Autonomous Vehicles and Legal Challenges: Navigating between Technology and Criminal Liability

Untung Kurniadi,* Yusriyadi, Ana Silviana,*** Zico Junius Fernando****

*Fakultas Hukum Universitas Diponegoro, Semarang, Indonesia
**Fakultas Hukum Universitas Diponegoro, Semarang, Indonesia
***Fakultas Hukum Universitas Diponegoro, Semarang, Indonesia
****Fakultas Hukum Universitas Bengkulu, Bengkulu, Indonesia
Email: zjfernando@unib.ac.id

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Abstract

Transformations in the automotive industry have driven the emergence of autonomous vehicles, promising a more automated future. However, this automation raises complex accountability and legal responsibility issues, especially in criminal law. This research addresses questions of criminal liability and examines the obstacles and challenges to regulatory standards related to autonomous vehicles. The research employs a doctrinal legal approach to explore these issues, examining the current legal framework, comparing it with international practices, and considering potential future legal adaptations. The methodology focuses on legislative, conceptual, comparative, and futuristic approaches. Through content analysis, the research reviews existing laws governing autonomous vehicles, compares them with regulations in other jurisdictions, and delves into the fundamental legal concepts involved. The futuristic approach provides insight into how laws might need to adapt to future technological advances. The findings indicate an urgent need to revise existing laws, with a particular emphasis on determining liability in various scenarios. While some states have taken proactive steps to address these issues, many other jurisdictions still need to catch up. In conclusion, while autonomous vehicles offer numerous opportunities, significant legal and accountability challenges must be addressed.

Keywords: *criminal law liability; autonomous vehicles; technology; justice*

Abstrak

Transformasi dalam industri otomotif telah mendorong munculnya kendaraan otonom, yang menjanjikan masa depan yang lebih otomatis. Namun, otomatisasi ini menimbulkan masalah akuntabilitas dan tanggung jawab hukum yang kompleks, terutama dalam hukum pidana. Masalah yang diangkat mengenai pertanggungjawaban pidana termasuk masalah hambatan dan tantangan standar regulasi terkait Kendaraan Otonom. Penelitian ini menggunakan pendekatan hukum doktrinal dengan mengkaji kerangka hukum yang berlaku, membandingkannya dengan praktik internasional, dan merefleksikan potensi adaptasi hukum di masa depan. Penelitian ini menggunakan metode penelitian doktrinal, dengan fokus pada pendekatan perundang-undangan, konseptual, komparatif, dan futuristik. Melalui analisis konten, kami menyelidiki kerangka hukum saat ini yang mengatur kendaraan otonom, membandingkannya dengan peraturan di yurisdiksi lain, dan memahami konsep hukum dasar yang mendasarinya. Pendekatan futuristik memberikan wawasan tentang bagaimana hukum perlu beradaptasi dengan kemajuan teknologi di masa depan. Hasil penelitian menunjukkan adanya kebutuhan mendesak untuk merevisi undang-undang yang ada, dengan penekanan khusus pada penentuan pertanggungjawaban dalam berbagai skenario. Selain itu, ditemukan bahwa meskipun beberapa negara telah memulai langkah-langkah proaktif untuk mengatasi masalah ini, banyak yurisdiksi lain yang masih perlu mengejar ketertinggalan.

Kesimpulannya, kendaraan otonom menawarkan banyak peluang, tetapi tantangan hukum dan akuntabilitasnya harus diatasi.

Kata kunci: pertanggungjawaban hukum pidana; kendaraan otonom; teknologi; keadilan

I. Introduction

In the early 20th century, the world witnessed a revolution in the automotive industry with the birth of the motor vehicle. More than a century later, humanity is on the threshold of another revolution, the transformation from conventional to autonomous vehicles.[1] This technology promises a future where vehicles can operate without human intervention, maximizing efficiency and, ideally, reducing the incidence of accidents. However, as this technology advances, important questions arise about how current criminal law applies and whether it can achieve a paradigm shift in how humans operate vehicles. Autonomous vehicles, commonly known as driverless vehicles, result from advances in information technology, artificial intelligence, and robotics.[2] The main benefits include the potential to reduce traffic congestion, reduce carbon emissions by optimizing fuel use, and, most importantly, reduce the number of accidents caused by human error. However, with these advances come legal and ethical challenges that have never been faced before.[3]

One of the crucial issues that arises is legal liability. In conventional systems, the vehicle driver is usually responsible if an accident occurs.[4] However, determining who should be responsible becomes more complicated when algorithms and sensors control vehicles. Is it a vehicle manufacturer? Software creator? Or perhaps users who choose to trust the technology? There is also the question of how current criminal law can be applied in the context of autonomous vehicles. Traditional criminal law is based on individual accountability for their actions. However, with autonomous vehicles, machines can now take these actions. This raises the question of how the traditional concept of "mens rea" or malicious intent, a key component in criminal law, applies in this context. These questions have received increasing attention recently, especially with the increase in autonomous vehicle trials on roads worldwide. Several incidents have highlighted the potential risks and legal loopholes that exist. For example, in the case of an accident involving an autonomous vehicle, who should stand trial? How do current laws apply to machines that make decisions based on code and algorithms, not human judgment?

Furthermore, there are questions about whether current criminal laws are adequate to address the challenges posed by autonomous vehicles. While some countries have begun introducing regulations and guidelines for autonomous vehicles, many still need a clear legal framework for handling incidents involving this technology. In the Indonesian context, this issue is becoming increasingly relevant in line with the country's ambition to become a leader in technology and innovation in the Southeast Asia region. With a rapidly developing economy and increasing urbanization, autonomous vehicles could solve the transportation challenges many large cities in Indonesia face. However, without a clear legal framework, adopting this technology may create more problems than solutions.[5]

1 A Seetharaman and others, 'Impact of Factors Influencing Cyber Threats on Autonomous Vehicles', *Applied Artificial Intelligence*, 35.2 (2021), 105–32 <https://doi.org/10.1080/08839514.2020.1799149>.

2 Martin Cunneen, Martin Mullins, and Finbarr Murphy, 'Autonomous Vehicles and Embedded Artificial Intelligence: The Challenges of Framing Machine Driving Decisions', *Applied Artificial Intelligence*, 33.8 (2019), 706–31 <https://doi.org/10.1080/08839514.2019.1600301>.

3 Fábio Duarte and Carlo Ratti, 'The Impact of Autonomous Vehicles on Cities: A Review', *Journal of Urban Technology*, 25.4 (2018), 3–18 <https://doi.org/10.1080/10630732.2018.1493883>.

4 Mohamed Alawadhi and others, 'Review and Analysis of the Importance of Autonomous Vehicles Liability: A Systematic Literature Review', *International Journal of System Assurance Engineering and Management*, 11.6 (2020), 1227–49 <https://doi.org/10.1007/S13198-020-00978-9/TABLES/7>.

5 Johnathon P Ehsani and others, 'State Laws for Autonomous Vehicle Safety, Equity, and Insurance', *Journal of Law, Medicine & Ethics*, 50.3 (2022), 569–82 <https://doi.org/DOI: 10.1017/jme.2022.96>.

It is important to emphasize that autonomous vehicles have the potential to change the way we live, work and interact with each other.[6] However, without a deep understanding of the legal and ethical challenges they bring, we may find ourselves in a situation where technology runs faster than our ability to regulate it. Therefore, researchers, policymakers, and the general public must understand and adapt to these challenges as technology advances.

This research offers novelty through a holistic approach that combines doctrinal, comparative and futuristic analysis, enabling a thorough assessment of the adaptation of the existing legal framework to autonomous vehicle technology. By comparing the regulations in Indonesia with international practices in developed countries such as the United States and China, this research provides insights into adopting best practices to improve national regulations. In addition, the futuristic analysis highlights the future evolution of the law, providing insight into how laws can be designed to anticipate upcoming technological advancements. This approach is not only reactive to current changes but also proactive in the face of future technologies, making a significant contribution to the criminal law literature related to autonomous vehicles.

II. Research Method

This study employs a doctrinal research approach, focusing on an in-depth textual exploration of various legal documents and literature to understand the impact of autonomous vehicle automation on criminal legal responsibility and accountability in today's digital era. The study uses a multi-dimensional approach, including legal, conceptual, comparative, and futuristic aspects. Sources of data include legislative texts, case law, academic articles, and policy papers. Collect data through document analysis and legal research methods, and conduct analysis using qualitative techniques to interpret and evaluate legal principles and their application to autonomous vehicle technology.

III. Criminal Law Liability of Autonomous Vehicles

Autonomous vehicles, which employ advanced robotic technology, are now increasingly gaining a place in the hearts of global consumers. As technology advances and awareness of safety and efficiency increases, people are increasingly considering adopting this mode of transportation into their daily lives.[7] The latest research from the Global Market Model states that in 2023, the autonomous car market worldwide is expected to grow by 16.84 per cent. This figure shows the potential and market interest in this type of vehicle.[8] In line with these predictions, the automotive and technology industries compete to present the best innovations in this field.[9] Many large companies have entered the autonomous vehicle arena, showing the significant potential of this market. Audi, BMW, Ford, General Motors, Tesla, Volkswagen, and Volvo are some of the long-established giants of the automotive industry that are now looking to integrate autonomous technology into their portfolios. On the other hand, Google, a previously unknown technology company in the automotive sector, has demonstrated its ambition by testing a fleet of self-driving cars. The fact that cars like the Toyota Prius and Audi TT, developed by Google, have navigated more than 140,000 miles on

6 Edward Wigley, 'Do Autonomous Vehicles Dream of Virtual Sheep? The Displacement of Reality in the Hyperreal Visions of Autonomous Vehicles', *Annals of the American Association of Geographers*, 111.6 (2021), 1640–55 <https://doi.org/10.1080/24694452.2020.1838256>.

7 Robert Sparrow and Mark Howard, 'Make Way for the Wealthy? Autonomous Vehicles, Markets in Mobility, and Social Justice', *Mobilities*, 15.4 (2020), 514–26 <https://doi.org/10.1080/17450101.2020.1739832>.

8 IMARC, 'Autonomous Vehicle Market Size, Growth, Forecast 2023-2028', *Www.Imarcgroup.Com/*, 2023 <https://www.imarcgroup.com/autonomous-vehicle-market> [accessed 3 October 2023].

9 Iman Herdiana, 'Riset Kendaraan Otonom Di Indonesia, Penelitian Garapan ITB Dan Mobil Pintar ITS', *Bandungbergerak.Id/*, 2021 <https://bandungbergerak.id/article/detail/607/riset-kendaraan-otonom-di-indonesia-penelitian-garapan-itb-dan-mobil-pintar-its> [accessed 1 October 2023].

California roads underscores the seriousness of this effort.[10]

Autonomous vehicles represent a sophisticated blend of sensory, computing and control technologies. These elements work together to create a safer and more efficient driving environment. At the heart of its operations, the vehicle relies on various sensors integrated into all parts. Radar sensors, for example, play a critical role in monitoring the position of other vehicles in the vicinity, providing essential information about distance and relative speed. Meanwhile, video cameras not only detect traffic lights and read road signs but also track other vehicles and pedestrians, ensuring that vehicles can react to varying traffic conditions. With the support of complex algorithms, machine learning systems and high-speed processors, these vehicles can interpret data in real time and make driving decisions accordingly. This, in turn, promises to increase safety and efficiency in transport while opening opportunities for a revolution in how we interact with our surroundings while on the road.[11]

In the context of technological development, criminal legal liability has always been one of the most controversial issues, especially when talking about technologies that have great potential to interact directly with human life, such as autonomous vehicles. Behind the technological advances that promise efficiency, safety and a revolution in how humans transport, there are complex legal aspects that must be faced. Criminal law has a framework for dealing with accidents or damage caused by vehicles.[12] However, in the autonomous vehicle scenario, a big question arises: Who should be responsible if an accident occurs? Was it the driver, even though he was not in control of the vehicle then? Vehicle manufacturer? Or the software developer who controls the vehicle? Traditional legal liability, which generally focuses on human negligence or error, may not be appropriate in autonomous vehicles. For example, who is to blame if an autonomous vehicle system fails to detect a pedestrian due to bad weather conditions and crashes into it?

Conventionally, a driver not paying attention would be accused of being at fault. However, in the case of autonomous vehicles, the driver's role is greatly minimized or even eliminated.[13] Many arguments suggest that responsibility should shift to the vehicle manufacturer or software developer, considering they are the ones who created and programmed the system. However, this raises other challenges. How do we determine that the error is in the software and not due to external factors? What if the accident was caused by software error and human intervention?

Additionally, there are deep ethical considerations in determining responsibility.[14] For example, what decision should the system make if an autonomous vehicle faces a situation where it must choose between hitting another driver or a pedestrian? Who is responsible for the decision?

The adoption of autonomous vehicles in various parts of the world has prompted changes in the legal framework to accommodate this technology.[15] Countries and regions embracing autonomous technology must face unique challenges in determining liability when accidents occur.[16] The United States, as one of the pioneers

10 Ida Farida, '7 Perusahaan Teknologi Mobil Otomatis Yang Berstatus Unicorn', *Www.Harianhaluan.Com/*, 2022 <https://www.harianhaluan.com/teknologi/pr-102436744/7-perusahaan-teknologi-mobil-otomatis-yang-berstatus-unicorn> [accessed 3 October 2023].

11 Tamil Selvan B and Srirangarajalu N, 'Self-Driving Car', *International Journal of Engineering Technology and Management Sciences*, 7.4 (2023), 275–80 <https://doi.org/10.46647/ijetms.2023.v07i04.038>.

12 Shi Rui, 'Research on Tort Liability of Autonomous Vehicles in Traffic Accidents', *BCP Social Sciences & Humanities*, 19 (2022), 157–63 <https://doi.org/10.54691/bcpssh.v19i.1599>.

13 Kiliaan A.P.C. van Wees, 'Technology in the Driver's Seat: Legal Obstacles and Regulatory Gaps in Road Traffic Law', *Perspectives in Law, Business and Innovation*, 2021, 21–37 <https://doi.org/10.1007/978-981-15-9255-3_2/COVER>.

14 Jo-Ann Pattinson, Haibo Chen, and Subhajit Basu, 'Legal Issues in Automated Vehicles: Critically Considering the Potential Role of Consent and Interactive Digital Interfaces', *Humanities and Social Sciences Communications*, 7.1 (2020), 1–10 <https://doi.org/10.1057/s41599-020-00644-2>.

15 Margarita Martínez-Díaz and Francesc Soriguera, 'Autonomous Vehicles: Theoretical and Practical Challenges', *Transportation Research Procedia*, 33 (2018), 275–82 <https://doi.org/10.1016/J.TRPRO.2018.10.103>.

16 Lisa Collingwood, 'Privacy Implications and Liability Issues of Autonomous Vehicles', *Information & Communications Technology*

in the development of autonomous vehicles, has seen legal changes at the state level. For example, in California, their approach emphasizes producer responsibility. This represents a recognition that autonomous vehicles, in many cases, operate without human intervention, so that when technological failures occur, vehicle manufacturers must be held responsible. An approach like this ensures manufacturers are incentivized to ensure their technology is safe and reliable. However, it is essential to understand that driver intervention is still possible in some autonomous vehicle models. If an accident occurs due to the driver's actions, liability will return to traditional legal principles. This reflects a balance between recognizing technological advances and ensuring drivers are responsible for their actions.[17]

Vehicles with self-driving technology rely on various sensors and cameras to map their environment and monitor driver behaviour. The information collected includes geographic position, direction of movement, speed and many other data. As this technology is adopted, concerns arise regarding privacy and how vehicle manufacturers use the data.[18] Some jurisdictions have responded by introducing data privacy regulations. For example, the European Union has adopted the General Data Protection Regulation (GDPR) governing the processing of personal information. Autonomous vehicle manufacturers in the region must ensure compliance with these privacy standards. However, concerns remain regarding the potential for data misuse, such as monitoring drivers or marketing the data to other entities without the owner's knowledge. In continuing this discussion, it is essential to emphasize that integrity and trust are crucial in adopting self-driving technology. Transparency in data processing and storage and giving individuals control over their personal information can be vital to building that trust. In addition, vehicle manufacturers and related service providers must commit to maintaining data security and preventing potential breaches that could harm consumers. Autonomous vehicle technology, which allows cars to function without human intervention, poses new challenges to existing traffic regulations. Most current regulations are designed to assume that a human controls the vehicle, so with the advent of self-operating vehicles, the question arises of how traffic regulations will adapt to this change.[19]

Another question that arises is regarding the driver's license. Traditionally, every individual operating a vehicle on the road must have a driver's license. However, with the ability of autonomous vehicles to operate without a driver, the question arises as to whether such vehicles require a special "license"? And can individuals without a driver's license "operate" an autonomous vehicle? The United States, through its several states, is exploring solutions to these questions[20] and, for example, considering whether it is possible for someone who does not have a driving license to be still able to "use" an autonomous car, given that they may only be acting as a passenger. In a broader context, changes to traffic regulations to accommodate autonomous vehicles show how technology can influence and change the legal framework. This exemplifies how legal adaptation is needed to remain relevant to current developments and innovation.

As time progresses, autonomous vehicle technology has advanced rapidly, holding new promises for more efficient, safer and

Law, 26.1 (2017), 32–45 <https://doi.org/10.1080/13600834.2017.1269871>.

17 Christopher Salatiello and Troy B. Felver, 'Current Developments in Autonomous Vehicle Policy in the United States: Federalism's Influence in State and National Regulatory Law and Policy', *Global Jurist*, 18.1 (2018), 1–10 <https://doi.org/10.1515/GJ-2017-0008/MACHINEREADABLECITATION/RIS>.

18 Araz Taeihagh and Hazel Si Min Lim, 'Governing Autonomous Vehicles: Emerging Responses for Safety, Liability, Privacy, Cybersecurity, and Industry Risks', *Transport Reviews*, 39.1 (2019), 103–28 <https://doi.org/10.1080/01441647.2018.1494640>.

19 Jaimee Lederman, Brian D Taylor, and Mark Garrett, 'A Private Matter: The Implications of Privacy Regulations for Intelligent Transportation Systems', *Transportation Planning and Technology*, 39.2 (2016), 115–35 <https://doi.org/10.1080/03081060.2015.1127537>.

20 Devon McAslan, Max Gabriele, and Thaddeus R Miller, 'Planning and Policy Directions for Autonomous Vehicles in Metropolitan Planning Organizations (MPOs) in the United States', *Journal of Urban Technology*, 28.3–4 (2021), 175–201 <https://doi.org/10.1080/10630732.2021.1944751>.

environmentally friendly transportation. In response to this potential transportation revolution, many countries worldwide have proactively taken steps to prepare by creating a legal environment that supports and regulates autonomous vehicle operations. From the United States to China and the European Union to Southeast Asia, national governments are trying to formulate rules and regulations that balance technological innovation and public safety. Amid global urbanization and the challenges of climate change, autonomous vehicles may be one of the solutions offered by technology to answer today's transportation issues:

1. United States of America

   In the United States, autonomous vehicle regulation combines federal- and state-level regulations. Here are some examples of federal and state regulations and guidance, such as the Federal Automated Vehicles Policy issued by the U.S. Department of Transportation. This document serves as an initial guide for developing and implementing autonomous vehicles.[21] This document covers many aspects, including safety, state regulatory models, public access and human rights. Automated Vehicles 3.0 updates the previous policy, focusing on integrating autonomous vehicles into the national transportation infrastructure.[22] In California, the so-called Vehicle Code, Division 16.6, regulates the testing and deployment of autonomous vehicles. This law establishes requirements such as the presence of a test operator, incident reporting, and insurance requirements.[23] California Code of Regulations, Title 13, Article 3.7, governs the granting of permits for autonomous vehicle testing by the California Department of Motor Vehicles (DMV). This regulation outlines companies' requirements to obtain a testing permit. Besides California, many other U.S. states have their autonomous vehicle regulations. For example, states such as Arizona, Florida, and Michigan have also developed specific rules for testing and using autonomous vehicles on the road.

2. European Union

   In the European Union, several member states have taken the lead in developing and implementing autonomous vehicle regulations. The following are some regulations issued by several member countries, such as the "Gesetz Zum Automatisierten Fahren" (Law Concerning Automated Driving) in Germany, issued in 2017. This law allows vehicles with high automation features to operate on German highways, provided a human driver is present and ready to take control whenever necessary.[24] This law also establishes a legal framework for liability in the event of an accident. In the Netherlands, it is known as "Experimenteerwet Zelfrijdende Auto" (Automatic Car Experimentation Act). The Netherlands has taken a progressive approach to autonomous vehicle testing. This law allows companies to test driverless vehicles on public roads under certain conditions. In the U.K., it is regulated by the "Automated and Electric Vehicles Act 2018" which is secured. This Act creates a framework for autonomous vehicle insurance.[25] The aim is to ensure that victims will receive compensation transparently and efficiently in an accident with an autonomous vehicle. Additionally, the U.K. government has issued various guidelines and codes of practice for testing autonomous vehicles on the road. As technology advances, more European Union member states will likely develop their own

21 (The U.S. Department of Transportation's Federal Automated Vehicles Policy, 2016)

22 (The U.S. Department of Transportation, 2018)

23 Justia US Law, 'California Autonomous Vehicles Laws - 2022 California Vehicle Code, DIVISION 16.6', *Law.Justia.Com/*, 2023 <https://law.justia.com/codes/california/2022/code-veh/division-16-6/> [accessed 2 October 2023].

24 BMDV, 'Gesetz Zum Autonomen Fahren Tritt in Kraft', *Bmdv.Bund.De/*, 2021 <https://bmdv.bund.de/SharedDocs/DE/Artikel/DG/gesetz-zum-autonomen-fahren.html> [accessed 3 October 2023].

25 Authors Channon and Matthew Channon, 'Automated and Electric Vehicles Act 2018: An Evaluation in Light of Proactive Law and Regulatory Disconnect', *European Journal of Law and Technology DEPOSITED IN ORE European Journal of Law and Technology*, 10.2 (2019), 1–36 <https://ore.exeter.ac.uk/repository/handle/10871/39560>.

rules and regulations to govern autonomous vehicles, and the European Union itself may take steps to create harmonized standards among its member states.

3. China
   Several cities, such as Beijing and Shanghai, have issued regulations for autonomous vehicle testing. Beijing, for example, began granting permits for testing autonomous vehicles on highways in 2017 with certain conditions. In China, the development of autonomous vehicles has received significant attention, and several large cities have taken the lead in formulating related regulations. Implementation Rules Supporting Testing of AutonomousDrivingVehiclesonBeijingRoads, published in 2017, are among the first in China to allow testing of autonomous vehicles on roads. These rules establish several conditions for obtaining a testing permit, including but not limited to insurance requirements, incident reporting, and the presence of a safety driver who can take over control if necessary. Shanghai has also started an initiative similar to Beijing's, but the specific details of their rules may differ. While no particular document names have been mentioned in your question, the city has also taken steps to support the testing of autonomous vehicles on the road. It has set specific criteria that companies wishing to conduct testing must meet. It is important to remember that regulations in China, as in many other countries, continue to evolve as technology advances and our understanding of autonomous vehicles' potential risks and benefits. Therefore, it is always good to refer to official sources for the latest and most complete information regarding relevant regulations in each city or province in China.[26]
4. Singapore
   With its futuristic vision, Singapore has established itself as a pioneer in developing and integrating autonomous vehicles. In 2017, the country released the "Autonomous Vehicles (A.V.) Testing Framework," a comprehensive regulatory framework designed to regulate on-road testing of autonomous vehicles. This framework emphasizes the importance of safety standards, ensuring that each vehicle under test is equipped with technology capable of dealing with potential damage by safely stopping the vehicle.[27] Additionally, participating companies must have adequate insurance, ensuring protection against potential loss or damage. They must also report any incidents or accidents to the authorities within the specified time. To add a layer of safety, Singapore also designates specific zones where testing can be conducted, providing a combination of real-world conditions and a controlled environment. The initiative reflects Singapore's balanced approach to embracing innovation while prioritizing public safety.[28]

The criminal sanctions applied to violations related to autonomous vehicles vary greatly depending on the jurisdiction and the specific rules violated. The following are some examples of criminal sanctions that may be applied in some jurisdictions:

1. United States of America
   Regulation of autonomous vehicles in the United States is uniquely complex, as each state has the authority to set its own rules. As a result, criminal sanctions applied for violations related to autonomous vehicles vary from state to state. For example, someone who operates an autonomous vehicle without a proper permit may face fines, license restrictions, or even imprisonment, depending on the severity and consequences of the violation. At the federal level, criminal sanctions for autonomous vehicles have not been clearly defined, with the U.S. Department of Transportation currently focusing more on issuing guidance for the industry. However, there is the potential for producers or other

26 Bowei Zou, Wenqiang Li, and Danni Wang, 'Analysis on Current Situation of China's Intelligent Connected Vehicle Road Test Regulations', *MATEC Web of Conferences*, 259 (2019), 1–8 <https://doi.org/10.1051/MATECCONF/201925902003>.

27 Si Ying Tan and Araz Taeihagh, 'Adaptive Governance of Autonomous Vehicles: Accelerating the Adoption of Disruptive Technologies in Singapore', *Government Information Quarterly*, 38.2 (2021), 1–15 <https://doi.org/10.1016/j.giq.2020.101546>.

28 Tan and Taeihagh.

companies to receive fines if they violate existing regulations. In California, as an illustration, companies that test autonomous vehicles without proper permits can be subject to hefty fines or operational restrictions. Additionally, there is an obligation to report incidents or accidents, and non-compliance with this requirement may result in fines. Drivers who do not comply with their role, particularly in semi-autonomous vehicles, may face fines or points on their licence. Other states, such as Arizona, Florida, and Michigan, also have sanctions that can include fines, license restrictions, or even prison time, depending on the circumstances of the violation. However, it is essential to note that many of these sanctions tend to be administrative. Thus, although there is the potential for fines or license restrictions, the possibility of imprisonment is usually reserved for cases involving intent or gross negligence.[29]

2. European Union

In the European Union, criminal sanctions related to the operation of autonomous vehicles vary between member states. In Germany, according to the "Gesetz zum automatisierten Fahren", drivers who do not take over control of the vehicle in critical situations or violate other rules can face fines or heavier sanctions, especially if such negligence causes an accident.[30] Meanwhile, in the Netherlands, violating "Experimenteerwet Zelfrijdende Auto" can result in fines or administrative sanctions, with the potential for the criminal action of severe violations.[31] In the U.K., violations of the Automated and Electric Vehicles Act 2018 or other regulations regarding the operation of autonomous vehicles on public roads can result in fines, additional points on a driving license, or even imprisonment, depending on the severity.[32] Overall, these sanctions are designed to ensure that the development and implementation of autonomous vehicle technology go hand in hand with public safety.

3. China

Regulations regarding autonomous vehicles have become a particular focus in some large cities such as Beijing, and violations of these regulations can result in significant sanctions. For example, companies or individuals who test or operate autonomous vehicles without appropriate permits may be subject to fines. Testing permits may be revoked entirely in cases of repeated or severe violations. Likewise, violating prescribed safety protocols, such as the absence of a safety driver during testing, may result in fines or other administrative sanctions. The importance of reporting after an incident or accident is also emphasized in this regulation, with companies that fail to report facing additional sanctions. Furthermore, in cases where violations result in serious accidents or even death, the guilty party may face criminal prosecution, hefty fines, or even prison time. With the increasing adoption of autonomous technology, China appears determined to ensure safety and compliance by implementing strict regulations and sanctions.[33]

4. Singapore

Public safety is a top priority in developing and testing autonomous vehicles in Singapore . Any violation of established regulations can result in criminal sanctions. Companies or individuals who ignore established safety protocols or operate vehicles without proper permits may be subject to significant fines. Additionally, violators may face prison sentence where negligence or intentional actions result in accidents or injuries. Singapore, with its firm and principled approach, shows that while it supports innovation and technological

29 Salatiello and Felver.

30 BMDV.

31 STIBBE, 'Testen van Zelfrijdende Auto's Sinds 1 Juli 2019 Vergemakkelijkt', *Www.Stibbe.Com/*, 2019 <https://www.stibbe.com/nl/publications-and-insights/testen-van-zelfrijdende-autos-sinds-1-juli-2019-vergemakkelijkt> [accessed 3 October 2023].

32 Channon and Channon.

33 D Danks and A J London, 'Regulating Autonomous Systems: Beyond Standards', *IEEE Intelligent Systems*, 32.1 (2017), 88–91 <https://doi.org/10.1109/MIS.2017.1>.

development, it will not compromise when it comes to safety and legal compliance.[34]

However, it is essential to note that many regulations regarding autonomous vehicles focus more on administrative regulations than criminal sanctions. Thus, violations are more likely to result in fines, license cancellation, or other administrative sanctions than prison sentences. As the adoption of autonomous vehicles increases, we expect regulations and sanctions to evolve and change with the technology and our understanding of the risks and benefits. It is always best to consult official sources or local legal experts for more specific and up-to-date details. The Kalayang Sky Train at Soekarno-Hatta Airport, Tangerang, Indonesia, is one of the early examples of the application of autonomous vehicles in Indonesia.[35] Although the scale of implementation is specific to the airport area, it marks an essential step in the development of automated transportation in the country. Indonesia is interested in autonomous vehicles as a country with rapid technological growth. However, Indonesia still needs to have a specific legal or regulatory framework that regulates the operation of autonomous vehicles on public highways. However, several initiatives have been carried out, such as testing and exhibition of autonomous vehicles on a particular scale. However, their implementation on public highways still requires an in-depth study of infrastructure, technology and other safety aspects. In a global context, autonomous vehicle regulation is a complex topic and involves many considerations, ranging from road user safety and legal liability to ethical issues.

As Indonesia progresses in its integration of autonomous vehicles into the transportation landscape, the existing legal framework, particularly Law No. 22 of 2009 concerning Road Traffic and Transportation (LLAJ), requires careful consideration.

Part Three
Obligations and Responsibilities
Paragraph 1

Obligations and Responsibilities of Drivers, Motor Vehicle Owners, and/or Transport Companies

Article 234[36]

1) Drivers, Motor Vehicle owners and/or Public Transport Companies are responsible for losses suffered by Passengers and/or property owners and/or third parties due to the driver's negligence.
2) Every Driver, Motor Vehicle owner, and/or Public Transport Company is responsible for damage to roads and/or road equipment due to the driver's negligence or error.
3) The provisions as intended in paragraph (1) and paragraph (2) do not apply if: a. the existence of force circumstances that cannot be avoided or are beyond the driver's ability; b. caused by the victim's own behaviour or a third party; and/or c. caused by movement of people and/or animals even though precautions have been taken.

Article 235[37]

1) If the victim dies as a result of a traffic accident, as referred to in Article 229 paragraph (1) letter c, the driver, owner and/or public transportation company is obliged to assist the victim's heirs in the form of medical expenses and/or funeral expenses without dropping the lawsuit criminal.
2) If there is injury to the victim's body or health as a result of a traffic accident as intended in Article 229 paragraph (1) letters b and c, the driver, owner and/or public transport company is obliged to assist

34 Denis V. Iroshnikov, Lyubov Yu. Larina, and Aleksandr I. Sidorkin, 'Autonomous Vehicles within the Urban Space and Transport Security Challenges: Legal Aspect', *Journal of Politics and Law*, 13.3 (2020), 133 <https://doi.org/10.5539/jpl.v13n3p133>.

35 Suci Wulandari Putri Chaniago et al, 'Kalayang Bandara Soekarno-Hatta: Rute Dan Jam Operasional', *Travel.Kompas.Com/*, 2023.

36 Law No. 22 of 2009 concerning Road Traffic and Transportation

37 Law No. 22 of 2009 concerning Road Traffic and Transportation

the victim in the form of medical expenses without dropping the lawsuit. criminal.

Article 236[38]

1) The party that causes a traffic accident as intended in Article 229 is obliged to compensate for losses, the amount of which is determined based on a court decision.
2) The obligation to compensate for losses as intended in paragraph (1) in Traffic Accidents as intended in Article 229 paragraph (2) can be carried out outside of court if there is an amicable agreement between the parties involved.

In Indonesia, which adheres to civil law or the continental European legal system, Law No. 22 of 2009 concerning Road Traffic and Transportation (LLAJ) stipulates the obligations and responsibilities of drivers, vehicle owners and/or public transportation companies.[39] Articles 234 to 236, provide a clear picture of this responsibility, especially in accidents. When autonomous vehicles enter the conversation, interpreting these articles becomes challenging. For example, if an autonomous vehicle is involved in an accident, who is considered the "driver"? Is it the autonomous system controlling the vehicle or the person sitting in the driver's seat, even though they may not have taken control when the accident occurred? If autonomous systems are responsible, how is legal responsibility transferred to the vehicle owner or the company that developed the system? Additionally, in cases where the loss is caused by a technical failure of the autonomous vehicle that the user could not anticipate, is the vehicle owner or user still liable? Or the responsibility shifts to the vehicle or software manufacturer.

Article 234 paragraph (3) provides several exceptions from responsibility, including "force majeure that is unavoidable or beyond the driver's ability." In the context of autonomous vehicles, the interpretation of "force majeure" or "beyond the driver's capabilities" becomes particularly relevant, as it may refer to circumstances in which autonomous vehicle technology encounters a situation that the system cannot anticipate or recognize. However, as interest in autonomous vehicles increases, a review or amendment of the LLAJ Law is needed to clarify legal responsibilities in the era of autonomous vehicles. Meanwhile, Indonesia, which adheres to a civil law legal system, will focus on written legal provisions and the court's interpretation of these provisions to provide legal guidance.

The Traffic and Road Transport Law in Indonesia stipulates the obligations and responsibilities of motor vehicle drivers, especially in traffic accidents.[40] According to Article 310, a driver who, through negligence, causes an accident with damage to vehicles or goods can be imprisoned for up to six months or a maximum fine of one million rupiah. If the accident results in minor injuries, the sanctions can increase to one year's imprisonment or a fine of two million rupiah. Furthermore, if the victim suffers serious injuries, the penalty is five years' imprisonment or a fine of ten million rupiah. However, when an accident results in death, the perpetrator can be imprisoned for up to six years or a fine of twelve million rupiah. Article 311 provides heavier sanctions for violations committed intentionally. Dangerously driving a vehicle is punishable by one year in prison or a fine of three million rupiah. If this deliberate action results in an accident with damage to property or vehicles, the penalty is two years in prison or a fine of four million rupiah. If the victim causes minor injuries, the penalty is four years in prison or a fine of eight million rupiah.

38 Law No. 22 of 2009 concerning Road Traffic and Transportation

39 Firman Widyaputra, 'Penegakan Hukum Undang Undang Nomor 22 Tahun 2009 Tentang Lalu Lintas Dan Angkutan Jalan Terhadap Pengendara Anak Usia Sekolah Di Wilayah Kota Malang (Studi Kasus Pada Satuan Lalu Lintas POLRESTA Malang)', *Airlangga Development Journal*, 1.2 (2019), 119–36 <https://doi.org/10.20473/adj.v1i2.18016>.

40 Latifa Alfira Ulya, 'Berkendara Nabrak Orang Lain Hingga Tewas Atau Luka-Luka, Bagaimana Sanksinya?', *Www.Gridoto.Com/*, 2019 <https://www.gridoto.com/read/221824485/berkendara-nabrak-orang-lain-hingga-tewas-atau-luka-luka-bagaimana-sanksinya?lgn_method=google> [accessed 2 October 2023].

In the most severe circumstances, if the act results in serious injury or death to the victim, the perpetrator can be imprisoned for ten to twelve years and a fine of twenty to twenty-four million rupiah.

Autonomous vehicles raise several legal questions in traditional traffic and transportation law systems that have never been faced. One of the main challenges is defining "driver" in the context of a vehicle capable of operating without human intervention. This ambiguity requires reviewing and adapting existing regulations to suit the realities of autonomous vehicle technology and to ensure that the law can be applied fairly and effectively in this new era of mobility.

Law no. 22 of 2009 concerning Road Traffic and Transportation (LLAJ) in Indonesia reflects the era before the emergence of autonomous vehicle technology. As a result, the Act focuses on the principles and regulations relevant to conventional human-controlled vehicles. With the emergence of autonomous vehicle technology, many provisions in this Act may no longer be appropriate or adequate to address the challenges and situations presented by autonomous vehicles. Liability in cases of accidents or incidents involving autonomous vehicles can be complex. It will depend on the jurisdiction, the level of vehicle autonomy, and the specific circumstances of the incident. However, here are some general principles that could be adopted in future regulations regarding liability:[41]

1. Driver
   Semi-Autonomous Vehicles: The driver usually manages vehicles requiring human intervention (like Tesla with its Autopilot). If the system prompts the driver to take over control and they do not do so promptly, the driver may be held liable. In Fully Autonomous Vehicles, liability can shift from the driver to fully autonomous vehicles without human intervention.
2. Vehicle Manufacturer & Software Developer
   The vehicle manufacturer or developer may be liable if a design error or software failure causes an accident. For example, if an autonomous system fails to detect a pedestrian due to an error in its algorithm, then the manufacturer or software developer may be sued.
3. Vehicle Owner
   In some jurisdictions, the owner of a vehicle may be liable regardless of who was driving it. However, if an autonomous vehicle is damaged due to the fault of a third party, the owner may have the right to sue that third party.
4. Third-party
   If an accident is caused by a third party's hardware or software error (for example, a navigation system or sensors from another supplier), that third party may be liable.
5. Government or Local Authority
   In cases where road infrastructure or traffic signs are inadequate or misleading and cause autonomous vehicle accidents, local authorities or governments may be held responsible.

As autonomous vehicle technology advances, many countries are working to update their laws and regulations to accommodate questions of liability.[42] This area of law is evolving. It will continue to adapt as technology and our understanding of autonomous vehicles' potential risks and benefits advance.

The analysis of criminal liability in autonomous vehicles can be based on the theories of several renowned criminal law experts, including Sudarto, Moeljatno, and Van Bemmelen. Sudarto, in his book "Hukum Pidana I," emphasizes the importance of fault in determining criminal liability. In the context of autonomous vehicles, the main issue is whether the fault can be attributed to a human (such as the driver or vehicle owner) or another entity, such as the manufacturer or software developer.

41 Roger Kemp, 'Autonomous Vehicles-Who Will Be Liable for Accidents? The Attraction of Autonomous Vehicles', *Digital Evidence and Electronic Signature Law Review*, 15 (2018), 33.

42 Andreia Martinho and others, 'Ethical Issues in Focus by the Autonomous Vehicles Industry', *Transport Reviews*, 41.5 (2021), 556–77 <https://doi.org/10.1080/01441647.2020.1862355>.

Moeljatno, in "Asas-Asas Hukum Pidana," states that fault must be proven for someone to be criminally liable. If the fault lies in the failure of autonomous technology that the user cannot control, the manufacturer or software developer may be held accountable. In cases of autonomous vehicle accidents, this question becomes complex because the driver's role is minimized or even eliminated. Van Bemmelen, in "The Theory of Criminal Law," introduces the concept of strict liability, which holds that criminal liability can be imposed without fault if there is a clear causal link between the action and the harmful outcome. This means that manufacturers or software developers can be held liable if their products cause accidents, regardless of human fault. These experts' theoretical approaches to criminal liability indicate that determining who is responsible no longer focuses solely on the driver but also involves manufacturers and software developers. Therefore, clear regulatory updates are needed to align with technological advancements and ensure that all parties involved can be held fairly and appropriately accountable.

Formulatingautonomousvehicleregulations in Indonesia requires a comprehensive approach that is future-oriented and focused on safety and innovation. The first thing that needs to be clearly defined is what "autonomous vehicle" means. Referring to international standards such as SAE International, these vehicles should be classified based on their level of automation. Furthermore, before these vehicles are allowed to operate on public roads, strict testing, evaluation, and certification procedures must be conducted to ensure they are safe to operate. One of the biggest challenges is determining liability, mainly if an accident occurs. Who will be responsible: the driver, the manufacturer, or another third party? This question also raises the need for adjustments to existing insurance schemes.

Additionally, stringent safety specifications need to be defined for the vehicle hardware and the software that controls it. The vehicle's interaction with its environment is also essential. How a vehicle will communicate with drivers, pedestrians, and other vehicles is crucial to ensuring road safety. It also raises questions about training and licensing and

Table 1. Essential Aspects of Autonomous Vehicle Regulations in Indonesia

No	Aspect	Description
1	Definition of Autonomous Vehicle	Clear definitions based on automation level.
2	Certification and Trials	Procedures for testing, evaluation, and certification.
3	Liability and Insurance	Determining liability in various scenarios and customizing insurance schemes.
4	Safety Standards	Safety specifications for hardware and software.
5	Interaction with Users	How the vehicle communicates with the driver and other road users.
6	Training and Licensing	Training or certification requirements for users.
7	Data Security and Privacy	Rules regarding data security and user privacy.
8	Software Updates	Procedure for software updates.
9	Infrastructure	Adapting traffic infrastructure for autonomous vehicles.
10	Ethics and Machine Decisions	Basic principles for decisions involving human safety.
11	Collaboration with Third Parties	Collaboration with manufacturers, developers and other stakeholders.
12	Environment and Energy Efficiency	Regulations around emissions, energy efficiency and charging infrastructure.
13	Integration with Transportation Systems	How autonomous vehicles integrate with other transportation systems.

whether special certification will be required for "drivers" of autonomous vehicles.

Data security and user privacy must be a priority in today's digital era. With all their sensors and capabilities, autonomous vehicles will collect vast amounts of data that must be stored and processed securely. Software updates, often essential for optimal operation, must be performed securely and trustworthy. From an infrastructure perspective, roads, traffic lights, and signs may need to be upgraded or adapted to meet the needs of autonomous vehicles. This raises ethical questions, especially when vehicles have to make decisions in human safety scenarios.[43] Collaboration with manufacturers, developers and other stakeholders is critical to creating an ecosystem supporting autonomous vehicle growth. Additionally, with the shift towards electric vehicles, considerations about emissions, energy efficiency and charging infrastructure are becoming increasingly relevant. Lastly, for the transportation system to be holistic, integrating autonomous vehicles with other transportation systems must be considered, creating a balanced and sustainable transportation network for Indonesia's future.

Indonesia, through Minister of Transportation Regulation No. 76 of 2021, has laid the groundwork for the development of intelligent transportation management systems, addressing the legal and technological challenges presented by autonomous vehicles. This regulation is critical as it supports the implementationofautonomousvehiclesbyproviding a framework for technologies that enable vehicles' efficient and safe operation on the road. Amid the rise of autonomous vehicles, the importance of core technologies such as communication between vehicles and road infrastructure not only improves safety, but also efficiency in traffic management and emergency response. Autonomous vehicles, which integrate advanced technologies in sensors and algorithms for self-navigation, require a new approach to the law governing liability in the event of an accident. In the context of Indonesian law, as stipulated in Law No. 22 of 2009 on Road Traffic and Transportation, this challenge becomes apparent as the law has yet to fully prepare for a scenario where humans are no longer drivers in the traditional sense. The question of who is responsible, whether the vehicle control system, the vehicle manufacturer, or the software developer, demands a careful review of the law. This review is essential to adjust to circumstances where vehicles can operate without human intervention and ensure that regulations support innovation without compromising safety and liability. The approach taken by California, which emphasizes producer responsibility, can be an example of how Indonesia might adapt its laws to provide the legal clarity needed in the era of autonomous vehicles. Furthermore, in a global context where countries such as the US and China have started to adapt and develop specific regulations for autonomous vehicles, Indonesia needs to accelerate the development of policies that address not only the testing and certification of autonomous vehicles but also the liability and insurance aspects. Provisions in Road Traffic and Transportation should be adjusted to include scenarios where technical failures or circumstances beyond human control may occur, and regulations should clearly define how liability can be fairly allocated between technology developers, manufacturers, and vehicle users.

As part of the Smart City Blueprint of the Archipelago and Presidential Regulation No. 24 Year 2022 on KSN-IKN, adding self-driving cars to the development of TOD areas and transportation infrastructure shows the need for supportive zoning, policies that make it easier for pedestrians, self-driving cars, and public transportation to interact, and good data and privacy management. These developments will not only determine the successful implementation of autonomous vehicles in Indonesia but will also provide examples of how regulations can be developed to support technological innovation while ensuring safety, fairness, and sustainability in a society that increasingly relies on smart mobility solutions. This reflects the unity between technological advancement and the need for dynamic regulations thatcanadapttothetimesandnewtechnologies.The

43 Martin Cunneen and others, 'Autonomous Vehicles and Avoiding the Trolley (Dilemma): Vehicle Perception, Classification, and the Challenges of Framing Decision Ethics ', *Cybernetics and Systems*, 51.1 (2020), 59–80 <https://doi.org/10.1080/01969722.2019.1660541>.

advancement of autonomous vehicle technology in Indonesia and the need for rapid legal adaptation invite deeper consideration of how policies can be developed to address not only safety and efficiency but also questions of ethics and social justice. This includes the importance of clarity in provisions relating to liability in the event of an accident. This is crucial given the unique characteristics of autonomous vehicles, which eliminate or reduce the human role in controlling the vehicle. To address this challenge, Indonesia may need to look to models that have been developed in other jurisdictions. For example, in the European and US contexts, regulation has focused on redefining the responsibilities of manufacturers and software developers, noting that damage or accidents may more often be caused by system failures than human error. A similar approach could be adopted in Indonesia by providing a clear framework for automotive and technology companies to ensure that every vehicle produced meets strict safety standards before being allowed to operate on the road. In addition, in implementing autonomous vehicle regulations, there needs to be a balance between promoting technological innovation and protecting public rights and safety. Indonesia could adopt strategies such as establishing test zones for autonomous vehicles before full implementation, similar to what has been done in Singapore and some US cities. This allows the government to monitor the technology's performance under controlled conditions and collect data that is essential for further regulatory improvements. In addition, data security and privacy aspects should be key considerations, given that autonomous vehicles collect and process a large amount of data to operate effectively. Existing regulations, such as GDPR in Europe, provide examples of how personal data should be protected. Indonesia could integrate similar principles into its autonomous vehicle regulations to ensure user data is protected and used ethically. Ultimately, Indonesia needs to shape policies that reflect current technological advancements and are proactive in anticipating future developments.

IV. Obstacles, Challenges in Arranging Regulation and Standardization of Autonomous Vehicle Safety in Indonesia

Autonomous vehicles, often called self-driving cars, are a technological breakthrough representing the future of transportation.[44] Behind this fascinating technological progress, various exciting aspects need further research, especially those related to the benefits and challenges it brings. With the integration of advanced technologies in the form of algorithms and machine learning, autonomous vehicles promise to revolutionize the way we interact with the world of transportation. Through this algorithm, vehicles can understand and respond to various variables on the road, controlling various aspects such as speed, braking and lane change maneuvers with a precision that exceeds human capabilities. Additionally, their adaptive capabilities enable smoother interaction with changing traffic conditions and other vehicles.

Table 2. Advantages and Disadvantages of Autonomous Vehicles

Aspect	Description
	Excess
Reduction of Accident Rates	Human factors cause most traffic incidents. Estimates show that the implementation of fully autonomous vehicles has the potential to reduce accidents by an average of 90%. Factors such as driver fatigue, distraction while driving, and the influence of alcohol can be minimized with vehicles that function automatically.

44 Arun S. Tigadi and others, 'Autonomous Vehicles: Present Technological Traits and Scope for Future Innovation', *EAI/Springer Innovations in Communication and Computing*, 2021, 115–43 <https://doi.org/10.1007/978-3-030-59897-6_7/COVER>.

Travel Efficiency	Autonomous vehicles can communicate with each other through technology. This enables optimal real-time analysis to determine the best route and adjust distance and speed during heavy traffic conditions.
Congestion Reduction	With real-time communication capabilities between vehicles, the safe distance between vehicles can be optimized, thereby reducing the potential for congestion.
Ease of Access for Certain Groups	Autonomous vehicles can provide more accessible transportation solutions for seniors and people with disabilities. Reducing transportation barriers can increase employment opportunities for individuals with disabilities and save healthcare costs.
Economic Benefits	Adopting autonomous vehicles can save up to trillions of U.S. Dollars in terms of productivity, fuel efficiency and accident prevention.
	Lack
Massive Adoption Addiction	All vehicles on the road should be autonomous for an autonomous vehicle system to work optimally. This can reduce individual freedom in driving manually.
Impact on Jobs	Autonomous vehicles, such as truck drivers and public transport, could threaten jobs in the transportation sector. Although some jobs will be lost, new opportunities in other sectors may emerge.
Cybersecurity Threats	Autonomous vehicles that rely on digital technology are vulnerable to cyber-attacks.
Ethical and Moral Issues	Artificial intelligence in autonomous vehicles may face dilemmas in situations that require moral judgment. For example, in scenarios that require a quick decision between avoiding children on the road or protecting the driver.

Interestingly, these autonomous vehicles have a capability hierarchy outlined by the Society of Automotive Engineers (SAE), where at the top, namely Level 5, the vehicle can operate without any human intervention at all, offering the potential for driving capabilities in almost any condition. These advances promise efficiency and the potential to improve safety, provide transportation solutions for previously limited ones, and optimize travel time, making room for more productivity while on the move.[45] From the hope of creating safer and more efficient roadways to concerns regarding ethics and economic impact, autonomous cars bring several advantages and disadvantages worth considering.

When considering the regulation and standardization of autonomous vehicle safety in Indonesia, several obstacles and challenges may be faced:

1. Traffic Infrastructure
   Traffic infrastructure in Indonesia faces various challenges that could affect the implementation of autonomous vehicles. One of the main obstacles is that the quality of roads in many areas may need to be improved to support autonomous vehicle operations. Not only may the road surface be damaged or uneven, but faded or unclear road markings can also hinder the ability of autonomous vehicle sensors to detect and navigate the surrounding environment.
2. Traffic Density
   Traffic density in Indonesia's big cities, especially Jakarta, poses challenges for implementing autonomous vehicles. With high vehicle volumes and often aggressive driving behaviour, autonomous vehicles must be equipped with sophisticated algorithms to respond dynamically. Motorcyclists, who usually move nimbly across lanes and adapt to tight spaces, add complexity to sensors and autonomous vehicle systems in making decisions. Plus, pedestrians sometimes cross the road suddenly without warning. All these dynamics demand a more mature approach and sophisticated technology for autonomous vehicles to function effectively and safely in typical Indonesian traffic conditions.

45 Catherine Menon and Rob Alexander, 'A Safety-Case Approach to the Ethics of Autonomous Vehicles', *Safety and Reliability*, 39.1 (2020), 33–58 <https://doi.org/10.1080/09617353.2019.1697918>.

3. Legal and Liability Issues
   Legal and liability issues are the main obstacles to integrating autonomous vehicles in Indonesia. In conventional traffic traditions, responsibility lies with the driver when an accident occurs. However, with the introduction of autonomous vehicles, the liability lines are becoming blurred. If an autonomous vehicle is involved in an accident, the question is whether the driver, the vehicle manufacturer, the software developer, or another party should be held responsible. How do we assess errors when human intervention is minimal or nonexistent? This requires deep thought and revision of the existing legal framework to ensure fairness and clarity in dealing with incidents involving autonomous vehicles.
4. Technology and its Availability
   Technology and its availability is one of the critical aspects in the implementation of autonomous vehicles in Indonesia. Although autonomous vehicle technology continues to develop rapidly in several developed countries, ensuring that the technology can be easily accessed and implemented in Indonesia may be complex. First, there are limitations in obtaining the latest technology, either due to import barriers, costs, or partnerships with global technology companies. Second, adapting technology to local conditions – from road conditions to traffic behaviour to environmental factors – requires specialized research and development. Additionally, post-sales support, such as software updates and hardware maintenance, must be available and reliable.
5. Limited Knowledge and Local Experts
   Limited knowledge and local experts are some of the significant challenges in implementing autonomous vehicles in Indonesia. As a relatively new and complex technology, autonomous vehicles require specific expertise in areas ranging from automotive engineering and artificial intelligence to technology ethics. Although Indonesia has demonstrated its capabilities in the information technology industry and several other technology sectors, autonomous vehicles demand specialization that the local workforce may still need to develop. These limitations affect the country's ability to develop this technology independently and implement, regulate and monitor its application appropriately.
6. Community Attitudes
   Society's attitude and acceptance of new technology are crucial in its successful implementation, and autonomous vehicles are no exception. In Indonesia, where driving traditions and habits are deeply embedded in everyday life, accepting a concept where vehicles can operate without human intervention may require significant adjustments. Autonomous vehicles may be seen as a symbol of innovation and technological progress.
7. Standardization
   Standardization is one of the crucial aspects in the development and implementation of autonomous vehicles. Establishing uniform safety and technical standards throughout Indonesia ensures that autonomous vehicles can operate effectively, safely and consistently in various regions and conditions. However, achieving these consistent standards is a challenging task. With various infrastructure conditions, regional regulations, and local needs that may vary in each region, strong coordination between the central government, regional governments, and the automotive industry is needed.
8. Environmental Aspects
   Environmental aspects play an essential role in the operation of autonomous vehicles, especially in tropical countries like Indonesia. Extreme weather conditions, such as seasonal flooding and heavy rains, are not only challenging from an infrastructure perspective but also in terms of autonomous vehicle technology. The sensors and cameras that are the eyes of an autonomous vehicle may have difficulty accurately detecting the environment when

obstructed by heavy rain or submerged in floodwaters. This can reduce the vehicle's ability to make safe and informed decisions.

9. Cyber Security
   Vehicle Cyber security is one of the primary considerations in developing autonomous vehicles, especially in the current digital era. Autonomous vehicles, with systems that rely heavily on information and communication technology, are not only instruments of transportation but also connected devices with potential vulnerabilities to cyber-attacks. Such attacks can manipulate vehicle systems, access personal data, or even take control of the vehicle, which can have severe consequences for road user safety. With the potential for attacks such as ransomware, malware, or intentional hacking to cause disruption or accidents, autonomous vehicle cybersecurity is a priority.

A multi-faceted and collaborative approach is needed to face the challenges of implementing autonomous vehicles in Indonesia. First, improving road infrastructure must be a priority, with investment from the government and partnerships with the private sector to ensure safer and more efficient roads for all users. Given the high traffic density in urban areas, developing unique algorithms adapted to local traffic conditions through collaboration between local universities and global technology companies is essential. This is reinforced by the need to establish a clear and comprehensive legal framework determining liability in autonomous vehicle accident scenarios. Along with this, strategic partnerships between local automotive manufacturers and world technology leaders can facilitate fast and efficient technology transfer. Education and training in the fields of Science, Technology, Engineering and Mathematics (STEM), especially with a focus on autonomous vehicles, enable the formation of a workforce that is skilled and ready to face new challenges in this industry. Public education campaigns, technology demonstrations, and involving the public in the decision-making process are vital to gaining public support and understanding of this technology's benefits and potential risks.[46]

Furthermore, standardization in autonomous vehicle technology ensures uniformity and safety across the country. Given environmental challenges, such as extreme weather conditions, investment in research and development of advanced sensors is essential. And finally, with more and more vehicles connected to the internet, cybersecurity is becoming a top priority. Joint efforts between governments, cybersecurity companies, and the automotive industry will ensure that autonomous vehicles are advanced and safe from cyber threats. With this integrated approach, Indonesia is ready to embrace the future of mobility with autonomous vehicles.[47]

Inaglobalcontext,manycountries,including the United States, the European Union, and Singapore have made strides in preparing for the era of autonomous vehicles. In the United States, the federal and state governments have developed regulatory frameworks for testing and deploying autonomous vehicles, with states such as California and Arizona leading the way in on-road testing. In the European Union, there is a more coordinated approach, with the European Commission guiding while member states adapt their regulations to ensure safety and interoperability across member states. Meanwhile, as a high-density city-state, Singapore has actively invested resources in autonomous vehicle research and development. They have implemented special test zones in areas such as one-north and forged partnerships with global technology companies to speed up development. These three areas have in common the recognition that autonomous vehicles are the future of transportation, and that early investment and proactive regulatory

46 A Caroline Sutandi and Wimpy Santosa, 'Integrated Road Safety Approach Towards Safer Road in Indonesia', *Agustus*, 14.2 (2014), 97–106.

47 Febby Mirza Juliansyah, 'Kepastian Hukum Terhadap Mobil Berteknologi Auto Pilot Ditinjau Dari Perspektif Hukum Lalu Lintas Jalan Di Indonesia', *Bureaucracy Journal : Indonesia Journal of Law and Social-Political Governance*, 2.2 (2022), 794–805 <https://doi.org/10.53363/bureau.v2i2.108>.

changes are needed to ensure a smooth and safe transition into this new era of mobility.[48]

The development of regulations and standardization of autonomous vehicles in Indonesia is a complex challenge in line with the unique characteristics and conditions of the country. Everything must be considered, from wide geographic diversity, with varying road conditions from urban to rural areas, to unique variations in driving culture. In addition, Indonesia's diverse socio-economic dynamics ensure that access and use of this technology must be designed to be inclusive and not leave out certain groups.

V. Closing

A. Conclusion

The conclusion from the study on the criminal legal liability of autonomous vehicles reveals that this technology presents significant new challenges to traditional legal frameworks. In the context of accidents, the responsibility typically borne by the driver must be reconsidered, given the minimal or non-existent role of the driver in autonomous vehicles. This necessitates regulatory changes that involve not only the driver but also the vehicle manufacturers and software developers who control the autonomous systems. Determining legal liability in accident cases requires a deep understanding of the involved technology and how errors or system failures can be identified and attributed. The approaches taken by countries like the United States, China, Singapore and European Union which emphasize manufacturer liability, can serve as examples for Indonesia in developing regulations that provide legal clarity and fairness in the era of autonomous vehicles.

A comprehensive and collaborative approach is required to address the various challenges in regulation and standardizing autonomous vehicle safety in Indonesia. Adequate traffic infrastructure, technology adaptable to local conditions, a clear legal framework, and public education are key to effective and safe implementation. Additionally, stringent cybersecurity standards and secure data management are crucial to prevent potential attacks and data misuse. Lessons from other countries show that early investment in research and development, along with proactive regulatory changes, can ensure a smooth transition to a new era of mobility with autonomous vehicles. With thorough preparation and collaboration among the government, industry, and society, Indonesia has the potential to become a regional leader in the safe and efficient integration and implementation of autonomous vehicle technology.

B. Recommendation

As Indonesia approaches the integration of autonomous vehicles, several strategic measures are essential. Firstly, the current Road Traffic and Transportation Law should be reviewed and amended to address issues related to autonomous vehicles, particularly in defining what constitutes a "driver" and establishing clear liability in accidents. Additionally, Indonesia could benefit from establishing a dedicated regulatory body to oversee the implementation and evolution of autonomous vehicle technology. Collaborating internationally to learn from countries with advanced autonomous vehicle policies can provide valuable insights and guidance. It is also crucial to invest in infrastructure improvements that support the operation of these vehicles, such as enhancing internet connectivity and adapting road signs for machine readability.

Educational campaigns and public engagement initiatives are vital to increase public awareness and acceptance of autonomous vehicles. Strengthening cybersecurity measures will protect against threats and maintain safety and public trust. Pilot testing in controlled environments should be conducted to gather data and refine regulations. Supporting local research and innovation can help tailor autonomous vehicle technology to Indonesia's unique context.

48 Tatiana Novaes Theoto and Paulo Carlos Kaminski, 'A Country-Specific Evaluation on the Feasibility of Autonomous Vehicles', *Product Management & Development*, 17.2 (2019), 123–33 <https://doi.org/10.4322/pmd.2019.013>.

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