



# LEGAL AND ETHICAL FRAMEWORKS FOR AI-DRIVEN AUTONOMOUS VEHICLES: NAVIGATING LIABILITY, SAFETY, AND REGULATORY CHALLENGES

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## ABSTRACT

*This study analyses the intricate legal and ethical environment related to the creation and use of AI-powered autonomous vehicles (AVs). With the growing presence of autonomous vehicles (AVs) on public roads, regulators, manufacturers, and society as a whole have unique difficulties in creating suitable systems to regulate their use. The article provides a perceptive synopsis of the complicated legal problems raised by the widespread use of automation and artificial intelligence (AI). This thorough analysis tackles problems at the nexus between technology and law, delving into the many facets of the changing legal scene. The responsibility and liability structures for self-governing AI systems, moral issues in the use of intelligent devices, and the complex nature of confidentiality of information in the era of widespread automation are some of the main areas of focus.*



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## 1. INTRODUCTION

The legal discussion has focused on responsibility and liability due to the fast transformation of technology, particularly with the emergence of independent AI systems. The article examines the complex difficulties of establishing responsibility for autonomous AI systems, investigates the developing legal criteria for responsibility, and addresses the wider consequences for legal systems and jurisdictions in which we get around

the unknown areas of machine learning (Mallinson, Azevedo, Best, Robles, & Wang, 2024). The implementation of self-governing artificial intelligence (AI) systems presents several difficulties in determining responsibility.

Conventional frameworks of accountability, which often rely on human action, have challenges when applied to cases in which computers make choices with little human involvement (Akpuokwe, Adeniyi, Bakare, & Eneh, 2024). The lack of transparency in AI decisions, often

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known as the "black box" issue, hinders the capacity to attribute culpability to a single entity. Autonomous artificial intelligence (AI) systems, especially those driven by intricate machine learning computations, may display behaviors that are difficult to anticipate or comprehend. Deciphering the complex network of mechanisms engaged in an AI system's decision-making or actions may be a challenging endeavor, making it hard to determine who should be held responsible (Nadeem, 2024). When AI functions autonomously, without continuous human supervision, the conventional framework of human responsibility encounters constraints. Assigning liability for errors or unwanted behavior of an AI system poses a challenging legal conundrum (Katiyar, Shukla, & Chawla, 2024). Legal institutions are adapting to address the distinct difficulties presented by autonomous AI systems, with the aim of establishing fresh benchmarks for liability. The goal is to achieve a harmonious equilibrium between promoting innovation and establishing responsibility for the outcomes of AI-powered activities (Saleh & Ahmed, 2024). Certain legal countries are now investigating the idea of strict liability, which means that they are considering making organizations accountable for the consequences of artificial intelligence systems they implement, regardless of whether or not they are at fault (Joy et al., 2022). There is a consideration of implementing no-fault insurance systems, which pay payment despite the need of proving negligence, in order to simplify the transparency procedures. During the past few years, lot of search and research is done on self-driving cars (Biswas & Wang, 2023; Zhang et al., 2023).

Based to a new Intel analysis, fully autonomous cars would cut on-road driving by about 250 million hours and save nearly 585,000 deaths annually in the US from 2035 and 2045. Although these benefits undoubtedly increase the usage of autonomous automobiles, a widespread public worry regarding the potential hazards of this advancement in technology. Recent mishaps with autonomous or semi-autonomous automobiles have raised concerns (Lim & Taeihagh, 2019). These accidents were caused by incorrect usage of partially autonomous features. This major problem hinders the acceptance of self-driving cars among highway travelers and the public as a whole. Autonomous cars rely on AI for real-time decision-making, hence malfunctions in the vehicle's intelligent control unit are often the primary cause of catastrophes. Autonomous driving AI systems must be "explainable," making real-time judgements that remain strong and secure, especially in crucial traffic situations, as required by both road users and controllers. Clarity should not only give insight into personal failures, but also guide public transit adherence to rules. Authorities have set security and compliance guidelines for smart bus systems, emphasizing the right to understanding. We are creating an environment to enhance the security and regulatory conformity of autonomous cars and increase public confidence and acceptance.

## **2. A LOOK AT CUTTING-EDGE AUTONOMOUS DRIVING TECHNOLOGIES**

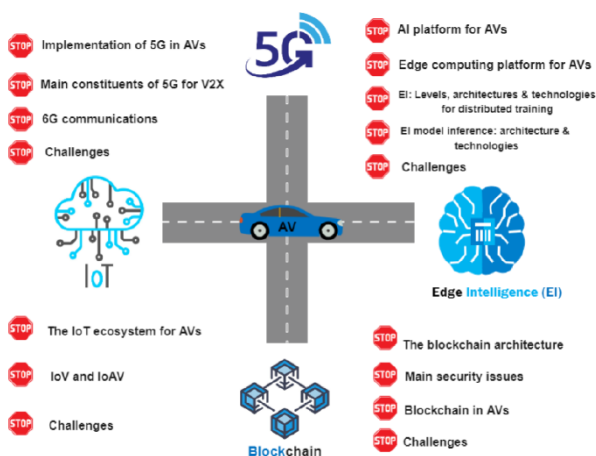
Fuzzy Intelligent transportation systems (ITSs) are platforms which combine a variety of technologies for automation, gadgets, controls, and communications to improve transport security and effectiveness while also being less costly to run and ecologically conscious. Among the numerous scopes of ITSs, roadway surface transport is extensively emphasised, with autonomous vehicles (AVs) playing the most important role. AVs include a broad variety of technology related to gadgets, driving dynamics, connectivity, along management, detecting, and a thorough understanding of human behavioural inclinations on the road. We are finally prepared to join the AV age after years of ongoing study, fuelled by a sudden surge in spending by technical behemoths throughout the globe. With the IoT, edge information, and fresh developments in smart contracts based on blockchain and networks of vehicles, AVs are going to be fitted with an array of desirable characteristics such as self-verification, self-execution, consistency, accuracy of data, and privacy to meet the needs of everyone. As it poses the ability to tackle financial and ecological constraints, decrease rush hour traffic and incidents, and cut emissions, AVs are being viewed as the greatest feasible answer of all.

By minimising the participation among human drivers, AVs might reduce fatalities that result from human mistakes like as racing and inattentive driving owing to the effects of alcohol or other drugs, which is responsible for an astounding 93% of all collisions. Based on research, partly automatic systems with features like front collision mitigation, lane departure alerts, and side view assistance, amongst others, may prevent accidents and minimise harm and fatalities by up to 33%! Among a slew of benefits, involving energy savings, enhanced management of fleets, a superior travelling expertise, and enhanced roadways, AVs may additionally enhance mobility for disabled individuals as well as those who are young or elderly to drive, allowing these individuals to expand their freedom while strengthening the lives. Yet, they are still a long way off owing to a number of technical limitations, as well as trust and safety concerns that are being thoroughly explored. With ongoing testing of AVs by technology heavyweights, a modern quantitative perspective is still absent (Lim & Taeihagh, 2019). More insights are needed to make AVs a safer and more trusted alternative for consumers, allowing them to be commercialised sooner. Vehicles that are autonomous are no more a pipe dream, with some existing examples built by Tesla, Google, and its competitors including self-driving capabilities. The IoT has served as a driving factor in the realisation of this ambition. The Internet of Vehicles (IoV), derived from IoT shortly to be renamed the Internet of Autonomous Vehicles (IoAV), is expected to change an automobile to a smart device that works in cooperation along its neighbours in may phases (Biswas

& Wang, 2023)., assisting and eventually regulate from human motorists very soon. The demand is to join a large linked network and become 'smarter' as a result of rapid advances in IoT, the data traffic generated by their conversations grows tremendously. With so much data floating about in many clouds, we can't anticipate low latency, fast reaction times, or high quality of service (QoS). The growth in AI has pushed our fantasy of totally autonomous automobiles on the road closer to reality. Because AI is required to analyse massive amounts of content, merging AI with computing at the edge has been viewed as an achievable option, resulting in edge intelligence (EI). It is by far a very complicated fusion of many technologies and notions. This encompasses, however isn't restricted to, intelligence offload, intelligence cooperation, and analysing data (where it originated) rather than in the cloud, using in a future. To attain total independence over vehicle operation, the automobile must match or even outperform our vision, involved in choices, and intellect, that may be accomplished by better computational techniques (Giannaros et al., 2023). V2X, is complementing technology that provides the vehicle with 360-degree consciousness of the environment, will benefit from the introduction of 5th and 6th generation wireless techniques. The AV infrastructure's different nature renders it susceptible to security and privacy assaults, which might threaten the safety of travellers and passengers. Blockchain, with its data openness, immutability, and decentralised approach, has surpassed conventional centralised security solutions as the ideal alternative for providing the much-needed security layer to AVs. As a result, enhancing and integrating the technologies mentioned above into a strong system will make our long-awaited AV vision come true. **Figure 1** displays the four technologies that allow for autonomous cars.

discusses weak AI, which is described as "specific activities requiring single human abilities, e.g., seeing, comprehending setting, probabilistic logic, and navigating intricacy". Strong AI refers to "a system with human or super intellect" that can conduct human cognitive processes such as ethical decisions, "figurative logic," and "overseeing sociological dilemmas". AI may be thought of in two ways: first, as standard computer programmes that use rule-based techniques to categorise information, and second, as a system capable of solving issues utilising a high-level thinking amid unpredictability, as well as learning from understanding. The technology in the other sense employs ML techniques that not only analyse data using "static mathematical models" in addition to gain insight from previous data to make upcoming judgements (Garikapati & Shetiya, 2024). These learn by analysing knowledge, usually by applying parameters to distinct input variables based on the recent relevance in producing outputs. The inner applied parameters are further improved with a fresh set of data to guarantee precision in forecasting, using different algorithms selecting the framework that best correlates by the actual function through decreasing errors in predictions based on established priorities and criteria for decision making (Illiashenko, Kharchenko, Babeshko, Fesenko, & Di Giandomenico, 2023).

Algorithms are included into both the hardware and software of autonomous vehicles (A. Bale, 2024). The AV's components consist of sensing parts to collect parameters in the surroundings, technology for the interaction within the system for sharing data to the cars and facilities (e.g., directing pedal, braking systems, simulations) that carry out the AV's motions (A. Kumar & Kumar, 2024). These physical components work with the AV's programmes, which includes thinking, or preparation, and monitoring (Agapiou, 2024). This works with the acquisition of sensors as well as information from the surrounding atmosphere by this system using all the available components. Considering choices allows it to complete its targets via handles that include goal planning, that requires making choices to allow "a high-level goals" like as choosing that path to follow, behavioural organising, which involves creating "local objectives" like as moving paths and passing, and motion (or local) organising, that generates the actions needed to accomplish local plans, like as accomplishing an assigned location, wherein computer programmes execute choices The secure utilisation of AVs relies on the appropriate performance of mechanisms in all software and hardware subsystems (Reddy & Tiwari, 2020).



**Figure 1.** Supporting technology for autonomous cars (Biswas & Wang, 2023).

### 3. LEGAL ISSUES

Algorithms are the decision-making machinery of AI, which was created to emulate human intellect. The work

As autonomous cars eventually assume over steering part, the legislation should change its program and execution (Garg, Kaur, & Goyal, 2024). International standards are used to ensure that individuals have the safest and most enjoyable travel experiences possible. As a result, autonomous cars must demonstrate that they

meet the required safety standards (Abbasi & Rahmani, 2023). Current study in the United States and Europe is focusing on this. Legal problems are among the most pressing concerns confronting AVs, including a wide range of public regulations, traffic rules, conventional car technical requirements. The usage of the word "autonomous" here in automobiles has many a times been misinterpreted since "autonomy" has larger philosophical implications, as opposed to the technological one, which merely indicates that it may operate independently of human interference while driving (Bekbolatova, Mayer, Ong, & Toma, 2024). Many nations' road traffic conventions nevertheless demand that the driver should be available must sometimes be ready to exercise command for automobile. It establishes a structure for semi-autonomous cars, although completely self-driving cars are still exempt, since they must demonstrate that they are safer than or equivalent to their predecessors. When confronted with unanticipated traffic conditions that need complicated decisions to be made in just a few seconds, human beings aren't expected to respond ideally can be pardoned to do poor choices. Yet, for AVs, who can analyse the probable effects of many alternatives and doing appropriate measures in milliseconds, erroneous choice-making constitutes a source of intense discussion and regulation. The AV should follow the accepted rules. For example, various factors influence if the motorist is willing to risk themselves to rescue others (Kumar, 2021). According to many research, people coding an AV are more likely to risk vehicle passengers than pedestrians when opposed to people driving a simulation device. A lot of emerging proof exists of a disconnect amidst ethical consideration judgements and moral behaviour (Zaman, 2024). Whatever is deemed acceptable for driving personal who are humans could vary for self-driving vehicles, and ethical judgements may differ depending on how the issue is presented. Is it acceptable if, as a result of AVs, fewer persons are hurt, yet pedestrians are most prone to injury than car passengers? As a result, the adoption of these may result in individuals having more at danger than the existing scenario (Wolniak & Stecula, 2024).

Bias in a system refers to the presence of deliberate or unintentional features that unjustly discriminate against certain persons or groups in society (A. S. Bale et al., 2022). In the context of American legislation against discrimination, discrimination is defined as either disparate treatment, which refers to the deliberate prejudice or the application of different laws to individuals based on their group membership, and/or unequal effect, which refers to the unequal outcomes experienced by various groups (Hagos & Rawat, 2022). AVs may be affected by bias when human designers create data sets, designs, and algorithm settings, which can result in unfair or discriminatory distribution of safety hazards (Sudhir, Tiwari, Khatokar, Vinay, & Mohan M S, 2021). Proper instructions to an AV utilising data only from one nation may lead to the AV acquiring knowledge of certain patterns that are exclusive to that

country, and therefore not correctly representing the mental state of driver that are applicable for many scenarios. Hence, the presence of an insufficient or excessive number of specific categories in the data might result in erroneous categorizations and prejudiced results (Khatokar, 2021). Furthermore, if the algorithm incorporates sensitive input variables, it has the potential to exhibit bias in relation to legal and moral norms. The algorithms of autonomous vehicles (AVs) can penalize or advantage certain individual-specific features, like sex and age, based on pre-defined tastes (Vinay et al., 2022). For example, the algorithms may prioritise the security of children or aim to minimise overall harm. However, this can result in allocating greater dangers to people who share the penalised defining features. These biases can be either subconsciously or purposely generated by algorithm commonly producers and AV vendors, often with the goal of maximising profit margins. But the absence of legal mechanisms which hold these interested parties accountable further exacerbates this issue.

Reducing bias in computers is essential to minimise discriminating results caused by autonomous vehicles (AVs). In the field of self-driving experts have proposed several methods to identify and counteract bias (Chamola et al., 2023). These methods include adjusting computational outputs to equalise the impact of bias on different groups, making minimal changes to eliminate bias from the data, involving people from categories that may face discrimination, conducting tests to evaluate injustice and to recognise changed user groups, and developing algorithms that can verify the nonexistence of data bias. In addition to bias that arises from data and the choosing of parameters and criteria, Researchers suggest that ethical principles, such as fairness, should be clarified in order to assess prejudice. In addition, experts suggest that accountability should be enhanced to detect biases. This can be achieved by developing methods that allow for the tracing of original input parameters all through the entire system (i.e., accountability). In addition, reviewing algorithms to improve their comprehension is recommended, as this enables the detection of biases and verification of what the system returns in opposition to safety standards.

Nevertheless, there are difficulties in detecting partiality in algorithms and discerning their prejudiced consequences. Initially, several algorithms are intentionally created to possess a high level of complexity in order to achieve enhanced accuracy. However, this complexity also results in the algorithm being obscure and challenging to grasp, even for the creators themselves. Consequently, the algorithm conceals the origins of bias. Additionally, as machine learning algorithms primarily rely on training data that is subject to alter as time passes, it becomes difficult to anticipate such discriminating consequences beforehand. Humans tend to trust algorithms too much and fail to question their decisions because they believe algorithms are unbiased and fair. This is known as "automation

bias." Furthermore, computers learn almost objective patterns from data, making it challenging to prove intent to discriminate in computer programmes from a legal standpoint. A growing concern arises when autonomous vehicles (AVs) with identical inclinations are used on a broad scale, since this might lead to the accumulation of biased outcomes. This process would result in the concentration and duplication of computational choices, together with their individual biased conclusions about risk allocation. This may result in some groups of individuals constantly being assigned a higher level of safety hazards, therefore perpetuating persistent discrimination. This prejudice is harder to identify since it arises from the accumulation of comparable driving effects.

The measures implemented to address different types of bias and prejudice will not be exclusive to autonomous vehicles (AVs). These measures include the publication of voluntary AI standards, enhancements in the development and checking of algorithm in domains. The governments of Japan and Singapore have issued independent standards for AI that prioritise the ability to explain and verification of AI-driven decisions, equality to address discrimination, openness through disclosure of data, and open avenues for interaction among stakeholders and consumers throughout the value-chain. Singapore's recommendations propose internal governance practices to enhance the responsibility of organisations that use AI and to address algorithmic discrimination. These practices include implementing new procedures for oversight and clarifying duty and procedures related to responsibility in operation administration and system creation. Furthermore, the South Korean government is actively working towards enhancing its ability to identify data bias, rectify software flaws, and evaluate ethical standards throughout the entire process of AI development. Similarly, the UK government plans to join forces with the Alan Turing Institute to cultivate AI expertise and create auditing tools to address and minimise "social inequalities" arising from predictive decision-making. Finally, the European Union (EU) enacted the General Data Protection Regulation (GDPR), which forbids any automated decision-making process that employs critical personal information and has a significant impact on individuals inside the EU. The General Data Protection Regulation (GDPR) includes a provision called the right to explanation. This provision is designed to enhance the understandability and openness of automated judgements. It requires companies to provide individuals with "significant information about the reasoning used" in a manner that is clear, comprehensible, and readily available (Purohit, Hashim, & Navale, 2022).

### **3.1. Ethics**

Ethics play a significant role in many driving situations, since they entail the distribution of risks among several individuals in the event of accidents, as well as in typical

situation in driving, including, determining the right space to maintain between a close car. Given that the danger allocation choices made by autonomous vehicles (AVs) are subject to evaluation based on both roadway regulations and moral standards, it is emphasised by scholars that AVs should adhere to ethical rules. These ethical rules encompass various ethical theories, rules, standards, and values that can be incorporated into the decision-making process of AVs. Multiple approaches have been put forth for codifying and design these ethical rules in AVs (Lobel, 2023).

Efforts to establish ethical guidelines for autonomous vehicles (AVs) have focused on the application of ethical challenges in hypothetical scenarios. An ethical dilemma refers to a scenario in which it is not feasible to choose between several options without violating a moral norm. The tram dilemma is a well-known thought experiment that may be shown by a hypothetical scenario. In this scenario, an autonomous vehicle (AV) has malfunctioning brakes and is faced with a choice: either continue on its present course and collide with five people, or swerve and collide with one person. Trolley problems, although useful are based on unrealistic assumptions about driving scenarios. These assumptions include the assumption of complete certainty in outcomes and the assumption that the passenger can determine how harm is distributed. Furthermore, trolley problems are vulnerable to inconsistencies in ethical reasoning among participants and fail to consider the potential. Decision-maker, the urgency of the choice, and the limitation of factors to be taken into account.

In addition to thought experiments, there have been two main technological techniques suggested for incorporating ethical standards into the algorithms of autonomous vehicles (AVs). The "top-down" approach entails the mapping of ethical theories, such as utilitarianism and deontology, to computational requirements and programming them into the algorithm. However, programming each ethical theory comes with its own limitations and issues that can compromise the safety of autonomous vehicles and contribute to the perpetuation of discrimination (Weldon, Narine, & Thomas, 2024).

Utilitarianism prioritises the ethical evaluation of results and, in the case of autonomous vehicles (AVs), involves designing methods in reducing the overall amounts of problems caused by accidents. However, this approach may include indifferences and difficulties, which may lead to new safe hazards. Various algorithms used aims to calculate every potential result, alternate courses of action, and their corresponding effects, with the goal of minimising a cost function that represents the projected overall amount of damage. Utilitarian algorithms, which aim to reduce overall pain rather than individual harm, do not take into account equity or justice. They may even employ incorrect qualities as criteria for decision-making, resulting in biased risk allocation judgements.

Furthermore, the implementation of utilitarian ethics in autonomous vehicles can give rise to safety risks due to technical challenges. These challenges include the possibility of wrong data and lot of time for operation, which can hinder the vehicle's capabilities to quickly calculate all potential actions.

Deontology, in contrast, prioritises acts driven by a fundamental respect for all people. This may be achieved in autonomous vehicles (AVs) in a hierarchical fashion. However, this approach presents additional obstacles that may result in new safety risks for AVs. However, the methods can be compelled to follow less than ideal formalities in order to follow these pacts. For instance, it may instruct the autonomous vehicle to stop when there is a conflict or when the rules cannot be fulfilled. This poses safety hazards for other drivers and limits the capacity of autonomous vehicles to adapt to new situations, unlike algorithms that prioritise utility and can readily modify probabilities and magnitudes of outcomes to improve decision-making. Furthermore, it is important to note that deontological norms may not include all driving circumstances (Zheng, 2023). Additionally, route dependencies might emerge if the autonomous vehicle is educated on a specific sequence of scenarios. Furthermore, several deontological concepts are included into the legal uncertainties of current traffic rules, which cannot be clearly captured in algorithms. This includes variations in the meanings of terms like "obstruction" or "safe" in various situations. Scholars have proposed merging utilitarianism and deontology to expand the autonomous vehicle's understanding of the situation and aid in decision-making. This combination has proven effective in practical applications. It supports the principle of serving individuals in the order they arrive, while utilitarian ethics justifies giving importance to major following users (Talamini, Bartoli, De Lorenzo, & Medvet, 2020).

The problems may be counterbalanced by the bottom-up approach, in which the model creates by itself followed by learning from previous driving experiences and human judgements that are considered morally right. However, this approach can also introduce safety risks to autonomous vehicles due to various implementation challenges, the possibility of the system overriding pre-programmed limitations, and increased opacity in decision-making (Familoni, 2024). An example of the bottom-up method is a greedy-search algorithm that iteratively seeks the best ethical solution based on human moral ideals. Some scholars contend that a decision-making system that starts from the bottom and moves upwards has the potential to be more ethical than that of an individual person. This is because it can eliminate the specific errors made by individuals and uncover new ethical principles that have not yet been identified (Khalifa & Al-Khalifa, 2024). Nevertheless, it is challenging to precisely define the overarching objectives of a self-learning system and to encourage the system to broaden the range of available options to

choose from. Furthermore, self-learning systems have the capability to momentarily alter their objectives as a means of acquiring knowledge (Mamta, 2024). This implies that an autonomous vehicle (AV) has the capacity to exhibit immoral conduct in order to learn from such instances and then make more ethical choices in the future (Dhabu, 2024). Furthermore, the bottom-up method might enhance the system's opacity by obscuring the underlying logic of the algorithm's self-generated rules. This exacerbates the difficulty of detecting bias, morally dubious rules, and mistakes (Sudhir et al., 2024).

In 2017, Germany's government published the world's first ethical guidelines for autonomous vehicles (AVs). The rules emphasise the importance of prioritising human life above all else, reflecting deontological principles (Celsi, 2023). Yet, if personal features are excluded, it may weaken the algorithm's capacity to reduce harm in unavoidable incidents, and it remains uncertain how these two opposing objectives may be harmonised (Jain et al., 2021). The rules also state that judgements in unavoidable accidents should not be pre-programmed and that an impartial organisation should thoroughly analyse the lessons learnt from these disasters (Rajani, Taj, Agnes, Amala, & Lal, 2024). Finally, the rules emphasise the need for transparency in the programming of autonomous vehicles (AVs) and the development of standards for "self-learning" processes. These processes should not be used for "safety-critical functions" unless they meet safety criteria.

#### **4. DISCUSSION**

The improvement of AI-driven autonomous vehicles (AVs) has ushered in a new age of transportation posing a lot of complex arrays of legal, ethical, and technological challenges. As these vehicles are increasing more and more on public roads, there is a fast-increasing need for robust regulatory frameworks and governing ethical guidelines. By integrating AVs with transportation systems there is a paradigm shift that requires careful consideration of various concepts like safety and liability to algorithmic decision-making and in turn impact on the society. There are a lot problems in the development of AVs. There are legal issues also related with these developments. So, there is a need for laying an adaptive legislation which will help in removing the problem of safety standards, and using the traditional values of drivers in AVs. It becomes important to understand who will take care of these event when there is an accident to an AV. It is important to understand the job of software developer, the owner of the vehicle should be considered according to the legal way. To implement the AV models after the consideration of ethical issues, it requires to answer the philosophical questions. This is true for situations where getting harm is most certain. Even though AI and ML have shown advancement wrt AV, there are many more unseen challenges. There can be a lot of discrimination against vital groups if the AV decision making models are not designed and tested

properly. For e.g., the Balck Box issue posing challenges in transparency and accountability. AVs can be protected from hacking and interferences by having a strong cybersecurity model. All these challenges pose a need for new research ideas in the field of AI and security. In order for the AV technology to get accepted by public is crucial, this requires demonstration of safety records above human intervention and also transparent communication because the public view plays vital role in integration of AV in day-to-day life. Education, media and other techniques help in improving the above without posing much loss in AV technology. The governing rules and guidelines for AV vary from country to country. Various jurisdictions have incorporated the guidelines locally, whereas others are in the process of framing strict

legal frameworks. In order to standardize AV development and deployment globally keeping in mind safety and standards, best practices with security have to be put in action. In a broad view, to improve research in the area of AV, more sophisticated and aligned AI-systems are needed, along with improved methods for testing and verifying AV safety. In the long run interdisciplinary collaboration between various stakeholders is essential in order to address the different views posed by AVs in order for the technology to have good impact over worldwide acceptance. It is observed that for an AV integration to be successful in the domain of transportation, it is very much necessary to involve the multidisciplinary approach so that the innovation will have proper process and the ethics are always considered.

## References:

- Abbasi, S., & Rahmani, A. M. (2023). Artificial intelligence and software modeling approaches in autonomous vehicles for safety management: A systematic review. *Information, 14*(2), 112.
- Agapiou, A. (2024). A systematic review of the socio-legal dimensions of responsible AI and its role in improving health and safety in construction. *Buildings, 14*(5), 1469. <https://doi.org/10.3390/buildings14051469>
- Akpuokwe, C. U., Adeniyi, A. O., Bakare, S. S., & Eneh, N. E. (2024). Legal challenges of artificial intelligence and robotics: A comprehensive review. *Computer Science & IT Research Journal, 5*(3), 544–561. <https://doi.org/10.51594/csitrj.v5i3.860>
- Bale, A. (2024). The impact of generative content on individuals' privacy and ethical concerns. *International Journal of Intelligent Systems and Applications in Engineering, 12*(4), 697–703.
- Bale, A. S., SaravanaKumar, S., Varun Yogi, S., Vura, S., Baby Chithra, R., Vinay, N., & Pravesh, P. (2022). Network and security leveraging IoT and image processing: A quantum leap forward. In *System assurances* (pp. 123–141). Elsevier.
- Bekbolatova, M., Mayer, J., Ong, C. W., & Toma, M. (2024). Transformative potential of AI in healthcare: Definitions, applications, and navigating the ethical landscape and public perspectives. *Healthcare, 12*(2), 125. <https://doi.org/10.3390/healthcare12020125>
- Biswas, A., & Wang, H.-C. (2023). Autonomous vehicles enabled by the integration of IoT, edge intelligence, 5G, and blockchain. *Sensors, 23*(4), 1963. <https://doi.org/10.3390/s23041963>
- Celsi, R. (2023). The dilemma of rapid AI advancements: Striking a balance between innovation and regulation by pursuing risk-aware value creation. *Information, 14*(12), 652.
- Chamola, V., Hassija, V., Sulthana, A. R., Ghosh, D., Dhingra, D., & Sikdar, B. (2023). A review of trustworthy and explainable artificial intelligence (XAI). *IEEE Access, 11*, 78994–79015. <https://doi.org/10.1109/access.2023.3294569>
- Dhabu, A. (2024). Legal implications of artificial intelligence in cross-border transactions. *International Journal of Law and Management, 66*(4), 123–145.
- Familoni, B. (2024). Cybersecurity challenges in the age of AI: Theoretical approaches and practical solutions. *Computer Science & IT Research Journal, 5*(4), 703–724.
- Garg, T., Kaur, G., & Goyal, R. (2024). Robustness and resilience of artificial intelligence-enabled electric vehicles: A safety and security perspective. In *Artificial intelligence-empowered modern electric vehicles in smart grid systems* (pp. 59–80). Elsevier.
- Garikapati, D., & Shetiya, S. S. (2024a). Autonomous vehicles: Evolution of artificial intelligence and learning algorithms. *arXiv*. <http://arxiv.org/abs/2402.17690>
- Garikapati, D., & Shetiya, S. S. (2024b). Autonomous vehicles: Evolution of artificial intelligence and the current industry landscape. *Big Data and Cognitive Computing, 8*(8), 90.
- Giannaros, A., Karras, A., Theodorakopoulos, L., Karras, C., Kranias, P., Schizas, N., ... Tsoilis, D. (2023). Autonomous vehicles: Sophisticated attacks, safety issues, challenges, open topics, blockchain, and future directions. *Journal of Cybersecurity and Privacy, 3*(3), 493–543. <https://doi.org/10.3390/jcp3030025>
- Hagos, D. H., & Rawat, D. B. (2022). Recent advances in artificial intelligence and tactical autonomy: Current status, challenges, and perspectives. *Sensors, 22*(24), 9916. <https://doi.org/10.3390/s22249916>

- Illiashenko, O., Kharchenko, V., Babeshko, I., Fesenko, H., & Di Giandomenico, F. (2023). Security-informed safety analysis of autonomous transport systems considering AI-powered cyberattacks and protection. *Entropy*, 25(8), 1123. <https://doi.org/10.3390/e25081123>
- Jain, S., Ahuja, N. J., Srikanth, P., Bhadane, K. V., Nagaiah, B., Kumar, A., & Konstantinou, C. (2021). Blockchain and autonomous vehicles: Recent advances and future directions. *IEEE Access*, 9, 130264–130328. <https://doi.org/10.1109/access.2021.3113649>
- Joy, S., Baby Chithra, R., Bale, A. S., Ghorpade, N., Varsha, S. N., & Naidu, A. S. (2022). A comparative study on recent trends in iris recognition techniques. In *2022 International Conference on Electronics and Renewable Systems (ICEARS)* (pp. 1521–1525). IEEE.
- Katiyar, D. N., Shukla, D. A., & Chawla, D. N. (2024). AI in autonomous vehicles: Opportunities, challenges, and regulatory implications. *Educational Administration: Theory and Practice*, 30(4), 2373–2380. <https://doi.org/10.53555/kuey.v30i4.2373>
- Khalifa, N., & Al-Khalifa, A. M. (2024). AI-powered innovation in digital transformation: Key pillars and industry impact. *Sustainability*, 16(5), 1790.
- Khatokar, A. (2021). Carbon nanodots: Chemiluminescence, fluorescence and photoluminescence properties. *Materials Today: Proceedings*, 43(Part 5), 3928–3931.
- Kumar, S. S., Sudhir Bale, A., Matapati, P. M., & Vinay. (2021). Conceptual study of artificial intelligence in smart cities with industry 4.0. In *2021 International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE)* (pp. 575–577). IEEE.
- Kumar, A., & Kumar, L. (2024). Navigating the future: The ethical, societal and technological implications of artificial intelligence. *Journal of Autonomous Vehicles and Systems*, 4(2), 45–67.
- 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>
- Lobel, O. (2023). The law of AI for good. *SSRN Electronic Journal*, 75(6), 1073. <https://doi.org/10.2139/ssrn.4338862>
- Mallinson, D. J., Azevedo, L., Best, E., Robles, P., & Wang, J. (2024). The future of AI is in the states: The case of autonomous vehicle policies. *Business and Politics*, 26(2), 180–199. <https://doi.org/10.1017/bap.2023.19>
- Mamta, B. S. (2024). Keyboard acoustic side channel attacks on Android phones in the AI era of digital banking: An elementary review. *International Journal of Intelligent Systems and Applications in Engineering*, 12(4), 292–300.
- Nadeem, M. (2024). AI in autonomous vehicles: State-of-the-art and future directions. *International Journal of Advanced Engineering Technologies and Innovations*, 1(1), 62–79.
- Purohit, T. P., Hashim, M. F., & Navale, S. (2022). Blockchain and its applications in industry 4.0. In *A roadmap for enabling industry 4.0 by artificial intelligence* (pp. 295–313). Wiley. <https://doi.org/10.1002/9781119905141.ch16>
- Rajani, M., Taj, N., Agnes, S., Amala, G., & Lal, K. (2024). Connecting autonomous engineering domains with the shared language of deep neural networks. In *2024 2nd International Conference on Artificial Intelligence and Machine Learning Applications Theme: Healthcare and Internet of Things (AIMLA)* (pp. 1–6). IEEE.
- Reddy, S. V., & Tiwari, S. (2020). Effect of residual stress on resonant frequency in Nitinol based thin film resonator. *IOP Conference Series: Materials Science and Engineering*, 872(1), 012008. <https://doi.org/10.1088/1757-899x/872/1/012008>
- Saleh, S., & Ahmed, M. (2024). A cyclic framework for ethical implications of artificial intelligence in autonomous vehicles. *International Journal of Advanced Computer Science & Applications*, 15(3), 123–135.
- Sudhir, A. B., Reddy, S. C., Chandramouli, H., Ponnuru, S., Saranya, S., & Lal, K. (2024). Review on intelligent social networking algorithms and their effects on predicting the adequacy of renewable energy sources via social media. In *2024 Second International Conference on Smart Technologies for Power and Renewable Energy (SPECOn)* (pp. 1–6). IEEE.
- Sudhir, A. B., Tiwari, S., Khatokar, A., Vinay, & Mohan, M. S. (2021). Bio-inspired computing – A dive into critical problems, potential architecture and techniques. *Trends in Sciences*, 18(23), 703. <https://doi.org/10.48048/tis.2021.703>
- Talamini, J., Bartoli, A., De Lorenzo, A., & Medvet, E. (2020). On the impact of the rules on autonomous drive learning. *Applied Sciences*, 10(7), 2394. <https://doi.org/10.3390/app10072394>
- Vinay, N., Bale, A. S., Tiwari, S., & Baby, C. R. (2022). Artificial intelligence as a tool for conservation and efficient utilization of renewable resource. In *Artificial intelligence for renewable energy systems* (pp. 37–77). Wiley.
- Weldon, M., Narine, G., & Thomas, L. (2024). Establishing a future-proof framework for AI regulation: Balancing ethics, transparency, and innovation. *Transactions: The Tennessee Journal of Business Law*, 25(1), 1–25.
- Wolniak, R., & Stecuła, K. (2024). Artificial intelligence in smart cities—Applications, barriers, and future directions: A review. *Smart Cities*, 7(3), 1346–1389. <https://doi.org/10.3390/smartcities7030057>

- Zaman, B. U. (2024). The weighty responsibility of creating AI navigating control and ethics. *Journal of Responsible Innovation, 11*(1), 1–15.
- Zhang L. Y., Duan X. K., Ma J., Zhang M., Wen Y., & Wang Y. (2022). Mechanism of Road Capacity under Different Penetration Scenarios of Autonomous Vehicles. *Int. Journal of Simulation Modelling, 21*(1), 172-183. <https://doi.org/10.2507/IJSIMM21-1-CO4>
- Zheng, D. (2023). The criteria of Chinese regulatory framework on artificial intelligence: Reflections based on cost-benefit analysis. *Asian Journal of Law and Economics, 14*(3), 265–280.

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