Autonomous Vehicles: From Technology to Law and Regulation

Manuscript received April 7, 2024; revised May 17, 2024

Didik Suhariyanto
Department of Law
Universitas Bung Karno
Indonesia
suhariyanto.didik@yahoo.co.id

Ridwan Usman
Dept. of Industrial Engineering
Universitas Indraprasta PGRI
Indonesia
ridwan.usman@unindra.ac.id

Syamsu Marlin
Department of Electrical Engineering
Universitas Bung Karno
Indonesia
syamsu.marlin45@gmail.com

Mega Tri Kurnia
Department of Computer System
Universitas Bung Karno
Indonesia
mega_trikurnia@ubk.ac.id

La Ode Mohammad Firman
Center of Excellence in New and Renewable Energy
University of Pancasila
Indonesia
laodefirman@univpancasila.ac.id

Shuaibu Alani Balogun
Department of Mechanical Engineering
Federal Polytechnic Bauchi
Nigeria
sabalogun@fptb.edu.ng

Ihwan Ghazali*
Faculty of Industrial and Manufacturing Technology and Engineering
Universiti Teknikal Malaysia Melaka
Malaysia
ihwan@utem.edu.my

Abstract*—The advent of autonomous vehicles marks a convergence of technological advancement, societal change, and regulatory evolution with profound implications. This transformative technology has shifted from science fiction to reality, sparking extensive discourse encompassing technological progress, legal intricacies, and ethical considerations. This scholarly exploration navigates the intricate terrain of autonomous vehicles, tracing their evolution from a technological marvel to a catalyst for profound changes in legal frameworks, regulations, and societal dynamics. Our journey begins by delving into the technological foundations and significant achievements that underpin autonomous vehicle development. This illuminates the complex algorithms, sensor arrays, and machine-learning capabilities driving these self-driving vehicles. Transitioning from technology, we delve into the intricate realm of law and regulation, where established norms of road safety, liability, and privacy intersect with autonomy's transformative potential. This paper scrutinizes the intricate network of legal frameworks and ethical considerations governing the testing, deployment, and daily operation of autonomous cars. With their integration into transportation systems gaining prominence, balancing innovation with regulation assumes critical importance. This study embraces technology, law, and regulation, aiming to understand the multifaceted dimensions arising when autonomous cars intersect with legal and ethical frameworks. We explore the dynamic nature of global regulatory paradigms, analyzing obstacles, achievements, and ethical dilemmas shaping progress. As we embark on this endeavor, our goal is to offer a valuable resource elucidating the intricate process of transitioning from technology to legal frameworks and regulations within the era of autonomous vehicles.

Keywords—Autonomous vehicles, ethics, law, legal frameworks, regulation, societal change, technological advancement, transportation.

I. INTRODUCTION

The development of autonomous vehicles signifies a notable merging of technological advancement, societal change, and regulatory development [1, 2]. This emerging technology can significantly alter not just our understanding of transportation but also the fundamental structure of our urban areas, economic systems, and legal frameworks. Autonomous vehicles have undergone a significant transformation, transitioning from the world of science fiction to actual reality. This advancement has sparked extensive conversations that intersect technological progress, legal complexities, and ethical deliberations [3].

This paper explores the complex terrain of autonomous vehicles, mapping their development from a technology to a driver for significant transformations in legal frameworks, regulations, and societal dynamics. The paper starts by delving into the technological underpinnings and significant achievements that form the basis of autonomous vehicle advancement. This provides a deeper understanding of the intricate algorithms, sensor arrays, and machine-learning capacities that drive the functionality of these remarkable self-driving vehicles.

Transitioning from the area of technology, our exploration ventures into the intricate sphere of law and regulation, whereby the established norms of road safety, liability, and privacy intersect with the transformative capabilities of autonomy [4, 5]. This paper explores the complex network of legal frameworks and ethical considerations that regulate the testing, deployment, and daily operation of autonomous cars. As the integration of these cars into our transportation system becomes increasingly important, it becomes crucial to manage the balance between innovation and regulation carefully.

This scholarly exploration encompasses the domains of technology, law, and regulation, to comprehend the intricate

 EISSN: 2961-872X ● PISSN: 2961-8924 ● DOI: 10.56741/esl.v3i02.565

and ambiguous aspects that arise when autonomous cars meet with our legal and ethical frameworks. This study explores the dynamic nature of global regulatory paradigms, analyzing the obstacles, significant achievements, and ethical quandaries that influence the trajectory of progress. As we commence this endeavor, our objective is for this document to function as a valuable resource, elucidating the intricate process of transitioning from technology to legal frameworks and regulations within the era of autonomous vehicles.

II. Current and Future Applications

The realm of self-driving autonomous vehicles holds a diverse array of current and future applications poised to transform the way we navigate and interact with the world.

A. Personal Transportation

Autonomous vehicles stand to revolutionize personal transportation, offering the potential for safer, more efficient, and more accessible mobility. These vehicles could seamlessly integrate into our daily lives, serving as convenient options for commuting, running errands, or fulfilling various everyday activities. The prospect of reducing traffic accidents and congestion is particularly enticing.

B. Public Transportation

Beyond personal use, autonomous vehicles hold immense promise in the realm of public transportation [6]. They could be deployed to provide efficient and cost-effective services such as bus or shuttle operations, alleviating the need for expensive infrastructure investments like rail lines or dedicated lanes. This shift has the potential to significantly enhance public transportation accessibility and efficiency, benefitting urban communities [7].

The logistics and freight industry is ready for disruption by autonomous vehicles [8]. These vehicles can transform the transportation of goods and materials, potentially replacing traditional trucking and delivery services. This shift not only reduces transportation costs but also streamlines and optimizes supply chains, making them more resilient and efficient.

C. Specialized Applications

Autonomous vehicles are not limited to conventional scenarios [9]. They find valuable applications in specialized and challenging environments, such as remote areas or disaster zones. These vehicles can navigate difficult terrains and execute specific missions, whether it's transporting people or goods to places where traditional modes of transportation may struggle.

In conclusion, the landscape of autonomous vehicles extends well beyond personal commuting. Their multifaceted potential applications span from enhancing individual mobility to reshaping public transportation, revolutionizing logistics, and addressing unique challenges in various environments. As technology continues to advance, we can anticipate the ever-evolving role of autonomous vehicles in our society.

D. Personal transportation

The advent of autonomous vehicles holds the promise of transforming individual mobility through enhanced safety, increased efficiency, and improved accessibility. Autonomous cars possess the potential to be employed for several purposes, including commuting, executing errands, and engaging in routine activities.

To enhance the authenticity of the autonomous vehicles simulation, both single-mode journeys and multi-modal excursions were taken into account [10]. The simulation of the base case only included non-AV journeys, while the future scenario incorporated AV modes in addition to the existing transport options. Multi-modal travels indicate that individuals do not limit themselves to utilizing only one mode of transportation. They exhibit a high degree of intermodality, with the travel chain encompassing multiple means of transportation. Fig. 1 displays the transportation modes that were utilized and the multi-modal trips.

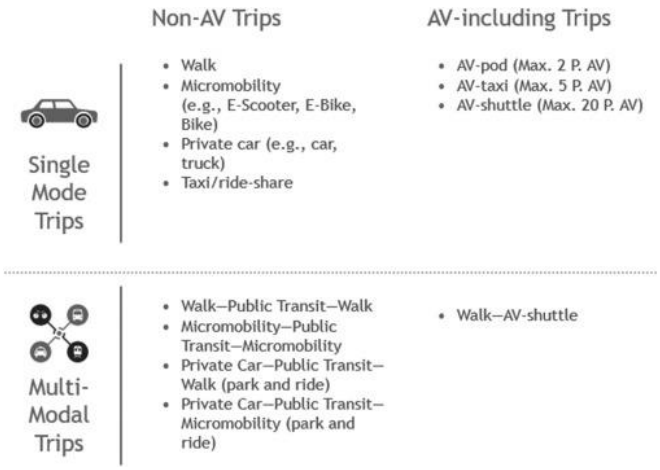

Fig. 1. Both single-mode trips and multi-modal excursions were in the experiment. The figure illustrates the various modes of transportation that are utilized, as well as the multi-modal transport networks [10].

One of the primary advantages associated with the utilization of autonomous vehicles for individual transportation lies in their capacity to substantially mitigate the occurrence of accidents resulting from human fallibility [11-14]. Based on data from the National Highway Traffic Safety Administration, it is observed that a significant majority, specifically 94%, of vehicular accidents can be attributed to human error, which encompasses behaviors such as distracted driving or driving under the influence. Autonomous vehicles, characterized by their immunity to such faults, possess the potential to mitigate the occurrence of accidents and consequently preserve human lives.

Furthermore, the implementation of autonomous cars has the potential to enhance the efficacy of individual transportation through the optimization of routes and the consequent reduction in fuel consumption. In addition, there is potential to enhance the accessibility of transportation for individuals who are unable to operate vehicles, including the elderly population and individuals with impairments.

In general, the utilization of autonomous vehicles for individual transportation holds the capacity to yield several advantages, encompassing enhanced safety, heightened efficiency, and augmented accessibility. Nevertheless, the widespread implementation of autonomous vehicles for personal transportation necessitates the resolution of various problems and restrictions, including factors such as cost, dependability, and regulatory concerns.

 EISSN: 2961-872X ● PISSN: 2961-8924 ● DOI: 10.56741/esl.v3i02.565

E. Public transportation

Autonomous vehicles have the potential to be utilized for the provision of public transportation services, including but not limited to bus or shuttle services. This has the potential to mitigate the necessity for costly infrastructure, such as railway systems or exclusive lanes, therefore enhancing the efficiency and accessibility of public transit.

One of the primary advantages associated with the utilization of autonomous cars in the context of public transportation lies in their capacity to mitigate the occurrence of accidents resulting from human fallibility substantially. Based on data from the National Highway Traffic Safety Administration, it is observed that the majority, specifically 94%, of vehicular accidents may be attributed to human error, encompassing behaviors such as distracted driving or driving under the influence. Autonomous vehicles, characterized by their absence of susceptibility to such errors, had the potential to mitigate the occurrence of accidents and consequently preserve human lives.

Furthermore, the integration of autonomous vehicles has the potential to enhance the efficacy of public transportation systems through the optimization of routes and the consequent reduction in fuel consumption. In addition, these vehicles have the potential to enhance service flexibility and responsiveness by enabling convenient rerouting or dispatching to accommodate dynamic shifts in demand.

In general, the utilization of autonomous cars in the context of public transportation holds promise for yielding numerous advantages, encompassing enhanced safety, heightened efficiency, and augmented accessibility. Nevertheless, the widespread use of autonomous cars for public transportation necessitates the resolution of numerous problems and restrictions, including factors such as cost, dependability, and regulatory concerns.

F. Other potential applications (e.g., delivery, agriculture, mining)

In addition to their traditional functions in individual and societal transportation, autonomous cars present a wide range of prospective uses, with the potential to significantly transform diverse sectors within multiple industries. The utilization of autonomous vehicles has the potential to revolutionize the delivery sector through the efficient transportation of products and commodities. This innovation possesses the capacity to replace conventional trucking and delivery services, resulting in decreased transportation expenses and improved supply chain efficiency.

Agricultural automation has emerged as a prominent field within the agricultural sector, wherein autonomous vehicles have been increasingly utilized to execute various duties such as crop planting, irrigation, and crop harvesting. The adoption of automation in agriculture not only results in reduced labor expenses but also enhances the overall effectiveness of agricultural activities, ultimately leading to enhanced crop productivity.

The integration of autonomous vehicles has the potential to yield substantial advantages for the mining sector. These vehicles can be utilized to transport various goods and equipment, in addition to performing duties such as drilling and blasting. These applications serve to reduce the likelihood of accidents and significantly improve the operational efficiency of mining activities.

Specialized conditions: Autonomous vehicles are particularly suitable for undertaking specialized activities in demanding conditions, such as distant regions or places affected by natural disasters. These entities possess the capability to traverse challenging landscapes and carry out precise objectives, such as the conveyance of individuals or commodities in regions where conventional transportation methods may encounter difficulties.

In essence, the multifaceted nature of autonomous vehicles transcends the conventional realm of transportation. The possible uses of these technologies encompass a wide range of industries, holding the potential to revolutionize the methods by which we transport commodities, develop crops, extract natural resources, and tackle distinct issues in different locations. With the progression of technology, it is foreseeable that there will be further development and expansion of autonomous vehicle applications.

III. Regulatory and Ethical Issues

The development and deployment of autonomous vehicles bring to the forefront a range of critical regulatory and ethical challenges that necessitate careful consideration. Foremost among these is the allocation of liability in the event of accidents involving autonomous vehicles. This complex issue hinges on determining responsibility, which may involve the vehicle itself, its software, human drivers, or pedestrians, making it a multifaceted concern. Additionally, the operation of autonomous vehicles requires the establishment of comprehensive standards and regulations. These frameworks should encompass various facets such as safety, performance, and cybersecurity, ensuring a structured and secure environment for their deployment.

Privacy concerns arise due to the extensive sensor and camera systems embedded in autonomous vehicles, which collect data about their surroundings and passengers. Safeguarding individuals' privacy by establishing protocols for the collection, usage, and storage of such data is of paramount importance. Furthermore, public acceptance plays a pivotal role in the widespread adoption of autonomous vehicles. Addressing concerns related to safety, reliability, and privacy is vital to instill confidence in users. As the technology evolves, time and education will likely be key factors in fostering public trust in autonomous vehicles. However, as the legislator, there is a need to identify the key challenges and their potential solutions. The implementation of autonomous vehicles has critical challenges. The challenges and potential solutions for autonomous driving in the area of criminal law are illustrated in Table 1.

In conclusion, as autonomous vehicles continue to advance and become more prevalent, navigating the intricate web of regulatory and ethical challenges is imperative. Balancing the imperatives of safety and privacy while unlocking the full potential of this transformative technology requires a thoughtful and multifaceted approach.

A. Overview of current regulations and standards

The current status of regulation about autonomous cars is marked by an ongoing process of evolution, which closely aligns with the dynamic advancements in the technology. Numerous regulatory frameworks and standards have been established or are currently being developed on a global scale.

The National Highway Traffic Safety Administration (NHTSA) in the United States has released extensive

guidelines about the examination and implementation of self-driving vehicles. In addition, a systematic Safety Assessment consisting of 15 points has been implemented, which manufacturers are required to comply with. Moreover, the National Highway Traffic Safety Administration (NHTSA) has put forward a series of Federal Motor Vehicle Safety Standards that are specifically tailored to cater to autonomous vehicles. It is important to note that the regulation of autonomous vehicles on roadways is mostly under the jurisdiction of individual states. Consequently, this has led to the existence of a fragmented landscape of state-level laws and regulations.

Furthermore, the advent of autonomous vehicles raises significant apprehensions regarding privacy, as these vehicles are equipped with sensors and cameras that possess the capability to gather vast amounts of data about both their surroundings and occupants. Ensuring the protection of individuals' privacy during the processes of data collection, utilization, and storage assumes utmost significance.

Table 1. Challenges and Potential Solutions for Autonomous Driving in the Area of Criminal Law

Challenge	Description	Potential Solutions
Liability	Determining who is liable in accidents involving autonomous vehicles, considering factors like ownership and control.	Establish clear legal frameworks outlining liability for accidents involving autonomous vehicles. Implement insurance policies tailored to autonomous driving technology.
Hacking and Cybersecurity	Vulnerability to hacking leads to criminal activities such as theft, ransomware, or using vehicles as weapons.	Implement robust cybersecurity measures, including encryption, authentication, and intrusion detection systems. Regularly update software and firmware to patch vulnerabilities.
Data Privacy	Protecting the privacy and security of data collected by autonomous vehicles to prevent crimes like identity theft.	Encrypt sensitive data, implement strict access controls and anonymize personally identifiable information (PII).
Regulatory Compliance	Ensuring compliance with laws and regulations to avoid criminal charges for manufacturers and operators.	Collaborate with policymakers to develop comprehensive regulations specific to autonomous vehicles. Conduct regular audits to ensure compliance with regulatory requirements.
Ethical Dilemmas	Addressing moral and ethical questions regarding decision-making in critical situations that may have criminal implications.	Develop ethical frameworks for autonomous systems, and prioritize human safety, and transparency in decision-making algorithms. Conduct thorough risk assessments and public consultations.
Intersection with Criminal Law	Preventing and responding to crimes facilitated by autonomous vehicles, such as smuggling or terrorist attacks.	Enhance collaboration between law enforcement agencies, cybersecurity experts, and manufacturers to detect and mitigate criminal activities. Implement strict access controls and monitoring systems for vehicle software.
Evidence Collection	Collecting and preserving evidence from autonomous vehicles for use in criminal investigations, ensuring its integrity and admissibility.	Develop protocols for collecting, preserving, and analyzing data from autonomous vehicles in compliance with legal standards. Establish chain-of-custody procedures and ensure data integrity through cryptographic techniques.

Within the European continent, the European Union has assumed a prominent role in establishing comprehensive directives about the advancement and implementation of autonomous cars. The aforementioned recommendations establish a fundamental framework for the examination and validation of self-driving automobiles, encompassing crucial elements such as safety, cybersecurity, and the safeguarding of data.

In contrast, Japan has developed its own set of guidelines under the purview of the Ministry of Land, Infrastructure, Transport and Tourism. The aforementioned standards offer guidance for the advancement and evaluation of self-driving vehicles, encompassing crucial areas such as safety, cybersecurity, and data privacy. With the increasing proliferation of autonomous vehicle technology and the growing understanding of associated difficulties, it is anticipated that the regulatory framework for autonomous vehicles will stay dynamic, accommodating the evolving demands of both society and technology.

B. Ethical considerations (e.g., liability, privacy, fairness)

The emergence and implementation of autonomous cars provide a multitude of ethical problems that necessitate meticulous scrutiny. The ethical difficulty of liability arises due to the complexity involved in identifying blame in the event of an accident involving autonomous cars. Determining the root cause of an accident can be a complex task, as it may entail various factors such as vehicle software, human factors, or acts taken by pedestrians.

Moreover, the inclusion of impartiality is of utmost importance. The management of autonomous vehicle accessibility and affordability necessitates careful consideration to mitigate the potential for social and economic imbalances to arise or worsen.

Finally, the process of making ethical decisions within autonomous vehicles presents a series of ethical quandaries. These vehicles may face circumstances in which they are required to allocate resources or prioritize objectives that conflict with one another. The establishment of ethical and transparent algorithms and decision-making processes in autonomous cars is of utmost importance. In summary, the increasing prevalence of autonomous vehicles necessitates a heightened focus on ethical problems. It is crucial to prioritize the resolution of these problems in a manner that upholds the rights and interests of all stakeholders involved.

IV. Regulation and Legal Framework for Autonomous Vehicles

The emergence and implementation of autonomous vehicles (AVs) have presented intricate legal and regulatory complexities on a global scale [15-17]. The establishment of a comprehensive framework is of utmost importance as autonomous driving technology progresses and becomes

 EISSN: 2961-872X ● PISSN: 2961-8924 ● DOI: 10.56741/esl.v3i02.565

increasingly incorporated into our transportation networks. This framework should encompass several aspects such as safety, liability, privacy, and ethical considerations. This section provides an analysis of the changing legal and regulatory framework around autonomous cars, highlighting the importance of adopting a unified strategy across different countries.

The regulation of autonomous vehicles (AVs) in the United States involves a distinctive dynamic between the federal and state governments [12, 18, 19]. The regulatory oversight of vehicle safety standards is entrusted to the National Highway Traffic Safety Administration (NHTSA), although the responsibility for licensing and traffic regulations lies with individual states. States such as California, Nevada, and Arizona have assumed a pioneering role in formulating legislation that is expressly designed to address the unique requirements of autonomous vehicles (AVs), thereby permitting their testing and implementation inside controlled environments. Nevertheless, the absence of standardization across state statutes underscores the necessity for federal legislation to guarantee uniformity and establish safety benchmarks nationwide. Fig. 2 shows the implemented and active connected vehicle projects [16].

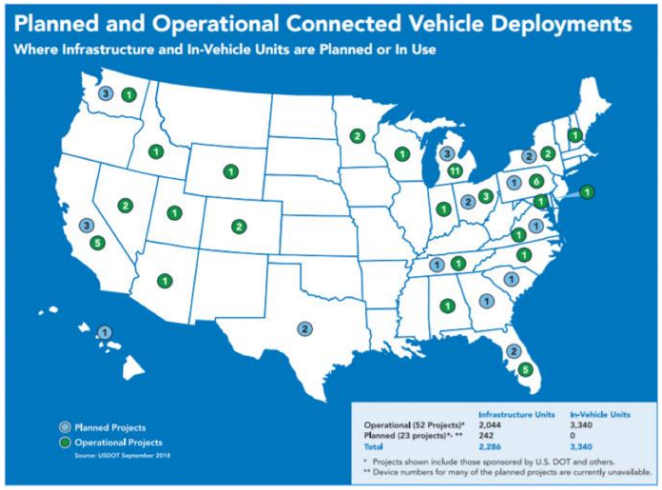

Fig. 2. Implemented and active connected vehicle projects [16].

The World Forum for Harmonization of Vehicle legislation, established by the United Nations Economic Commission for Europe (UNECE), operates on a global level and focuses on the development of initiatives aimed at standardizing legislation about autonomous vehicles (AVs). The World Forum of the United Nations Economic Commission for Europe (UNECE) acknowledges the importance of global harmonization to promote the extensive integration of autonomous vehicles (AVs) and enhance the efficiency of cross-border activities.

The topic of culpability in the occurrence of accidents or malfunctions is a key legal concern about autonomous vehicles (AVs). The conventional liability frameworks in the automotive industry are predicated upon the attribution of fault to human drivers based on their negligence. As autonomous vehicles (AVs) continue to advance in their level of autonomy, there is a growing emphasis on the concept of product liability. In this context, manufacturers and technology suppliers may be held accountable for accidents that occur due to flaws within the AV system. To guarantee equitable and impartial results, legal frameworks must adjust and accommodate these evolving dynamics.

The insurance sector encounters a unique array of issues with autonomous vehicles (AVs). Insurers are required to reevaluate risk profiles, considering many elements like the degree of vehicle autonomy, data gathering practices, and the causation of accidents. There is a suggestion among experts that to effectively mitigate risks associated with autonomous vehicles (AVs), it may be imperative to develop a hybrid insurance model that integrates elements of both regular auto insurance and product liability coverage.

Autonomous vehicles (AVs) produce substantial quantities of data, encompassing real-time sensor data, position information, and occupant data. The issues about the ownership, accessibility, and safeguarding of data assume utmost significance. The regulatory frameworks should strive to strike a delicate equilibrium between the imperative of facilitating data access and analysis for enhancing safety measures, and the imperative of protecting individual privacy and security.

Autonomous vehicles (AVs) are vulnerable to cyberattacks due to their reliance on interconnected systems and communication networks [14, 20, 21]. Regulatory agencies must set cybersecurity standards and processes to effectively address these risks and safeguard the occupants and infrastructure of autonomous vehicles (AVs). The regulation of autonomous cars is a complex task that encompasses various dimensions, including municipal, national, and international levels. As the progression of technology persists, legislators and regulators must engage in cooperative efforts with industry participants to construct adaptable and all-encompassing legal structures. The prioritization of safety, liability, privacy, and security considerations is crucial within frameworks that aim to promote innovation and responsible deployment of autonomous cars within transportation networks. Fig. 3 shows the attack surface model for operations in connected and automotive driving systems.

V. Conclusion

Autonomous vehicles that operate without human intervention are an emerging technology that exhibits swift advancement, holding the capacity to transform the realm of transportation and yield numerous advantages, including enhanced safety, heightened efficiency, and augmented accessibility. Nevertheless, the widespread deployment of autonomous vehicles necessitates the resolution of numerous problems and restrictions, encompassing cost, dependability, legal complexities, and ethical deliberations.

This paper presents a comprehensive examination of the legal and regulatory environment around autonomous vehicles, encompassing significant aspects such as regulatory frameworks, liability and insurance, and data privacy and security. The statement emphasizes the necessity of flexible and coordinated legal structures to effectively tackle the intricate obstacles presented by autonomous driving technology.

To fully harness the capabilities of autonomous cars, it is imperative to effectively tackle the obstacles and constraints associated with them by employing a blend of technological advancements, regulatory structures, and ethical deliberations.

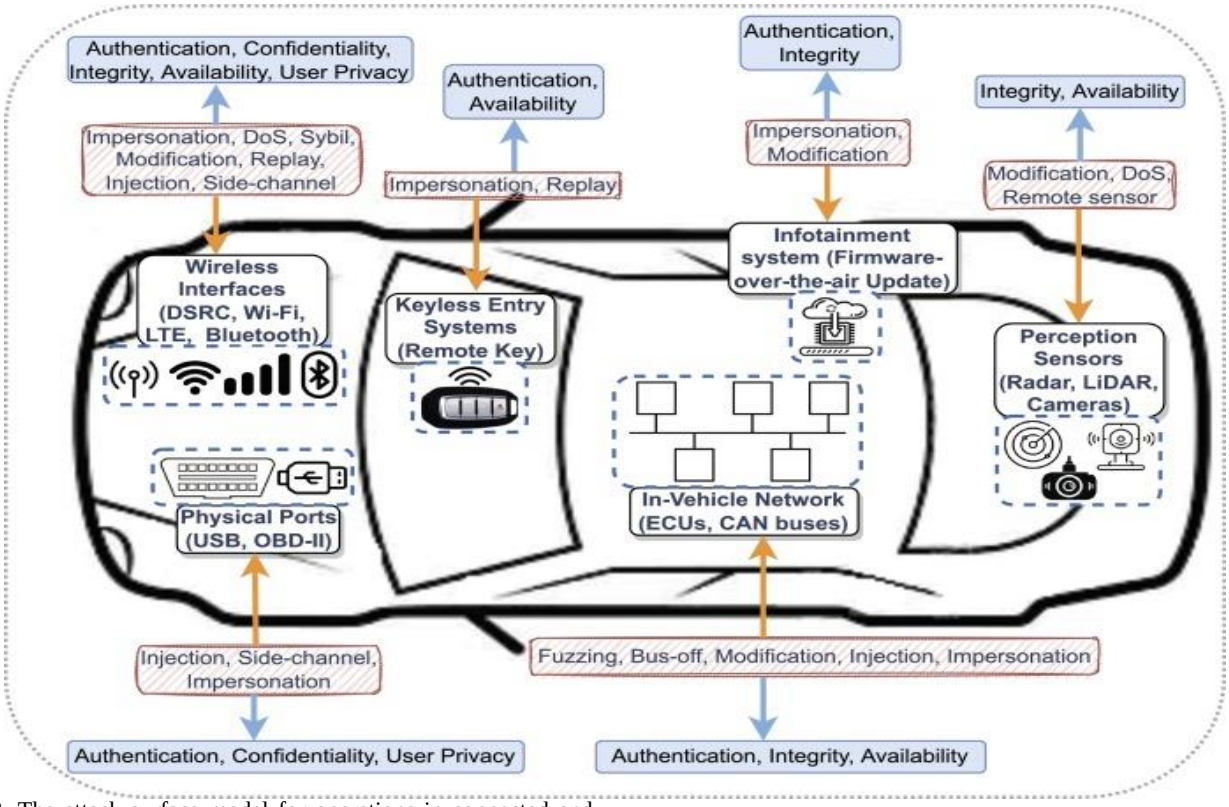

Fig. 3. The attack surface model for operations in connected and automotive driving systems [22].

By adopting this approach, it is possible to facilitate the development and implementation of autonomous cars in a manner that yields advantages for the entirety of society. In general, the prospective trajectory of autonomous vehicles is imbued with promise and engenders a sense of anticipation. It will be intriguing to observe the evolution and application of this technology in the forthcoming years.

VI. References

[1] A. Nikitas, A.-E. Vitel, and C. Cotet, "Autonomous vehicles and employment: An urban futures revolution or catastrophe?," Cities, vol. 114, p. 103203, 2021.

[2] A. Chehri and H. T. Mouftah, "Autonomous vehicles in the sustainable cities, the beginning of a green adventure," Sustainable Cities Soc., vol. 51, p. 101751, 2019.

[3] I. Krontiris et al., "Autonomous vehicles: Data protection and ethical considerations," in Proceedings of the 4th ACM Computer Science in Cars Symposium, 2020, pp. 1-10.

[4] O. I. Abiodun, E. O. Abiodun, M. Alawida, R. S. Alkhawaldeh, and H. Arshad, "A review on the security of the internet of things: Challenges and solutions," Wireless Pers Commun, vol. 119, pp. 2603-2637, 2021.

[5] R. Girasa, Artificial intelligence as a disruptive technology: Economic transformation and government regulation. Springer Nature, 2020.

[6] E. Wigley and G. Rose, "Who's behind the wheel? Visioning the future users and urban contexts of connected and autonomous vehicle technologies," Geografiska Annaler: Series B, Human Geography, vol. 102, no. 2, pp. 155-171, 2020.

[7] A. Ceder, "Urban mobility and public transport: future perspectives and review," International Journal of Urban Sciences, vol. 25, no. 4, pp. 455-479, 2021.

[8] C. Dong, A. Akram, D. Andersson, P.-O. Arnäs, and G. Stefansson, "The impact of emerging and disruptive technologies on freight transportation in the digital era: current state and future trends," The International Journal of Logistics Management, vol. 32, no. 2, pp. 386-412, 2021.

[9] S. Riedmaier, T. Ponn, D. Ludwig, B. Schick, and F. Diermeyer, "Survey on scenario-based safety assessment of automated vehicles," IEEE Access, vol. 8, pp. 87456-87477, 2020.

[10] M. A. Richter, M. Hagenmaier, O. Bandte, V. Parida, and J. Wincent, "Smart cities, urban mobility, and autonomous vehicles: How different cities need different sustainable investment strategies," Technological Forecasting and Social Change, vol. 184, p. 121857, 2022/11/01/ 2022, doi: https://doi.org/10.1016/j.techfore.2022.121857.

[11] A. Shetty, M. Yu, A. Kurzhanskiy, O. Grembek, H. Tavafoghi, and P. Varaiya, "Safety challenges for autonomous vehicles in the absence of connectivity," Transp. Res. Part C Emerg. Technol., vol. 128, p. 103133, 2021.

[12] H. U. Ahmed, Y. Huang, P. Lu, and R. Bridgelall, "Technology developments and impacts of connected and autonomous vehicles: An overview," Smart Cities, vol. 5, no. 1, pp. 382-404, 2022.

[13] A. Chougule, V. Chamola, A. Sam, F. R. Yu, and B. Sikdar, "A Comprehensive review on limitations of autonomous driving and its impact on accidents and collisions," IEEE Open Journal of Vehicular Technology, 2023.

[14] A. Haddaji, S. Ayed, and L. C. Fourati, "Artificial Intelligence techniques to mitigate cyber-attacks within vehicular networks: Survey," Computers and Electrical Engineering, vol. 104, p. 108460, 2022.

[15] L. Hansson, "Regulatory governance in emerging technologies: The case of autonomous vehicles in Sweden and Norway," Research in transportation economics, vol. 83, p. 100967, 2020.

[16] Y. Aoyama and L. F. A. Leon, "Urban governance and autonomous vehicles," Cities, vol. 119, p. 103410, 2021.

[17] N. E. Bezai, B. Medjdoub, A. Al-Habaibeh, M. L. Chalal, and F. Fadli, "Future cities and autonomous vehicles: analysis of the barriers to full adoption," Energy and Built Environment, vol. 2, no. 1, pp. 65-81, 2021.

[18] M. Firlej and A. Taeihagh, "Regulating human control over autonomous systems," Regulation & Governance, vol. 15, no. 4, pp. 1071-1091, 2021.

[19] D. Schepis, S. Purchase, D. Olaru, B. Smith, and N. Ellis, "How governments influence autonomous vehicle (AV) innovation," Transportation Research Part A: Policy and Practice, vol. 178, p. 103874, 2023.

[20] R. Gupta, A. Kumari, and S. Tanwar, "A taxonomy of blockchain envisioned edge-as-a-connected autonomous vehicles," Transactions on Emerging Telecommunications Technologies, vol. 32, no. 6, p. e4009, 2021.

[21] M. Girdhar, Y. You, T.-J. Song, S. Ghosh, and J. Hong, "Post-accident cyberattack event analysis for connected and automated vehicles," IEEE Access, vol. 10, pp. 83176-83194, 2022.

[22] T. Limbasiya, K. Z. Teng, S. Chattopadhyay, and J. Zhou, "A systematic survey of attack detection and prevention in connected and autonomous vehicles," Vehicular Communications, vol. 37, p. 100515, 2022.

 EISSN: 2961-872X ● PISSN: 2961-8924 ● DOI: 10.56741/esl.v3i02.565