://doi.org/10.2105/AJPH.2016.303628
- Foot, P. (1967). *The Problem of Abortion and the Doctrine of the Double Effect*. Oxford Review. https://doi.org/10.1093/0199252866.001.0001
- Franke, U., Gorzig, S., Lindner, F., Mehren, D., & Paetzold, F. (1997). Steps towards an intelligent vision system for driver assistance in urban traffic. *Proceedings of Conference on Intelligent Transportation Systems*, 601–606. https://doi.org/10.1109/ITSC.1997.660542
- Frey, C. B., & Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting and Social Change*, *114*, 254–280. https://doi.org/10.1016/j.techfore.2016.08.019
- García, O. S. S. (2020). *Forecast: Industry revenue of "repair and maintenance" in the U.S. 2012-2024*. Statista. https://www.statista.com/forecasts/884972/repair-and-maintenance-revenue-in-the-us
- Geddes, N. B. (1940). *Magic Motorways*. New York: Random House.
- Gerdes, R. M., Winstead, C., & Heaslip, K. (2013). CPS: An Efficiency-motivated Attack against Autonomous Vehicular Transportation. *Proceedings of the 29th Annual Computer Security Applications Conference*, 99–108. https://doi.org/10.1145/2523649.2523658
- Goetz, A. R. (2019). Transport challenges in rapidly growing cities: Is there a magic bullet? *Transport Reviews*, *39*(6), 701–705. https://doi.org/10.1080/01441647.2019.1654201
- Gong, K., Zhang, L., Ni, D., Li, H., Xu, M., Wang, Y., & Dong, Y. (2020). An expert system to discover key congestion points for urban traffic. *Expert Systems with Applications*, *158*, 113544. https://doi.org/10.1016/j.eswa.2020.113544
- Gong, K., Zhang, L., Ni, D., Li, H., Xu, M., Wang, Y., & Dong, Y. (2020). An expert system to discover key congestion points for urban traffic. *Expert Systems with Applications*, *158*, 113544. https://doi.org/10.1016/j.eswa.2020.113544
- Graham-Rowe, E., Gardner, B., Abraham, C., Skippon, S., Dittmar, H., Hutchins, R., & Stannard, J. (2012). Mainstream consumers driving plug-in battery-electric

and plug-in hybrid electric cars: A qualitative analysis of responses and evaluations. *Transportation Research Part A: Policy and Practice*, *46*(1), 140–153.

- Griggs, T., & Wakabayashi, D. (2018). *How a Self-Driving Uber Killed a Pedestrian in Arizona.* The New York Times.
- Grumert, E., & Tapani, A. (2012). Impacts of a Cooperative Variable Speed Limit System. *Procedia - Social and Behavioral Sciences*, *43*, 595–606. https://doi.org/10.1016/j.sbspro.2012.04.133
- Grumert, E., & Tapani, A. (2012). Impacts of a Cooperative Variable Speed Limit System. *Procedia - Social and Behavioral Sciences*, *43*, 595–606. https://doi.org/10.1016/j.sbspro.2012.04.133
- Guerra, E. (2016). Planning for cars that drive themselves: Metropolitan planning organizations, regional transportation plans, and autonomous vehicles. *Journal of Planning Education and Research*, *36*(2), 210-224. https://doi.org/10.1177/0739456X15613591
- Guzman, L. A., Arellana, J., & Alvarez, V. (2020). Confronting congestion in urban areas: Developing Sustainable Mobility Plans for public and private organizations in Bogotá. *Transportation Research Part A: Policy and Practice*, *134*, 321–335. https://doi.org/10.1016/j.tra.2020.02.019
- Haboucha, C. J., Ishaq, R., & Shiftan, Y. (2017). User preferences regarding autonomous vehicles. *Transportation Research Part C: Emerging Technologies*, *78*, 37–49. https://doi.org/10.1016/j.trc.2017.01.010
- Haratsis, B., Carmichael, T., Courtney, M., & Fong, J. (2018). *Autonomous vehicles employment impact study*. Australia and New Zealand Driverless Vehicle Initiative. http://cdn-advi.s3.amazonaws.com/wp-content/uploads/2018/09/Autonomous-Vehicles-Employment-Impact-Survey-COR050918-5.pdf
- Hasan, M. A., Frame, D. J., Chapman, R., & Archie, K. M. (2019). Emissions from the road transport sector of New Zealand: Key drivers and challenges. *Environmental Science and Pollution Research*, *26*(23), 23937–23957. https://doi.org/10.1007/s11356-019-05734-6
- Hasan, S. F., Siddique, N. H. and Chakraborty, S. (2018) *Intelligent transportation systems: 802.11-based vehicular communications*. Second edition. Springer.
- House of Lords (2017). *Connected and Autonomous Vehicles: The future?* Science and Technology Select Committee.
- Hussain, R., & Zeadally, S. (2019). Autonomous Cars: Research Results, Issues, and Future Challenges. *IEEE Communications Surveys & Tutorials*, *21*(2), 1275–1313. https://doi.org/10.1109/COMST.2018.2869360
- IEEE. (2019). AI Engineers: The autonomous-vehicle industry wants you: Cruise's AI chief, Hussein Mehanna, talks jobs, careers, and self-driving cars. *IEEE Spectrum*, *56*(09), 4. https://doi.org/10.1109/MSPEC.2019.8818574
- Illing, W. (1930). *Utopolis: Roman*. Der Bücherkreis, Berlin.
- ITSAG (2018). *Unlocking commercial opportunities from intelligent transport systems.* The Intelligent Transport Systems Advisory Group. https://www.transport.govt.nz/assets/Uploads/Our-

Work/Documents/608887f8ad/Deloitte-Access-Economics-ITS-Final-Report-24-January-2018.pdf

- Jensen, J. B. (2018). Self-Driving but Not Self-Regulating: The Development of a Legal Framework to Promote the Safety of Autonomous Vehicles. *Washburn Law Journal*, *57*(3).
- Jonas, A., Byrd, S. C., Shankar, R., & Ono, M. (2014*). Nikola's Revenge: TESLA's New Path of Disruption.* Morgan Stanle.
- Jones, E. C., & Leibowicz, B. D. (2019). Contributions of shared autonomous vehicles to climate change mitigation. *Transportation Research Part D: Transport and Environment*, *72*, 279–298. https://doi.org/10.1016/j.trd.2019.05.005
- Kalra, N. (2017). *Challenges and Approaches to Realizing Autonomous Vehicle Safety*. RAND Corporation. https://doi.org/10.7249/CT463
- Kalra, N., & Paddock, S. M. (2016). Driving to safety: How many miles of driving would it take to demonstrate autonomous vehicle reliability? *Transportation Research Part A: Policy and Practice*, *94*, 182–193. https://doi.org/10.1016/j.tra.2016.09.010
- Kane, M., & Whitehead, J. (2017). How to ride transport disruption –a sustainable framework for future urban mobility. *Australian Planner*, *54*(3), 177–185. https://doi.org/10.1080/07293682.2018.1424002
- Katrakazas, C., Theofilatos, A., Papastefanatos, G., Härri, J., & Antoniou, C. (2020). Chapter Three—Cyber security and its impact on CAV safety: Overview, policy needs and challenges. In *Advances in Transport Policy and Planning* (Vol. 5, pp. 73–94). Academic Press. https://doi.org/10.1016/bs.atpp.2020.05.001
- Kencebay, B. (2019). User acceptance of driverless vehicles and robots with aspect of personal economy. *Journal of Transnational Management*, *24*(4), 283–304. https://doi.org/10.1080/15475778.2019.1664234
- Ketzel, M., Omstedt, G., Johansson, C., Düring, I., Pohjola, M., Oettl, D., Gidhagen, L., Wåhlin, P., Lohmeyer, A., Haakana, M., & Berkowicz, R. (2007). Estimation and validation of PM2.5/PM10 exhaust and non-exhaust emission factors for practical street pollution modelling. *Atmospheric Environment*, *41*(40), 9370–9385. https://doi.org/10.1016/j.atmosenv.2007.09.005
- Khondaker, B., & Kattan, L. (2015). Variable speed limit: A microscopic analysis in a connected vehicle environment. *Transportation Research Part C: Emerging Technologies*, *58*, 146–159. https://doi.org/10.1016/j.trc.2015.07.014
- Kröger, F. (2016). Automated driving in its social, historical and cultural contexts. In *Autonomous Driving*. Springer, Berlin, Heidelberg.
- Larsen, R., Rich, J., & Rasmussen, T. K. (2019). Hub-based truck platooning: Potentials and profitability. *Transportation Research Part E: Logistics and Transportation Review*, *127*, 249–264. https://doi.org/10.1016/j.tre.2019.05.005
- Lavieri, P. S., & Bhat, C. R. (2019). Modeling individuals' willingness to share trips with strangers in an autonomous vehicle future. *Transportation Research Part A: Policy and Practice*, *124*, 242–261. https://doi.org/10.1016/j.tra.2019.03.009

- Lee, C., & Coughlin, J. F. (2015). PERSPECTIVE: Older Adults' Adoption of Technology: An Integrated Approach to Identifying Determinants and Barriers. *Journal of Product Innovation Management*, *32*(5), 747–759. https://doi.org/10.1111/jpim.12176
- Legacy, C., Ashmore, D., Scheurer, J., Stone, J., & Curtis, C. (2019). Planning the driverless city. *Transport Reviews*, *39*(1), 84–102. https://doi.org/10.1080/01441647.2018.1466835
- Levin, S., & Wong, J. C. (2018). Self-driving Uber kills Arizona woman in first fatal crash involving pedestrian. *The Guardian*.
- Li, S., Sui, P.-C., Xiao, J., & Chahine, R. (2019). Policy formulation for highly automated vehicles: Emerging importance, research frontiers and insights. *Transportation Research Part A: Policy and Practice*, *124*, 573–586. https://doi.org/10.1016/j.tra.2018.05.010
- Liebner, M., Klanner, F., Baumann, M., Ruhhammer, C., & Stiller, C. (2013). Velocity-Based Driver Intent Inference at Urban Intersections in the Presence of Preceding Vehicles. *IEEE Intelligent Transportation Systems Magazine*, *5*(2), 10–21. https://doi.org/10.1109/MITS.2013.2246291
- Lim, H. S. M., & Taeihagh, A. (2018). Autonomous Vehicles for Smart and Sustainable Cities: An In-Depth Exploration of Privacy and Cybersecurity Implications. *Energies*, *11*(5), 1062. https://doi.org/10.3390/en11051062
- Lim, H. S. M., & Taeihagh, A. (2019). Algorithmic Decision-Making in AVs: Understanding Ethical and Technical Concerns for Smart Cities. *Sustainability*, *11*(20), 5791. https://doi.org/10.3390/su11205791
- Lin, C.-F., Juang, J.-C., & Li, K.-R. (2014). Active collision avoidance system for steering control of autonomous vehicles. *IET Intelligent Transport Systems*, *8*(6), 550–557. https://doi.org/10.1049/iet-its.2013.0056
- Lindberg, G., & Fridstrøm, L. (2015). *Policy strategies for vehicle electrification* (p. 47). Retrieved from International Transport Forum website: https://www.itf-oecd.org/sites/default/files/docs/dp201516.pdf
- Linkov, V., Zámečník, P., Havlíčková, D., & Pai, C.-W. (2019). Human Factors in the Cybersecurity of Autonomous Vehicles: Trends in Current Research. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.00995
- Litman, T. (2020). *Autonomous Vehicle Implementation Predictions: Implications for Transport Planning*. Victoria Transport Policy Institute.
- Liu, F., Zhao, F., Liu, Z., & Hao, H. (2019). Can autonomous vehicle reduce greenhouse gas emissions? A country-level evaluation. *Energy Policy*, *132*, 462–473. https://doi.org/10.1016/j.enpol.2019.06.013
- Luo, Y., Xiang, Y., Cao, K., & Li, K. (2016). A dynamic automated lane change maneuver based on vehicle-to-vehicle communication. *Transportation Research Part C: Emerging Technologies*, *62*, 87–102. https://doi.org/10.1016/j.trc.2015.11.011
- Macfarlane, J. (2019). When apps rule the road: The proliferation of navigation apps is causing traffic chaos. It's time to restore order. *IEEE Spectrum*, *56*(10), 22–27.

- Maciejewski, M., & Bischoff, J. (2018). Congestion effects of autonomous taxi fleets. *Transport*, *33*(4), 971-980. https://doi.org/10.3846/16484142.2017.1347827
- Makarova, I., Shubenkova, K., Mukhametdinov, E., & Pashkevich, A. (2018). Safety related problems of transport system and their solutions. *2018 XI International Science-Technical Conference Automotive Safety*, 1–9. https://doi.org/10.1109/AUTOSAFE.2018.8373333
- Masaki, I. (1992). *Vision-based Vehicle Guidance*. Springer-Verlag.
- MBIE. (2020). *Occupation Outlook: Drivers*. Ministry of Business Innovation and Employment. https://occupationoutlook.mbie.govt.nz/service-industries/drivers/
- Milakis, D. (2019). Long-term implications of automated vehicles: An introduction. *Transport Reviews*, *39*(1), 1–8. https://doi.org/10.1080/01441647.2019.1545286
- Milakis, D., Arem, B. van, & Wee, B. van. (2017). Policy and society related implications of automated driving: A review of literature and directions for future research. *Journal of Intelligent Transportation Systems*, *21*(4), 324–348. https://doi.org/10.1080/15472450.2017.1291351
- Milakis, D., Thomopoulos, N., & Wee, B. van (2020). Policy Implications of Autonomous Vehicles. In *Advances in Transport Policy and Planning*. Academic Press. https://doi.org/10.1016/bs.atpp.2020.06.001
- Ministry of Transport. (2019a). *Current Regulatory Settings for Autonomous Vehicles. M*inistry of Transport. https://www.transport.govt.nz/multi-modal/technology/specific-transport-technologies/road-vehicle/autonomous-vehicles/regulatory-settings-for-autonomous-vehicles/
- Ministry of Transport. (2019b). *Autonomous including driverless vehicles.* Ministry of Transport. https://www.transport.govt.nz/multi-modal/technology/specific-transport-technologies/road-vehicle/autonomous-vehicles/
- Ministry of Transport. (2019c). *Overview of Ministry's AV Work Programme.* Ministry of Transport. https://www.transport.govt.nz/assets/Import/Uploads/Land/Documents/OC191125-Overview-of-Ministrys-work-on-Autonomous-Vehicles-Work-Programme.-signed-by-Minister-Twyford.-For-Release.pdf
- Ministry of Transport. (2020a). *Road deaths.* Ministry of Transport.https://www.transport.govt.nz/mot-resources/road-safety-resources/road-deaths/
- Ministry of Transport. (2020b). *Social cost of road crashes and injuries - June 2019 update.* Ministry of Transport. https://www.transport.govt.nz/assets/Import/Uploads/Research/Documents/SocialCostof-RoadCrashesandInjuries2019.pdf
- Mohl, R. A. (2004). Stop the Road: Freeway Revolts in American Cities. *Journal of Urban History*, *30*(5), 674–706. https://doi.org/10.1177/0096144204265180
- Monteil, J., Nantes, A., Billot, R., Sau, J., & Faouzi, N. E. (2014). Microscopic cooperative traffic flow: Calibration and simulation based on a next generation

simulation dataset. *IET Intelligent Transport Systems*, *8*(6), 519–525. https://doi.org/10.1049/iet-its.2013.0035

- Moody, J., Bailey, N., & Zhao, J. (2020). Public perceptions of autonomous vehicle safety: An international comparison. *Safety Science*, *121*, 634–650. https://doi.org/10.1016/j.ssci.2019.07.022
- Morando, M. M., Tian, Q., Truong, L. T., & Vu, H. L. (2018). Studying the Safety Impact of Autonomous Vehicles Using Simulation-Based Surrogate Safety Measures. *Journal of Advanced Transportation, vol. 2018*. https://doi.org/10.1155/2018/6135183
- MVMA (2016). *Motor vehicle management Act*. Statutes of the Republic of Korea. http://elaw.klri.re.kr/eng_service/lawView.do?hseq=35841&lang=ENG
- Naranjo, J. E., Jiménez, F., Anaya, J. J., Talavera, E., & Gómez, O. (2017). Application of vehicle to another entity (V2X) communications for motorcycle crash avoidance. *Journal of Intelligent Transportation Systems*, *21*(4), 285–295. https://doi.org/10.1080/15472450.2016.1247703
- New Zealand Parliament (2019). *Privacy Bill 2018: Bills Digest 2588.* New Zealand Parliament. https://www.parliament.nz/en/pb/bills-and-laws/bills-digests/document/52PLLaw25881/privacy-bill-2018-bills-digest-2588
- NHTSA (2013). *Preliminary Statement of Policy Concerning Automated Vehicles*. National Highway Traffic Safety Administration. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=10&ved=2ahUKEwjYmaDl-_zkAhXPbSsKHVXNB6MQFjAJegQIBBAC&url=https%3A%2F%2Fwww.nhtsa.gov%2Fstaticfiles%2Frulemaking%2Fpdf%2FAutomated_Vehicles_Policy.pdf&usg=AOvVaw1kzgMhDIOOc-olHnCFb4os
- NHTSA. (2017). *Automated driving systems 2.0 a vision for safety.* National Highway Traffic Safety Administration.
- NHTSA. (2017). *Traffic Safety Facts 2017. A Compilation of Motor Vehicle Crash Data.* (p. 216). U.S. Department of Transportation. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812806
- NHTSA. (2018). *NHTSA and vehicle cybersecurity*. National Highway Traffic Safety Administration.
- Nikitas, A., Kougias, I., Alyavina, E., & Njoya Tchouamou, E. (2017). How Can Autonomous and Connected Vehicles, Electromobility, BRT, Hyperloop, Shared Use Mobility and Mobility-As-A-Service Shape Transport Futures for the Context of Smart Cities? *Urban Science*, *1*(4), 36. https://doi.org/10.3390/urbansci1040036
- Nourinejad, M., Bahrami, S., & Roorda, M. J. (2018). Designing Parking Facilities for Autonomous Vehicles. *Transportation Research Part B: Methodological*, *109*, 110–127. https://doi.org/10.1016/j.trb.2017.12.017
- NZIER. (2017). *Benefits from Auckland road decongestion*. New Zealand Institute of Economic Research. https://nzier.org.nz/static/media/filer_public/6f/df/6fdfdada-923e-4199-8da9-cc940ae25bc1/nzier_report_on_auckland_benefits_of_decongestion.pdf

- Papadoulis, A., Quddus, M., & Imprialou, M. (2019). Evaluating the safety impact of connected and autonomous vehicles on motorways. *Accident Analysis & Prevention*, *124*, 12–22. https://doi.org/10.1016/j.aap.2018.12.019
- Park, E. S., Carlson, P. J., Porter, R. J., & Andersen, C. K. (2012). Safety effects of wider edge lines on rural, two-lane highways. *Accident Analysis & Prevention*, *48*, 317–325. https://doi.org/10.1016/j.aap.2012.01.028
- Parkinson, S., Ward, P., Wilson, K., & Miller, J. (2017). Cyber Threats Facing Autonomous and Connected Vehicles: Future Challenges. *IEEE Transactions on Intelligent Transportation Systems*, *18*(11), 2898–2915. https://doi.org/10.1109/TITS.2017.2665968
- Petit, J., & Shladover, S. E. (2015). Potential Cyberattacks on Automated Vehicles. IEEE Transactions on Intelligent Transportation Systems, 16(2), 546–556. https://doi.org/10.1109/TITS.2014.2342271
- Pettigrew, S., Cronin, S. L., & Norman, R. (2019). Brief Report: The Unrealized Potential of Autonomous Vehicles for an Aging Population. *Journal of Aging & Social Policy*, *31*(5), 486–496. https://doi.org/10.1080/08959420.2018.1500860
- Piao, J., McDonald, M., Hounsell, N., Graindorge, M., Graindorge, T., & Malhene, N. (2016). Public Views towards Implementation of Automated Vehicles in Urban Areas. *Transportation Research Procedia*, *14*, 2168–2177. https://doi.org/10.1016/j.trpro.2016.05.232
- Pickering, J. E., Podsiadly, M., & Burnham, K. J. (2019). A Model-to-Decision Approach for the Autonomous Vehicle (AV) Ethical Dilemma: AV Collision with a Barrier/Pedestrian(s). *IFAC-PapersOnLine*, *52*(8), 257–264. https://doi.org/10.1016/j.ifacol.2019.08.080
- Pinto, C. (2012). How Autonomous Vehicle Policy in California and Nevada Addresses Technological and Non-Technological Liabilities. *Intersect: The Stanford Journal of Science, Technology, and Society*, *5*. https://ojs.stanford.edu/ojs/index.php/intersect/article/view/361
- Porter, L., Stone, J., Legacy, C., Curtis, C., Harris, J., Fishman, E., Kent, J., Marsden, G., Reardon, L., & Stilgoe, J. (2018). The Autonomous Vehicle Revolution: Implications for Planning/The Driverless City?/Autonomous Vehicles – A Planner's Response/Autonomous Vehicles: Opportunities, Challenges and the Need for Government Action/Three Signs Autonomous Vehicles Will Not Lead to Less Car Ownership and Less Car Use in Car Dependent Cities – A Case Study of Sydney, Australia/Planning for Autonomous Vehicles? Questions of Purpose, Place and Pace/Ensuring Good Governance: The Role of Planners in the Development of Autonomous Vehicles/Putting Technology in its Place. *Planning Theory & Practice*, *19*(5), 753–778. https://doi.org/10.1080/14649357.2018.1537599
- Riggs, W. (2019). *Disruptive transport: Driverless cars, transport innovation and the sustainable city of tomorrow.* Routledge.

- Ross, C., & Guhathakurta, S. (2017). Autonomous Vehicles and Energy Impacts: A Scenario Analysis. *Energy Procedia*, *143*, 47–52. https://doi.org/10.1016/j.egypro.2017.12.646
- SAE (2018). *Levels of Driving Automation Standard for Self-Driving Vehicles*. SAE International. https://www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-%E2%80%9Clevels-of-driving-automation%E2%80%9D-standard-for-self-driving-vehicles
- Salmon, K. (2019). *Jobs, robots & us: Why the future of work in New Zealand is in our hands.* Bridget Williams Books.
- SCA. (2017). Spy Car Act of 2017. *United States Congress*. https://www.congress.gov/bill/115th-congress/senate-bill/680 [Google Scholar]
- Schindler, J., Dariani, R., Rondinone, M., & Walter, T. (2018). *Dynamic and Flexible Platooning in Urban Areas*. AAET. https://elib.dlr.de/119655/1/AAET_2018_UrbanPlatooning.pdf
- Schoettle, B., & Sivak, M. (2014). *Public Opinion about Self-Driving Vehicles in China, India, Japan, The U.S., The U.K. and Australia.* Michigan: Transportation Research Institute.
- Schoettle, B., & Sivak, M. (2015). A preliminary analysis of real-world crashes involving self-driving vehicles. *University of Michigan Transportation Research Institute*.
- Schoonmaker, J. (2016). Proactive privacy for a driverless age. *Information & Communications Technology Law*, *25*(2), 96–128. https://doi.org/10.1080/13600834.2016.1184456
- Sener, I. N., Zmud, J., & Williams, T. (2019). Measures of baseline intent to use automated vehicles: A case study of Texas cities. *Transportation Research Part F: Traffic Psychology and Behaviour*, *62*, 66–77. https://doi.org/10.1016/j.trf.2018.12.014
- SFCTA. (2017). *TNC's Today - A Profile of San Francisco Transportation Network Company Activity*. Draft Report. San Francisco, CA: San Francisco County Transportation Authority. https://www.sfcta.org/sites/default/files/2019-02/TNCs_Today_112917_0.pdf
- Shammut, M., Cao, M., Zhang, Y., Papaix, C., Liu, Y., & Gao, X. (2019). Banning Diesel Vehicles in London: Is 2040 Too Late? *Energies*, *12*(18), 3495. https://doi.org/10.3390/en12183495
- Shladover, S. E., Su, D., & Lu, X.-Y. (2012). Impacts of Cooperative Adaptive Cruise Control on Freeway Traffic Flow. *Transportation Research Record*, *2324*(1), 63–70. https://doi.org/10.3141/2324-08
- Siegel, G. (2005). *Technologies of Accident. Forensic Media, Crash Analysis and the Redefinition of Progress* [PhD Dissertation]. University of North Carolina, Chapel Hill.
- Somashekar, P. (2020). *The potential impact of Autonomous vehicles on the labor market in The Netherlands*. Delft University of Technology. http://resolver.tudelft.nl/uuid:ea395903-161a-4bd0-b93b-8dee7f202945

- StatsNZ. (2019). *National accounts (income and expenditure).* Stats NZ. https://www.stats.govt.nz/information-releases/national-accounts-income-and-expenditure-year-ended-march-2019
- Stephens, T. S., Gonder, J., Chen, Y., Lin, Z., Liu, C., & Gohlke, D. (2016). *Estimated Bounds and Important Factors for Fuel Use and Consumer Costs of Connected and Automated Vehicles.* National Renewable Energy Laboratory (NREL). https://doi.org/10.2172/1334242
- Taeihagh, A., & Lim, H. S. M. (2019). Governing autonomous vehicles: Emerging responses for safety, liability, privacy, cybersecurity, and industry risks. *Transport Reviews*, *39*(1), 103–128. https://doi.org/10.1080/01441647.2018.1494640
- Transportation and Public Works (1991). *Intelligent Vehicle-Highway Systems Act of 1991 of the Intermodal Surface Transportation Efficiency Act.* Congress. https://www.congress.gov/bill/102nd-congress/house-bill/2950
- Valverde, M. (2009). Laws of the Street. *City & Society*, *21*(2), 163–181. https://doi.org/10.1111/j.1548-744X.2009.01020.x
- Wadud, Z., MacKenzie, D., & Leiby, P. (2016). Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles. *Transportation Research Part A: Policy and Practice*, *86*, 1–18. https://doi.org/10.1016/j.tra.2015.12.001
- Wang, M., Daamen, W., Hoogendoorn, S., & Arem, B. V. (2014). Potential impacts of ecological adaptive cruise control systems on traffic and environment. *IET Intelligent Transport Systems*, *8*(2), 77–86. https://doi.org/10.1049/iet-its.2012.0069
- Wang, Z., Chen, X. M., Ouyang, Y., & Li, M. (2015). Emission Mitigation via Longitudinal Control of Intelligent Vehicles in a Congested Platoon. *Computer-Aided Civil and Infrastructure Engineering*, *30*(6), 490–506. https://doi.org/10.1111/mice.12130
- Wenger (2005). Automotive radar-status and perspectives. In *Compound Semiconductor Integrated Circuit Symposium.* IEEE. https://ieeexplore.ieee.org/document/1531741
- Wetmore, J. (2003). Driving the dream. The history and motivations behind 60 years of automated highway systems in America. *Automotive History Review*, *7*, 4–19.
- Wetmore, J. (2019). *Revisiting the Dream of Automated Vehicles. Visions of Hands-Free Driving over the past 80 years*. Unpublished Manuscript.
- World Health Organization. (2018). *Road traffic injuries.* https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries
- Xie, Y., Zhang, H., Gartner, N. H., & Arsava, T. (2017). Collaborative merging strategy for freeway ramp operations in a connected and autonomous vehicles environment. *Journal of Intelligent Transportation Systems*, *21*(2), 136–147. https://doi.org/10.1080/15472450.2016.1248288
- Yigitcanlar, T., Kamruzzaman, Md., Foth, M., Sabatini-Marques, J., da Costa, E., & Ioppolo, G. (2019). Can cities become smart without being sustainable? A systematic review of the literature. *Sustainable Cities and Society*, *45*, 348–365. https://doi.org/10.1016/j.scs.2018.11.033

- Zakharenko, R. (2016). Self-driving cars will change cities. *Regional Science and Urban Economics*, *61*, 26–37. https://doi.org/10.1016/j.regsciurbeco.2016.09.003
- Zhang, C., Yang, F., Ke, X., Liu, Z., & Yuan, C. (2019). Predictive modeling of energy consumption and greenhouse gas emissions from autonomous electric vehicle operations. *Applied Energy*, *254*, 113597. https://doi.org/10.1016/j.apenergy.2019.113597
- Zhang, W., & Wang, K. (2020). Parking futures: Shared automated vehicles and parking demand reduction trajectories in Atlanta. *Land Use Policy*, *91*, 103963. https://doi.org/10.1016/j.landusepol.2019.04.024
- Zhou, M., Qu, X., & Jin, S. (2017). On the Impact of Cooperative Autonomous Vehicles in Improving Freeway Merging: A Modified Intelligent Driver Model-Based Approach. *IEEE Transactions on Intelligent Transportation Systems*, *18*(6), 1422–1428. https://doi.org/10.1109/TITS.2016.2606492
- Zmud, J., Sener, I. N., & Wagner, J. (2016). Self-Driving Vehicles: Determinants of Adoption and Conditions of Usage. *Transportation Research Record*, *2565*(1), 57–64. https://doi.org/10.3141/2565-07

Reference for Cover Page Photo

- O'Flaherty, D. (2018). *AI in Action: Autonomous Vehicles*. HPC Wire. https://www.hpcwire.com/solution_content/ibm/auto-aero-defence/ai-in-action-autonomous-vehicles/