# Autonomous Vehicles: Are We Ready?

Abdelrahman Ahmed

6 June 2016

**Executive Summary**

Autonomous vehicles are increasingly becoming an integral part of reality; however, eliminating human interaction from driving creates significant concerns regarding the ethics, safety, and reliability of autonomous vehicles. The objective of this report is to examine the advantages and disadvantages of autonomous vehicles. The report draws attention to the fact that autonomous vehicles will not only save lives by reducing motor-vehicle accidents caused by human error, but also by reducing greenhouse gases that damage the environment. It also notes that traffic congestion can be minimised by developing a smart and autonomous public transportation system. Autonomous vehicles will also allow non-drivers, such as the elderly and disabled, to have access to better transportation as well as in-vehicle technology, such as health monitoring systems. The report also looks at the negative aspects of introducing autonomous vehicles, such as how it would eliminate a large number of jobs. Furthermore, the convenience and accessibility may increase the demand for vehicles, thus increasing traffic congestion. In addition, it stresses the importance of the ethical concerns regarding inevitable accidents in which a vehicle will have to take a pre-determined action, as well as the security issues in which a vehicle can be compromised by hackers. The report concludes that the continued development of autonomous vehicles is essential as their adoption will save numerous lives and the many benefits supersede any concerns regarding ethics and reliability.

# Table of Contents

# 1 Introduction

Autonomous vehicles are not far from being a reality, and their introduction promises a number of world-changing benefits. Millions of people lose their lives every year in accidents caused by human error; this was the main motivation behind the development of autonomous vehicles (Rajasekhar & Jaswal, 2015). Autonomous vehicles promise to remove the human factor from the equation, thus reducing the amount of traffic accidents. It will also contribute to saving the environment by using electric vehicles that will reduce toxic emissions. Autonomous public transportation will also reduce traffic congestion with better cruise control, taking people's requests in advance and supporting shared rides. Autonomous vehicles will also make transport more accessible for non-drivers. However, there are also many ethical concerns in regards to autonomous vehicles when it comes to inevitable accidents where a vehicle will have to make a pre-programmed decision about whose safety to prioritise. Some also question their security and reliability, as a computerised vehicle would naturally inherit issues facing personal computers today, such as vulnerability to hacking. In addition to this, the widespread use of autonomous vehicles will lead to major job losses in sectors that rely solely on vehicles and transportation. Despite these ethical and reliability concerns, autonomous vehicles should continue to be developed and implemented, as they save lives.

The report reviews the benefits that autonomous vehicles will bring to society, such as eliminating accidents, increasing traffic efficiency, reducing air pollution and providing accessibility to older and disabled people. It then examines concerns relating to autonomous vehicles, including growing unemployment, ethical issues regarding the vehicle decision-making during an accident and lastly reliability of autonomous vehicles.

# 2 Background

An autonomous vehicle can be defined as a vehicle which is capable of comprehending its immediate environment, determining the route required to reach its destination and driving itself without any human intervention (Rajasekhar & Jaswal, 2015). The National Highway Traffic Safety Administration has classified vehicle automation into five different levels (Aldana, 2013). No-Automation (Level 0) in which the driver is in complete control of the vehicle, including steering and brakes, at all times. Function-specific Automation (Level 1) involves one or more specific control functions, including stability control and pre-charged brakes, where the vehicle is only assisting the driver in cases where it can act faster. The driver is fully engaged and maintains primary control of the vehicle. Combined Function Automation (Level 2) incorporates automation of at least two primary controls designed to function simultaneously to relieve the driver, such as cruise control and lane centering. Drivers are responsible for

monitoring the road and are expected to take control at anytime. Limited Self-Driving Automation (Level 3) enables drivers to relinquish complete control of safety-critical functions under certain conditions and relies on the vehicle to automatically surrender control back to the driver during unexpected conditions. Drivers are expected to be available to take control occasionally, but do not have to constantly monitor the roadway. Finally, the Full Self-Driving Automation (Level 4) in which the vehicle is designed to operate all safety-critical driving tasks and observe the roadway at all times. Drivers are only required to provide the destination for their journey (Aldana, 2013).

# 3 Effects on Traffic Accidents

The automotive industry has long invested in the development of autonomous systems that attempt to minimise human interaction with vehicles. Today, systems such as antilock brakes, auto-parking, and cruise control have been widely implemented and proven to make driving more efficient and safer for both passengers and pedestrians. These individual systems are considered precursors to a fully autonomous vehicle that will help reduce accidents caused due to human error (Lee et al., 2015). Motor-vehicle accidents are one of the leading causes of death in the United States (Centers for Disease Control and Prevention, 2015), and according to the National Highway Traffic Safety Administration the critical reason for 94% of accidents was assigned to drivers (Singh, 2015). The statistics in Figure 1 show that recognition errors, such as driver's inattention and other distractions, and decision errors, such as misjudgements and illegal maneuvers, account for 72% of the errors in crashes. Other driver-related critical reasons included performance errors, such as overcompensation and poor directional control, and non-performance error where sleep was the most common cause (Singh, 2015). An autonomous vehicle, however, is constantly learning and improving, it cannot be distracted and it does not require rest. It has the ability to recognise and understand its immediate environment using sensors to keep distance between vehicles and avoid collision (Choi & Ji, 2015). Pattern and lane recognition software also allows the vehicle to stay in lane and recognise the path ahead to reach its destination. These features allow vehicles not only to reduce errors caused by drivers, but also to improve significantly over time by learning to eliminate any potential errors that may cause accidents. Therefore, it is a moral obligation for manufacturers and people to further the development, and advocate the widespread use, of autonomous vehicles in order to reduce accidents and save lives (Choi & Ji, 2015).

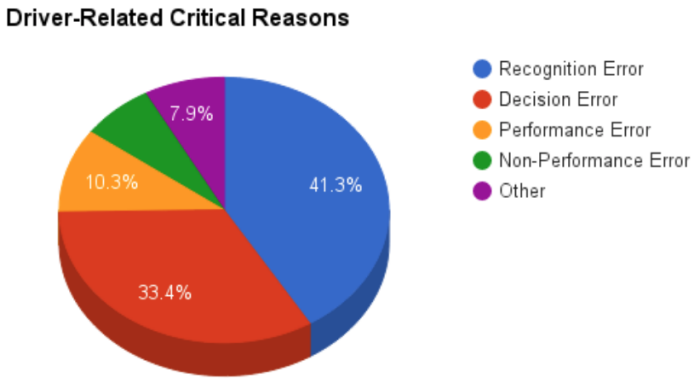


Figure 1: Based on 94% of crashes attributed to driver error reported by the National Motor Vehicle Crash Causation Survey. The percentages are based on unrounded estimate frequencies with an average margin of error of +/- 2.3% (Singh, 2015, p. 2)

# 4 Effects on Traffic Congestion

Traffic congestion is one of the largest problems facing transport and many of the issues behind traffic congestion can be attributed to driver errors which can be eliminated by the introduction of fully autonomous vehicles (van Arem et al., 2006). These vehicles will incorporate already existing systems which have currently help with traffic efficiency, such as Adaptive Cruise Control (ACC). ACC is a radar-based system that provides comfort and convenience to drivers by continually adjusting the speed to match the preceding vehicle. The system also automatically decelerates when it approaches a slower vehicle, and accelerates when upfront vehicles changes lanes or accelerates. Vehicle-to-vehicle communication can further advance the development of driver assistance systems (van Arem et al., 2006). It can also optimise public transportation by allowing autonomous taxi cars to cooperate, and to take customers' requests in advance instead of cruising around the city for unplanned customers, and support shared rides to further reduce the amount of vehicles needed. To enhance the efficiency of the public transportation system, a control center could be put into effect to coordinate the vehicles, manage the requests sent by customers and assign each request to a vehicle. It can also be used to optimise routes for the vehicles by identifying traffic jams and locating open roads (Lam et al., 2016). Several companies, such as Uber and Lyft, have begun to offer private taxi services that implement some of these features. Nonetheless, they will be unable to support the high demand and continue to be efficient and flexible without changing the existing public transportation system (Lam et al., 2016).

# 5 Effects on Transportation

Transportation is critical to everyday life, and it involves more than simply getting from point A to point B. Autonomous vehicles have greatly improved transportation accessibility for older and disabled people who were previously unable to drive (Yang & Coughlin, 2014). Making new technologies more accessible and easier to use is a top priority for the technology industry in order to appeal to the aging population as well as people with disabilities. This poses a number of safety and technological challenges to the automobile industry, which is leading to the development of better in-vehicle technology that can optimise the safety and wellbeing of the driver, such as health monitoring systems and advanced navigation systems. For instance, developing car seats that can monitor the driver's heart rate and warn of an imminent heart attack. Furthermore, using sensors on steering wheels to measure heart rate, blood-oxygen level and blood pressure (Yang & Coughlin, 2014). In addition to this, researchers focus on advancing navigational systems in order to make them simpler to use, for example, minimising visual processing and distractions, reducing navigation errors and enhancing overall performance (Yang & Coughlin, 2014).

# 6 Effects on Employment

The adoption of autonomous vehicles will have a huge impact on those jobs that completely rely on transportation, such as public transport drivers, trucking and delivery services. Over time these jobs will likely disappear as autonomous vehicles become more popular and available (Rajasekhar & Jaswal, 2015). Nevertheless, these issues are not unique to autonomous vehicles and people are affected by any advancements made in science and technology. In fact, technology has helped create more jobs than it has destroyed in the last 144 years by lowering costs, raising disposable income and eliminating dull, repetitive and dangerous work. Innovation in technology has also resulted in more people being engaged in jobs involving nursing and care (Stewart et al., 2015). Autonomous vehicles will invigorate employment in knowledge-intensive sectors such as science, engineering and artificial intelligence.

# 7 Effects on the Environment

The increase in traffic demand has led to a large increase in traffic congestion and has an adverse effect on traffic safety, air pollution and energy consumption. Traffic congestion can also be attributed to inefficient drivers. By making driving easier and more accessible, innovations in technologies, such as driver assistance systems, are contributing to the problems faced by increasing the demand rather than reducing it (van Arem et al., 2006). However, not only will autonomous

vehicles improve traffic safety by reducing traffic accidents, they will also have a very positive impact on the environment as autonomous vehicles are electric, thus reducing carbon dioxide emissions and energy consumption (Rajasekhar & Jaswal, 2015). Furthermore, a smart and autonomous public transportation system would be able to counter the excess demand as people would be less willing to drive with a flexible and efficient public transportation system available (Lam et al., 2016).

# 8 Ethical Concerns

Some accidents are inevitable, even for autonomous vehicles. In such an accident an autonomous vehicle would have to make a pre-programmed decision, therefore it needs to be programmed to know what do in the case of an accident. This leads to a lot of ethical concerns. Manufacturers have to decide if autonomous vehicles should adopt a utilitarian doctrine and minimise harm, or protect the driver and passengers at all costs. A study was conducted to identify the moral codes people are willing to accept and be subjected to in relation to self driving cars. Participants were generally comfortable with a utilitarian autonomous vehicle that will minimise harm during an accident, but they were unwilling to own a car like that for themselves (Bonnefon et al., 2016). However, it is important to consider that the reliability of the study is compromised by the fact that the survey did not have a large sample size and did not cover different factors which could be considered in a moral algorithm, such as having a child or pregnant person on board. These ethical concerns make autonomous vehicles difficult to sell as 'people mostly agree on what should be done for the greater good of everyone, but it is in everybody's self-interest not to do it themselves' (Bonnefon et al., 2016, p. 8). However, some of these concerns might become moot over time as advancements are made in the technological capabilities of autonomous vehicles, such as algorithms and communication architecture, which help reduce accidents that may otherwise have been unavoidable (Rajasekhar & Jaswal, 2015).

# 9 Security Concerns

A fully autonomous vehicle may not be perfect and will require a lot of time and extensive research to ensure its reliability. A computerised vehicle will inherit all the issues currently facing personal computers such as hacking. Researchers argue that the industry's hurry to develop autonomous vehicles will open up new security issues, as autonomous vehicle will require additional sensors and constant Internet connectivity. These issues can make it possible for hackers to remotely control brakes and other critical components in a vehicle (Simonite, 2016). Stefan Savage, a computer science professor at the University of Califor-

nia, argued that the industry is 'a long way from securing the non-autonomous vehicles, let alone the autonomous ones' (Simonite, 2016, para. 5). In spite of all this, the fact that autonomous vehicles will save lives and reduce carbon emissions is a compelling reason to continue investing in the development and adoption of them around the world.

# 10 Conclusion

Autonomous vehicles have a lot of potential and their benefits will significantly supersede the ethical and reliability concerns. For the time being, semi-autonomous vehicle drivers are held responsible for traffic accidents, as they are still required to monitor the roadway and take control of the vehicle if necessary. However, as the technology develops and the majority of complications will be circumvented, and a consensus will need to be reached regarding which moral principles people are willing to accept in the programming of autonomous vehicles. This is because these vehicles made need to execute premeditated decisions which could end lives. It is inevitable that certain jobs depending on transportation will gradually cease to exist; however, autonomous vehicles will promote employment opportunities in a variety of fields such as manufacturing, hardware and software engineering, and especially artificial intelligence. Autonomous vehicles will offer more opportunities for older and disabled people by providing them an easy way to drive and better in-vehicle technology for their safety and wellbeing. Additionally, the innovation in cruise control and vehicle-to-vehicle communication systems will yield a better and smarter public transportation system that will contribute to reducing the traffic congestion by providing flexible and efficient means of transport. Autonomous vehicles will save a countless number of lives by preventing the majority traffic accidents, as well as reducing greenhouse gas emissions. Thus, it is a moral responsibility of governments, technology companies and people to continue to support and invest in the development of fully autonomous vehicles.

# References

Aldana, Karen. U.S. department of transportation releases policy on automated vehicle development, 30 May 2013. URL https://www.transportation.gov/briefing-room/us-department-transportation-releases-policy-automated-vehicle-development.

Bonnefon, J.-F., Shariff, A., and Rahwan, I. The social dilemma of autonomous vehicles. *Science*, 352:1573–1576, June 2016. doi: 10.1126/science.aaf2654.

Centers for Disease Control and Prevention. Injury statistics query and reporting system, 2015. URL http://www.cdc.gov/injury/wisqars/overview/key_data.html.

Choi, Jong Kyu and Ji, Yong Gu. Investigating the importance of trust on adopting an autonomous vehicle. *International Journal of Human–Computer Interaction*, 31(10):692–702, 2015. doi: 10.1080/10447318.2015.1070549. URL http://dx.doi.org/10.1080/10447318.2015.1070549.

Lam, Albert Y. S., Leung, Yiu-Wing, and Chu, Xiaowen. Autonomous-vehicle public transportation system: Scheduling and admission control. *Trans. Intell. Transport. Sys.*, 17(5):1210–1226, May 2016. ISSN 1524-9050. doi: 10.1109/TITS.2015.2513071. URL http://dx.doi.org/10.1109/TITS.2015.2513071.

Lee, Jae-Gil, Kim, Ki Joon, Lee, Sangwon, and Shin, Dong-Hee. Can autonomous vehicles be safe and trustworthy? effects of appearance and autonomy of unmanned driving systems. *International Journal of Human–Computer Interaction*, 31(10):682–691, 2015. doi: 10.1080/10447318.2015.1070547. URL http://dx.doi.org/10.1080/10447318.2015.1070547.

Rajasekhar, M. V. and Jaswal, A. K. Autonomous vehicles: The future of automobiles. In *2015 IEEE International Transportation Electrification Conference (ITEC)*, pp. 1–6, Aug 2015. doi: 10.1109/ITEC-India.2015.7386874.

Simonite, Tom. Your future self-driving car will be way more hackable, 26 January 2016. URL https://www.technologyreview.com/s/546086/your-future-self-driving-car-will-be-way-more-hackable.

Singh, Santokh. Critical reasons for crashes investigated in the national motor vehicle crash causation survey, 2015. URL https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115.

Stewart, Ian, De, Debapratim, and Cole, Alex. Technology and people: the great-job creating machine, 2015. URL https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/finance/deloitte-uk-technology-and-people.pdf.

van Arem, B., van Driel, C. J.G., and Visser, R. The impact of cooperative adaptive cruise control on traffic-flow characteristics. *Trans. Intell. Transport. Sys.*, 7(4):429–436, December 2006. ISSN 1524-9050. doi: 10.1109/TITS.2006.884615. URL http://dx.doi.org/10.1109/TITS.2006.884615.

Yang, J. and Coughlin, J. F. In-vehicle technology for self-driving cars: Advantages and challenges for aging drivers. *International Journal of Automotive Technology*, 15(2):333–340, Mar 2014. ISSN 1976-3832. doi: 10.1007/s12239-014-0034-6. URL https://doi.org/10.1007/s12239-014-0034-6.