Ethical Risks and Benefits Analysis of Autonomous Driving

Hisham Iqbal Khokhar

1. Introduction

In this day and age, autonomous driving technology heavily relies on both Robotics and artificial intelligence which have advanced significantly in recent years. The automobile industry is putting a lot of effort into making self-driving cars a reality. As this industry pushes its boundaries of innovation, the journey towards fully autonomous vehicles has become a major focus. This path is guided by the increasing levels of automation, carefully classified to track progress toward complete autonomy. These levels of automation needed for autonomous vehicles are described by the six levels of autonomous vehicles established by the Society of Automotive Engineers (SAE), an American engineering organisation that establishes technical standards for the automotive sector.

Here is quick overview of those stages with examples of both commercial goods and research projects at each stage.

1.1. No automation – Level 0

At level 0, The driver is responsible of overseeing all driving functions including braking, acceleration, and steering, with complete absence of any automation. Systems like Assisted Emergency Braking (AEB) and Electronic Stability Control (ESC) may be installed in vehicles, but they necessitate constant driver intervention. Although they are increasingly found in most cars, these driver aid technologies do not meet the SAE definition of automated.

For instance, The Toyota Safety Sense system, which comes with the well-known Toyota Corolla, has features like Lane Departure Warning and Forward Collision Warning. Although these features offer direction and aid in preventing collisions, driving is still necessary.

1.2. Driver assistance – Level 1

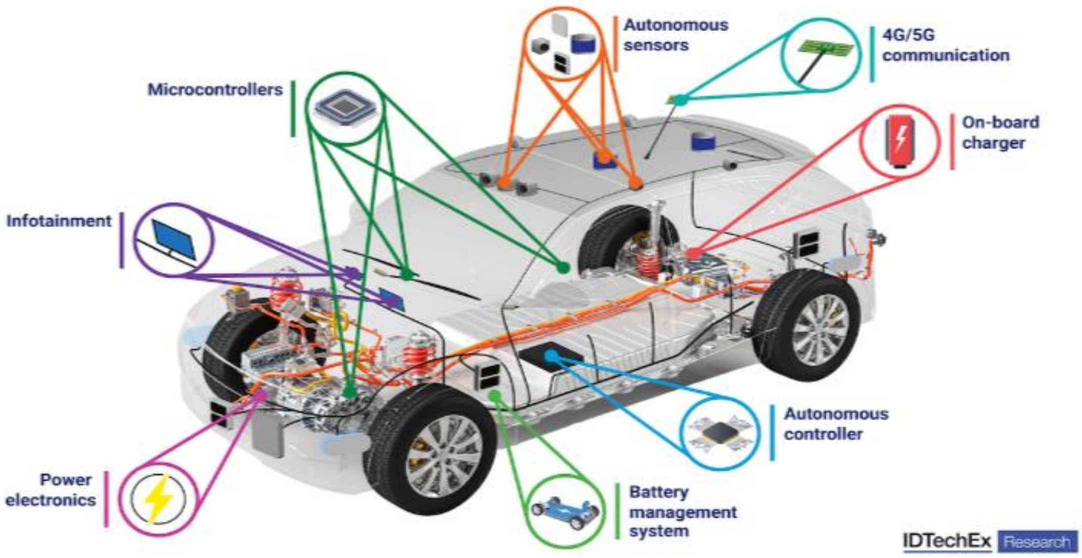
Level 1 drivers assume complete responsibility for their driving, paying close attention to traffic, holding the steering wheel, and being ready to brake. However, the driver does have access to aid technologies. When braking, acceleration, and lateral or longitudinal steering are supported by the assistance system, but not all at once. For example, Level 1 includes Automatic Cruise

Control (ACC) and Lane Keeping Assist (LKA), which enable the car to change its speed and distance from the car in front. They can be turned off or overridden at any moment by the driver.

For instance, Early iterations of Tesla's autonomous vehicles are regarded as level 1. Autonomous autonomy is demonstrated by the adaptive control capacity to regulate speed, which drivers must constantly monitor and control. The Honda Recording Package, which is offered on cars like the Honda Accord, is another such.

1.3. <u>Partial automation - Level 2</u>

Autonomy at Level 2 incorporates advanced driving assistance systems (ADAS) such as automated acceleration and deceleration and combined control. Only in designated sites and under specific conditions can vehicles of this class be operated. ADAS is intended to assist drivers. Accordingly, ADAS features ought to be regarded as "hands-free" systems as opposed to completely autonomous driving systems.



Circuitry and electrical components within a car, many of which work together to comprise ADAS. Source: IDTechEx

Although the car may steer, accelerate, and brake on the highway under specific circumstances, the driver must stay vigilant and prepared to step in. For instance, Tesla's Autopilot, in its most sophisticated iterations, is a fantastic illustration of Level 2 autonomy. Similarly, Cadillac cars with General Motors' Super Cruise feature can drive hands-free on some highways, but the driver must stay vigilant.

1.4. Conditional Automation – Level 3

Driving at Level 3 necessitates a significant advancement in technology, compared to Level 2, and although some manufacturers are waiting for regulatory approval, Level 3 is not yet authorised worldwide. At this level, the conditional automation system is activated, making the car conditionally autonomous, which means the human "driver" acts as a passenger. In specific locations and under certain conditions, the vehicle can steer, brake, and accelerate on its own, allowing the "driver" to take their hands off the wheel and eyes off the road. However, if the vehicle requires it, you must be prepared to take over full control.

For Instance, Conditional Automation, featured in some of the A8 models, was among the initial instances of Level 3 autonomy, allowing drivers to be relieved of specific functions such as lane maintenance or speed regulation. Another notable instance of Level 3 automation is Waymo's self-driving technology, which can function completely autonomously in defined scenarios but depends on human intervention when needed.

1.5. High automation – Level 4

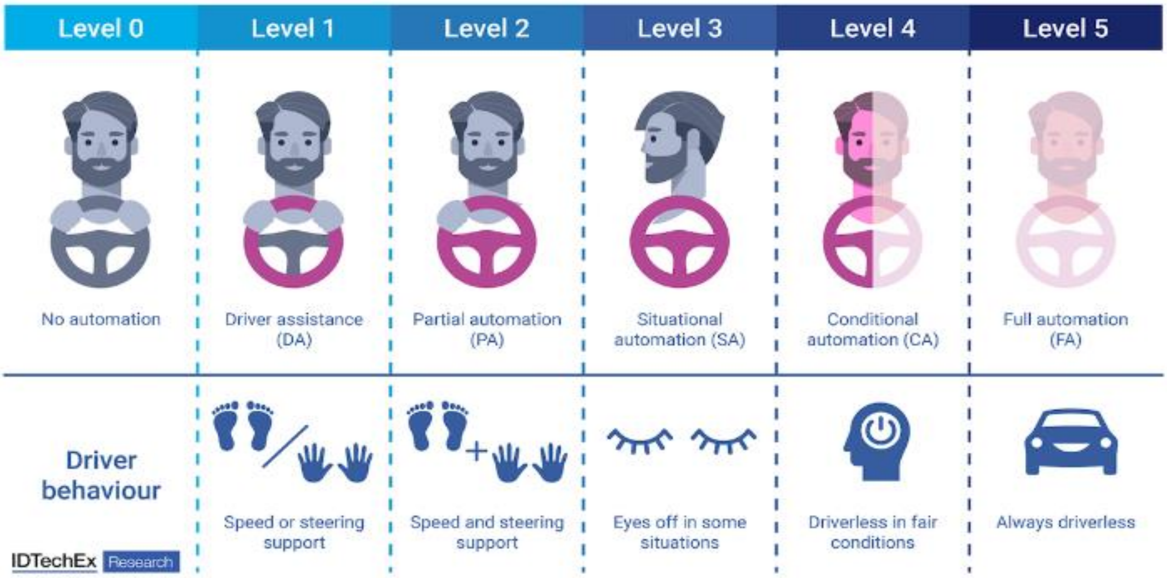
At Level 4, vehicles can function independently requiring minimal human involvement in most situations, particularly in well-defined settings like specific urban zones or highways. These vehicles are capable of handling challenging driving scenarios and can continue operating even if the driver doesn’t respond to intervention requests. However, Level 4 systems may still face limitations due to weather conditions, certain types of roads, or specific geographic areas.

For Instance, Waymo's self-driving taxi service operating in Phoenix, Arizona serves as a prime illustration of Level 4 autonomy. The Waymo fleet can operate in designated zones and under specific conditions. Another example is the Nuro R2, an autonomous delivery vehicle designed to navigate cities independently to deliver items.

1.6. Complete Automation – Level 5

At this level, vehicles can navigate in all environments, unaffected by weather or road conditions, without requiring steering wheels or pedals thus making the vehicle operate entirely autonomously without needing any human involvement in any situation. With this degree of automation, the vehicle becomes completely driverless, capable of managing any driving situation a person might face.

For Example, while no commercially available vehicle currently achieves full autonomy at level 5, Tesla's goals for fully self-driving technology and the ongoing advancements by companies like Waymo, Baidu, and Uber suggest potential future uses for Level 5 automation.



The SAE levels of driving automation. Source: IDTechEx

2. Current Impact analysis

While the previously mentioned autonomous driving technologies still have the potential to revolutionise the transportation systems, it also comes with a variety of societal implications. Most large automobile manufacturers and tech companies have engaged in addressing such issues, invest in research and development in completely autonomous vehicles and have already entered the consumer market. It involves both benefits and concerns regarding the labour market, sustainability, and road safety.

2.1. Autonomous Vehicles and road safety

According to the World Health Organisation, more than 1.3 million people die each year globally due to road accidents, and over 90% of them are due to human error (World Health Organisation, 2021). It can potentially cut down driving under the influence of alcohol, distractions, and other human errors since it relies less on human operators, which can potentially decrease accidents and casualties. Using advanced algorithms, cameras, and sensors, autonomous systems can continuously monitor their surroundings and react to different road conditions at a speed faster than human drivers. Under controlled conditions, Tesla's Autopilot and General Motors' Super Cruise have been able to avoid accidents (Shladover, 2018, Milakis, 2017). It should be noted that neither of these technologies is perfect and, considering their current limitations, an operator should always be attentive and prepared to take over the driving task. Furthermore, recent studies show autonomous driving technology is safer than human drivers. For example, the recorded crash rates for any injury involving an autonomous vehicle by Waymo decreased by 85%, and 57%

reduction for police-reported crashes (Autonomous Vehicle Industry Association, 2024). These findings suggest autonomous driving technology can enhance road safety significantly.

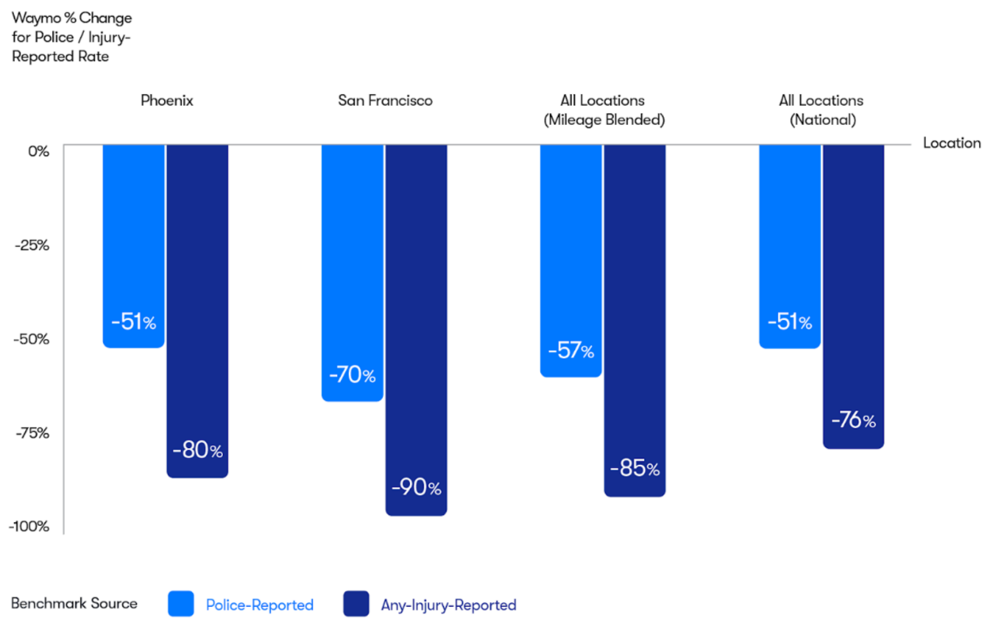


Figure 1: Comparative reduction in crash rates for Waymo autonomous vehicles across multiple locations.

2.2. Ethical Challenges in Autonomous Driving

Even with these possible improvements in safety, significant apprehensions persist. Multiple prominent incidents concerning Tesla's Autopilot and Uber's autonomous testing vehicles illustrate that the advent of autonomous vehicles has not entirely mitigated the likelihood of accidents (Stilgoe, 2018). Detractors argue that operators have not adequately responded to perilous circumstances, which can be attributed to an excessive dependence on technology coupled with a lack of awareness regarding its limitations. Moreover, the current implementation is exacerbated by the ethical dilemmas surrounding responsibility in cases of collisions. For instance, should an accident occur, it is often unclear whether the fault lies with the driver, the manufacturer, or the IT company. This uncertainty poses a challenge to legislators, insurers, and software providers when defining liability and compensation.

2.3. Environmental Impact of Autonomous Vehicles

Autonomous driving offers potential and challenges in terms of sustainability. Advocates contend that self-driving cars can optimise driving habits to minimise pollution and fuel usage. Smoothing accelerations, decelerations, and optimising routes can increase fuel economy to meet environmental goals (Litman, 2020). Additionally, ride-sharing services created by Waymo, aim to maximise vehicle utilisation that would eventually lead to reduced numbers of automobiles on the road, less traffic, and reduced emissions. The increasing adoption of autonomous ridesharing and vehicles driving closely together to decrease aerodynamic drag-could dramatically increase the adverse environmental impacts related to transportation.

2.3.1. Environmental Concerns

On the other hand, large-scale production of self-driving cars has a set of environmental concerns. The sensors, computational elements, and batteries of these cars need huge amounts of rare earth metals and other materials, which are usually not sourced sustainably (Bishop, 2020).

Besides that, the big quantity of power used by computers necessary for running complex AI models for autonomy increases the general carbon footprint of these cars. Thereby, the whole life cycle of an autonomous vehicle's manufacture through disposal-is now an important determinant of the long-term sustainability of the technology.

2.4. Labor Market Implications

Another concern is how autonomous driving will affect the labour market. Employment loss may result from autonomous cars, especially in industries like delivery services, ride-hailing, and haulage. Millions of people work as delivery, taxi, and truck drivers; many of these jobs may be at risk as autonomous driving technology becomes more widely used (Fagnant, 2015). While new jobs will be created such as software development, infrastructure management, and vehicle maintenance. It is uncertain whether new job opportunities would replace the number of lost jobs. Hence, policymakers need to take proactive planning to upskill workers ensuring their skill sets evolve with the global trends.

3. Ethical Challenges of Autonomous Decision-Making in Intermediate-Level Autonomous Cars

3.1. Why Are Ethical and Safety Challenges Crucial in Autonomous Vehicle Development?

Since humans are not hardwired like machines, humans have the nature of making last-minute decisions due to various factors related to human nature, perception, and situational awareness, which is why programming a machine that can predict human nature is challenging.

As we already know, at intermediate levels (Levels 1-3), AVs are not fully autonomous, but they can manage certain comparatively simple driving tasks such as lane keeping or adaptive cruise control.

In these situations, complex ethical challenges arise, specifically when AVs interact with pedestrians, Given the variability of human behaviour and of the critical decisions to be made within some situations.

There have been cases where restrictions in sensor technology and detection algorithms caused failures to recognize unusual objects like a pedestrian with a bicycle which raises serious safety concerns. Moreover, while Level 3 autonomous systems are dependent upon human operators to take over, when necessary, their response time could be too slow in cases of an accident; thus, giving AV manufacturers a reason to develop a more definable protocol over when an AV takes control from a human driver. Other ethical issues arise in the manner of decision-making algorithms of AVs, debating the issue of whether AV manufacturers should prioritise safety or not.

For example, an AV would stop to save a pedestrian, if this is not done well in advance to warn trailing drivers, there is a potential conflict between the protection of pedestrians and the protection of passengers. Debate about how much responsibility should be reasonably passed on to an AV compared to the human driver always exists, especially in those cases where AVs fail to recognize an object or rather fail to act in time.

Furthermore, recent studies show autonomous driving technology is safer than human drivers. For example, the recorded crash rates for any injury involving an autonomous vehicle by Waymo decreased by 85%, and 57% reduction for police-reported crashes (Autonomous Vehicle Industry Association, 2024). These findings suggest autonomous driving technology can enhance road safety significantly.

It is now known that real-world testing has also revealed the unpleasant fact that even minor programming faults can create dangerous situations. Thus, there is an urgent need for effective and comprehensive detection algorithms.

3.2. Real-World Examples

3.2.1. Uber's Self-Driving Car Fatality (2018)

One of the most widely discussed real-life scenarios involving an AV at Level 3 autonomy was Uber's self-driving car accident in Tempe, Arizona. During a night-time test run, a pedestrian, Elaine Herzberg, was struck and killed by an Uber vehicle operating in autonomous mode. (Wakabayashi, D. 2018)

The pedestrian was walking a bicycle across the road outside of a crosswalk. The Uber AV was in Level 3 autonomy, with a safety driver present, though the driver was not actively paying attention to the road prior to the time of the incident. The vehicle's sensors detected the pedestrian but failed to classify her correctly as an imminent threat, and the emergency braking system was disabled at the time of testing to prevent unpredictable behaviour. (National Transportation Safety Board (NTSB), 2019)

This incident highlighted several critical ethical issues, such as the limitations of sensor technology in detecting non-traditional objects (a pedestrian with a bicycle), as well as the decision-making algorithm's failure to act quickly. Moreover, it raised questions about the role of the human operator in Level 3 autonomy—since the safety driver was expected to intervene but was not alert enough to prevent the collision. The incident exposed the need for more robust safety features and clearer guidelines on when and how an AV should override human control to prevent harm.

Figure 2: Self-Driving Uber Car Kills Pedestrian in Arizona, Where Robots Roam, New York Times, 19 March

3.2.2. Volvo's Decision-Making Tests (2015)

In another scenario, Volvo conducted several tests for its "IntelliSafe" technology, designed to detect pedestrians and cyclists and make quick decisions to avoid accidents (The Verge, 2015; Auto Evolution, 2015). However, in one notable test, Volvo's automatic emergency braking system failed to detect a cyclist in a crosswalk during a public demonstration in the Dominican Republic. (Auto Evolution, 2015)

In this test, the vehicle was supposed to come to a stop when it detected the cyclist. However, due to a software glitch, the system did not engage the brakes, and the car continued to move forward. Thankfully, no one was harmed, but the incident clearly exposed the limitations of Level 2 systems and the ethical implications of relying on software to make life-saving decisions in real-time situations.

This test failure pointed to the difficulty of developing reliable and robust pedestrian detection algorithms. While the technology was designed to protect vulnerable road users, the test failure showed how even small programming issues could lead to dangerous situations. The incident raised ethical questions about when and how these systems should be deployed in real-world environments and how much responsibility should fall on manufacturers when these systems fail. (The Verge, 2015; Auto Evolution, 2015)

3.3. How can we interpret the main takeaways?

Considering the above real-world scenarios, we now know that decisions made by AV programming based on prioritising pedestrians, passengers, or reducing overall harm are literally the core of ethics and responsibility debates that surround AVs. Whether it is a failure in pedestrian detection, difficulties in recognizing road hazards, or the prioritisation of passenger safety over pedestrians, these incidents highlight the need for rigorous testing and transparent decision-making frameworks. As the technology continues to evolve, addressing these ethical challenges will be crucial to ensuring the safe and fair deployment of autonomous vehicles in society.

4. Ethical Risks and Opportunities

4.1. Questions around Liability

Accidents and other incidents involving fully autonomous vehicles raise important liability questions. An example of such an incident occurred in 2018 in Tempe, Arizona, where an autonomous vehicle caused an accident, killing a pedestrian, Elaine Herzberg (DeArman, 2019). It was established that the vehicle's emergency brake system was disabled to reduce erratic behaviour, placing full responsibility on the vehicle's 'safety driver' to intervene. However, the 'safety driver' was distracted, and thus, this caused an accident, resulting in death.

This incident raises complex questions of liability across multiple parties, including the operator, Uber as the owner, and the manufacturer. It illustrates the need to define a clear liability framework for fully autonomous vehicles involved in accidents through appropriate regulations.

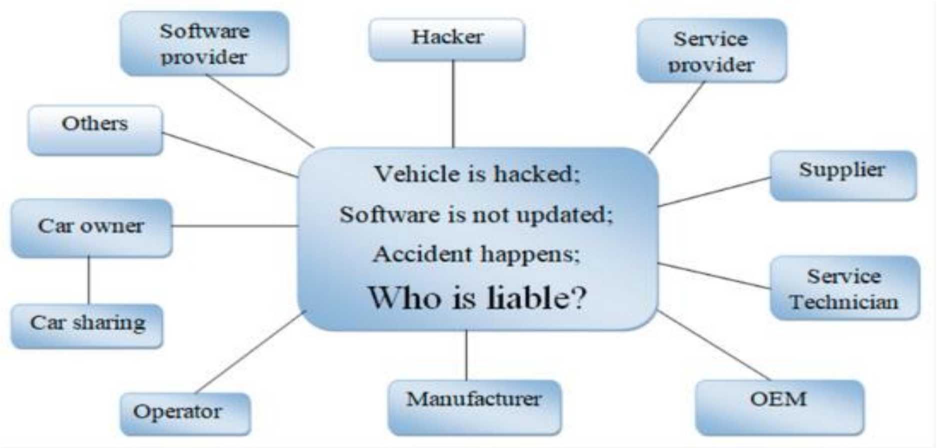


Figure 3: Complexity of liability in autonomous vehicle incidents involving various stakeholders (Uzair, 2021).

4.2. Cybersecurity and Data Privacy

Cybersecurity and data privacy are critical ethical considerations for fully autonomous vehicles. Yan, Xu and Liu (2016) investigated the real-life cybersecurity vulnerabilities of autonomous vehicles, focusing on sensor systems that play a crucial role in their decision-making and navigation.

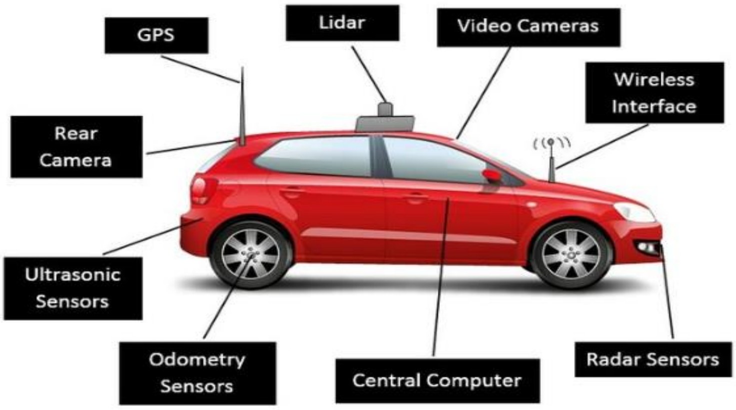


Figure 4: Key sensors and data systems in a fully autonomous vehicle, necessary for data collection and processing (El Hamdani & Benamar, 2018).

Their findings showed that contactless attacks targeting sensor systems on the Tesla Model S resulted in malfunctions such as missed obstacles, the display of false readings, and "blindness," leading to potential collisions (Yan et al., 2016). These findings highlight a significant ethical challenge for the future if level 5 autonomous vehicles cannot ensure robust security against hacking.

4.3. Bias and Discrimination

Algorithmic bias is a significant ethical issue for fully autonomous vehicles, mainly due to biased and discriminatory training data. Wu (2023) reports in a literature review that object detection systems in autonomous vehicles show reduced accuracy in identifying darker-skinned pedestrians compared to lighter-skinned ones. This finding implies that people of colour have a greater risk of accidents involving autonomous vehicles.

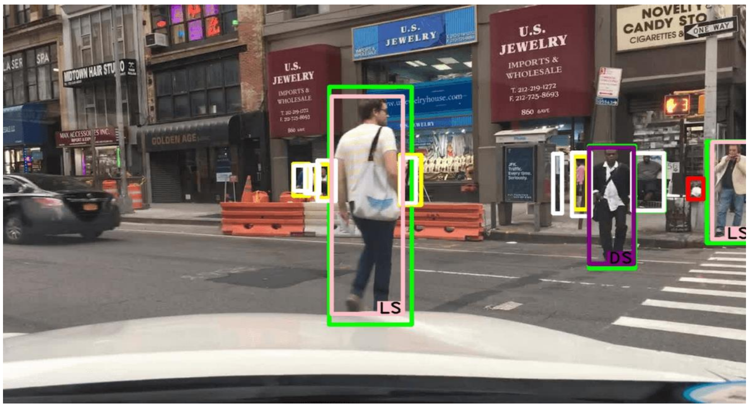


Figure 5: Autonomous vehicle recognition systems may struggle to detect pedestrians with darker skin tones accurately, highlighting safety concerns related to bias in object detection (DeepLearning.AI, 2023).

Moreover, autonomous vehicles have shown regional disparity manifesting as performance differences between rural and urban areas. RAND research revealed that autonomous vehicle systems generally perform more effectively in urban areas compared to rural ones due to variations in road markings and GPS coverage (Fraade-Blanar et al., 2018). These findings underline the need for a more inclusive and representative development environment and data to enhance autonomous vehicle performance across diverse settings.

4.4. Benefits of Autonomous Vehicles

4.4.1. Reduction in Accidents

Human errors such as speeding, inattention, and risky driving behaviour are some of the biggest causes of accidents and fatalities on the roads. Tippannavar and Yashwanth (2023) highlight that one of the critical benefits of Level 5 autonomous vehicles is their potential to significantly reduce these incidents.

In simulations conducted by Waymo, researchers found that fully autonomous vehicles could have prevented most crashes typically caused by human error (Schwall et al., 2020). Their data, collected from 6.1 million miles of automated driving, showed that autonomous vehicles avoided a wide range of common accident types, including severe incidents like driving on the wrong side of the road, failing to yield, and speeding. These errors were primarily attributed to other road users rather than the autonomous vehicles themselves (Schwall et al., 2020). As autonomous technology becomes more widely adopted, these findings suggest a potential reduction in accidents, which could also bring significant economic savings.

4.4.2. Improved Travel Experience

Fully autonomous vehicles hold the potential to enhance passengers' travel experiences. A study was conducted, which examined various aspects of travel experience metrics, explicitly focusing on self-driving shuttle buses. The results indicate that autonomous driving can deliver a smoother travel experience by maintaining controlled acceleration between 0.9 and 1.47 m/s^2 and limiting sudden changes in motion (jerk) to 0.3–0.9 m/s^3 (Bae et al., 2019).

Additionally, optimised velocity planning in autonomous vehicles helps minimise abrupt changes in speed and direction, particularly during turns, by accounting for factors like path curvature and dynamic stability. This approach ensures a consistent, comfortable speed throughout the journey (Bae et al., 2019). These enhancements in speed control and motion provide a more comfortable travel experience compared to traditional rule-based driving systems.

4.4.3. Reduced fuel Consumption and Emission

Research evidence suggests that autonomous vehicles can drive more efficiently, resulting in reduced fuel consumption. Existing research suggests that the fuel efficiency of autonomous driving is achieved mainly through optimised driving patterns and smoother traffic flows. In a simulation using data from SUMO, Li et al. (2023) found that fully autonomous vehicles demonstrated a potential fuel saving of up to 18%. Although fuel consumption may increase due to communication and surveillance systems necessary for level 5 autonomous vehicles, this is expected to decrease as vehicle-to-vehicle technology adoption grows (Geary & Danks, 2019).

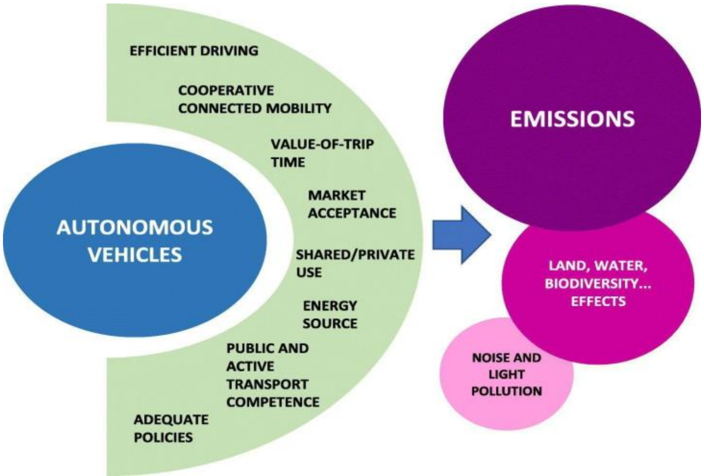


Figure 6: Factors influencing the environmental impact of autonomous vehicles, highlighting the connection between efficient driving, market acceptance, and emissions.

Beyond fuel savings, reduced fuel consumption contributes to lower emission rates. If self-driving cars are electrified, total greenhouse gas emissions could be reduced by over 80% compared to fossil fuel-based vehicles (Geary & Danks, 2019). The findings suggest reduced financial and environmental costs of autonomous vehicles, especially compared to fossil fuel-based conventional vehicles.

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This study was found to be essential for defining clear, industry-wide standards on autonomous driving levels, widely adopted by regulators and automotive manufacturers for consistency. It also provides technical definitions that prevent misunderstandings about automation levels. However, it doesn’t account for rapid technological advancements or specific real-world scenarios, sometimes limiting its adaptability to complex driving environments. Additionally, SAE classifications focus solely on automation, not addressing ethical or regulatory topics.

Wakabayashi, D. (2018). "Self-Driving Uber Car Kills Pedestrian in Arizona, Where Robots Roam." *The New York Times*. Retrieved from https://www.nytimes.com/2018/03/19/technology/uber-driverless-fatality.html

Wakabayashi's article examines the fatal accident involving an autonomous Uber vehicle that killed a pedestrian in Tempe, Arizona, shedding light on safety concerns surrounding self-driving technology. It discusses the response from law enforcement, Uber, and the broader autonomous vehicle industry, while highlighting Arizona's lenient regulatory stance, which has made it a popular location for autonomous testing. The article underscores critical issues around public safety, ethical considerations, and regulatory gaps in the rapidly evolving field of autonomous driving.

DeepLearning.AI (2023) Autonomous vehicle recognition systems struggling to accurately detect pedestrians with darker skin tones, raising safety concerns about bias in object detection. Available at: https://www.deeplearning.ai/the-batch/children-and-people-with-darker-skin-face-higher-street-risks-with-object-detectors-research-finds/

This article from DeepLearning.AI highlights a critical issue in autonomous vehicle safety: bias in object detection systems, which have been shown to struggle with accurately recognizing pedestrians with darker skin tones. The findings underscore significant ethical concerns, as these detection inaccuracies may lead to higher safety risks for specific demographic groups. By examining these biases, the article calls attention to the need for greater inclusivity and rigorous testing in AI development to ensure equitable safety standards across all populations.

Autonomous Vehicle Industry Association (2024). "Waymo reduces crash rates compared to human drivers over 7+ million AV miles." *The AV Industry*. Available at: https://theavindustry.org/resources/blog/waymo-reduces-crash-rates-compared-to-human-drivers

This source reports on the safety performance of Waymo's autonomous vehicles, which have been shown to have lower crash rates compared to human drivers over millions of miles. The article provides recent data, making it a relevant resource for studies focused on the safety efficacy of AV technology. By comparing AV crash rates directly with those of human drivers, it sheds light on the potential for autonomous vehicles to enhance road safety and reduce accidents. The analysis serves as critical evidence in support of AV deployment, helping researchers and policymakers assess the risks and benefits of widespread AV adoption.

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