Autonomous Vehicles - Do We Really Know The Risks?

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1 Introduction

Most traditional car manufacturers, many start up companies and large information technology companies are currently heavily investing in the development of autonomous vehicles, or AVs for short. Some companies already have products in the market. For example, Tesla, who is selling their cars with what they call "Autopilot". Other manufacturers offer driving assist features, such as adaptive cruise control and lane following. General Motors, like many other traditional car manufacturers, are dramatically increasing their spending on the development of AVs (Wayland, 2021). Others, such as Apple, are still focusing on their development. AVs are large and potentially dangerous robots that exhibit autonomous behaviour. While many social robots and conversational agents rarely pose a threat to our physical well-being, several crashes of AVs have demonstrated the destructive potential of these robots not only for the drivers, but also for pedestrians and cyclists.

In this episode of the HRI Podcast we will have another look at the safety of autonomous vehicles.

AVs are expected to have a considerable impact on the future of transportation (Litman, 2020; National Roads and Motorists' Association, 2018). Positive effects of AVs include the potential to be more environmentally friendly by driving more economically (Fagnant and Kockelman, 2015). Due to their ability to communicate with each other and with the infrastructure AVs are able to reduce traffic congestion by re-routing vehicles to their destinations. They also have the potential to radically change our transportation system since ride sharing and even car ownership sharing becomes much easier to implement. Our society could be serviced by a fleet of autonomous robotic taxis that could even offer car pooling trips. They would also enable people that are currently unable to drive to take advantage of an individual based transportation system. Children, people with disabilities and the elderly could safely ride to their destinations (Lutin et al., 2013).

Possibly most important, AVs are able to increase road safety (Petrovic et al., 2020). The US National Highway Traffic Safety Administration's (NHTSA) showed that 94% of car crashes can be attributed to human error (Department of Transportation, 2015). AVs do not get drunk, high or distracted. They can be programmed to absolutely comply with speed limits and traffic rules. They can even warn each other about accidents or obstacles on the road ahead. It has even been argued that once AVs have reached a safety record that is better than that of average human drivers, humans should be banned from driving altogether (Sparrow and Howard, 2017).

While AVs can avoid some human errors, they are also likely to introduce new sources of human-robot interaction errors. Tesla cars, for example, with active autopilot, have been involved in several fatal crashes, starting as early as 2016 [1]. The first bystander killed by an AV has been Elaine Herzberg on March 18, 2018 by an autonomous Uber car. The accident report notes that the autopilot was programmed with a certain threshold to continue driving even if an abnormal sensor reading was received (National Transportation Safety Board, 2019). This threshold is necessary, since otherwise AVs would have to stop too frequently, making it a safety risk for others. Such risk taking is normal for conventional driving. For example, our streets would be much safer if the speed limit would be universally reduced to 30km/h. We accept the trade off between safety and speed despite the fact that it results in thousands of deaths each year.

Despite the high probability that AVs will kill a certain number of people it would be foolish to stop their development. The progress in the aviation industry can serve as an example. In the early days of aviation, piloting an airplane was incredibly dangerous. Both Wright brothers crashed with their airplanes and suffered severe injuries. It did not stop them from building the first motorised airplane. Since then, air travel has become one of the safest form of transportation. According to National Transportation Safety Board, there are on average less than 1 fatality per 100,000 flight hours [2]. It has to be pointed out that most airplanes already extensively use autopilots. While the aviation industry has very strict safety regulations, processes and reporting, the same cannot yet be observed for AVs. Fatal AV crashes receive a disproportionately large amount of media attention which can inhibit their development which in turn can costs people's lives (Bohn, 2016).

Independent, accurate and reliable information about the safety of AVs is necessary, similar to the reporting done in the aviation industry. Without such clear information about the safety record of AVs, it will be difficult, if not impossible, for people to consent to their usage, which further complicates the regulations of risk and responsibilities. It has been shown that communicating the risks of AVs is a challenge in itself (Bartneck and Moltchanova, 2020). But the risk and responsibilities are still being negotiated between the manufacturers, insurance companies, governments, and drivers. The Department of Motor Vehicles (DMV) in California is a good example of making safety data of autonomous vehicles available publicly. Their incidents are being published online and have already been analysed up until the year 2017 (Favaro et al., 2017).

[1] https://www.tesladeaths.com

[2] https://www.bts.gov/content/fatality-rates-mode

The uptake of AVs and its associated regulatory changes are unparalleled within the human-robot interaction community. This has partly to do with danger that AVs pose to humans, but also due to their high potential usefulness. It can be argued that AVs are the most commercially successful form of human-robot interaction. The interaction between AVs, drivers and other participants in the traffic, however, remains difficult.

The Partners in Automated Vehicle Education (PAVE) showed in their 2020 report that Americans are sceptical of current AV technology [3]. Again, independent, clear and reliable information is necessary to build trust of the general public towards AVs. Kyle Loades, the chairman from National Roads and Motorists' Association (NRMA) explained that the best way to adopt a new technology and build up users' trust is through trials (National Roads and Motorists' Association, 2018). The success of the trials can of course only be evaluated if the resulting data are being shared openly.

1.1 Autonomy

Before further exploring AV safety, we have to define the key concept of autonomy, since this is the most distinguishing feature of this human-robot interaction. The fundamental question is who is in control of the vehicle, the computer or the driver.

Autonomous vehicles can be classified into six levels (Standard J3016_202104) according to the Society of Automotive Engineers (SAE International, 2021). The same levels are also being used by the U.S. Department of Transportation U.S. Department of Transportation (2018).

Level 0 No Driving Automation – The human driver is in control, even when enhanced by active safety systems

Level 1 Driver Assistance – The vehicle can either steer or control the speed, but not both at the same time. The human driver preforms the other task.

Level 2 Partial Driving Automation – The car can steer and control the speed. The human driver supervises the system at all times.

Level 3 Conditional Driving Automation – The human driver at this level on standby to take back control in case of a failure.

Level 4 High Driving Automation – The human driver is no longer expected to intervene in the driving, but the driver can take back control if desired.

Level 5 Full Driving Automation – The human driver can no longer take back control of the vehicle.

[3] https://pavecampaign.org/wp-content/uploads/2020/05/PAVE-Poll_Fact-Sheet.pdf

1.2 AV Market Overview

Most current AVs have achieved level 3 under the SAE standards, while the Waymo's 2020 safety report claimed that their AVs had the ability of level 4 which can demonstrate 28 core competencies of The U.S. Department of Transportation's recommendation. These technologies, unlike the traditional adaptive cruise-control or lane assistance, also include the safe stop when the system fails (Waymo, 2020).

While the levels of autonomy are reasonably well defined, the terminology used by the car industry is much more ambiguous. Tesla, for example, refers to its system as "Autopilot". The Munich Regional Court has ruled in their decision from 14 July 2020 (Az. 33 O 14041/19) that Tesla branding its autonomous tech "Autopilot" is misleading for consumers. In May 2021 the California Department of Motor Vehicles started to investigate Tesla over its self-driving claims (Mitchel, 2021). Starting in 2020 Tesla states on its "Autopilot" website that "Current Autopilot features require active driver supervision and do not make the vehicle autonomous." Only in 2021 and after at least three years of delays did Tesla roll out its "Full Self-Driving" software update in its beta program (Hawkins and Lawler, 2021). The latter enables drivers who paid for the "Autopilot" to use many driver-assist features on local, non-highway streets.

Mercedes Benz decided to pull its 2017 E-Class TV commercial after complaints were made by Consumer Reports and the Center for Automotive Safety about the depiction of self driving Buss (2016). In 2021, Waymo decided to use the term "fully autonomous" instead of "self driving" in an attempt to differentiate itself from the driving assist features of other manufacturers McFarland (2021). Waymo's AVs currently only operate publicly in Phoenix and soon in New York and San Francisco. It is impossible to purchase the cars directly for personal use.

Companies that offer autonomous features or adaptive features require drivers to adhere to their instructions. For example, Tesla's owner manual strictly warned the driver has to watch the road and prepare to take over the car at all time and never depend on the cruise control (Tesla, 2020). While Tesla and others require the drivers to adhere to their guidelines while driving, it has become clear that drivers do not always do so. Rafaela Vasquez was watching her mobile phone when the fatal accident occurred killing Elaine Herzberg. In 2019, a Tesla driver was video recorded sleeping behind the wheel while the car was driving in autopilot on a highway (Brown, 2019).

Jake Fisher, an engineer working for Consumer Reports, showed how easy it is to trick a Tesla Model Y so that it could drive on autopilot with nobody in the driver's seat (Barry, 2021). Drivers used little weights attached to the steering wheel to trick Tesla's torque sensor into believing that the driver still has his/her hands on the steering wheel (see Figure 1).

Probably as a response to these problems, Tesla activated its in-car-camera in April 2021 to monitor the driver (Lawler, 2021). The car can now tell if the driver is paying attention to the road. It is unclear why Tesla waited for such a long time to activate this safety feature. Drivers might dislike being watched

Figure 1: Weight for the steering wheel to trick Tesla's torque sensor (source: Ali Express)

and recorded while driving since this is a considerable intrusion of their privacy. Tesla claims that the video processing is taking place in the car and that the video recordings do not leave the car unless the driver enables the "data sharing" feature (Korosec, 2021). In 2021 Tesla started to require drivers to consent to the video recordings made automatically during a crash being made available to Tesla (Dent, 2021). This new requirement highlights the difficulty of human-agent interaction in AVs and consequently the legal uncertainty.

1.3 Robot Taxis

Robot taxis prohibit the passenger to intervene with the operation of the car. This mode of operation provides a much clearer human-robot interaction paradigm since the passenger are not allowed to touch the driving wheel. The AV might not even have a driving wheel. In this human-robot interaction, the taxi operator takes full responsibility for the AVs driving. This simplification of the human-robot interaction is highly desirable for the passengers, assuming the AVs performance is at least as good as that of a human taxi drivers.

The operation of robot taxi services are technically demanding. Several test of robot taxis have been performed such as in Singapore in 2016 by NuTonomy and in Phoenix in 2017 by Waymo. Waymo moved on and started to offer its robot taxi services to everybody in 2020 in Phoenix. On June 4th, 2021 the California Public Utilities Commission issued GM's Cruise a permit to operate robot taxis in California (Prosper, 2021). This was the first time the commission issued such a permit. Waymo had applied for a similar permission but has not yet received it (Moon, 2021c). Volkswagen targets 2025 for their fully autonomous electric taxi called ID.Buzz (Moon, 2021a). Toyota was trialling their AV mini bus during the 2021 Olympics, but had to temporarily suspend the operation after and accidents with a visually impaired pedestrian (Shivdas and Kelly, 2021). Still, Toyota worked with Aurora to deploy autonomous Sienna minivans by the end of 2021 (Bonifacic, 2021). Huyndai's Motional Company started public road testing of its robot taxi "IONIQ 5" in Boston, Pittsburgh, Las Vegas and Singapore. They expanded their testing to Los Angeles in August 2021 (Holt, 2021). They intend to collaborate with Lyft and expand their services across the USA by 2023. Lyft is also collaborating with Ford to offer robot taxi services in Miami in 2021 and Austin in 2022 (Shah, 2021).

Besides passenger vehicles and taxis, AVs are also entering the market for commercial vehicles. This includes trucks that still do have a human driver on board, such as Tesla's semi and driverless delivery vehicles. FedEx, for example, teamed up with Nuro for the so called last-mile-logistics (FedEx, 2021). Their delivery drones bring packages to their destinations without human supervision. Trials to deliver pizzas with AVs have also started, for example with Domino's Robotic Unit or through a collaboration with Nuro (Buss, 2021).

1.4 Safety Data During Development And Deployment

The safety of AVs is recorded during different phases in the development of AVs. Car manufacturers test their AVs during their early development on their own private test tracks and information about these is difficult to acquire since it is commercially sensitive. The only formal reporting necessary would probably be to comply to the work safety regulations. If a test driver is injured then reports on the work accident would have to be recorded. Work safety reports are not necessarily openly available since they include personal and medical information.

Once the development has matured, companies can start testing their AVs on public roads. Depending on the national and regional laws, companies may be required to report incidents to the authorities. This information is then publicly available through the government agencies. The California Department of Motor Vehicles (DMV), for example, has regulation which requires every company to register before they can start testing their AVs on the roads (Department of Motor Vehicle California, 2019). More importantly, there are several rules and laws the manufacturers should obey before they test or deploy their AVs. The companies have to report every collision and every disengagement to the DMV. In Arizona, all "Incident records" has to be reported to the Arizona Department of Transportation.

Once the AVs are being sold to consumers, there is no longer a formal requirement to specifically report incidents beyond what the police is already recording for all vehicles on the road. It is important to note that not all incidents are being reported to the police and hence their records will always be incomplete. It can, however, be assumed that almost all accidents that include injuries and deaths are being reported. Accidents that occur during AV trials are also being recorded by this process in addition to the reporting to other government agencies, such as the DMV. The NHTSA, for example, operates the "Fatality Analysis Reporting System and the Crash Report Sampling System"[4] which records both, accidents with conventional cars and since 2019 also specifically accidents with AVs.

The AV manufacturers are not obliged to record crash information and neither are any other vehicle manufacturers. While the technology to automatically record all crashes is already available and is being used for commercial vehicles, this could be considered a massive invasion of privacy for private drivers. Tesla, as mentioned above, is one of the very few companies that requires drivers to share video recordings of crashes.

2 Data Sources

There are three main sources of information on AV safety that is publicly available. First, the companies developing AVs might report their own safety records. Second, some government agencies require AV developers to publish the safety data when conducting test on public roads within their jurisdiction. The police might record accidents that included an AV. The University of Berkeley operates the "Transportation Injury Mapping System"[5] which gives research access to crash data from government agencies. Third, the media reports on many crashes that involve AVs. Each of these data sets have their limitations.

I will not be talking about road safety features that are inherent in the infrastructure, such as the road conditions or road design. I will also not talk about weather conditions or the fitness of the vehicles.

2.1 Company Self Reports

Elon Musk once claimed that their Tesla cars would achieve level 5 by the end of 2021(Hyatt, 2021). In 2018 it was claimed in a tweet that Tesla is the safest car in the world (tweet, 2018). Additionally, the Highway Loss Data Institute's (HLDI) reported in their Insurance Losses Report(HLDI, 2016), that the Tesla Model S had higher insurance losses than other vehicles. This indicates that Tesla's crash severity and frequency is higher than other cars'. This report does not appear to support the claims made by Elon Musk and the Tesla company.

Besides Tesla, other companies, such as Waymo, NVIDIA, and AutoX, published annual safety reports. In AutoX's 2018 safety report, they claimed that in order to achieve level 4 under the SAE standard, they were testing two AI system simultaneously. These systems generate their own datasets using a black box system. The resulting data are then used in their further research (AutoX, 2018).

Waymo has published a 48 pages safety report in 2020 and stated that they had tested AVs for more than 20 million miles on public roads(Waymo, 2020). The report didn't include any information on fatalities or injuries. Waymo claims to currently drive more than 100,000 miles per week in San Francisco but nothing is reported regarding safety record (Dolgov, 2021). Waymo does publish

[4] https://www.nhtsa.gov/crash-data-systems/crash-report-sampling-system
[5] https://tims.berkeley.edu

the "Waymo Open Dataset" that includes recordings of the sensor readings for some of their trips [6]. Waymo did disclose their AV data from their trials in Phoenix. It reported on 47 crashes during 2019 and 2020.(Hawkins, 2020).

2.2 Government Agencies

Most if not all of the OECD countries have government agencies that monitor road safety. In the US, the NHTSA reports on road safety. Their 2020 annual report summarises the data of the year 2018. There were 33,654 fatal crashes, 1,894,000 crashes with injuries and 4,807,000 crashes with property damage only (Department of Transportation, 2020). The economic cost of traffic crashes in 2010 was estimated at 242 billion USD. These numbers illustrate the considerable impact that traffic accidents have on society.

The NHTSA operates several crash databases, including the Crash Report Sampling System (CRSS) (DOT, 2020) and the "Fatality Analysis Reporting System" (FARS). FARS records "the presence of an automation system", "the highest level of automation system" and "the highest level of automation system that was known to have been engaged" accordingly. This data only started to be recorded in 2019 and there are only few entries so far. There is only one registered fatality case with level autonomy 2 recorded in Pennsylvania, while the overall fatality in Pennsylvania ranked 8th within the US. Most fatalities are recorded in Texas, but for this state, no AV-related data have been recorded by the police so far.

Not only large countries have to deal with the consequences of road accidents. In New Zealand, hundreds of people lose their lives on the road and many more are injured every year. According to the OECD 71.6 people per 1 million inhabitants died in 2019 on New Zealand's roads, which is considerably higher compared to Australia (47.1) Germany (36.6) and the UK (27.6 in 2018) (OECD, 2021). In 2019, New Zealand Government published the "New Zealand's Road Safety Strategy 2020-2030" (Road to Zero) report (Ministry of Transport, 2019). This report showed that most developed countries have lower rate of road fatalities per 100,000 population than New Zealand. For example, in 2017 Norway, a country that has a similar road network and population density distribution to New Zealand, had only 2 deaths per 100,000 inhabitants, while New Zealand had 7.9. The Ministry of Transport in New Zealand estimated in 2017 that the the average social cost is 4.916 million dollar per fatal crash, 923,000 dollar per reported serious crash, and 104,000 dollar per reported minor crash. The total social cost of motor vehicle injury crashes in 2016 is estimated at approximately 4.17 billion dollar (of Transport, 2017).

By DMV regulation(Department of Motor Vehicle California, 2019), all companies actively testing autonomous cars on public roads in California are required to disclose the number of miles driven and how often human drivers were forced to take control of their vehicles, otherwise known as a "disengagement". The information is recorded in individual incident reports that are stored in sep-

[6] https://waymo.com/open/

arate PDF files. The forms were originally filled in by hand and not available as a structured data set. The earlier years' data from 2014 to 2017 are very incomplete, while from 2018 the records start to be more comprehensive. The format of the reports also evolved over the years and hence different and sometimes more extensive information is available in more recent years. More importantly, the information from the recent years are now available in structured tables.

Several robot taxi trials have been completed in Phoenix, Arizona and hence the Arizona Department of Transport (ADOT) should have a considerable data set. While their publicly available crash data information system records car crashes every year since 2000, the AVs information was only registered since 2010. Data relevant to AVs are stored in "Incident" and "Unit" files from their data system. Unlike the DMV, ADOT does not make a dedicated data set about AV trials available.

2.3 Media

The media frequently reports on car crashes, in particular if it involves an AV. While this is another source of information, the reliability of reporting cannot be guaranteed. Moreover, not every crash gets reported in the newspaper. Another problem is the collection of the data. The website Tesla Deaths[7] attempts to list every death reported in the media that involved their autopilot. Like most crowdsourcing projects, the quality control of the data is their main challenge.

2.4 Perceived Safety

While objective safety data is important, the population's perception of road safety does not always align. People are, for example, overly concerned about the safety of airplanes.

Studies surveyed 185 experienced industry professionals to understand their opinions on AVs' supposed safety benefits and drawbacks (Rezaei and Caulfield, 2021). The findings showed that incorrect understanding of surrounding objects by AVs could be a significant concern that leads to accidents. And while AVs might reduce the number of accidents, severity of accidents may remain unchanged or even worsen. Overall, the consensus was that AVs have potential to increase road safety but more research is required.

3 Standardisation

There are first attempts to define industry wide standards for AV safety, such as through organisations like The Autonomous[8], which has ARM, Audi, BMW, Volkswagen, Samsung, Continental, NXP, Waymo, and the Swedish Royal Institute of Technology as its members. Their goal is to develop technical criteria, methods, processes and standards for the safety of AVs. Ford started to share

[7] https://www.tesladeaths.com/
[8] https://www.the-autonomous.com/

driver-collected accident data with other car makers through their Local Hazard Information system (Summers, 2021). This enables vehicles to warn others of difficult driving conditions ahead.

In 2018, the International Organizaition for Standardization issued the safety standard called Automotive Safety Integrity Level (ASIL) (International Organization for Standardization, 2018). This is the international standard for all manufacturers to comply with, and there is also ISO Standard called "Terms and Definitions of Test Scenarios for Automated Driving Systems"(International Organization for Standardization, 2021) which all manufacturers are requested to comply with during their AVs testing. Common indicators for vehicles safety include:

While safety indicators seem clear at first glance, the devil is, as so often, in the details. Fatalities do not necessarily occur during a crash or shortly after. At times, people die weeks after the event. A common approach is to set a deadline, such as 30 days. Still, this cannot be calculated automatically, since a person can also die within 30 days after the crash due to an unrelated issue.

4 Discussion

AVs have great potential in the future of transportation. They will most likely become the most beneficial and dangerous form of human-robot interaction. Their predicted casualty rate is likely to be far above that of autonomous killer robots during these relatively peaceful times. 94% of crashes are caused by human error (Alexandra et al., 2020). The majority of these are due to errors in "Sensing and perceiving", "Predicting errors", "Planning and deciding", "Execution and performance errors", and "Incapacitation". AVs will be able to prevent at least one third of all crashes.

The question of whether a mixed model of responsibility would work is unanswered. This is a fundamental question in human-robot interaction. It is conceivable that drivers will continue to misuse or trick technology to not have to pay attention to the road (see Figure 1). The risk that drivers are willing to take with the current state of AV technology only highlights how attractive a fully autonomous vehicle would be. A recent study revealed that between 70-99 percent of the drivers do not fully understand how the different driving assistance technologies work and what they can and cannot do (Tsapi et al., 2021).

4.1 Government responses

Government agencies, such as NHTSA, have started to respond to the challenges of AVs. In 2021 the NHTSA ordered car companies to report incidents that involve semi-and full autonomous driving systems within one day of learning of the accident (Administration, 2021). The Tesla company is subject to an investigation by the NHTSA since August 2021 for several crashes with in-road or roadside first responders (Posada, 2021). In September 2021 the NHTSA directly ordered Tesla to share data about its autopilot by October 2021 or face substantial fines otherwise (Moon, 2021b). NHTSA is particularly interested to find out how the driver assistance system works and whether there are specific limits on how it can be used. In June 2022 the NHTSA release a first report on AV crashes (NHTSA, 2022). They found that 367 crashes in the last nine months involved AVs that were using autopilots. The data files have also been made available online [9]. This is certainly a step in the right direction, but NHTSA acknowledged that there were several limitations, such as incident reports might be incomplete or that a single crash could have been counted more than once.

Faced with the high costs associated with crashes, the national governments run many programs to improve the road safety. The NHTSA annually releases a "five-star safety rating program" for each car[10]. This helps the consumer to make purchasing decisions. A one star rated car is less safe than a five star rated vehicle. The star ratings are based on vehicle crash tests. Fitting new safety technologies into cars, including those with autonomous features, is likely to improve the safety ratings of those cars and thereby their acceptance in society. This rating program needs to be based on real world data and hence the reporting of the police on AV accidents needs to improve in order for the five-star safety rating program to be meaningful.

4.2 Data considerations

Crashes and the associated loss of life, well-being and property are the most important indicators for road safety. While some government agencies have started to include reporting options for AVs, their uptake is still insufficient. The police officers on the scene of an accident face several problems. First, they have no real way of assessing what AV capabilities a vehicle has. Tesla's autopilot, for example, is an *optional* feature. In particular after serious crashes, the police would be unable to start AVs involved in the crash in order to assess what, if any, autopilot is available. Even worse, just because a car has got autonomous features, does not necessarily mean that they were active during the accident.

The human driver is also not a reliable source of information. Many drivers could be tempted to report that their car was in control during the accident in order to avoid having to take responsibility themselves. The only solution seems to be a black box system in which a detailed logged is automatically recorded and archived. This log could even be automatically synchronised with the cloud to protect itself against loss of data. While this approach is technically possible and even already available for commercial vehicles and airplanes, there are considerable privacy concerns. Still, AVs could record far more information than just crashes. Similar to airplanes, it could record near misses. These are likely to be far more frequent than actual crashes.

Another important aspect of AV safety is the competence of the autonomous systems. The DMV in California requires all permit holders to report disen-

[9] https://www.nhtsa.gov/laws-regulations/standing-general-order-crash-reporting

[10] https://www.nhtsa.gov/ratings

gagements. A high number of disengagements is often considered an indicator of poor performance. This approach can only be considered naive. An AV that recognises its own inability of handling a certain situation is safer than a system that is unable to recognise its own limitations. Furthermore, it would even be desirable if the AV could detect the inability of a human driver. The AV could take the control away from a human driver in order to prevent a crash. Failing of the system to engage its autonomous features could then also be recorded as a performance indicator. AVs efforts to avoid crashes are rarely acknowledged. Waymo ran simulations and concluded that its autopilot could have avoided 88 out of 91 crashes (Waymo, 2021).

It is important to note that the disengagements, crashes, injuries and deaths are to some degree independent of each other. AVs can crash with or without the autopilot engaged and the autopilot may or may not disengage prior to the crash. The autopilot can also be the cause of the crash.

4.3 Company responses

The safety information that many companies release about their AVs is insufficient and not always trustworthy. While large numbers, such as Waymo's claim to have driven 20 million miles on public roads sound impressive (Waymo, 2020), they do not say much about actual safety. Car companies do of course want to convince customers of their safety, but at the same time they also want to avoid revealing too much information to their competitors. Waymo even sued the DMV in California to prevent the release of AV crash data (Hawkins, 2022). The companies are also inclined to report their safety in a way that emphasises their success. One company might, for example, choose to report only miles driven, while another might report on its low number of crashes. Only standardised transparent government guidelines and tests that apply to all companies can provide the basis for relevant and reliable information for the customers.

Unfortunately, many governments bend to the companies concerns about commercial sensitivity and abstain from publishing the results of their AV tests. The only objective information available on many of these trials is through police records. Fortunately, most trips using AVs end without a crash. Hence more information about the safety of AVs can be obtained through normal usage compared to the relatively few crashes.

5 Conclusions

The levels of autonomy should be extended by another level. Robot Taxis do not only drive completely autonomously, but they also prevent passengers from taking back control. This level of autonomy comes with even higher responsibilities for the AV and its passengers. It also presents additional requirements on how other traffic participants interact with the AV. In 2022 an AV without driver or passengers drove away from police officers who wanted to stop it (Vallance, 2022). Clearly, these type of AVs require an additional level of autonomy.

We desperately need a warranty of fitness (WOV) system for AVs that objectively tests the performance of AVs. The US government has started to critically approach this problem, but they cannot be congratulated on their fast response. Already in 2019 a Tesla car with an active auto pilot ran a red light and killed Gilberto Alcazar Lopez and Maria Guadalupe Nieves-Lopez (GITLIN, 2022). It is arguably the first case involving felony charges to result from a fatal crash involving an automated driving system. The court case only started in 2022 and there is still no clear legal foundation for this case. Who will be responsible for this tragic accident, Tesla or the driver Kevin Riad? On what basis will the judges decide on the responsibilities? Even more important, why has the US legal system not already provided the necessary guidance for the judges?

There is also a considerable conflict of interest for AV companies that offer car insurances, such as Tesla and General Motors. In principle, the idea to offer cheaper premiums to safer drivers sound like a good idea. I even argued that a black box system would be desirable to provide objective data. The degree to which a driver obeys speed limits, for example, can be automatically recorded and transmitted back to Tesla. But how can a company be trusted when it is responsible for the performance of the AVs, the recording of data and the associated insurance claims. Drivers that experience a malfunction of the autopilot that leads to a crash will have a hard time defending their case if their own recollection of the situation contradicts Tesla's position.

We desperately need government actions to design and implement objective and independent data recording systems for AVs. The technology for it is already widely available. Customers require this information to decide how much trust they have in this form of human-robot interaction.

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