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Unmanned Vehicles: Navigating the Environmental Implications

Kiruthika D[1] & Jeevishaa S[2]

ABSTRACT

Unmanned vehicles, or autonomous vehicles, represent a significant shift in transportation technology with notable environmental consequences. This paper delves into the multifaceted environmental impact of unmanned vehicles across diverse sectors. It investigates how autonomous technologies influence greenhouse gas emissions, traffic patterns, and urban planning, thereby shaping the sustainable development of cities and regions. The analysis focuses on key areas such as energy consumption, air quality, urban sprawl, and regulatory challenges associated with unmanned vehicles. It addresses both the potential benefits, such as reduced carbon emissions through optimized routes, and challenges like electronic waste and resource use in manufacturing. The paper also reviews India's current policies on integrating autonomous vehicles into sustainable transport systems, emphasizing the need for strong regulations and innovation to ensure environmental sustainability. By navigating these complexities, policymakers, researchers, and industry stakeholders can foster innovation while ensuring environmental sustainability in the era of autonomous vehicles.

KEYWORDS:

Unmanned vehicles- Sustainability- Transportation- Environment-Policies.

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INTRODUCTION:

Since the mid-twentieth century, automobiles have become a cornerstone of urban life, revolutionizing the way people travel within and between cities. The convenience and mobility they offer have reshaped city structures and influenced daily life. Alongside these benefits, the widespread use of automobiles has introduced significant environmental challenges, particularly within the transportation sector, which is now recognized as one of the fastest-growing contributors to global greenhouse gas (GHG) emissions[3]. These emissions, primarily from the burning of fossil fuels, are a major driver of climate change, highlighting the urgent need for more sustainable solutions within the sector. As the world grapples with the escalating impacts of climate change, the transportation sector

[1]Assistant Professor of Law, Chennai Dr. Ambedkar Government Law College, kiruthikaadv@gmail.com

[2] Advocate, Madras High Court, Chennai, India. jeevi1482000@gmail.com

[3] Md. Mokhlesur Rahman, Jean-Claude F. Thill, "Impacts of Connected and Autonomous Vehicles on Urban Transportation and Environment: A Comprehensive Review" Sustainable Cities and Societies (May 2023).

faces the dual challenge of improving energy efficiency and reducing emissions while meeting the growing demand for mobility. The environmental consequences of increased personal vehicle usage are becoming more apparent, and the need for innovative solutions is more pressing than ever.

In recent years, technological advancements, particularly in the field of Artificial Intelligence (AI), have given rise to new possibilities within the transportation industry. The concept of "autonomous vehicles" (AVs) has emerged as a potential game-changer, promising to revolutionize how we think about mobility[4]. These vehicles, which operate without direct human control, represent a significant shift in the way transportation systems are designed and managed. While automation has been a familiar concept in other industries, its application in transportation is still in its nascent stages, yet it holds the potential to transform society profoundly.

This paper aims to explore the environmental implications of unmanned, AVs within the broader context of their development and adoption. The paper will address several critical questions like the current status of AV and how do AVs impact the transportation system, energy consumption, and the environment. In this context, the focus is specifically on the environmental impact of AVs. Given that AVs are expected to be incrementally introduced over the coming decades, understanding their potential environmental consequences is crucial for shaping future transportation policies and ensuring sustainable urban development. This paper, therefore, aims to fill a critical gap in the literature by consolidating existing knowledge and providing a comprehensive overview of the environmental implications of AVs.

OVERVIEW OF AUTONOMOUS VEHICLES: DEFINITION & CONCEPT:

Autonomous Vehicles, often referred to as self-driving cars, driverless cars, or robotic cars, represent a groundbreaking shift in the realm of transportation[5]. These vehicles have the ability to drive and navigate without direct human input, relying on a sophisticated array of technologies including sensors, radar, Global Positioning Systems, and computer vision. The core feature that sets AVs apart from conventional vehicles is their varying levels of automation, which range from assisting human drivers to completely taking over the vehicle's control.

The concept of autonomous vehicles hinges on advanced AI systems that manage the vehicle's operations. These systems work in tandem with sensors, actuators, complex algorithms, machine learning frameworks, and powerful processors to allow the vehicle to sense its environment and make real-time driving decisions[6]. AVs are equipped with a variety of sensors distributed throughout the vehicle, each serving a critical function in ensuring safe navigation. A self-driving car employs these

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[4] Shivanshi Yadav, Nagresh Kumar, Vimal Kumar, Devanshi Yadav, "Autonomous Vehicle in Indian Context: A Review" *International Journal of Novel Research and Development (IJNRD)* 7 (July 2022).

[5] *Ib*id, at 1.

[6] Lakshahttps://www.legalserviceindia.com/legal/article-10606-autonomous-vehicles-legislations-for-liabilities.html#:~:text=Currently%2C%20in%20India%2C%20there%20is,1988%22%20(MV%20ACT)y Soni, Mandvi Khangarot, "Autonomous Vehicles: Legislations for Liabilities", Legal Service India, 2023, available at < > (16 August 2024).

JSS Journal for Legal Studies and Research
[ISSN 2321-4171]

sensors and AI to navigate roads independently, reacting to the environment, which includes other vehicles, pedestrians, and various road signs, without requiring human intervention.

According to the Society of Automotive Engineers (SAE) and the National Highway Traffic Safety Administration (NHTSA), vehicle autonomy is classified into six levels, ranging from Level 0 (no automation) to Level 5 (full automation). At Level 0, the vehicle is entirely controlled by a human driver[7]. As we progress through the levels, the degree of autonomy increases, with Level 5 vehicles being capable of fully autonomous operation in all environments and conditions without any human intervention.

Automated Electric Vehicles (A-EVs), a subset of AVs, are particularly notable for their integration of AI with a range of sensing technologies, including cameras, laser imaging, radar sensors, and detection and ranging systems. These technologies enable A-EVs to perceive their surroundings and make decisions autonomously. As AV technology continues to evolve, it is poised to bring about substantial changes not only in how we think about transportation but also in the very fabric of society.

EVOLUTION OF AUTONOMOUS VEHICLES:

The journey towards automation and self-driven machinery is not a recent phenomenon but dates back centuries, beginning between 300 BC and 1200 AD[8]. During this period, the Greeks and Arabs were particularly intrigued by the concept of reducing manual labor and introducing automated processes. However, it was not until the 18th century that we witnessed the emergence of fully automated machines. Despite these early advancements in automation, the notion of self-driving vehicles did not take root until the 1920s. Initial experiments were rudimentary and often met with limited success, but the seeds were sown for future innovations. The timeline of autonomous vehicles began as early as 1926 with the "Linriccan Wonder," the world's first radio-controlled car. The world's first semi-automated car was introduced in 1977 by Japan's Tsukuba Mechanical Engineering Laboratory. This project required specially marked streets that the vehicle's cameras could record, interpret, and process through an analog computer, allowing the vehicle to reach speeds of up to 30 kilometers per hour (19 mph) with the support of an elevated rail. But, significant advancements were made after the introduction of the vision-guided Mercedes-Benz robotic van in the 1980s. This era laid the foundation for modern-day autonomous vehicles, demonstrating the potential of combining machine vision with vehicle control systems.

Globally, the excitement surrounding autonomous vehicles has grown rapidly, with significant advancements in the United States. Google's partner company, Waymo, has been at the forefront of this

[7] Tata Capital, "Future of Self-Driving cars in India", Tata Capital, 17 May 2022, available at < https://www.tatacapital.com/blog/loan-for-vehicle/future-of-self-driving-cars-in-india/> (17 August 2024).

[8] Radha Basu, "The Evolution and Future of Autonomous Mobility in India", BW Auto World, 13 May 2022, available at < https://bwautoworld.com/article/the-evolution-and-future-of-autonomous-mobility-in-india-428719> (17 August 2024).

movement, operating a fleet of autonomous vehicles under the name "Waymo One" in various locations across the country. In October 2020, Waymo expanded its services to the general public, becoming the first self-driving service to operate without vehicle safety drivers. The technology developed by Waymo is setting the stage for broader applications of autonomous driving systems worldwide.

While self-driving cars have become a reality in some parts of the world, their presence in India remains in its early stages. Currently, India has only a few prototypes and demonstration projects, though several companies are actively involved in researching and developing this technology. Indian corporations such as Tata Motors, Mahindra & Mahindra, and the Indian Institute of Technology (IIT) Madras are among the key players working on self-driving automobile technology[9]. In 2017, Mahindra & Mahindra showcased its first-ever driverless tractor, positioning itself as a pioneer in the autonomous vehicle sector. This tractor was developed in response to growing concerns about food scarcity, illustrating how autonomous mobility innovations can address critical challenges faced by farmers and other allied sectors. The future of autonomous vehicles in India appears promising, with the Indian Autonomous Vehicle Market projected to exceed USD XX Billion by 2032, growing at a CAGR of 20.8% from 2022 to 2032[10]. India's Delhi Metro Rail Corporation (DMRC) has made significant strides in the realm of autonomous vehicles. India's first non-motorized railway operations cover a 38-kilometer long stretch, representing a major technological achievement. These driverless trains, equipped with high-tech cameras and hearing aids, offer enhanced reliability by reducing human intervention, thus ensuring passenger safety. This development represents a significant milestone not only for the DMRC but also for the entire country.

The enthusiasm and investment in autonomous vehicles are unmistakable. From the early experiments in automation to the current developments in driverless technology, the evolution of autonomous vehicles reflects a broader trend towards greater innovation and efficiency in transportation. The ongoing advancements signal a future where autonomous vehicles could become a staple in both personal and public transportation systems, radically transforming the way we travel and interact with our environment.

APPLICATIONS OF AUTONOMOUS VEHICLES:

AVs have the potential to revolutionize multiple sectors, including transportation, logistics, urban planning, and agriculture. In India, a country with one of the largest automobile industries globally, the introduction of AVs could lead to significant shifts in employment, manufacturing, and transportation dynamics. However, several challenges must be overcome, such as infrastructural inadequacies, non-compliance with traffic laws, and the socio-economic impact on employment, particularly in sectors like driving[11]. Despite these challenges, the benefits and applications of AVs are numerous. One of the most significant advantages is the potential to enhance traffic safety and reduce accidents.

[9] Bhasker Canagaradjou, Shashank Yadav, "Driving Mobility Through Autonomy in India", Ipsos Business Consulting (2018).

[10] Automotive and Transportation, "India Autonomous Vehicle Market", (July 2023).

[11] Aditya Fouzdar, "Laws Regarding Autonomous Vehicles in India", Lexlife India, 10 June 2021, available at < https://lexlife.in/2021/06/10/autonomous-vehicles-and-laws-autonomous-vehicles-and-laws/> (17 August, 2024).

JSS Journal for Legal Studies and Research
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AVs, with their superior reliability and faster reaction times compared to human drivers, could drastically reduce traffic collisions, which would lead to fewer road injuries and fatalities. This improvement in road safety is particularly important in India, where traffic accidents are a major concern[12].

AVs could also optimize traffic flow and reduce congestion by minimizing the need for large safety gaps between vehicles and ensuring more consistent driving patterns. This improvement could lead to increased roadway capacity, less traffic congestion, and shorter travel times, making urban mobility more efficient. AVs could revolutionize parking and urban space management. These vehicles could drop off passengers and then park themselves in any suitable space, returning only when summoned[13]. This ability could drastically reduce the need for extensive parking facilities, freeing up valuable urban space for other uses and potentially transforming urban infrastructure and planning.

The adoption of AVs could lead to significant cost savings. As AVs will rely on network communication for navigation and traffic management, the need for physical road signage and traffic police could decrease, leading to reduced Government spending on infrastructure and operational systems. AVs also offer enhanced mobility solutions for individuals who cannot drive due to age, disability, or other factors, thereby enabling greater independence and contributing to more inclusive urban environments. In the logistics sector, autonomous technology can revolutionize goods transport by implementing more efficient systems, such as autonomous trucks, which can operate continuously without human intervention. AVs could also support more effective car-sharing models, reducing the need for private vehicle ownership and contributing to environmental sustainability.

AVs equipped with advanced security systems may reduce incidents of vehicle theft. The reduction in accidents could also lower vehicle insurance costs, making it more affordable for consumers. The user experience in AVs is likely to be enhanced as well, with passengers enjoying smoother rides and the elimination of driving-related stress and fatigue, allowing them to focus on other activities during their commute. AVs also have significant applications in the military and security sectors. They can be deployed in military operations to conduct reconnaissance, supply missions, and other dangerous tasks without putting human lives at risk. In addition, AVs can be used for security patrols and surveillance in sensitive areas[14].

In the agricultural sector, autonomous vehicles such as driverless tractors can play a crucial role in improving productivity. These vehicles can automate various farming activities, reducing the need for manual labor and helping to address labor shortages in rural areas. While the potential benefits of AVs are considerable, challenges such as legal liabilities, software reliability, and the risk of misuse

[12] Keshav Bimbraw, “Autonomous Cars: Past, Present and Future - A Review of the Developments in the Last Century, the Present Scenario and the Expected Future of Autonomous Vehicle Technology”, Nokia Bell Labs, (January 2015).

[13] Somaiyeh MahmoudZadeh , David M.W. Powers. et al., Autonomy and Unmanned Vehicles, (Springer, Australia, 2019).

[14] Viraj Ranjan Singh, “Autonomous Vehicles and the Challenges in India”, Lexplosion, 2 September 2021, available at < https://lexplosion.in/autonomous-vehicles-and-the-challenges-in-india/> (17 August 2024).

for criminal activities must be addressed. The successful implementation of AVs in India will require significant advancements in infrastructure, technology, and regulatory frameworks. Nevertheless, the integration of autonomous vehicles into various sectors promises to transform how we live, work, and interact with our surroundings, paving the way for a more efficient, safer, and inclusive future.

ENVIRONMENTAL IMPACT OF UNMANNED/AUTONOMOUS VEHICLES:

The environmental impact of unmanned or AVs) is an increasingly important topic as these technologies become more prevalent. This impact can be understood through a variety of lenses, including air quality, noise pollution, wildlife, soil, and more, need to be carefully considered to ensure that the widespread adoption of AVs contributes positively to the planet's health. The environmental impact of autonomous vehicles is a complex interplay of positive and negative effects., making it crucial to assess both the potential positive and negative environmental outcomes associated with their widespread adoption[15].

Air Quality and Emissions: One of the most significant impacts of autonomous vehicles is on air quality and greenhouse gas emissions. AVs, particularly electric ones, have the potential to drastically reduce emissions by optimizing driving patterns, reducing idling, and enabling smoother acceleration and braking. The reduction in tailpipe emissions could significantly improve urban air quality, which is currently a major concern in densely populated areas. But, if AVs lead to an increase in vehicle miles traveled due to the convenience of autonomous driving, the overall emission reductions might be offset, particularly if the AVs are not predominantly electric. The energy required to power the sophisticated sensors and computing systems in AVs could contribute to emissions if this energy is sourced from fossil fuels.

Noise Pollution: Autonomous vehicles, especially electric ones, are generally quieter than traditional internal combustion engine vehicles, which could lead to a reduction in urban noise pollution. This decrease in noise is particularly beneficial in cities, where traffic noise is a significant issue. But, the near-silent operation of AVs could also pose new challenges, such as the need for artificial noise generation to alert pedestrians and cyclists of an approaching vehicle, which might add to noise levels in a different way.

Wildlife-Related Disturbances: The introduction of AVs could have both positive and negative effects on wildlife. On one hand, the reduction in noise pollution and emissions could create a more favorable environment for wildlife in urban and suburban areas. On the other hand, the ability of AVs to operate continuously, including at night, might lead to more frequent disturbances to nocturnal animals, potentially disrupting their natural behaviors.

Soil and Land Degradation: The impact of AVs on soil and land degradation largely depends on the broader implications of their use, such as changes in land use and urban planning. If AVs reduce the need for extensive parking facilities, this could free up land that might otherwise have been paved, re-

[15] Supra note 1, at 1.

ducing soil sealing and promoting natural land cover. But the expansion of road networks to accommodate increased traffic or urban sprawl facilitated by AVs could lead to soil degradation and loss of natural habitats.

Urban Sprawl and Land Use: AVs have a dual-edged impact on land use and urban sprawl. On the one hand, they could reduce the need for parking spaces and large vehicle ownership, potentially freeing up urban land for other uses and reducing the impervious surfaces that contribute to soil and water degradation. On the other hand, the convenience and lower travel costs associated with AVs could encourage urban sprawl, as people may choose to live farther from city centers, knowing that AVs can handle longer commutes. This sprawl could lead to increased land degradation, loss of natural habitats, and higher energy consumption, as longer trips become more common[16].

Resource Consumption: The production and operation of AVs involve the use of various natural resources, including rare earth metals for batteries and electronic components. The large-scale adoption of AVs could increase the demand for these resources, leading to environmental degradation associated with mining and processing. The energy-intensive manufacturing of AVs could contribute to resource depletion if not managed sustainably.

Habitat Disruption : The deployment of AVs could lead to habitat disruption in several ways. For instance, the construction of new infrastructure to support AV technology, such as data centers, communication networks, and road modifications, could encroach on natural habitats. The reduction in parking space demand might encourage urban expansion into previously undeveloped areas, potentially disrupting local ecosystems.

Water Pollution: The environmental benefits of AVs could extend to water quality if their adoption leads to a reduction in road traffic and associated pollutants like oil, heavy metals, and debris, which are often washed into water bodies during rainstorms. But the manufacturing and disposal of AVs, particularly their electronic components and batteries, could contribute to water pollution if not managed correctly[17].

correctly

Marine Life Interference: Although AVs primarily operate on land, their impact on marine life should not be overlooked. The production and disposal of AVs could lead to marine pollution, particularly if waste from electronic components and batteries is not properly managed. Any increase in vehicle emissions that contributes to ocean acidification or climate change could indirectly affect marine ecosystems[18].

[16] Zhong, S., Liu, A., Jiang, Y. et al. "Energy and environmental impacts of shared autonomous vehicles under different pricing strategies." npj Urban Sustain 3, 8 (2023).

[17] Morteza Taiebat, Austin L. Brown. et al., "A Review on Energy, Environmental, and Sustainability Implications of Connected and Automated Vehicles", ACS Publications, 52, (7 September 2018).

Energy Use and Efficiency: AVs have the potential to improve energy efficiency in transportation by reducing unnecessary acceleration, optimizing routes, and promoting vehicle sharing, which could collectively lower energy use and GHG emissions. For instance, automated systems can adjust driving patterns to match trip requirements, leading to better energy utilization. In a fully automated system, daily driving could increase energy efficiency by up to 200%[19], with the potential for zero GHG emissions during travel. But the increased demand for energy to charge AVs, especially in a scenario where AVs replace public transport or lead to urban sprawl, could offset these benefits. Studies suggest that charging millions of AVs would require a substantial increase in electricity production, potentially leading to increased demand for non-renewable energy sources, such as oil, unless there is a corresponding expansion in renewable energy capacity[20].

SWOT Analysis of Avs: A SWOT analysis of AVs reveals that while they present significant opportunities for reducing energy use, emissions, and improving traffic efficiency, they also pose threats in the form of increased energy consumption, urban sprawl, and potential negative impacts on sustainable development. The reduction in travel costs could encourage more frequent and longer trips, increasing overall energy consumption and emissions. This dual nature of AVs makes it imperative to carefully plan and regulate their deployment to maximize environmental benefits while mitigating potential harms[21].

While AVs have the potential to significantly reduce emissions, improve air quality, and enhance energy efficiency, they also pose risks such as increased energy consumption, urban sprawl, and habitat disruption. The long-term impact of AVs on the environment will depend on how they are integrated into existing transportation systems, the energy sources used to power them, and the policies implemented to manage their uses

INTERNATIONAL LEGAL FRAMEWORKS GOVERNING UNMANNED VEHICLES:

The following are the relevant international frameworks which can be interpreted in the context of unmanned vehicles and how each relevant international framework and its provisions apply:

Vienna Convention on Road Traffic 1968[22]: The Vienna Convention on Road Traffic of 1968 primarily sets international standards to enhance road safety and facilitate international road traffic by establishing uniform traffic rules. However, the convention was established long before the advent of unmanned vehicles, such as autonomous cars. Consequently, it does not explicitly address the specifics of unmanned vehicle operations. Nevertheless, Article 8 of the Convention states that every moving vehicle or combination of vehicles must have a driver, which poses a regulatory challenge for

[18] Samantha Heiberg, Emily Emond. et al., "Environmental Impact Assessment of Autonomous Transportation Systems", MDPI Open Access Journals, 16 (13), 5009, (June 2023).

[19] Ibid. at 9.

[20] Supra note 14, at 8.

[21] Üstün Atak, "SWOT Analysis of Unmanned Surface Vehicle for Environmental Monitoring Tasks in Maritime Ports", Bandirma Onyedi Eylul University, Turkey, JITSA, AUSUD, (2020).

[22] United Nations Organization, "United Nations Economic and Social Council's Conference on Road Traffic", (Secretary General, 1968).

the integration of autonomous vehicles. This requirement means that for unmanned vehicles to be legally compliant under the current framework, they would need to be reinterpreted as having a driver, albeit in a non-traditional sense, such as through remote control or advanced AI systems acting as the "driver."

Trials of Fully Automated Driving Systems on Public Roads: Road tests for fully automated driving systems have been carried out globally under both the Vienna and Geneva Conventions on Road Traffic. The fundamental requirement for these tests differs in interpretation across various regions, with some places allowing exemptions while others rely on manufacturer self-certification. International Organization of Motor Vehicle Manufacturers (OICA) is currently pushing for the harmonization of both technical and road traffic rules relating to fully automated driving. In terms of fully autonomous driving, the United States is leading at Level 4 according to the Society of Automotive Engineers (SAE) classification, yet there is no comprehensive legal framework governing AVs on a nationwide scale. Efforts to regulate and legislate AVs are ongoing, with deployment approvals largely relying on self-certification by manufacturers. Legal requirements for fully autonomous vehicles differ across states. States like Arizona, Texas, Nevada, and Michigan have adopted relatively permissive regulations, permitting driver testing and even regular operation of AVs on public roads without safety drivers for several years.

International Convention for the Safety of Life at Sea (SOLAS)[23]: Although SOLAS primarily addresses manned vessels, unmanned maritime vehicles should follow similar safety standards to ensure their operations do not pose risks to other vessels or the marine environment.

Convention on Biological Diversity (CBD)[24]: This provision can be interpreted in such a way that the Unmanned vehicles operating in areas of high biodiversity must take measures to protect and conserve these environments. This includes avoiding disruptions to local wildlife and habitats. Before operating in ecologically sensitive areas, unmanned vehicles should conduct environmental impact assessments to understand and mitigate potential adverse effects on biodiversity and ecosystems.

International Civil Aviation Organization[25] (ICAO): UAVs should comply with air traffic management rules to ensure safe and efficient operations, which can reduce the risk of environmental harm resulting from accidents or operational disruptions.

European Union Legislation: The European Aviation Safety Agency (EASA) has established regulations for unmanned aerial vehicles (UAVs) focusing on their operational use rather than their technological characteristics. The European Roadmap outlines the integration of civil remotely-piloted aircraft into the European Aviation System through three categories: Open, Specific, and Certified.

23 International Maritime Organisation, "International Convention for the Safety of Life at Sea (SOLAS)", (1974).

24 The Convention on Biological Diversity, 2006, art. 14.

25 International Civil Aviation, "Convention on International Civil Aviation done at Chicago", (1944).

This framework addresses various levels of integration and standardization, ongoing research initiatives, and the societal impacts of these technologies.[26] Certification is essential for the national authorization of aviation (NAA) concerning UAV operations under specified and certified conditions. This certification facilitates high-risk operations in densely populated areas, provided that the UAV systems meet the required capabilities and operational demands.[27]

EU Regulation 2018/1139: Common Rules in the Field of Civil Aviation[28]*:* Interpreting this regulation includes safety and environmental provisions that apply to UAVs within the EU, ensuring that their operations are conducted safely and with minimal environmental impact.

EU Regulation 2019/947: On the Operation of Unmanned Aircraft[29]*:* Provides specific operational rules for UAVs, including requirements for environmental protection, such as avoiding sensitive areas and conducting risk assessments.

UN Regulation for Level 3 Vehicle Automation: The revision, developed by the Working Party on Automated/Autonomous and Connected Vehicles, is based on insights from various countries that implemented the UN Regulation on Automated Lane Keeping Systems. This led to the establishment of the inaugural binding international regulation for "level 3" vehicle automation, which was approved in June 2020.[30]. These advancements were shaped by UNECE's framework on automated and autonomous vehicles, emphasizing safety as a central element of UN's regulatory efforts for the future of transportation. Such systems are permitted to operate only under specific conditions, on roads that restrict pedestrians and cyclists and feature physical barriers separating opposing traffic flows. Additionally, the driver retains the ability to override these systems at any time and may be prompted by the system to resume control of the vehicle if necessary. The regulation specifies in detail the performance standards that vehicle manufacturers must fulfill before selling vehicles in countries that enforce these requirements. It includes provisions for type approval, technical standards, audit and reporting processes, and testing under both controlled and real-world conditions. Additionally, any new features must comply with stringent cyber security and software update standards outlined by the relevant UN Regulations.

Autonomous Driving at the UNECE World Forum for Harmonization of Vehicle Regulations[31]: The World Forum for Harmonization of Vehicle Regulations, hosted by United Nations Economic Commission for Europe (UNECE), is the intergovernmental platform responsible for the regulatory

[26] Joonas Lieb, Andreas Volkert, "Unmanned Aircraft Systems Traffic Management: A comparison on the FAA UTM and the European CORUS ConOps based on U-space", Conference: 39th Digital Avionics Systems Conference (DASC 2020), (October 2020).

[27] Syed Agra Hassnain Mohsan, "Unmanned Aerial Vehicles (UAVs): Practical aspects, applications, open challenges, security issues, and future trends" 16 Springer Link (January 2023).

[28] EUR-Lex, "Document 32018R1139", EUR-Lex, 2018, available at < https://eur-lex.europa.eu/eli/reg/2018/1139/oj> (17 August 2024).

[29] European Union Aviation Safety Agency, "Commission Implementing Regulation (EU) 2019/947", (June 2019).

[30] United Nations Economic and Social Council, Inland Transport Committee, "Reference document with definitions of Automated Driving under WP.29 and the General Principles for developing a UN Regulation on automated vehicles", (April 2018).

[31] United Nations Economic Commission for Europe, "WP.29 Introduction", The UNECE World Forum for Harmonisation of Vehicle Regulations, (1998).

JSS Journal for Legal Studies and Research
[ISSN 2321-4171]

frameworks addressing vehicle safety and environmental performance, their subsystems, and parts. It has a dedicated Working Party on Automated/Autonomous and Connected Vehicles, which brings together countries such as the EU, USA, China, Japan, and Canada to develop internationally harmonized regulations, resolutions, and guidelines governing automated driving functionalities.

These frameworks collectively establish a comprehensive legal environment for unmanned vehicles, ensuring they operate safely and sustainably while mitigating their environmental impacts.

APPLICABILITY OF EXISTING INDIAN LAWS ON AUTONOMOUS VEHICLE:

Applying existing Indian laws to AVs presents a significant challenge due to the lack of regulations specifically tailored to this emerging technology. Most legal frameworks in place were not originally designed to address the intricacies of AV technology, particularly in areas like privacy and data security and environmental protection but still interpreting the provisions in possible ways. Nevertheless, existing legal principles and statutes offer a foundation to navigate these complexities.

Information Technology Act, 2000: The Information Technology Act, 2000 (IT Act) plays a crucial role in the regulation of cyber activities in India and is particularly relevant to AVs concerning data protection and cybersecurity. Although the Act does not explicitly address AVs, certain provisions are pertinent:

- **Section 43A[32]:** This section requires corporate bodies handling sensitive personal data to implement adequate security measures. Given that AVs process large amounts of sensitive data, compliance with this section is critical to prevent legal issues.
- **Section 72A[33]:** This provision penalizes the unlawful disclosure of information, whether by breaching a legal contract or without the consent of the individual concerned. Since AVs continuously collect and store data, adherence to these regulations is crucial for manufacturers and operators to avoid potential legal consequences.

The IT Act's focus on cybersecurity can be adapted to ensure that AV systems are protected against unauthorized access and data breaches, which are major concerns for internet-connected vehicles.

Motor Vehicles Act, 1988 [34](Amended in 2019): Primarily designed for conventional vehicles, the Motor Vehicles Act, 1988, was amended in 2019 to include provisions that could be extended to AVs. These amendments provide a foundation for further regulations specific to AV technology. The amendments introduce rules for new categories of vehicles, potentially encompassing AVs, with respect to certification, safety standards, and insurance requirements. Liability issues, particularly con-

[32] Information Technology Act, 2000 (Act 21 of 2000), s. 43A
[33] Ibid, s. 72A
[34] Motor Vehicles Act, 1988 (Act 59 of 1988)

cerning fault in accidents involving AVs, are also addressed, highlighting the need for AV-specific regulations to clarify these matters. The Act's framework could be expanded to establish clear operational standards for AVs, such as defining the concept of a 'driver' in an AV context and setting liability norms for AV-related accidents.

Digital Personal Data Protection (DPDP) Act, 2023[35]: The Digital Personal Data Protection (DPDP) Act, influenced by international standards like the GDPR, is set to significantly enhance privacy protections in India, with particular implications for AVs: The Act emphasizes limiting data collection to what is necessary for specific purposes. For AVs, this requires clearly defined and justified data collection practices. The Act mandates that data collection must be based on explicit consent. AV manufacturers and operators must develop mechanisms to ensure that passengers and potentially affected pedestrians are informed and can consent to data collection. The Act grants individuals rights over their data, including access, correction, and deletion. AV operators must establish processes that allow individuals to exercise these rights effectively. These frameworks highlight the need for specialized legal and regulatory measures to govern the operation of autonomous vehicles in India.

ENVIRONMENTAL LAWS ADDRESSING AUTONOMOUS VEHICLE:

The Environmental Protection Act, 1986: This Act provides a framework for the protection and improvement of the environment. While it does not directly address unmanned vehicles, its broad mandates can be applied to the environmental impact of UVs, such as noise pollution, emissions, and habitat disturbance. This Act empowers the central government to take measures necessary to protect and improve the environment[36] which can include regulations on UV emissions and their environmental impact. The Act further Prohibits the operation of any industry[37] which can be extended to UVs, without ensuring compliance with environmental standards.

The Air (Prevention and Control of Pollution) Act, 1981[38]: This Act aims to prevent and control air pollution, which can be relevant to UVs, especially drones that may contribute to air pollution through their operations. The Act requires industries to obtain consent from the State Pollution Control Board before emitting pollutants[39], a principle that could extend to the operations of UVs. It also Prohibits the release of air pollutants beyond permissible limits[40].

The Noise Pollution (Regulation and Control) Rules, 2000[41]: These rules regulate noise levels to prevent and control noise pollution. The operation of unmanned vehicles, especially drones, is subject to these regulations to ensure they do not exceed prescribed noise limits. The rules establishes noise level standards for different areas[42] which could apply to the operation of UVs.

[35] Digital Personal Data Protection (DPDP) Act, 2023 (Act 22 of 2023)
[36] The Environmental protection Act, 1986 (Act No. 29 of 1986), s. 3.
[37] Ibid, s. 7.
[38] The Air (Prevention and Control of Pollution) Act, 1981 (Act No. 14 of 1981).
[39] Ibid, s. 21.
[40] Ibid, s. 22.
[41] The Noise Pollution (Regulation and Control) Rules, 2000.
[42] Ibid, rule. 3.

JSS Journal for Legal Studies and Research
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The Aircraft Act, 1934: This Act regulates all aircraft, including drones (a category of unmanned aerial vehicles). It sets the framework for the safe operation of unmanned vehicles in Indian airspace. It empowers the Directorate General of Civil Aviation (DGCA) to enforce regulations[43], ensuring that UVs operate safely. It grants the central government the power to make rules regulating the operation, use, possession, and maintenance of all aircraft[44], including UVs.

India's legal frameworks for unmanned vehicles are evolving to address both environmental and data protection concerns. The combination of environmental laws, data protection regulations, and transport/aviation statutes provides a foundational legal structure. However, there remains a need for more specific regulations that directly address the unique challenges posed by the increasing deployment of UVs.

INDIAN GOVERNMENT INITIATIVES ON AUTONOMOUS VEHICLE REGULATION:

India's approach to the regulation and adoption of autonomous vehicles is still evolving, with the Government taking cautious steps to ensure that the technology is introduced in a safe, sustainable, and socially beneficial manner. While there are several initiatives aimed at preparing the country for AVs, few are discussed here.

The Draft Automotive Mission Plan, 2026 outlines a vision for making India a global hub for automotive manufacturing, acknowledging the need to integrate autonomous and connected vehicle technologies. Complementing this, the National Electric Mobility Mission Plan (NEMMP) 2020, although centered on electric vehicles (EVs), lays the groundwork for the introduction of autonomous EVs by encouraging the development of necessary infrastructure like charging stations and smart grids[45]. The Ministry of Road Transport and Highways (MoRTH) has been actively involved in policy advocacy for AVs, including the consideration of a regulatory sandbox for testing AV technologies on Indian roads. The Bharatmala Pariyojana, a large-scale highway development project, could support AV deployment through improved infrastructure, while the Smart Cities Mission promotes the integration of AVs into urban transport systems within India's developing smart cities. NITI Aayog, India's premier policy think tank, has been advocating for the inclusion of AVs in its National Strategy for AI and has called for comprehensive policy frameworks addressing data privacy, cybersecurity, and ethical considerations related to AVs. The FAME India Scheme, which promotes EV adoption through subsidies, indirectly supports the transition to autonomous vehicles. The Indian government has also engaged in global partnerships and encouraged industry collaborations to advance AV technologies, while the Bharat New Vehicle Safety Assessment Program (BNVSAP) might expand to

[43] The Aircraft Act, 1934 (Act No. 22 of 1934), s. 5A.
[44] Ibid, s. 9A.
[45] Ministry of Heavy Industries & Public Enterprises, "National Electric Mobility Mission Plan", Press Information Bureau, 10 March 2015, available at https://pib.gov.in/newsite/printrelease.aspx?relid=116719 (16 August 2024).

include AV safety standards[46]. The National Urban Transport Policy (NUTP) promotes the adoption of intelligent transport systems, crucial for AV operations, while pilot projects and research centers like ICAT and ARAI are helping gather data and certify AV technologies. On the legal and ethical front, the government is working on data privacy laws and cybersecurity frameworks and addressing liability and insurance issues related to AVs. Finally, public awareness campaigns have been initiated to educate citizens about the benefits and challenges of AV technology, crucial for gaining public trust and acceptance.

CHALLENGES IN INTEGRATING UNMANNED VEHICLES:

India faces several challenges in integrating unmanned vehicles into its landscape, particularly concerning their environmental impact. The regulatory and legal framework in India is still evolving and may not fully address the environmental consequences of UVs, especially in remote areas where ensuring compliance can be difficult. There is a significant lack of comprehensive environmental impact assessments, with limited research available on how UVs affect wildlife and their habitats[47]. Technologically, the energy consumption of UVs, such as drones, contributes to carbon emissions, underscoring the need for energy-efficient solutions. Socio-economic factors also play a role, as public perception and acceptance of UVs are influenced by their perceived environmental impacts, making transparent communication vital. It is crucial to ensure that the benefits of UV technology are equitably distributed and do not worsen economic disparities remains a key challenge. As UVs must operate in diverse climatic conditions across India, they must be designed to withstand extreme weather events, particularly in disaster management scenarios where they could otherwise cause additional environmental harm. Continuous innovation and research are crucial to developing environmentally sustainable UV technologies, requiring significant investment in research and development[48]. Establishing and enforcing safety standards to prevent accidents and minimize environmental harm is essential. By proactively tackling these multifaceted issues, India can leverage the benefits of unmanned vehicles while minimizing their environmental impacts.

FUTURE DIRECTIONS AND MITIGATION STRATEGIES:

Approximately 95% of road accidents result from human error[49], but advancements in technology and machine learning in autonomous vehicles are expected to eliminate most of these mistakes. The Indian Government is concerned that the introduction of autonomous vehicles could lead to the

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[46] Bharat New Car Safety Assessment Program, "Safety Beyond Regulation", available at <https://www.bncap.in/> (15 August, 2024).

[47] Kareem Othman, "Exploring the Implications of Autonomous Vehicles: A Comprehensive Review", Springer Link 7, (March, 2022).

[48] ET Spotlight, "Driverless cars face unique challenges on India's chaotic roads", The Economic Times, (June, 2017), available at <https://economictimes.indiatimes.com/industry/auto/driverless-cars-face-unique-challenges-on-indias-chaotic-roads/articleshow/59379769.cms> (17 August 2024).

[49] Express Drives Desk, "Human error cause of road accidents in 95% cases: How Advanced Driver Assistance Systems can help", Express Drives, 8 May 2020, available at <https://www.financialexpress.com/auto/car-news/human-error-road-accidents-advanced-driver-assistance-system-adas-lane-keep-assist-blind-spot/1952532/> (16 August 2024).

loss of over a crore jobs, given that a significant portion of the population works as drivers. But, this shift would also create numerous opportunities in the IT and ITES sectors, as the development and maintenance of autonomous vehicles require substantial input from IT professionals. To navigate the challenges and regulatory changes associated with autonomous vehicles in India, compliance management software could be instrumental.

Initially, autonomous vehicles should be permitted for private use before gradually being introduced for public applications such as on-demand taxis and long-distance travel. The adoption of autonomous vehicles is anticipated to decrease road accidents by adhering to speed limits and lane discipline, among other safety measures. Testing of these vehicles in India should be allowed, and efforts must begin to adapt infrastructure and legislation to accommodate this new technology.[50] The following mitigation strategies are recommended:

- Implementing stringent emission standards for unmanned vehicles.
- Setting limits on noise pollution, particularly for AVs operating in urban areas.
- Adopting green manufacturing processes or Eco-friendly Production to reduce the carbon footprint of producing unmanned vehicles.
- Establishing programs for the recycling and repurposing of vehicle components.
- Pre-deployment Analysis by conducting thorough environmental impact assessments before deploying unmanned vehicles in new areas.
- Investing in carbon offset projects to compensate for emissions produced by unmanned vehicles.
- Supporting reforestation projects to balance the carbon emissions of unmanned vehicle operations.
- Industry Collaboration and Partnering with other industries to develop and implement environmentally friendly technologies.
- Working with governments and academic institutions to research and develop new mitigation strategies.

It is time India reform its rules to help autonomous vehicle development. The Motor Vehicle Act should be modified to include the definition of the operator of vehicles; in this case, the responsibility for automated driving systems will lie with the software developer, the manufacturer, or both. Liability in case of accidents shall lie with the autonomous driving system or the manufacturer or both. Stricter laws for jaywalking and traffic rules will also help the autonomous vehicle development. The best case would be that a different law with regard to the autonomous vehicle has to come out in India[51].

[50] Viraj Ranjan Singh, "Autonomous Vehicles and the Challenges in India", Lexplosion, 2 September 2021, available at < https://lexplosion.in/autonomous-vehicles-and-the-challenges-in-india/> (17 August 2024).

[51] The Motor Vehicles Act, 1988, (Act No.59 of 1988).

RECOMMENDATIONS AND CONCLUSION:

- Develop comprehensive regulations specifically addressing the environmental impacts of unmanned vehicles to ensure sustainable deployment.
- Create mechanisms for continuous monitoring and public reporting of the environmental impacts of UVs to ensure transparency and accountability. Mandate detailed environmental impact assessments for all UV projects to understand and mitigate their effects on ecosystems.
- To cut down on power usage, create and employ energy-efficient designs and components. Reduce reliance on fossil fuels by powering unmanned vehicles with renewable energy sources like solar panels.
- Reduce noise pollution by implementing stringent noise pollution standards and quieter propulsion systems and noise-reducing technologies, particularly in sensitive locations to minimize disturbance to wildlife and human populations.
- To increase energy efficiency and decrease resource consumption, build unmanned vehicles using lightweight, environmentally friendly components.
- Create and utilize batteries with less of an adverse effect on the environment, such as ones with greater energy densities, longer life spans, and safer disposal techniques.
- Create policies and procedures for the recycling and appropriate disposal of unmanned vehicle parts, including electronics and batteries.
- Install sensors on unmanned vehicles to track and reduce pollutants and make sure they adhere to environmental laws.
- Choose landing zones that will have the least negative effects on the environment; stay away from places with fragile ecosystems.
- Strengthen coordination among transportation, environmental and public safety agencies to streamline governance and regulatory enforcement.
- Align UV policies and practices with Sustainable Development Goals to ensure a balanced approach to technological advancement and environmental protection.
- Increase funding for research and development focused on creating UV technologies that are environmentally sustainable and resilient to climate change.

AVs present significant opportunities for technological advancement and efficiency in various sectors across India. However, their deployment must be managed carefully to mitigate potential environmental impacts. By strengthening regulatory frameworks, conducting thorough environmental impact assessments, and promoting energy-efficient technologies, India can harness the benefits of UVs while safeguarding its rich biodiversity and natural resources. Effective integration of UVs into urban and rural planning, coupled with public engagement and multi-agency coordination, is essential.