A Review of the Autonomous Electric Vehicles: Challenges and Future Scope

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A Review of the Autonomous Electric Vehicles: Challenges and Future Scope

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Abstract: Rapid urbanisation and continuous developments in road infrastructure have sparked a rising interest in the design of driverless electric cars in India. This study gives a comprehensive review of Autonomous Electric Vehicle (AEV). The paper explores various challenges associated with Autonomous Electric Vehicles, like, technological prerequisites for Autonomous Electric Vehicle (AEV), specifics of driving on various types of Indian roads/highways and the possible gains and losses of adopting Autonomous Electric Vehicle (AEV). This article presents a review on the current aspects and future scope of the Autonomous Electric Vehicle (AEV) industry as well as the consumer perceptions and adoption of AEV. A tadpole-structured AEV for navigating crowded narrow city roads and maximising energy efficiency is discussed in the paper. The potential and viability of AEVs in India and globally are discussed, along with related factors including safety, infrastructure, legislation, and public acceptability. It also emphasises that ATEVs hold on potential to revolutionize transportation in India, offering solutions to some of the most pressing challenges such as traffic congestion, road accidents, and pollution. The study also gives an overview of global market size and public attitude towards the adoption of AVs which can be comparable with Indian scenarios and will help to implement ATEVs in India.

Keywords: Tadpole Electric Vehicle; Autonomous Electric Vehicle; Electric Vehicle; Driverless EV

1. Introduction

In recent years, India has witnessed a rapid transformation in its urban landscape, marked by a significant increase in urbanisation[1)]. This change has brought forth many challenges, particularly in traffic congestion, air pollution, and energy consumption[2)]. The sprawling urban centres are often characterized by overburdened public transportation systems, increasing reliance on personal vehicles, and consequent environmental degradation[3)]. As of 2023, major Indian cities regularly feature among the most polluted globally, and traffic congestion has become a daily struggle, leading to significant economic and health impacts[4,5)]. Electric vehicles don't emit any substances[6)]. They run on electric power and not directly on fossil fuels[7)]. However, the mileage offered by electric vehicles is not comparable to that of traditional vehicles. Amidst these challenges, the concept of Autonomous Electric Vehicles (AEVs) emerges as a beacon of hope[8)]. AEVs represent a novel approach to addressing the multifaceted transportation issues in India[2)]. Their electric nature contributes to reducing air pollution and dependence on fossil fuels, while their autonomous capabilities offer a potential solution to the problem of traffic congestion[5,9)].

The paper discusses the regulatory and policy landscape[10)] that needs to evolve to support the adoption of ATEVs. It also explores public acceptance and the societal implications of transitioning to this novel mode of transportation[11)]. Through a combination of literature review, case studies, and analysis of pilot projects, this paper aims to offer valuable insights into the viability and potential impact of ATEVs on Indian roads. It seeks to contribute to the ongoing discourse on sustainable and intelligent transportation solutions, emphasizing the need for innovative approaches to address the burgeoning transportation challenges of rapidly urbanizing Indian cities[4)].

The systematic literature review[12)] highlights the significant role of autonomous technologies in transforming road transportation, including the transport of humans, goods, and services[13)]. Emphasizes the challenges and opportunities presented by autonomous vehicles (AVs) in enhancing road safety, reducing traffic congestion, and impacting travel behaviour[14)]. Sheds light on the socio-demographic perceptions towards AVs, with findings indicating that young adult males exhibit a more positive perception of the safety of automated vehicle technology. This demographic is also identified as potentially leading to rapid actualization of road transportation safety benefits due to their openness towards AV technology[15]. The review also extends to the importance, impacts, public perceptions, and applications of AVs in road transportation[16]. Addresses the necessity for a deeper understanding of public attitudes towards AVs and the need for targeted public education and outreach programs to increase the acceptability of AVs in road transportation. Research[17] identifies AVs as a potential means to significantly reduce traffic accidents and fatalities, although it calls for more research into their public transportation integration hazards and limitations.

The socioeconomic effects of AVs are discussed in[18], highlighting the potential job creation in data analysis and software development while also acknowledging possible job losses in the transportation sector. The study[19] points out the essential infrastructural upgrades required to accommodate large-scale AV deployment, including traffic management systems, roads, highways, and charging or refuelling infrastructures. The review[20] emphasizes the complicated legal and regulatory issues surrounding AVs and underscores the necessity of developing new technologies for managing and coordinating AVs with other transportation modes. Environmental impacts of AVs are considered, with a focus on the development of new powering technologies and legislation to encourage their use.

The core objective of this paper is to undertake a systematic review of the role that AEVs can play in ameliorating the transportation challenges faced by Indian cities[15]. This review delves into an exploration of the Indian road conditions, which are marked by their diversity and complexity, to assess the technological requirements and driving scenarios that are conducive to the deployment of Autonomous Tadpole Electric Vehicles (ATEVs). The paper aims to provide a comprehensive understanding of the potential benefits and challenges associated with the adoption of ATEVs in the Indian context. It is structured to examine the technological prerequisites for the successful operation of ATEVs, evaluate the safety considerations that must be addressed, and assess the infrastructural enhancements required for their integration into the existing transportation ecosystem.

1.1 Tadpole Electric Vehicle (ATEV)

Three-wheeled vehicles provide more mileage as compared to their four-wheel counterparts, as they are lighter and more aerodynamic. Designing an energy-efficient and stable structure for three-wheeled electric vehicles would ensure considerable mileage along with long battery life. Additionally, three-wheeled vehicles allow the use of innovative light weight structures such as Tadpole and Delta as shown in Fig. 1 and 2 that maximize the speed, range and stability of such vehicles[21]. By using such electric vehicles, global warming can be slowed down by reducing CO_2 emissions[11,17].

Tadpole Electric Vehicle (TEV), are characterized by their unique three-wheel design as shown in Fig. 2 (two wheels at the front and one at the back)[21]. One subset of autonomous vehicles developed with Indian roads in mind is the Autonomous Tadpole Electric Vehicle (ATEV)[22]. It combines the advantages of an electric vehicle (EV) with those of autonomous driving technology to provide a mode of transportation that is at once practical, secure, and friendly to the environment[21,23]. Tadpole design provides stability and manoeuvrability for ATEVs. The improved stability and manoeuvrability of this design make it possible for the vehicle to make its way through tight spaces and heavy traffic with ease[12]. ATEVs are propelled by electric motors that draw power from rechargeable batteries. Electric propulsion has several benefits over traditional internal combustion engines, including fewer exhaust pollutants, less noise pollution, and cheaper running expenses[24].

Tadpole Autonomous Electric Vehicles (AEVs) are a promising alternative to traditional vehicles in the Indian market, offering significant environmental benefits and cost-efficiency. The initial purchase price of AEVs may be higher than those of internal combustion vehicles, but subsidies under the Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme can reduce these costs by up to 20-30%[122].

Electric vehicles have lower operational costs, with electricity costs at INR 7 per kWh and a vehicle efficiency of 6 km/kWh. In comparison, petrol vehicles with a fuel efficiency of 18 km/litre and petrol cost of INR 90 per litre would have a cost of INR 5 per kilometre, resulting in substantial savings over an annual driving distance of 20,000 kilometres.

Maintenance costs for AEVs are estimated to be about 50% less than those for petrol vehicles, with annual maintenance for a petrol vehicle around INR 10,000, while for an AEV it could be around INR 5,000. The major long-term cost for AEVs is the battery, which lasts about 7-10 years and can range from INR 1 lakh to 3 lakhs, depending on capacity and technology. However, battery prices are decreasing annually due to advancements in technology and increased production scales.

AEVs also offer significant reductions in greenhouse gas emissions, with electricity sourced from renewable resources resulting in nearly negligible emissions over the vehicle's lifecycle. The total cost of ownership for a Tadpole AEV over 10 years is approximately INR 12.84 lakhs, significantly lower than the INR 17 lakhs for a petrol vehicle. This makes them a financially viable and environmentally responsible choice for consumers[7].

AEVs can operate without human intervention by using sophisticated sensor systems. These systems include cameras, LiDAR (Light Detection and Ranging), radar, and ultrasonic sensors. With the help of these detectors, the car can avoid collisions with people and other vehicles. Autonomous vehicles are made possible by data analysis and decision-making capabilities made possible by high-tech algorithms and systems[25].

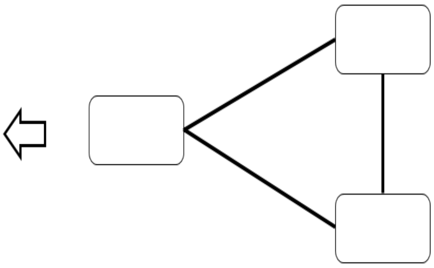

Fig. 1: Delta structure[21]

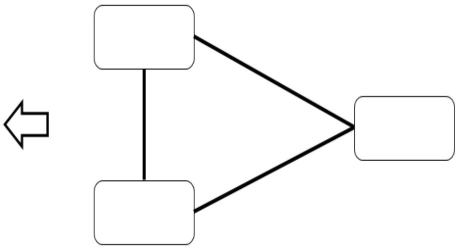

Fig. 2: Tadpole structure[21]

A distinct architectural design known as RHEA was conceived and subsequently developed. The scope of this project encompassed the design and control of robots, WiFi connection, and the development of software interfaces for human users. Nevertheless, the writers acknowledged the necessity of diminishing the dimensions, intricacy, and expenses associated with agricultural robots[26]. Figure 3 shows the proposed architecture for ATEV which can be implemented in Indian challenging conditions.

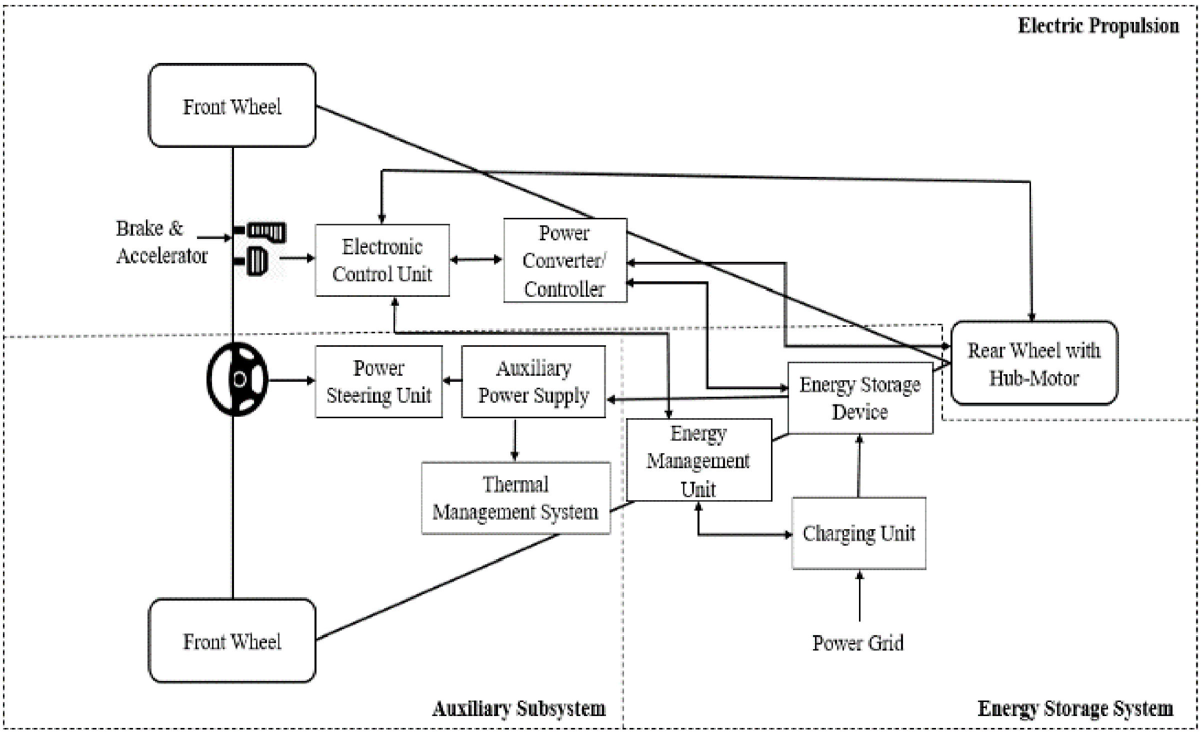

Fig. 3: ATEV architecture.

1.2 SAE Levels of Autonomy

An autonomous vehicle's conceptual framework has four levels of taxonomy for automated vehicles. The National Highway Traffic Safety Administration (NHTSA) established these categories in 2013. In 2014, the Society of Automotive Engineers International (SAE) introduced a new level of classification in the subject of automation, represented by the diagram shown in Fig. 4. The Society of Automotive Engineers (SAE) rating system for levels of automation in automobiles was officially adopted by the National Highway Traffic Safety Administration (NHTSA) in 2016[5]. In conceptual theory, an automated vehicle system can be classified as "autonomous" if the internal automated system of the vehicle is able to carry out the dynamic vehicle driving functions inside a driving environment. According to the Federal Automated Vehicles Policy of the United States Department of Transportation, a vehicle is considered autonomous if it possesses automated systems at levels 3 to 5. The constraint about various levels of autonomy is their inadequate enforcement, and scholars have categorised all of these levels as autonomous[17].

The first two levels, 0 and 1, are referred regarded as "traditional" since the driver remains responsible for monitoring the environment. Starting with stage 3, the vehicle takes up the mission. This is a crucial aspect, as it necessitates the vehicle to gather and analyse all the essential information from its surroundings. Moreover, the vehicle might assume responsibility for the driving task within specific boundaries. Level 5 automation represents the highest level of automation, when cars are capable of fully autonomous driving on all sorts of roads, at any speed, and in any weather conditions.

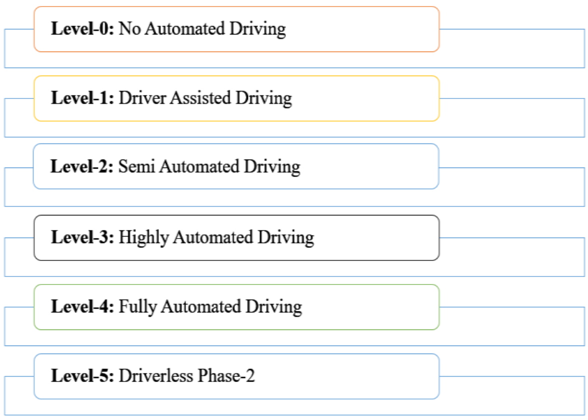

Fig. 4: SAE levels of autonomy.

Except for prototypes, AUDI is currently the only car manufacturer offering a model to the public that meets the SAE3-level standards. Other automobile manufacturers are presently developing vehicles that meet SAE3 and SAE4 standards, which are expected to be released shortly. Contrary to the optimistic claims made by certain companies, the majority of projections, concur that it will require a considerable amount of time to make technologically advanced SAE5-level[4,11,17,33,34].

1.3 Impact of Autonomous Vehicles on Mobility

Autonomous vehicles (AVs) have been developed with strict limits to ensure safety and convenience, but their introduction could lead to increased congestion due to decreased capacity. The solution lies in collaboration between vehicles, where they share information and make collective decisions to ensure safety and optimize system efficiency. Driving automation offers a chance to execute dynamic traffic management tactics, which should be formulated in conjunction with vehicle automation and applied as the rate of autonomous vehicle adoption increases. Motorway traffic is the first scenario to prioritize, as it offers a highly regulated traffic environment and many motorways already possess the necessary technology. Motorway platooning has the potential to be one of the initial traffic management measures implemented with AVs, creating a convoy-like formation where autonomous vehicles travel securely with minimal gaps at elevated velocities. However, there are uncertainties regarding the implementation of generalized motorway platooning, such as the minimum level of vehicle automation, specific types of vehicles involved, average spacing between platoon vehicles, average speed maintained, and maximum length of the platoon.

In a mixed traffic environment, the need to protect human drivers' safety while improving overall efficiency is even more urgent and difficult. Empirical evidence shows that the presence of connected and autonomous vehicles (CAVs) leads to a notable enhancement in traffic efficiency, but analysing the effects of sophisticated traffic management systems is challenging. Semi-autonomous probe vehicles or simulations are being employed to study the impact of autonomous vehicles on traffic flow from a microscopic perspective. The growing user base of car-sharing, ride-hailing, and ride-sharing platforms is causing a shift towards using vehicles over owning them. Private vehicles are often parked for extended periods, leading to high costs and traffic congestion. The shift towards using vehicles is predicted to increase due to the availability and decreasing cost of sharing and hailing services. Electric autonomous vehicles (AVs) are well-suited for these mobility initiatives due to their technology and reduced labour expenses. The automobile fleet in Europe and the U.S. is projected to decrease by 22-25% by 2030. This indicates an increased level of individual mobility within society, with shared vehicles accommodating more passengers[34].

Suggests that vehicle-kilometres per passenger may increase due to private autonomous vehicles performing empty trips. Sharing systems can enhance mobility efficiency and sustainability by replacing private vehicle journeys with mass transit trips. Mass transit must adapt by incorporating on-demand services like Mobility as a Service (MaaS). The anticipated decrease in transportation expenses will lead to increased vehicle kilometres, increased transportation of goods and individuals, and an expanded user base for autonomous vehicles. The decline in road fatalities in developed nations is attributed to advancements in vehicle technology, driver assistance systems, and traffic administrations' efforts to combat accidents. However, there is a prevailing trend in the development process. To achieve the Zero Vision objective, a high penetration rate of fully autonomous vehicles and effective implementation of cooperative traffic management measures are needed. Additionally, there is a risk of excessive self-assurance among occupants and pedestrians crossing roads without seat belts. Autonomous vehicles and V2X technology also present a heightened risk of being targeted by hackers or terrorists, leading authorities to build a highly fortified system resistant to such attacks.

1.4 Current Market Perspective of ATEV

The global autonomous vehicle market is expected to grow at a Compound annual growth rate (CAGR) of 12.1% from 2025 to 2033, driven by technological advancements and increasing consumer demand for safer and more efficient transportation options as shown in Table 1. Europe holds the largest market share due to strong government support and major automotive manufacturers investing in autonomous technology[124]. North America is expected to expand significantly due to technological advancements and favourable government policies, with key industry players like Google and Apple playing a significant role. The Asia-Pacific region is witnessing the fastest growth, largely due to efforts by Chinese and Japanese companies and governments to promote AEVs. The growth of the AEV market across these regions is a result of regulatory support, consumer interest, and technological readiness, which are key to fostering the adoption of autonomous driving technologies[125].

Table 1. Current market growth and adoption rates of autonomous electric vehicles (AEVs).

Region	2024 Market Size (USD Billion)	2033 Market Size (USD Billion)	CAGR (2025-2033)
Global	23.36	65.3	12.10%
Europe	Largest market share	Continues to lead	Steady growth
North America	Rapid growth	Significant expansion expected	Accelerating
Asia-Pacific	Fastest growing	Major expansion	Highest CAGR

2. Challenges

2.1 Public Acceptance and Adoption of ATEV's

The successful integration of Autonomous Tadpole Electric Vehicles (ATEVs) in India hinges not just on technological advancements and regulatory frameworks, but also significantly on public acceptance and adoption. Understanding the factors that influence public perception and devising strategies to foster acceptance is crucial for the widespread adoption of ATEVs.

Autonomous vehicles face safety challenges due to limited connectivity, including occlusions, traffic rule infractions, and ambiguity in predicting behaviour. These obstacles increase the risk of crashes. The Responsibility Sensitive Safety (RSS) framework may be an alternative, but it may undermine traffic efficiency. I2V and V2V communication can help autonomous vehicles detect each other and synchronize lane changes, but it also comes with costs and technical challenges. Despite these challenges, connectivity is crucial for ensuring the safety of autonomous vehicles[17]. Autonomous Transportation Electric Vehicles in India require technological trust, cost and accessibility, and cultural and social factors to gain acceptance. Public demonstrations, transparent communication, and targeted media campaigns can increase awareness and trust. Real-world examples, clear information about ATEV capabilities, and media campaigns can help dispel doubts and build confidence. Using these strategies can help create a positive perception of ATEVs in India.

Electric vehicles (EVs) require skilled experts to manage and maintain fleets, conduct maintenance and repairs, and educate security personnel, medical responders, and firefighters about potential hazards. Training of specialists can be done by senior staff members, repair technicians, or car manufacturers. Educational programs can raise awareness about ATEVs, while stakeholder involvement can provide valuable feedback. Addressing employment concerns is crucial, as driving is a significant source of employment in India. Strategies like public demonstrations, educational initiatives, transparent communication, and stakeholder engagement are essential for building public confidence and acceptance. Ensuring ATEVs are seen as safe, reliable, and beneficial additions to the transportation ecosystem is key to their successful integration into Indian society[29].

Figure 5 displays the global adoption rate of autonomous electric vehicles by the public in 2022, categorised by regions. The primary engine of the area's swift growth is the government's alterations to traffic regulations, which seek to streamline the integration of autonomous vehicles on public thoroughfares. In 2013, the National Highway Traffic Safety Administration (NHTSA), a regulatory body responsible for traffic safety in the United States, authorised the testing of autonomous vehicles in certain states, such as California, Nevada, Michigan, Florida, and Washington D.C. Europe is expected to emerge as the most lucrative hub for the driverless car business in the near future, defying initial predictions. This is due to a shift in client demand towards automated products and a growing acceptance of autonomous autos. In 2018, the U.K. Department of Transport announced that autonomous vehicles would be permitted to drive on public roads without the requirement of additional insurance or licencing. In 2018, the government has successfully established infrastructure for autonomous and connected vehicles. Furthermore, the UK government has demonstrated its commitment to autonomous vehicles and plans to convert all vehicles on the road into driverless ones by 2021 through legal amendments.

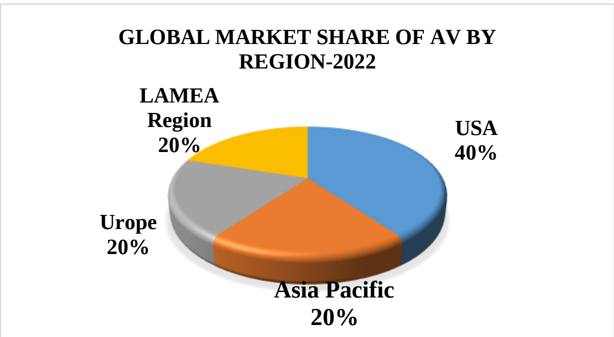

Fig. 5: Global market share of AV by region 2022.

2.2 Current Public Perceptions of AVs

The public perception of autonomous vehicles (AVs) is divided into general acceptance and skepticism. A 2023 Pew Research Centre survey revealed that only 32% of respondents believed AVs would become common within the next decade, with concerns including safety, reliability, privacy issues, and liability in accidents. A 2022 study by the American Automobile Association found that 71% of participants felt unsafe sharing the road with fully autonomous vehicles[122)].

Misconceptions about AV capabilities were also prevalent, with 55% believing AVs could function perfectly in all weather conditions. Environmental and traffic impact was acknowledged by 48% of respondents, but there was uncertainty about their practical implementation in congested urban environments. Economic and job impacts were also a concern, with 62% of respondents worried about the displacement of professional drivers[29)].

Table 2. Summary of consumer attitudes towards AEVs.

Region	Familiarity with ADAS (%)	Interest in AEVs (%)	Concerns	Willingness to Pay for Full Autonomy (%)
Global Average	High (>50%)	Growing	Safety, Privacy	Low
China	Very High	Very High	Safety, Privacy	Moderate
India	Moderate	High	Safety, Infrastructure	Low
USA	High	Moderate	Safety, Cost	Low
Europe	High	Moderate	Privacy, Safety	Low

As given in Table 2, consumers worldwide are familiar with and desire Advanced Driver Assistance Systems (ADAS), indicating readiness for more sophisticated autonomous features in vehicles[126)]. However, they show a preference for conditional autonomy over full autonomy due to safety and reliability concerns. Consumers are wary of full autonomy and prefer systems where they can maintain some control. They also show high interest in autonomous vehicles that provide cost savings and increased convenience[127)]. However, there is a discrepancy between the desirability of such features and the willingness to pay for them, highlighting the need for strategic pricing and value demonstration by manufacturers.

2.3 Indian Road Conditions and Challenges for AEVs

India's road network, spanning over 5.8 million kilometres, is one of the largest in the world. It encompasses a wide array of road types including national highways, state highways, district roads, and rural paths. This vast network is as diverse in its quality and maintenance as it is in its geography, ranging from smooth, well-paved highways in urban areas to rough, unpaved tracks in rural regions. The variability of the Indian road landscape presents a unique set of challenges for vehicular transportation, particularly for innovative concepts like Autonomous Electric Vehicles (AEVs)[14,27)]. Urban centres in India are infamous for their traffic congestion, especially during peak hours. Cities like Mumbai, Delhi, and Bangalore frequently experience severe traffic jams that result in long travel times and increased pollution. This congestion is not just a product of high vehicle density but also due to inadequate urban planning and limited road space. For AEVs, navigating through such congested environments poses significant challenges. The vehicles must be equipped with advanced algorithms and sensors capable of handling stop-and-go traffic and unpredictable movements of other vehicles[28)].

Despite considerable advancements in infrastructure, many roads in India still suffer from poor maintenance. Potholes, uneven surfaces, and the absence of clear signage are common, particularly in rural and semi-urban areas. Such conditions can be troublesome for AEVs, as they rely heavily on sensor inputs and smooth surfaces for optimal operation. The unpredictable nature of these roads demands that AEVs have robust suspension systems and highly adaptive navigation technologies[29)]. Indian roads are often characterized by a mix of driving styles, which include frequent unexpected lane changes, non-standard signalling, and a general disregard for traffic laws. These habits create an environment of unpredictability and chaos that poses a significant challenge to the programming of AEVs. The vehicles must be equipped with sophisticated decision-making algorithms capable of interpreting and predicting human driver behaviours and reacting appropriately in real-time.

A unique aspect of Indian roads is the frequent presence of pedestrians and livestock, even on busy streets and highways. This adds another layer of complexity for AEVs, which must have advanced detection systems capable of identifying and reacting to the movements of such unpredictable elements. The safety of these road users is paramount, necessitating the need for highly sensitive and accurate perception systems in AEVs[30)]. India's climatic diversity brings a range of weather conditions, from heavy monsoons to intense summers and cold winters in some regions. These conditions can affect road visibility, sensor performance, and vehicle handling. AEVs operating in India must be capable of functioning reliably under varying weather conditions, which calls for weather-proof sensors and adaptive control systems[13)].

2.4 Implications of Road Conditions for ATEVs

The aforementioned road conditions and challenges have several implications for the deployment and operation of ATEVs in India. ATEVs must be equipped with state-of-the-art sensors and navigation systems that can adapt to the diverse and unpredictable Indian road conditions. This includes high-resolution cameras, LiDAR, radar, and ultrasonic sensors, all working in tandem to provide a comprehensive understanding of the vehicle's surroundings. The physical design of ATEVs needs to account for rough road surfaces. This implies a robust suspension system and a chassis strong enough to withstand frequent jolts and uneven terrain. Given the irregular driving habits prevalent on Indian roads, ATEVs require sophisticated AI algorithms that can adapt to unpredictable scenarios, ensuring safety and efficient navigation[31)]. ATEVs need to be designed with the capability to operate efficiently in a range of weather conditions, necessitating weather-resistant materials and sensors, along with algorithms capable of adjusting to changes in weather. Ensuring the safety of pedestrians and animals is crucial. ATEVs must have fail-safe mechanisms to prevent accidents, even in scenarios with sudden pedestrian crossings or animals on the road[32)].

The deployment of ATEVs in India requires a multifaceted approach, addressing the unique challenges posed by the country's diverse and often difficult road conditions. It necessitates advancements in technology, robust vehicle design, and innovative algorithmic solutions to ensure safe and efficient navigation of ATEVs on Indian roads. This also opens avenues for research and development in autonomous vehicle technology, specifically tailored to meet the demands of the Indian traffic and road environment[15)].

2.5 Technological Requirements

Autonomous Electric Vehicles (AEVs) require advanced technologies for navigation and operation in the challenging Indian road environment. Key components include sensor systems, localization and mapping, decision-making and control algorithms, and communication systems. Sensor systems, such as cameras, LiDAR, radar, and ultrasonic sensors, provide crucial data about the vehicle's surroundings as shown in Fig. 6. Advanced self-driving vehicles use specialized sensors to observe ambient factors and vehicle conditions, and the control algorithm regulates the actuator accordingly[35)]. Autonomous agricultural vehicles employ GPS technology to track and document the vehicle's path, facilitating accurate retrieval of map data through the internet. Cooperative autonomous driving encompasses the integration of vehicles, infrastructure, cloud technology, and passengers' personal devices, necessitating accuracy and synchronisation. The initial structure of AEVs comprises four elements: the sensing system, the client system, the action system, and the human-machine interface (HMI). Sensor refining encompasses a range of sensors, each possessing distinct advantages and disadvantages, tailored for specific driving functions[26)].

The client system is crucial for autonomous vehicles (AVs) to extract accurate information from sensor data and guide them in decision-making. Various hardware platforms are being developed, including computer boxes and system-on-chip (SoC) solutions.

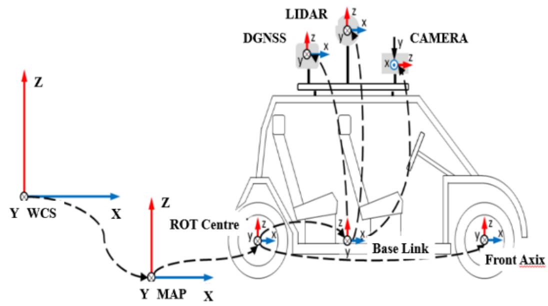

Fig. 6: Data acquisition dvices and its placement on vehicle.

However, these systems lack computing capabilities for fast and continuous data processing. Cloud computing is essential for system resilience. Perception tasks involve localization, detection, and tracking, achieved through data fusion at various levels. Deep learning algorithms are ideal for object recognition. AVs face challenges in decision-making, including prediction, path planning, and obstacle avoidance based on prior observations[34)].

A unique auto-encoder model, trained in an adversarial manner, is proposed for reconstructing static background LiDAR data without relying on segmentation masks. Additionally, suggest alternative options that can utilise existing segmentation masks to enhance LiDAR reconstruction. Additionally, it improves the performance of SLAM in situations with changing conditions. Nevertheless, certain limitations in the process of reconstruction are addressed in reference[25)]. Subsequent efforts to tackle these challenges can further enhance the quality of reconstruction and expand their suitability for real-world applications. Cameras offer visual data enabling AEVs to recognize and track objects, read traffic signs, and discern lane markings. High-resolution cameras are particularly important in congested urban areas, where the ability to detect small obstacles and interpret complex visual scenes is critical. Radar technology, utilizing radio waves, excels in detecting and tracking moving objects, especially in low-visibility conditions like rain or fog, making it indispensable for Indian weather conditions. Ultrasonic sensors are crucial for close-range detection, aiding in manoeuvres like parking and navigating through tight spaces. For AEVs in India, these sensors must be robust enough to handle dust, pollution, and varied weather, while maintaining high accuracy and reliability.

2.6 Localization and Mapping

Autonomous Vehicles (AVs) in India require accurate localization and comprehensive mapping to navigate the complex road network. Advanced technologies like Real-time kinematic Global Positioning System (RTK GPS) enhance localization accuracy, while the Inertial Measurement Unit (IMU) provides data on acceleration, direction, and angular velocity[55]. The HD semantic map, generated using Simultaneous Localization and Mapping (SLAM), provides detailed information about the road and traffic aspects, with 15,242 labelled items[56]. This technique enables AEVs to create maps of their surroundings and locate themselves within them, crucial in dynamic environments with frequent changes in road layouts and obstacles[36].

Localization and mapping technologies play a crucial role in the navigation of Autonomous Vehicles (AVs) in India[57]. The Real-Time Kinematic Global Positioning System (RTK GPS) enhances position data precision, enabling accurate lane discipline even in congested cities like Mumbai. Inertial Measurement Unit (IMU) measures and reports a vehicle's specific force, angular rate, and magnetic field, which pertain to its motion dynamics[116].

SLAM technology enables a vehicle to create a map of its environment while simultaneously tracking its location within that map[58]. This is particularly useful in dynamic environments, such as India's chaotic urban settings where new construction or temporary obstacles are common. SLAM helps AEVs adapt quickly and efficiently to changes[59].

A case study in Bengaluru demonstrated the robustness of SLAM in maintaining operational efficiency amidst unpredictable road conditions[60]. An AV pilot project in Bengaluru utilized SLAM to navigate effectively, using LiDAR and high-resolution cameras to collect real-time data about its surroundings[61]. The vehicle successfully adjusted its route in real-time, demonstrating the robustness of SLAM in maintaining operational efficiency amidst unpredictable road conditions[117].

High Definition (HD) semantic maps contain detailed annotations of road elements, such as lane markings, traffic signs, and pedestrian crossings, which are crucial for the decision-making processes of AVs[62]. These maps are dynamically updated with data from SLAM operations, ensuring that the AV has the latest information on its surroundings[118]. For example, in a pilot study conducted on the Delhi-Noida route, AEVs used updated HD semantic maps to navigate complex intersections and heavy traffic efficiently[53].

The integration of RTK GPS, IMU, and SLAM technologies in AVs provides a robust framework for accurate localization and comprehensive mapping, essential for navigating India's intricate and dynamic road networks[54].

2.7 Detection System and It’s Analysis

Object detection is a crucial aspect of computer vision, and detection pipelines typically involve obtaining input images, extracting features, and using classifiers or localizers[63]. The YOLO detection system, compared to Deformable Parts Models (DPM) and Region-based Convolutional Neural Network (R-CNN), uses a solitary convolutional neural network for feature extraction, bounding box prediction, non-maximal suppression, and contextual reasoning[64]. This results in a more efficient and precise model compared to DPM. However, the R-CNN requires meticulous calibration and operation at a sluggish pace, requiring over 40 seconds per image during testing[37]. Different detection networks are shown in Fig. 7 to take inputs from the surroundings and provide to decision-making network to operate vehicles accordingly[65].

YOLO, a convolutional neural network, is a versatile detection system that combines elements of R-CNN and MultiBox[66]. It uses convolutional features to suggest possible bounding boxes in images, but imposes spatial limitations and a lower number of bounding boxes per image. YOLO eliminates the pipeline altogether, focusing on speed and accuracy. It is designed to identify specific categories like faces or individuals, reducing variance. MultiBox, a convolutional neural network, forecasts regions of interest but is limited in comprehensive item detection[67]. OverFeat, a computer vision algorithm, trains a convolutional neural network to accurately determine object locations but prioritizes localization over detection performance. Both YOLO and OverFeat are designed for a unified, collectively optimized model[38,68,69]. The grid method used for bounding box prediction is derived from the MultiGrasp system, which employs regression to determine grasping positions[70]. Nevertheless, the challenge of detecting grasps is significantly less complex compared to object detection. MultiGrasp solely requires the prediction of a solitary graspable region for a picture that encompasses a single object. The task does not include estimating the dimensions, position, or limits of the object, nor predicting its category. It just aims to identify a region that is appropriate for grabbing[37]. The YOLO algorithm simultaneously predicts the bounding boxes and class probabilities for many objects belonging to various classes within an image[71,72].

Table 3. Comparative of lidar, radar and ultrasonic[37].

Sensor Type	Functionality	Potential Improvements
LiDAR	Emits laser beams to measure distances and create 3D maps.	Develop robust sensors for high-dust and high-moisture areas; Reduce costs through local manufacturing.
Radar	Uses radio waves to detect objects and measure their speed.	Enhance radar imaging capabilities; Integrate with other sensors for comprehensive coverage.
Ultrasonic	Uses sound waves for short-range detection around the vehicle.	Increase range and accuracy; Develop noise cancellation techniques.

Table 3 provides a concise view of how each sensor type operates, their functionality and the improvements that could make them more effective for AEVs in the Indian market. By addressing these challenges, AEVs can be better adapted to the complex and varied driving conditions in India, enhancing their functionality and adoption.

2.8 Charging Infrastructure Requirements and Challenges

Charging infrastructure is categorized based on the speed of charging as given in Table 4. Level 1 Charging uses a standard 120-volt household outlet, providing 4-5 miles of range per hour[128]. Level 2 Charging uses a 240-volt outlet, offering 12-80 miles of range per hour. This is suitable for both home and public use[73,74]. DC Fast Charging uses direct current (DC) for fast charging, providing up to 100 miles of range in just 10 minutes. These stations are primarily located along highways and in public charging stations for long-distance travel[129,130].

Table 4. Charging types and its typical use.

Charger Type	Voltage	Typical Use Case	Range Per Hour of Charging
Level 1	120V	Home, overnight charging	4-5 miles
Level 2	240V	Home/public, daily use	12-80 miles
DC Fast Charge	480V+	Public, long trips	100 miles in 10 minutes

Wireless electric car charging employs inductive power transfer to transmit electricity between two coupled coils[75,76]. The utilisation of near-field technology involves the establishment of an adequate spatial separation between the two coils, resulting in the generation of a magnetic field that facilitates the transmission of energy via induction to a nearby receiving coil in an electric vehicle[77,78].

Wireless power transmission is potentially the sole feasible option for dynamic or quasi-dynamic charging[24]. To precisely gauge the electricity consumption of Shared Autonomous Electric Vehicles (SAEVs), a comprehensive dataset that includes the operational data of Uber and Lyft is employed[41,79]. The study examines three assumptions concerning the growth of the SAEV fleet. It forecasts that by 2030, the SAEV fleet will account for almost 10% of the current TNC market if medium adoption levels are achieved[80,81]. The study also establishes scenarios for the SAEV fleet, such as Cruise Origin, by considering various estimations of the average passenger count per trip[90].

The optimal charging method is "Smart Charging," which enables flexibility in the charging schedule and automatically adapts according to real-time power wholesale pricing[42,91]. The whole daily energy requirement of SAEVs is allocated into hourly charging profiles, comprising seven unique charging schemes: "Night-time Charging," "Daytime Workplace Charging," and "Daytime Public Charging." These schemes are created based on the charging patterns derived from the Electric Vehicle Miles Travelled (e-VMT) research[92,93]. This research closely observes the daily usage patterns and charging behaviours of electric vehicles (EVs)[135]. The "Charging Inverse to Netload" technique combines base load demand data and renewable generation data to optimise billing operations[43,94]. Is enclosed in square brackets. The "Charging Inverse to Ride Requests" design leverages TNC data to enhance billing operations during periods of heavy trip demand. The "Uniform Charging" system ensures a steady and regular charging pattern throughout the whole day[95,136]. These charging profiles contribute to the demand-side input of the power system operation model[96]. The user's text is enclosed in tags[47]. strategically placed charging stations for electric vehicles with fast charging capabilities are crucial for operational efficiency[137]. Smart grid technology and standardization across different manufacturers enhance reliability and user convenience[138]

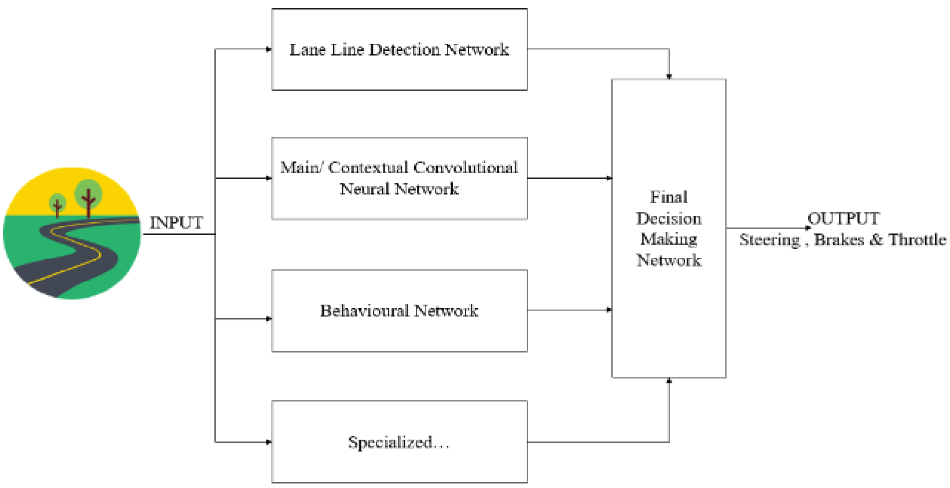

Fig. 7: Different inputs networks in autonomous electric vehicles.

3. Solutions for ATEV

3.1 Decision-Making and Control Algorithms

Artificial Intelligence Vehicles are based on decision-making and control algorithms, which process sensor inputs to make real-time navigational decisions[97)]. Machine Learning and AI algorithms are used to analyse sensor data, identify and categorize objects, and make decisions based on pre-established models and rules. In India, these algorithms must be trained on local driving conditions and behaviours, accounting for unpredictable scenarios[98)]. To accurately define each choice scenario, the technology must be evaluated objectively and a nonlinear relational model of classification concepts is established[99)].

Conceptual framing is crucial for governance and regulation, and it is essential to avoid a universal and all-encompassing approach. The research investigates the lack of academic focus on conceptual framing in anticipatory governance and suggests a more introspective and iterative approach[100)]. By reintroducing clarity in conceptual framing and recognizing the significance of conceptual frameworks, we can advance discussions on the use of AVs, allowing for better support of technologies with positive social and emotional learning (SEL) consequences and informed assessment of potentially negative SEL implications[39)]. Path planning in Indian traffic involves determining the optimal route considering road conditions, traffic, and obstructions. Recent research on path tracking control using 4-wheel steering (4WS) and 4-wheel drive (4WD) uses linear-quadratic regulator (LQR) and $H\infty$ methods. Controller design methodologies include sliding mode control (SMC) and model predictive control (MPC)[82)]. However, ensuring consistent performance across different scenarios is challenging due to assumptions regarding the reference path[40)].

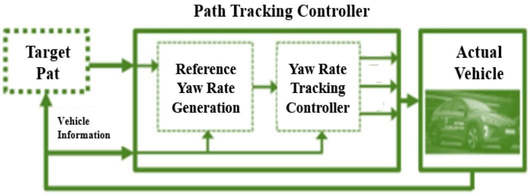

Fig. 8: Schematic diagram of the path tracking controller[40)].

Vehicle Dynamics Control as shown in Fig. 8 systems manage vehicle dynamics, ensuring stability and precision in India's varied terrain[101)]. Blockchain-based technology is more suitable for automated electric vehicles, as it records vehicle details through IoT devices. This ensures transparency and safety, especially in case of hacking[41)]. Despite extensive research, security in automotive vehicle-based communications remains lacking[102)]. Machine learning approaches are suitable for predicting traffic trends and optimizing vehicle routing and traffic flow, incorporating them into Roadside Units for intelligent decision-making[33)]. A path-tracking controller was designed specifically for electric cars equipped with in-wheel motors and advanced 4-wheel independent steering, driving, and braking systems[103)].

The controller underwent a transformation, becoming a yaw rate tracking system through the utilisation of pure pursuit and path-based approaches. The control allocation method, known as WPCA, was employed to distribute the control yaw moment across the tyre forces produced by different actuators[83)]. A simulation was conducted to verify the efficacy of the proposed methodology[104)]. The findings indicate that 4-wheel steering (4WS) outperforms 4-wheel independent steering (4WIS) in terms of enhancing ride comfort, minimising side-slip angle, and reducing lateral offset inaccuracy[40)]. The study proposes a real-time predictive control mechanism for autonomous electric vehicles (AEVs) to improve path following and stability, especially in challenging operating situations. The vehicle is a distributed drive electric vehicle, allowing for independent regulation of torques[105)].

The nonlinear model predictive control (NMPC) technique is used to minimize PF tracking error and stabilize the vehicle[84)]. The study also suggests a relaxation function approach and a Lyapunov-based constraint to ensure stability. The technique is proven effective in enhancing steering capacity, achieving power factor effects, stabilizing the vehicle, and being applicable in real-time. Future AI and machine learning advancements are needed to improve AEVs' navigation capabilities[42)].

3.2 Autonomous Electric Vehicle Communication Networks

The concept of reference model control (RFM) is presented in[33)]. It endures further improvements and innovations in order to operate as disturbance compensation. The simulations entail the comparison of three control strategies: state feedback control (SFC), state feedback with disturbance compensation (SFC + DC), and state feedback with RFM (SFC + RFM). The control design involves the combination of reference model control and state feedback. The objective of disturbance compensation and RFM control is to implement a compensatory influence on the reference signal for the purpose of tilt control. This strategy can enhance the response time of the DTC system. The compensation angle is employed to modify the output of the state feedback tilt controller, as the state feedback controller supplies the position reference to SMDU[85)].

The integration of autonomous vehicles (AEVs) into India's traffic ecosystem requires effective communication systems. V2V (Vehicle-to-Vehicle) communication enables AEVs to exchange information with nearby vehicles, improving road safety[86)]. However, challenges exist in charging infrastructures, such as the need for steady power supply and rapid-charging infrastructure[106)]. V2I (Vehicle-to-Infrastructure) communication enables AEVs to interact with traffic signals and roadside sensors for real-time traffic management. Control centre communication is crucial for remote monitoring and emergency response. Future advancements should focus on improving sensor robustness, localization, AI algorithms, and standardized communication systems[13)]. The successful deployment of ATEVs in India depends on the integration and advancement of these key technologies, ensuring safe and efficient navigation in diverse road conditions[107)].

3.3 Architectures Used on Autonomous Driving

The fuel economy of hybrid electric vehicles (HEV) is significantly influenced by driving cycle data, as conventional engine management systems (EMS) rely on normal operating cycles. Classical EMS systems struggle to achieve theoretical optimums due to the uncertainty and complexity of traffic conditions. Design factors include work capacity, functionality, damage, vehicle efficiency, environmental impact, renewable energy use, weight, and aesthetic appeal[108)]. Sensors used in autonomous farm vehicles include motion measurement, artificial landmarks, and local feature detection. Navigation systems typically use neural networks, genetic algorithms, fuzzy logic control, dead reckoning, image processing, statistical-based engineering, and Kalman filters[33,109)]. The study compared machine learning and deep learning models for a wall-following robot controller using ultrasonic sensors. Three datasets were used, complete with 24 inputs and simplified with 4 and 2 inputs. Decision tree models achieved 100% accuracy for the simplified dataset, while GBC achieved 99.82% precision for the complete dataset. Monte-Carlo cross-validation was used for evaluation[43)].

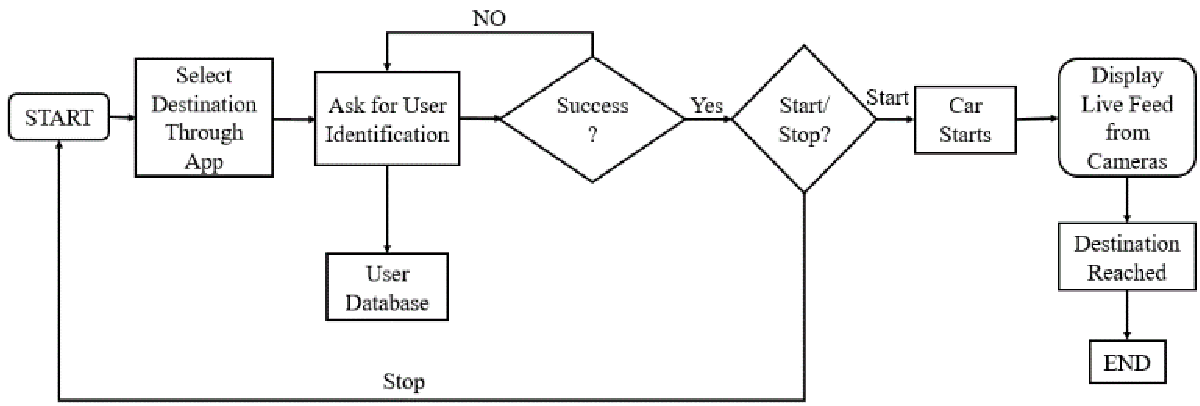

Fig. 9: Perception system application flow.

While discussing datasets used to train self-driving vehicle systems, focusing on perception and prediction components required as shown in Fig. 9. The datasets are evaluated for their suitability for a traditional and advanced technology stack. The raw sensor input is processed by a perception algorithm, estimating car and pedestrian positions and planning vehicle trajectory[87)]. The perception task involves accurately determining the three-dimensional placements of objects near a self-driving vehicle (SDV). Deep learning methods are currently the most advanced techniques for solving various sub-problems related to autonomous driving, including 3D object detection and semantic segmentation. The KITTI dataset, Waymo Open Dataset, and nu Scenes are widely used as benchmarks for training computer vision and autonomous driving systems[110)].

The primary objective of this research article[36)] is to enhance perception by accurately forecasting the future positions of detected objects, specifically a few seconds ahead. To achieve favourable outcomes, comprehensive data about the surroundings, such as semantic maps containing potential driving patterns, is essential. The Argoverse Forecasting dataset is the most significant open dataset available, offering 300 hours of perception data and a compact HD semantic map that encodes the placements of lane centres. The process of designing and implementing a self-driving vehicle path is the ultimate element in the autonomous driving system, but it has garnered the least attention from the community and shown the least development when considering machine learning solutions. Most study work primarily focuses on predicting ego-motion in open-loop systems, but these approaches exhibit a substantial decrease in performance when evaluated in closed-loop scenarios[111)]. The authors adhere to a contemporary methodology that utilises imitation learning and perturbations in their work, offering a machine learning planning baseline that can be trained and assessed successfully using their dataset. This indicates a high potential for machine learning planning solutions in the future while emphasizing the necessity of datasets to train them[118)].

The comparison of machine learning and deep learning models for wall-following robots offers valuable insights into their potential applications in autonomous vehicles (AEVs). Traditional machine learning models, such as Support Vector Machines (SVM), Decision Trees, or Linear Regression, are less computationally intensive and easier to interpret, but may struggle with complex environments with variable and intricate sensor inputs[112)].

Deep learning models, such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), have been adapted for wall-following robots, automatically learning to extract features from raw sensor data and adapting dynamically to changes in the environment[113]. These models excel in handling high-dimensional data and can learn complex patterns, making them ideal for navigating through dynamically changing environments. However, they require a significant amount of data to train effectively and are computationally intensive[119].

The findings from the use of machine learning and deep learning in wall-following robots have direct implications for AEV technology, particularly in environmental interaction, adaptability, real-time processing, safety and reliability, and data and resource management. Machine learning models provide superior performance in complex and variable environments, while deep learning models can be used in scenarios where safety and interpretability are critical[120].

The comparison of machine learning and deep learning in wall-following robotics offers valuable insights into their potential applications in AEVs. A blend of both approaches might be necessary to achieve the optimal balance of performance, interpretability, and computational efficiency in AEVs[121]. Future research could focus on hybrid models that combine the strengths of both machine learning and deep learning to enhance the robustness and reliability of autonomous vehicles in diverse operational conditions[36].

The CARLA-64 dataset, a collection of 64 beams of LiDAR data, is used in a model for a CARLA simulator. The model's performance on real-world datasets like KITTI can improve its generalization capacity. The KITTI-64 dataset is used to demonstrate outcomes in a well-accepted real-world scenario[114]. The Ati Realworld Dataset, created using 16-beam VLP-16 Puck LiDAR scans, is used for paired correspondence data. The model is trained adversarial for reconstructing static background LiDAR data without segmentation masks. Alternative options are provided to enhance LiDAR reconstruction and Simultaneous Localization and Mapping performance[35]. Gives a comparative analysis of K-nearest neighbours (KNN), Support Vector Machines (SVM), and Neural Networks (NN) has been conducted. The performance metric indicates that SVM outperforms the other analysed classifiers. The results clearly indicate that the features needed for training the classifier model should be robust and distinct in order to explore various techniques of unsupervised and supervised learning to enhance performance. The SVM approach demonstrated an accuracy estimation of approximately 99.38%, indicating the superior efficacy of SVM in forecasting future models or apparatuses. The SVM-based models and instruments have potential applications in various sectors such as restorative sciences, law, finance, politics, medicine, education, and other domains[115].

3.4 Safety Considerations for AEVs

The reasons behind these incidents remain undetermined. Other incidents include a Tesla Model 3

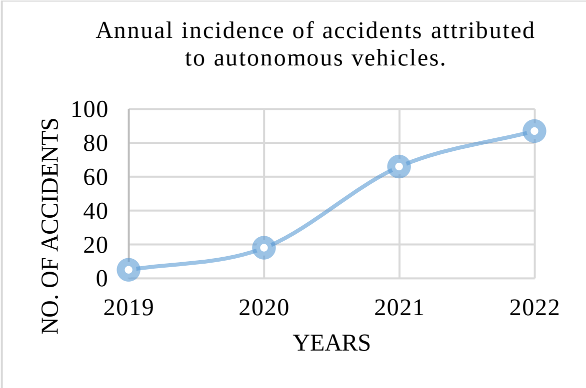

Fig. 10: Annual incidence of accidents attributed to autonomous vehicles[17].

collision with a Mercedes SUV and a police car without decelerating, a pedestrian killed by a Tesla Model S in Florida, and Google's Lexus SUV experiencing its first accident with a bus[116].

Figure 10 shows the number of accidents happened with AEV globally from year 2019 to year 2022[17]. Safety is crucial in developing and deploying Autonomous Tadpole Electric Vehicles (ATEVs), especially in India's complex road conditions. Risk assessment, mitigation strategies, cyber security measures, and emergency response systems are essential for safe operation. Autonomy can break automobile fixation, allowing vehicles of all sizes to mix, become modular, and reduce energy consumption, enabling sustainably powered transportation[44].

3.5 Risk Assessment and Mitigation Strategies

Risk assessment for AEVs involves identifying potential hazards and developing strategies to mitigate them, especially in India due to diverse road conditions and traffic behaviours[45]. Hazard identification involves identifying unpredictable pedestrian behaviour, non-standardized traffic patterns, varied road surfaces, and environmental factors. Risk analysis considers likelihood and impact, prioritizing risks based on severity and likelihood. Mitigation strategies involve advanced sensor technologies, robust algorithms, and fail-safe mechanisms for AEVs[39].

Blockchain technology addresses three key risk issues in establishing trust networks among autonomous vehicles: security, privacy, and resilience. It operates on peer-to-peer connections, allowing intelligent vehicles to interact directly without third-party involvement[33]. The robustness of blockchain networks is ensured by a large number of vehicle nodes, even in cases of malware infection or cyber-attacks. Autonomous vehicles are vulnerable to hacking and unauthorized access, potentially leading to terrorist acts. Therefore, autonomous cars must undergo rigorous verification to ensure absolute protection against hackers and external interference[11].

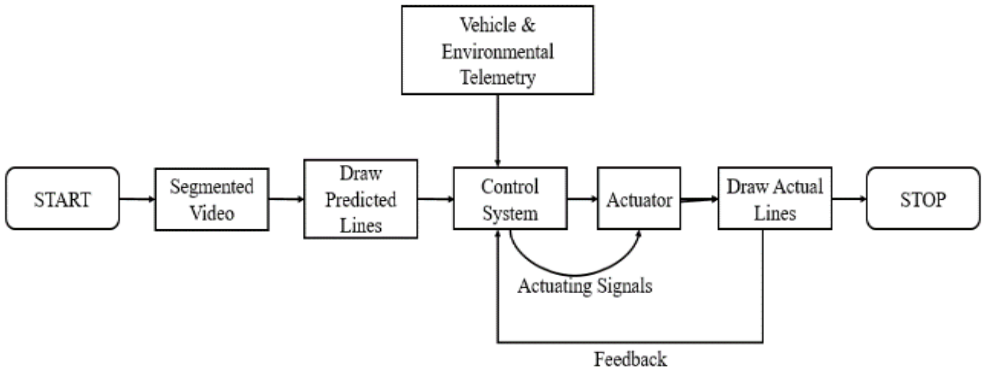

Fig. 11: Feedback-based autonomous riding system.

ATEVs, relying on software and connectivity, are vulnerable to cyber security threats. To protect them, robust measures are needed. These include secure communication protocols, intrusion detection systems, secure software development practices, and regular software updates. Encryption and authentication mechanisms are crucial for data transmission, while intrusion detection systems monitor network activity and alert for potential threats. Regular updates prevent exploitation during the update process[16]. Emergency response systems are crucial for autonomous vehicles (ATEVs) in India. These systems should allow swift communication with emergency services, relay critical information, and ensure effective coordination with emergency services. Clear emergency procedures and training are essential for operators and passengers.[88] ATEVs should be integrated into existing emergency response frameworks for a coordinated response as shown in Fig. 11. Addressing safety considerations for ATEVs in India requires rigorous risk assessment, robust cyber security measures, and comprehensive emergency response systems[89]. These measures form the backbone of public trust and acceptance, paving the way for a new era of smart and safe transportation[41].

3.6 Infrastructure Requirements for AEVs in India

Explores the use of soft robotic actuators like IPMC and SMA artificial muscles to enhance the durability of a foraging soft robot. However, there is a potential compromise between mechanical durability and thermodynamic effectiveness[51]. The focus is on establishing full energetic autonomy and focusing on high efficiency and low power control. The study also explores the use of a pliable oral cavity for a flexible automaton. The Ministry of Power's 2018 blueprint for establishing charging stations includes allowing charging in residential areas, renewing licensing for centralized stations, and testing public charging stations. The integration of Autonomous Tadpole Electric Vehicles in India's transportation system requires significant infrastructural developments, including road infrastructure upgrades, charging networks, and effective V2I communication systems[19,52].

India's road infrastructure is crucial for the deployment of ATEVs. Improvements include improving road quality, enhancing signage and lane markings, and adapting to urban and rural environments[48]. Regular inspections and maintenance of roads minimize the impact on navigation and safety systems. Standardized road signs and smart signalling systems can also improve efficiency[46,49].

3.7 Public Perception of Autonomous Vehicles

To address these concerns, strategies for public education and outreach include educational campaigns explaining the technology behind AVs, public demonstrations, maintaining transparency about AV capabilities and limitations, collaborating with community leaders to disseminate accurate information, and focusing on benefits such as increased mobility for the elderly and disabled, reduced traffic congestion, and environmental advantages[50,123].

Understanding and addressing public perceptions through targeted education and outreach initiatives are crucial for successful integration of AV technology. By focusing on areas of concern identified through surveys and studies, stakeholders can guide the public dialogue towards a more informed and positive reception of AV technology[115].

3.8 Vehicle- to- Infrastructure (V2I) Communication Needs

Autonomous vehicles (AVs) require external assistance for computational tasks and collaboration to achieve efficient and secure mobility. To achieve this, they must interact with infrastructure, the cloud, pedestrians, mobile phones, and other personal gadgets, transforming into Connected Autonomous Vehicles (CAVs). The international term for these information exchanges is V2X communications. The primary focus is to create a resilient, potent, secure, and dependable communications infrastructure that can efficiently transfer vast amounts of data at fast rates, maintaining minimal delays. The system must be impervious to hacker and terrorist threats and function to a certain degree even in failures. Governments often use a combination of wireless standard 802.11p and mobile networks, particularly 5G, to ensure interoperability among countries. The emergence of Vehicular Adhoc Networks (VANETs) through V2I and V2V communications is another ambitious endeavour[34)].

V2I communication systems are crucial for real-time information exchange between autonomous vehicles and road infrastructure, enhancing safety and traffic management. Integrating ATEVs with smart traffic lights and sensors optimizes traffic flow, reduces congestion, and improves road efficiency. Real-time information sharing allows ATEVs to receive updates on road conditions, construction zones, and alternative routes. V2I systems also aid in emergency response integration, providing real-time data for quicker responses. Data security and privacy are essential for ensuring the privacy of this data. Collaboration between government authorities, infrastructure developers, and technology providers is essential for achieving these objectives.

4. Regulatory and Policy Considerations

ADAS technology is gaining global popularity, with varying standards and guidelines across the United States and the European Union. The impact of these variations on safety remains uncertain. The European Union mandates pre-market approval for all vehicles, while the U.S. market relies on compulsory self-certification. The U.S. government has adopted a flexible approach, but lacks government safety regulations, allowing manufacturers to innovate for lower automation levels. Regulations may vary from state to state until federal legislation is enacted. The efficacy of certain technologies in terms of safety is still in the developmental stage. India's legal framework for autonomous vehicles needs examination and potential overhaul[17)]. India's current legal framework for vehicles and road traffic is primarily geared towards human-driven vehicles, with no clear guidelines for autonomous vehicles. The Motor Vehicles Act does not explicitly account for autonomous vehicles, making it difficult to determine liability and insurance in accidents. Additionally, there are no specific safety standards or testing protocols for autonomous vehicles, as existing standards are tailored to conventional vehicles[90)].

The introduction of autonomous and electric vehicles necessitates the creation of a specialized regulatory framework. This includes testing and certification, data protection and privacy, infrastructure adaptation, and public safety[92)]. Regulations should cover safety criteria, performance standards, and pilot projects. Additionally, policies should guide infrastructure changes, including road modifications and V2I communication systems[10)]. The automotive industry in India is actively focusing on adopting and adapting international standards for autonomous vehicles. ISO and SAE standards offer guidelines on safety, testing, and performance metrics for ATEVs[29)]. India could use these standards as a basis for developing its regulatory framework. However, these standards need to be customized to suit India's unique road, traffic, and socio-economic conditions. India should also aim to collaborate with international bodies and other countries in developing autonomous vehicle regulations. The regulatory and policy landscape for ATEVs in India is at a nascent stage, requiring significant development. This includes creating new regulations for testing, certification, liability, insurance, and data protection[5)].

The European Union has implemented a regulatory framework (EU Reg. 2019/2144) to improve road safety through advanced safety technologies and establish a legal framework for automated vehicles[131)]. This includes new standards for vehicle equipment and safety technologies. The US is moving towards more comprehensive federal guidelines, particularly concerning safety standards and liability issues surrounding autonomous vehicles. The UK has proposed new legal frameworks specifically designed for autonomous vehicles, focusing on defining driver responsibility and implementing a 'user-in-charge' concept. India's recent policies are yet to be integrated into a cohesive national framework for autonomous vehicles, but there is a significant push towards electric vehicles as a foundational step towards integrating autonomous technologies[132,133)]. The government's focus has been on incentives, infrastructure development, and pilot projects for the eventual adoption of AEVs[134)].

4.1 Current Pilot Projects

The self-driving car market is experiencing significant growth, with prominent businesses such as Tesla, Waymo, General Motors, Mercedes Benz, Ford, BMW, Volkswagen, and Nissan actively engaged in developing these autonomous vehicles. Notable autonomous automobiles include the Tesla Model S, which boasts level two automation, adaptive cruise control, lane departure warnings, and self-parking capabilities. The Audi A8 is a high-end sedan equipped with level three automation, providing advanced driver aid technology but not complete autonomy. The Nissan Leaf is a cost-effective electric vehicle equipped with level two automation, adaptive cruise control, and lane departure warnings. The BMW 7 Series is a high-end sedan equipped with level two automation, which encompasses features such as adaptive cruise control and self-parking capabilities. Waymo One is a ride-hailing service that utilises completely autonomous vehicles to transport people in specific regions of Arizona[17)]. The case studies of Waymo and Singapore highlight the importance of customizing autonomous vehicle technology to local conditions in India, given its diverse traffic scenarios, road infrastructure, and socio-cultural dynamics. Phased implementation, starting with controlled environments or specific use cases, can help address safety concerns and gradually adapt ATEVs in India. A supportive regulatory framework is crucial for ensuring safety and fostering innovation, and India needs to develop and implement regulations conducive to testing and operation of ATEVs.

Public engagement and trust building are also essential for the acceptance of ATEVs in India. In summary, the lessons learned from international case studies and Indian pilot projects can guide the successful introduction of ATEVs in India.

Recent advancements in road transport systems and the integration of artificial intelligence have led to significant changes. The fundamental structure of road transport networks is discussed in[11]. Rapid technological breakthroughs have driven revolutionary changes, such as the widespread adoption of laptops and AI portable gadgets. The integration of autonomous vehicle technologies in road transport systems is a notable advancement, but it is crucial to understand the constraints associated with their implementation to develop viable solutions.

Government financing, supporting regulatory environment, and investment in digital infrastructure are expected to significantly stimulate the market for autonomous automobiles in the projection period. Furthermore, it offers autonomous mobility for those with disabilities as well as for those who do not possess a driver's licence. They provide a superior degree of adaptability and convenience for resting, reading, or even working while travelling, hence enhancing their productivity. In addition, the automobile industry has seen the emergence of autonomous vehicles due to the increasing technical progress and variety. Autonomous cars represent a significant advancement in the automobile industry, after the advent of electric and hybrid vehicles.

Table 5. Summary of autonomous vehicle market.

Parameter Description	Details of Parameter
Base Year	2022
Forecast Period	2023 to 2032
Current Market Size	Rs. 12 Lakh Crore
Forecast of Market	Rs. 184 Lakh Crore
Market Growth	35%
Largest Market Region	Asia Pacific
Fastest Growing Market	North America
Sectors Covered	Application, Level of Automation, Propulsion, Vehicle, Area
Companies Revealed	Daimler AG, Google LLC, General Motors Company, Nissan Motor Company, Honda Motor Co., Ltd., Toyota Motor Corporation, Tesla, Volvo Car Corporation, Uber Technologies, Inc., and Volkswagen AG, BMW AG, Audi AG, Ford Motor Company,

The increasing incidence of accidents caused by human error has necessitated the integration of autonomous technology into the automotive industry. In addition to the advantages, the exorbitant price of autonomous cars, increasing apprehension about security and safety, and inadequate infrastructure to accommodate automated vehicles in emerging nations impede the market's expansion. However, the market for autonomous cars is anticipated to be driven by government programmes aimed at promoting electric and hybrid vehicles soon. Table 5 gives an overview of the global market size and predicted growth by 2030.

4.2 The Influences of Autonomous Vehicles on Road Transportation

4.2.1 Security

Autonomous vehicles have significantly reduced road accidents in industrialized nations, with 40% of fatal accidents attributed to alcohol consumption, marijuana overdose, or weariness. Self-driving vehicles, which rely on minimal human intervention, are less likely to cause accidents. About 90% of road accidents occur due to driver mistakes. The potential benefits of autonomous vehicles include economic and environmental benefits. Annually, over 30 to 40 thousand Americans die from vehicular collisions, resulting in injuries for around 2.2 million people. However, autonomous vehicles have limitations, such as their inability to quickly identify nearby objects or individuals. Researchers predict that autonomous vehicles will overcome this issue in the future by accurately identifying and discerning objects and individuals on the road[11].

4.2.2 The problem of excessive traffic and congestion on roads.

Researchers have developed an external sensor to improve road safety and alleviate traffic congestion on highways and intersections. This sensor accurately detects lead car braking decisions, allowing autonomous vehicles to navigate safely. Autonomous vehicle systems use adaptive cruise control for decision-making, including route selection and platoon coordination. To achieve autonomous junctions, 95% of vehicles must be introduced into the road transport network. Autonomous vehicles reduce traffic congestion by allowing vehicles to travel closely together, increasing the capacity of current road lanes.

4.2.3 Travel patterns

The introduction of autonomous cars is expected to significantly change travel patterns, particularly in areas such as providing transportation options for the elderly, disabled, and young individuals. This will lead to changes in parking arrangements in metropolitan areas, reduced illegal parking on-road lanes, and the proliferation of car ride-sharing programs. These changes can be achieved by measuring vehicle-miles traveled (VMT) and promoting vehicle-focused development. Studies have shown that autonomous vehicle usage increases automobile mileage, decreases parking costs, and increases market shares. Non-public autonomous vehicles have also shown significant changes in transportation preferences when time value and parking expenses decrease[11]. Have shown that private autonomous vehicle travel hours increase, leading to decreased parking costs and increased acceleration. These advancements will also reduce brake deterioration, travel durations, and fuel expenses and energy consumption. However, demand management must be applied cautiously to ensure these changes are implemented.

Autonomous vehicles (AVs) have the potential to significantly increase Vehicle Miles Traveled (VMT) by 20-30% due to increased accessibility for non-drivers and added convenience for regular users. Studies suggest that AVs could add up to 2 billion hours of annual travel time in the U.S. alone, translating into significant increases in VMT due to the ease of travel and extended mobility for the elderly, disabled, and youth[11].

Parking arrangements are expected to decrease by up to 50% with the adoption of AVs, as they can find remote parking spots and operate continuously without long-term parking during peak hours. Cities like San Francisco have reported a potential reduction in illegal parking incidents by up to 20%, as AVs are programmed to adhere strictly to traffic and parking regulations. Research conducted by the Boston Consulting Group (BCG) highlighted that AV technology could decrease illegal parking instances significantly due to precise positioning and real-time data access[34].

Analysts predict a 30% rise in the usage of car-sharing services in urban areas, with ride-sharing fleets like Uber and Lyft seeing utilization rates jump by over 40%. A simulation study by MIT’s Computer Science and Artificial Intelligence Laboratory (CSAIL) demonstrated that replacing private car and taxi services with ride-sharing AVs could reduce the number of cars on city streets by 40% while meeting urban mobility demands.

AVs can also reduce travel duration and fuel expenses by up to 40% in high-traffic urban areas due to optimized route selection and cooperative intersection management. Ford Motor Company's case study in Los Angeles showed that AVs optimized for traffic flow reduced trip times and fuel usage significantly during peak congestion periods.

5. Conclusion

The exploration of Autonomous Tadpole Electric Vehicles (ATEVs) in the perspective of India's exceptional and challenging road conditions presents a compelling case for the future of transportation. This review has highlighted key aspects of AEVs, including their technological requirements, safety considerations, infrastructure needs, regulatory challenges, and public acceptance factors. ATEVs hold the potential to revolutionize transportation in India, offering solutions to some of the most pressing challenges such as traffic congestion, road accidents, and pollution. Their adoption could lead to significant improvements in road safety, efficiency in transportation, and a reduction in environmental impact. ATEVs also present an opportunity to position India at the forefront of automotive technology innovation and sustainable urban planning. Study also gives an overview of global market size and public attitude towards adoption of AVs which can be comparable with Indian scenarios and will help to implement ATEVs in India.

Industry stakeholders should prioritize research and development to improve sensor technology and software algorithms for India's unique road conditions. They should collaborate with government bodies to shape policies supporting the integration of autonomous vehicles (ATEVs), lobby for incentives and infrastructure support. Implement educational campaigns and pilot projects to raise public awareness and acceptance of ATEVs, while collaborating with urban planners to ensure infrastructure development aligns with ATEV needs, such as charging stations and smart road systems. Transparency in communicating benefits and safety features is crucial.

6. Future Scope and Recommendations

6.1 Customized Technology Development

Future research should focus on developing ATEV technologies that are specifically tailored to Indian conditions. This includes enhancing sensor accuracy in diverse environments, improving AI algorithms for unpredictable traffic scenarios, and developing robust vehicle designs.

6.2 Pilot Projects and Real-World Testing

Implementing more pilot projects across various Indian cities can provide valuable insights into the real-world performance of ATEVs. These projects should be used to test and refine the technologies, infrastructure requirements, and public interaction strategies.

6.3 Collaborative Policy Formulation

Policymakers, industry experts, and academic researchers should collaborate to develop a comprehensive and flexible regulatory framework that encourages innovation while ensuring safety and public welfare.

6.4 Public Outreach and Education

Continuous efforts are needed to educate the public about the benefits and safety features of ATEVs. Building public trust through transparent communication and engagement is essential for the acceptance of this new technology.

6.5 Growing emphasis on vehicle platooning

Vehicle platoons are modern vehicles traveling together at high speeds, closely following each other. This technology aims to improve safety, fuel economy, and reduce travel time. The European government initiated the "ENSEMBLE" project in 2018 to implement truck platooning, partnering with DAF, Daimler, Iveco, MAN, Scania, and Volvo. The project aims to create self-driving trucks and showcase platooning capabilities over three years. The increasing use of vehicle platooning is expected to increase the need for autonomous vehicles.

7. CRediT authorship contribution statement

7.1 Amol Shinde

Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing – Original Draft Preparation.

7.2 Raju Kumar Swami

Supervision, Project Administration, Funding Acquisition, Writing – Review & Editing.

7.3 Sameer Nanivadekar

Visualization, Resources, Validation, Writing – Review & Editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1) A. Zope, R. K. Swami, and A. Patil, "SEM approach for Analysis of Lean Six Sigma Barriers to Electric Vehicle Assembly," Automotive Experiences, 6(2) 416–428 (2023). doi: 10.31603/ae.9690.
2) Krishna Baraskar, "EVS IN INDIA: COMPREHENSIVE REVIEW OF TECHNOLOGICAL ADVANCEMENT, MARKET GROWTH, OPPORTUNITIES, AND CHALLENGES," International Research Journal of Modernization in Engineering Technology and Science, 05(08) 1773-1781 (2023). doi: 10.56726/irjmets44200.
3) A. Zope, R. K. Swami, and A. Patil, "LEAN SIX SIGMA BARRIERS WITH POTENTIAL SOLUTIONS IN ELECTRICAL VEHICLE ASSEMBLY: A REVIEW," Proceedings on Engineering Sciences, 5(3) 375–382 (2023). doi: 10.24874/PES05.03.002.
4) A. Tripathy and B. Shanker, "Future of Indian Auto Industry: Choices and Challenges," 566 1-37 (2018). https://ssrn.com/abstract=3147878 (Accessed March 27, 2024).
5) M. Kumar, K. P. Panda, R. T. Naayagi, R. Thakur, and G. Panda, "Comprehensive Review of Electric Vehicle Technology and Its Impacts: Detailed Investigation of Charging Infrastructure, Power Management, and Control Techniques," Applied Sciences (Switzerland), 13(15) 1-58 (2023). doi: 10.3390/app13158919.
6) J. K. Maherchandani, R. R. Joshi, R. Tirole, R. K. Swami, and B. P. Ganthia, "Performance Comparison Analysis of Energy Management Strategies for Hybrid Electric Vehicles," Lecture Notes in Electrical Engineering, 852(1) 245–254 (2022). doi: 10.1007/978-981-16-9239-0_18.
7) S. Gupta, S. Poonia, T. Varshney, R. K. Swami, and A. Shrivastava, "Design and Implementation of the Electric Bicycle with Efficient Controller," Lecture Notes in Electrical Engineering, 862(1) 541–552 (2022). doi: 10.1007/978-981-19-0252-9_49.
8) A. Zope, R. K. Swami, and A. Patil, "Topsis based Ranking of Lean Six Sigma Barriers to Electric Vehicle Assembly," 2023 IEEE 3rd International Conference on Sustainable Energy and Future Electric Transportation (SEFET), IEEE, 3(1) 1–8 (2023). doi: 10.1109/SeFeT57834.2023.10245316.
9) S. Mishra et al., "A comprehensive review on developments in electric vehicle charging station infrastructure and present scenario of India," Sustainability (Switzerland), 13(4) 1–20 (2021). doi: 10.3390/su13042396.
10) V. Singh, V. Singh, and S. Vaibhav, "Analysis of electric vehicle trends, development and policies in India," Case Stud Transp Policy, 9(3) 1180–1197 (2021). doi: 10.1016/j.cstp.2021.06.006.
11) I. O. Olayode, B. Du, A. Severino, T. Campisi, and F. J. Alex, "Systematic literature review on the applications, impacts, and public perceptions of autonomous vehicles in road transportation system," Journal of Traffic and Transportation Engineering, 10(6) 1037-1060 (2023). doi: 10.1016/j.jtte.2023.07.006.
12) H. Lajuardhie, A. S. Satyawan, A. Faroqi, and F. A. Rasyid, "A Steering Stability Control for A Three-Wheeled Autonomus Electric Vehicle," 8th International Conference on Wireless and Telematics (ICWT), IEEE Conference Publication, IEEE Xplore, 8(1) 1–5 (2022). https://ieeexplore.ieee.org/document/9935468 (Accessed January 27, 2024).
13) Sudarshan Gnanavendan, Jithin Dev S, and Senthil Kumaran Selvaraj, "Challenges, Solutions and Future trends in EV-Technology: A Review," IEEE Access, 1(1) 1–9 (2017). doi:10.1109/ACCESS.2024.3353378
14) J. Monios and R. Bergqvist, "The transport geography of electric and autonomous vehicles in road freight networks," J Transp Geogr, 80(1) 102-500 (2019). doi: 10.1016/j.jtrangeo.2019.102500.

15) A. Ghazi, D. Yadav, S. Muthusamy, O. P. Mishra, and A. K. Loganathan, “The scope and adaptation strategy for autonomous vehicles from the perspective of Indian smart city,” Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 45(3) 8716–8736 (2023). doi: 10.1080/15567036.2023.2232331.
16) G. Kumar, A. T. James, K. Choudhary, R. Sahai, and W. K. Song, “Investigation and analysis of implementation challenges for autonomous vehicles in developing countries using hybrid structural modeling,” Technol Forecast Soc Change, 185(1) 12-2080 (2022) doi: 10.1016/j.techfore.2022.122080.
17) 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, 5(1) 142-161 (2023). doi: 10.1109/OJVT.2023.3335180.
18) Uysal, E., & Ozturk, A., "Comparison of machine learning algorithms on different datasets" 2022 30th Signal Processing and Communications Applications Conference (SIU), 1(1) 1–4 (2018). doi:10.1109/siu.2018.8404193
19) S. Sachan and P. P. Singh, “Charging infrastructure planning for electric vehicle in India: Present status and future challenges,” Regional Sustainability, 3 (4) 335–345 (2022). doi: 10.1016/j.regsus.2022.11.008.
20) F. Ahmad and M. Bilal, “A Comprehensive Analysis of Electric Vehicle Charging Infrastructure, Standards, Policies, Aggregators and Challenges for the Indian Market,” Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 45(3) 8601–8622 (2023). doi: 10.1080/15567036.2023.2228734.
21) A. Shinde, R. Kumar Swami, and S. Nanivadekar, “OPTIMIZATION OF SWING ARM FOR TADPOLE STRUCTURED ELECTRIC VEHICLE,” Journal of Research Administration, 5(2) 2370–2382 (2023). https://www.researchgate.net/publication/375893353 (Accessed January 31, 2024).
22) Ján Dižo, Miroslav Blatnický, Rafał Melnik, and Michal Karľa, “Improvement of Steerability and Driving Safety of an Electric Three-Wheeled Vehicle by a Design Modification of its Steering Mechanism,” LOGI – Scientific Journal on Transport and Logistics,13(1) 49–60 (2022). doi:10.2478/logi-2022-0005
23) A. Ramji and S. Venugopal, “Creating a Sustainable Mobility Ecosystem in India: Vision 2030,” 2019 IEEE Transportation Electrification Conference (ITEC-India), IEEE, 1(1) 1–6 (2019) doi: 10.1109/ITEC-India48457.2019.ITECINDIA2019-256.
24) T. C. Folsom and R. Cotter, “Automation of ultra-light vehicles,” 2017 IEEE Conference on Technologies for Sustainability (SusTech), IEEE, 1(1) 1–6 (2017). doi: 10.1109/SusTech.2017.8333514.
25) F. Un-Noor, S. Padmanaban, L. Mihet-Popa, M. Mollah, and E. Hossain, “A Comprehensive Study of Key Electric Vehicle (EV) Components, Technologies, Challenges, Impacts, and Future Direction of Development,” Energies (Basel), 10(8) 12-17 (2017). doi: 10.3390/en10081217.
26) A. Ghobadpour, G. Monsalve, A. Cardenas, and H. Mousazadeh, “Off-Road Electric Vehicles and Autonomous Robots in Agricultural Sector: Trends, Challenges, and Opportunities,” Vehicles, 4(3) 843–864 (2022). doi: 10.3390/vehicles4030047.
27) A. S. Duggal et al., “Infrastructure, mobility and safety 4.0: Modernization in road transportation,” Technol Soc, 67(1) 101-791 (2021). doi: 10.1016/j.techsoc.2021.101791.
28) MITTAL, G., GARG, A., PAREEK, K. "A review of the technologies, challenges and policies implications of electric vehicles and their future development in India", Energy Storage, 6(1) 21-28 (2024). doi: 10.1002/est2.562.
29) P. G. Pereirinha, M. González, I. Carrilero, D. Anseán, J. Alonso, and J. C. Viera, “Main Trends and Challenges in Road Transportation Electrification,” Transportation Research Procedia, 33(1) 235–242 (2018) doi: 10.1016/j.trpro.2018.10.096.
30) P. K. Tarei, P. Chand, and H. Gupta, “Barriers to the adoption of electric vehicles: Evidence from India,” J Clean Prod, 291(1) 125-847 (2021). doi: 10.1016/j.jclepro.2021.125847.
31) C. B. Prajeesh and A. S. Pillai, “Indian smart mobility ecosystem – Key visions and missions,” 255(1) 50-55 (2022) doi: 10.1063/5.0124596.
32) N. V Jayadharashini, “Driving the future - electric mobility a paradigm shift & amp; its challenges,” in 2019 IEEE Transportation Electrification Conference (ITEC-India), IEEE, 1(1) 1–4 (2019). doi: 10.1109/ITEC-India48457.2019.ITECINDIA2019-146.
33) Ashwin Kavasseri Venkitaraman and Venkata Satya Rahul Kosuru, “A review on autonomous electric vehicle communication networks-progress, methods and challenges,” World Journal of Advanced Research and Reviews, 16 (3) 13–24 (2022). doi: 10.30574/wjarr.2022.16.3.1309.
34) M. Martínez-Díaz and F. Soriguera, “Autonomous vehicles: Theoretical and practical challenges,” Transportation Research Procedia, Elsevier, 33(1) 275–282 (2018). doi: 10.1016/j.trpro.2018.10.103.
35) P. Kumar et al., “DSLR: Dynamic to Static LiDAR Scan Reconstruction Using Adversarially Trained Autoencoder,” The Thirty-Fifth AAAI Conference

on Artificial Intelligence (AAAI-21), 1(1) 1–9 (2021). https://dslrproject.github.io/dslr (Accessed August 27, 2024).

36) J. Houston et al., “One Thousand and One Hours: Self-driving Motion Prediction Dataset,” 4th Conference on Robot Learning (CoRL 2020), Cambridge MA, USA., 1(1) 1–10 (2020). http://arxiv.org/abs/2006.14480 (Accessed August 28, 2024).

37) “YOLOv3: An Incremental Improvement.” https://pjreddie.com/yolo/ (Accessed January 30, 2024).

38) J. Redmon, S. Divvala, R. Girshick, and A. Farhadi, “You Only Look Once: Unified, Real-Time Object Detection,” 1-10 (2015). http://arxiv.org/abs/1506.02640 (Accessed January 30, 2024).

39) M. Cunneen, M. Mullins, and F. Murphy, “Autonomous Vehicles and Embedded Artificial Intelligence: The Challenges of Framing Machine Driving Decisions,” Applied Artificial Intelligence, 33 (8) 706–731 (2019). doi: 10.1080/08839514.2019.1600301.

40) Y. Jeong and S. Yim, “Path Tracking Control With Four-Wheel Independent Steering, Driving and Braking Systems for Autonomous Electric Vehicles,” IEEE Access, 10(1) 74733–74746 (2022). doi: 10.1109/ACCESS.2022.3190955.

41) S. Jain et al., “Blockchain and Autonomous Vehicles: Recent Advances and Future Directions,” IEEE Access, 9(1) 130264–130328 (2021). doi: 10.1109/ACCESS.2021.3113649.

42) N. Guo, X. Zhang, and Y. Zou, “Real-Time Predictive Control of Path Following to Stabilize Autonomous Electric Vehicles Under Extreme Drive Conditions,” Automotive Innovation, 5(4) 453–470 (2022). doi: 10.1007/s42154-022-00202-3.

43) I. Hammad, J. Gu, K. El-Sankary, S. Member, and I. Member, “Comparative Study on Machine Learning Algorithms for the Control of a Wall Following Robot,” IEEE International Conference on Robotics and Biomimetics (ROBIO) -2019, 1(1) 2995-3000, (2019). doi:10.1109/ROBIO49542.2019.8961836

44) T. Folsom, “Self-driving Tricycles,” International Symposium on Bicycle Urbanism, Seattle, WA, 1(1) 1–13. (2013). https://www.researchgate.net/publication/356840160 (Accessed January 30, 2024).

45) H. Philamore, I. Ieropoulos, A. Stinchcombe, and J. Rossiter, “Toward Energetically Autonomous Foraging Soft Robots,” Soft Robot, 3(4) 186–197 (2016). doi: 10.1089/soro.2016.0020.

46) R. Dua, S. Hardman, Y. Bhatt, and D. Suneja, “Enablers and disablers to plug-in electric vehicle adoption in India: Insights from a survey of experts,” Energy Reports, 7(1) 3171–3188 (2021), doi: 10.1016/j.egyr.2021.05.025.

47) P. Barman and L. Dutta, “Charging infrastructure planning for transportation electrification in India: A review,” Renewable and Sustainable Energy Reviews, 192(1) 114-265 (2024). doi: 10.1016/j.rser.2023.114265.

48) Pandey, A., Guha, A., Kumar, A., Bej, N., & Parhi, D. R., "Navigation method for pioneer P3-DX ground wheeled robot in V-REP platform using Type-2 Fuzzy Neural Network (T2FNN) Architecture" Lecture notes in mechanical engineering, 1(1) 571–580, (2020). doi: 10.1007/978-981-15-7779-6_52

49) A. Waters, “A Novel Universal Corner Module for Urban Electric Vehicles: Design, Prototype, and Experiment.” http://hdl.handle.net/10012/12217 (Accessed March 27, 2024)

50) J. Lowry and James. Larminie, "Electric vehicle technology explained," Wiley, 2012. https://www.iqytechnicalcollege.com/BAE%20685-Electric%20Vehicle%20Technology.pdf (Accessed July 12, 2022)

51) V. Chinubhai Shah and K. Arturas Supervisor, “Designing and Investigating of Electric Tricycle.” https://epubl.ktu.edu/object/elaba:28859297/28859297.pdf (Accessed March 27, 2024).

52) A. Ewert, S. Schmid, M. Brost, H. Davies, and L. Vinckx, “Small Electric Vehicles An International View on Light Three-and Four-Wheelers,” (2021). doi: 10.1007/978-3-030-65843-4

53) “Electric and Plug-in Hybrid Vehicle Roadmap 2050." https://www.iea.org/reports/electric-and-plug-in-hybrid-electric-vehicles-roadmap (Accessed January 30, 2024).

54) P. R. Shukla, S. Dhar, M. Pathak, and K. Bhaskar, “Electric Vehicle Scenarios and a Roadmap for India Working Group III contribution to the IPCC 6th Assessment Report (AR6) View project Linking sectoral and economy-wide models View project,” (2014). doi: 10.13140/2.1.4544.0325.

55) “Electric vehicles Setting a course for 2030.” https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html (Accessed January 29, 2024).

56) P. R. Shukla, S. Dhar, M. Pathak, and K. Bhaskar, “PROMOTING LOW CARBON TRANSPORT IN INDIA Electric Vehicle Scenarios and a Roadmap for India,” (2014). https://backend.orbit.dtu.dk/ws/portalfiles/portal/104752085/Electric_Vehicle_Scenarios_and_a_Roadmap_for_India_upload.pdf (Accessed January 27, 2023).

57) K. Sreeram, P. K. Preetha, and P. Poornachandran, “Electric Vehicle Scenario in India: Roadmap, Challenges and Opportunities,” Proceedings of 2019 3rd IEEE International Conference on Electrical, Computer and Communication Technologies, ICECCT 2019, Institute of Electrical and Electronics

Engineers Inc.,1(1) 1-7 (2019). doi: 10.1109/ICECCT.2019.8869479.
58) K. V. Singh, H. O. Bansal, and D. Singh, “A comprehensive review on hybrid electric vehicles: architectures and components,” Journal of Modern Transportation, 27(2) 77–107 (2019). doi: 10.1007/s40534-019-0184-3.
59) S. Rokadiya and A. Bandivadekar, “Hybrid and electric vehicles in India: Current scenario and market incentives,” (2016). http://www.theicct.org/sites/default/ (Accessed January 15, 2024).
60) I. Husain, "Electric and Hybrid Vehicles: Design Fundamentals," Routledge & CRC Press, (2021). https://www.routledge.com/Electric-and-Hybrid Vehicles-DesignFundamentals/Husain/p/book/9780367693930?srsltid=AfmBOooxTXC_vNh6fsfLB2XCjXd1Jg8zYTw4Dg-_LjmXNazQqd62swC. (Accessed July 12, 2022).
61) M. Ehsani, Y. Gao, S. E. Gay, and A. Emadi, “Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design,” (2018). https://nibmehub.com/opac-service/pdf/read/Modern%20Electric%20Hybrid%20Electric%20and%20Fuel%20Cell%20Vehicles%203rd%20Edition.pdf (Accessed July 11, 2022).
62) Z. Q. Zhu and D. Howe, “Electrical machines and drives for electric, hybrid, and fuel cell vehicles,” Proceedings of the IEEE, 95(4) 746–765 (2007). doi: 10.1109/JPROC.2006.892482.
63) SÁNCHEZ-REPILA, D., POXON, J. E. W., , "HYBRID ELECTRIC VEHICLES: CURRENT CONCEPTS AND FUTURE MARKET TRENDS," Universitat Politecnica de Catalunya, (2000). https://upcommons.upc.edu/bitstream/handle/2099/9732/Article002.pdf. (Accessed January 15, 2024).
64) M. Trzesniowski, "Complete vehicle," Springer Fachmedien Wiesbaden, (2023). doi: 10.1007/978-3-658-39667-1.
65) VARMORA, T., KUMAR, M., RAJENDRA, S. K., "Design and optimization of hybrid electric vehicle", Smart innovation, systems and technologies,1(1) 199–209 (2019). doi: 10.1007/978-981-32-9578-0_18.
66) REDDY, M. V., KUMAR, B. R., KUMAR, P. P., *et al.* "Design, analysis and fabrication of effie-cycle: A hybrid tadpole vehicle", AIP Conference Proceedings, 2317(1) 4-15 (2021). doi: 10.1063/5.0036599.
67) A. Zandieh, “Dynamics of a Three-Wheel Vehicle with Tadpole Design.”, (2014). https://core.ac.uk/download/pdf/144148031.pdf (Accessed May 16, 2022).
68) A. Ranpariya, A. Thattil, S. Vachhani, D. Raval, P. Sharma, and U. G. Students, “Design of the Tadpole Type Three-Wheel Vehicle with Dynamic Conditions,” International Research Journal of Engineering and Technology, 06(04) 4605-4609, (2019). https://www.irjet.net/archives/V6/i4/IRJET-V6I41003.pdf (Accessed January 3, 2023).
69) A. Tahjib, H. Tanzin, S. M. I. Rahman, B. S. Islam, and H. Azim, “Development of a Solar Powered Electric Vehicle based on Tadpole Design,” International Conference on Robotics, Electrical and Signal Processing Techniques, 1(1) 206–210 (2021) doi: 10.1109/ICREST51555.2021.9331052.
70) S. Rokadiya and A. Bandivadekar, “Hybrid and electric vehicles in India: Current scenario and market incentives,” (2016). http://www.theicct.org/sites/default/ (Accessed January 15, 2024).
71) N. M. Sarode and M. T. Sarode, “Current Scenario of Electric Mobility in India and its Challenges.”International Journal of Engineering Research & Technology (IJERT), 9(8) 510-515 (2020). https://pdfs.semanticscholar.org/2d7d/b0213f001634e43e4c91bcef00c63bafb585.pdf (Accessed January 15, 2024).
72) S. A. Bagloee, M. Tavana, M. Asadi, and T. Oliver, “Autonomous vehicles: challenges, opportunities, and future implications for transportation policies,” Journal of Modern Transportation, 24(4) 284–303 (2016). doi: 10.1007/s40534-016-0117-3.
73) F. Czerwinski, “Current trends in automotive lightweighting strategies and materials,” Materials, 14(21) 1-27 (2021). doi: 10.3390/ma14216631.
74) PAUDEL, A. M., KREUTZMANN, P. "Design and performance analysis of a hybrid solar tricycle for a sustainable local commute", Renewable and Sustainable Energy Reviews, 41(1) 473–482 (2014). doi: 10.1016/j.rser.2014.08.078.
75) X. Jiang, L. Chen, X. Xu, Y. Cai, Y. Li, and W. Wang, “Analysis and optimization of energy efficiency for an electric vehicle with four independent drive in-wheel motors,” Advances in Mechanical Engineering, 10(3) 1-9 (2018). doi: 10.1177/1687814018765549.
76) MARQUES LOUREIRO, J. F. D. D., "Energy consumption estimation in lap time simulation." (2018). https://scholar.tecnico.ulisboa.pt/api/records/zGg8AhKBTqKFPMAJcuqxR5cd0EUvHEIh3p/file/5444470ce5d2ded223e36bf0db303989401e2fd1d7f88c9348cb6666befefe46.pdf. (Accessed September 9, 2023).
77) W. Zhang and J. Xu, “Advanced lightweight materials for Automobiles: A review,” Materials and Design, 221(01) 1-20 (2022). doi: 10.1016/j.matdes.2022.110994.
78) R. Pütz and T. Serné, "Race Car Handling Optimization: Magic Numbers to Better Understand

a Race Car," Springer Fachmedien Wiesbaden, (2022). doi: 10.1007/978-3-658-35200-4.

79) "VEHICLE ELECTRIFICATION JANUARY (2023)." https://www.techbriefs.com/component/content/article/47571-doc-8915 (Accessed January 30, 2024)
80) "Materials Innovations Guide for Medical Components and Equipment." https://www.mobilityengineeringtech.com/documents/public/7916-materials-innovations-guide-for-medical-components-and-equipment/file (Accessed March 27, 2024).
81) Gisbert Lechner, Harald Naunheimer "Automotive transmissions fundamentals selection design and application", (1999). http://www.volkspage.net/technik/manuaisecatalogos/02/automotivetransmissions_fundamentalsselectiondesignandaplication.pdf (Accessed January 23, 2022).
82) SUVAC, A., CUCU, L., STOICA, M., et al. "Development and optimization of a three-wheeled electric vehicle frame using structural materials", Journal of Physics Conference Series, 1297 (1) 12-21 (2019). doi: 10.1088/1742-6596/1297/1/012021
83) SUMARSONO, D. A., JATI, M. K., MUIZ, M. A. "Modelling of tilting and steering control system for a tadpole Three-Wheeled vehicle", Journal of Physics Conference Series, 1519 (1) 01-20 (2020). doi: 10.1088/1742-6596/1519/1/012008
84) B. Sunday, U. Thomas, I. S. Ityokumbul, and A. Nasir, "EFFECT OF NUMBER OF PASSENGERS [LOADING] ON CENTRE OF GRAVITY OF A THREE WHEELED VEHICLE [KEKE-NAPEP] CG of Four Wheeled Vehicle CG of Three wheeled Vehicle Effects of Loading on CG Static Stability Factor," 15(3) 628–637 (2019). www.azojete.com.ng (Accessed August 28, 2024).
85) A. J. Waters and A. Khajepour, "OPTIMIZATION OF NOVEL CORNER MODULE FOR URBAN ELECTRIC VEHICLE," (2017). http://www.asme.org/about-asme/terms-of-use (Accessed May 19, 2022).
86) T. Nabil et al., "Design and Fabrication of Prototype Battery Electric Three Wheeled Vehicles," Journal of Asian Electric Vehicles, 17(2) 1823-1834 (2019). https://www.jstage.jst.go.jp/article/jaev/17/2/17_1823/_pdf (Accessed August 28, 2024).
87) O. Ellerstrand and T. E. Kilicasan, "Optimization of Front Suspension Uprights on a Three-wheeled Electric Vehicle Ecoist," (2017). http://www.mek.lth.se/ (Accessed May 16, 2022).
88) S. P. Vijaya Ram, "MASS OPTIMIZATION USING GENERATIVE DESIGN FOR REAR ACCESSORY ASSEMBLY IN A TWO-WHEELER," International Journal of Mechanical Engineering, 6(3) 2143-2148 (2021). https://kalaharijournals.com/resources/DEC_285.pdf (Accessed May 16, 2022).
89) Rudolf Limpert, "Brake Design and Safety Second Edition." (1999). https://ia803101.us.archive.org/33/items/BrakeDesignAndSafetyRudolfLimpert2ed/Brake%20Design%20and%20Safety%20-%20Rudolf%20Limpert%20-%202ed.pdf (Accessed January 23, 2022).
90) Karin. Jonasson and Media-tr., "Analysing hybrid drive system topologies" (2002). https://lucris.lub.lu.se/ws/files/5954222/587899.pdf (Accessed July 27, 2022).
91) L. Shui, F. Chen, A. Garg, X. Peng, N. Bao, and J. Zhang, "Design optimization of battery pack enclosure for electric vehicle," Structural and Multidisciplinary Optimization, 58(1) 331–347 (2018). doi: 10.1007/s00158-018-1901-y.
92) GENTA, G., MORELLO, L. "The automotive chassis," (2019). doi: 10.1007/978-3-030-35635-4.
93) B. Heissing and M. Ersoy, "Chassis Handbook," 2010. doi: 10.1007/978-3-8348-9789-3
94) S. Luo, "Human Vehicle Dynamics Coupling of Miniature Electric Vehicle Roll Stability: Effects of Driver Weight, Wheel Base and Track Width," Journal of Physics: Conference Series, 2002(1) 1-7 (2021). https://iopscience.iop.org/article/10.1088/1742-6596/2002/1/012018 (Accessed May 16, 2022).
95) S. A. Sree Ram, P. Raja, and K. Sreedaran, "Optimization of rollover stability for a three-wheeler vehicle," Adv Manuf, 5(3) 279–288 (2017). doi: 10.1007/s40436-017-0191-8.
96) YIM, H., LEE, K. "Preliminary Modular Design for Electric Personal Mobility with Design-Engineering Collaboration", World Electric Vehicle Journal, 7 (3) 426–435 (2015). doi: 10.3390/wevj7030426.
97) M. Ataei, A. Khajepour, and S. Jeon, "Rollover stabilities of three-wheeled vehicles including road configuration effects," Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 231 (7) 859–871 (2017). doi: 10.1177/0954407017695007.
98) E. C. Tsirogiannis, G. E. Stavroulakis, and S. S. Makridis, "Electric car chassis for Shell Eco Marathon competition: Design, modelling and finite element analysis," World Electric Vehicle Journal, 10(1) 1-13 (2019). doi: 10.3390/wevj10010008.
99) SEWARD, D., "Race car design," Bloomsbury Publishing Plc, (2014). https://api.pageplace.de/preview/DT0400.9781137030153_A25657226/preview9781137030153_A25657226.pdf. (Accessed September 30, 2023).
100) P. Kale and P. Ardak, "Design, Fabrication of Human-Powered Vehicle," Lecture Notes in Mechanical Engineering, 1(1) 593–598 (2021). doi: 10.1007/978-981-15-7779-6_54.

101) "Human Powered Vehicle Concept Design," https://idealeague.org/human-powered-vehicle concepts/ (Accessed May 12, 2024)

102) Abhijit M. Mane, Akshay S. Chorge, Akshay Muragode, and Pranesh Bamankar, "Design and fabrication of universal tilting three wheeler mechanism," International Engineering Research Journal (IERJ),1(1) 102–104 (2017). https://www.academia.edu/32995024/Design_and_fabrication_of_universal_tilting_three_wheeler_mechanism (Accessed August 28, 2024).

103) S. E. Manios, N. D. Lagaros, and E. Nassiopoulos, "Nested topology optimization methodology for designing two-wheel chassis," Front Built Environ, 5(34) 1-12 (2019). doi: 10.3389/fbuil.2019.00034.

104) N. Rohithkumar, R. Tatapudi, D. Danyharsha, D. Yadav, S. Kumar, and M. Engineering, "Optimization of Swingarm Design using Generative Design," JETIR, 8 (6) 599-612 (2021). https://www.jetir.org/papers/JETIR2106783.pdf (Accessed August 28, 2024).

105) R. Maryniuk, "Development of a Modular Urban Electric Vehicle," (2017). https://uwaterloo.ca/mechatronic-vehicle-systems-lab/sites/default/files/uploads/files/maryniuk_rhyse_thesis_-_draft_1_-_nov_14.pdf (Accessed January 15, 2024).

106) J. Peng, H. He, and N. Feng, "Simulation research on an electric vehicle chassis system based on a collaborative control system," Energies (Basel), 6 (1) 312–328 (2013). doi: 10.3390/en6010312.

107) GILLESPIE, T., "Fundamentals of vehicle dynamics," SAE International, (2021). doi: 10.4271/9781468601770.

108) ZEHETNER, J., HORN, M. "VEHICLE DYNAMICS CONTROL WITH TORQUE VECTORING AND ACTIVE REAR STEERING USING SLIDING MODE CONTROL", IFAC Proceedings Volumes, 40(10) 1–8 (2007). doi: 10.3182/20070820-3-us-2918.00003

109) KANDASAMY, R. "Design of solar tricycle for handicapped person", IOSR Journal of Mechanical and Civil Engineering, 5(2) 11–24 (2013). doi: 10.9790/1684-0521124

110) LENZO, B., "Vehicle dynamics," (2021). doi: 10.1007/978-3-030-75884-4.

111) B. Sunday, U. Thomas, I. S. Ityokumbul, and A. Nasir, "EFFECT OF NUMBER OF PASSENGERS [LOADING] ON CENTRE OF GRAVITY OF A THREE WHEELED VEHICLE [KEKE-NAPEP] CG of Four Wheeled Vehicle CG of Three wheeled Vehicle Effects of Loading on CG Static Stability Factor," 15(3) 628–637 (2019). www.azojete.com.ng (Accessed May 16, 2022).

112) "Policy Guidelines for Electric 2-& 3-wheelers for Southeast Asia," (2020). https://www.un.org/Depts/Cartographic/english/htmain.htm. (Accessed January 15, 2024).

113) M. Palanivendhan, S. Devanand, J. Chandradass, J. Philip, and S. Sajith Reddy, "Design and analysis of 3-wheeler chassis," Materials Today: Proceedings, Elsevier Ltd, 45(7) 6958–6968 (2021). doi: 10.1016/j.matpr.2021.01.417.

114) F. Xiong, X. Zou, Z. Zhang, and X. Shi, "A systematic approach for multi-objective lightweight and stiffness optimization of a car body," Structural and Multidisciplinary Optimization, 62(6) 3229–3248 (2020). doi: 10.1007/s00158-020-02674-5.

115) K. Ishii, K. Shimono, Y. Suda, T. Ando, H. Mukumoto, and K. Urakawa, "Mapping and Localization Method for Autonomous Vehicles on Roads Using Environmental Magnetic Field," Lecture Notes in Mechanical Engineering, 1(1) 777–783 (2024). doi: 10.1007/978-3-031-70392-8_110.

116) H. Huang, D. Yu, J. Yang, and X. Liu, "AUTONOMOUS VEHICLES LOCALISATION BASED ON SEMANTIC MAP MATCHING METHOD," The international archives of the photogrammetry, remote sensing and spatial information sciences/International archives of the photogrammetry, remote sensing and spatial information sciences, 48(1) 901–908 (2023). doi: 10.5194/isprs-archives-xlviii-1-w2-2023-901-2023.

117) R. Tyler, A. Neish, and B. Manning, "Localization & Mapping Requirements for Level 2+ Autonomous Vehicles," arXiv (Cornell University), (2022). doi: 10.48550/arxiv.2212.08231.

118) A. Chalvatzaras, I. Pratikakis, and A. A. Amanatiadis, "A Survey on Map-Based Localization Techniques for Autonomous Vehicles," IEEE Transactions on Intelligent Vehicles, 8(2) 1574–1596 (2023). doi: 10.1109/tiv.2022.3192102.

119) Breyner Posso-Bautista, Eval Bladimir Bacca-Cortés, and E. Caicedo-Bravo, "Autonomous vehicle localization method based on an extended Kalman filter and geo-referenced landmarks," Revista de Investigación Desarrollo e Innovación, 12(1) 121–136 (2022). doi: 10.19053/20278306.v12.n1.2022.14213.

120) "BEE Department of Heavy Industry (DHI)," https://evyatra.beeindia.gov.in/central-govt-initiative-details/dhi-fame-scheme-phase-1-2015/ (Accessed May 12, 2024).

121) Atul Zope, Raju Kumar Swami, and A. Patil, "Electric Vehicles: Consumer Perceptions and Expectations," Lecture notes in mechanical engineering, 1(1) 221–236 (2024). doi: 10.1007/978-981-99-7445-0_20

122) Amol Shinde, Atharva Ambre, and Chirag Nor, "CASE STUDY ON MARKET SHARE OF EV IN INDIA CASE STUDY ON MARKET SHARE OF EV IN INDIA CASE STUDY ON MARKET

SHARE OF EV IN INDIA," Futuristic Trends in Mechanical Engineering , 3(2) 185–191 (2024). https://iipseries.org/assets/docupload/rsl20242C0894B7DBCA682.pdf (Accessed November 9, 2024).

123) SHINDE, A., SWAMI, R. K., NANIVADEKAR, S. "Advances and Innovations in Small Electric Vehicles Structural Design: A review", Lecture Notes in Electrical Engineering, 1240(13) 263–275 (2024). doi: 10.1007/978-981-97-6091-6_18.

124) Agrawal, H., Kumar, P., & Singh, P., "Revolutionizing EV Charging stations through IoT," 3rd International Conference on Power Electronics and IoT Applications in Renewable Energy and Its Control (PARC), 1(1) 356–360 (2024). doi: 10.1109/PARC59193.2024.10486546

125) Ansari, S., & Gupta, O. H., "Differential positive sequence power angle-based microgrid feeder protection," International Journal of Emerging Electric Power Systems, 22(5) 525–531 (2021). doi:10.1515/ijeeps-2021-0071

126) BHUTKAR, G., KUMAR, Y., R, S., *et al.* "Energy Management system for EV charging infrastructure", E3S Web of Conferences, 591(1) 04-14 (2024). doi: 10.1051/e3sconf/202459104004.

127) Bose, S., Hari Gupta, O., & Warule, P. "Development of Plant Model and Control Software of On Board Charger for Electric Small Commercial Vehicles in MATLAB," 2023 IEEE Renewable Energy and Sustainable E-Mobility Conference (RESEM), 1(1) 1–7 (2023). doi: 10.1109/RESEM57584.2023.10236395

128) Chandra, I., Singh, A., Singh, N. K., Samuel, P., Gupta, O. H., & Singh, A. K., "Hybrid PSO-based Optimal Location of Electric Vehicle Charging Station in Distribution Networks," 2024 IEEE Students Conference on Engineering and Systems (SCES), 1(1) 1–6 (2024). doi: 10.1109/SCES61914.2024.10652265

129) Emmanuel Augustine Etukudoh, Ahmad Hamdan, Valentine Ikenna Ilojianya, Cosmas Dominic Daudu, & Adefunke Fabuyide, "ELECTRIC VEHICLE CHARGING INFRASTRUCTURE: A COMPARATIVE REVIEW IN CANADA, USA, AND AFRICA," Engineering Science & Technology Journal, 5(1) 245–258, (2024). doi: 10.51594/estj.v5i1.747

130) Kant, K., & Gupta, O. H., "DC Microgrid: A Comprehensive Review on Protection Challenges and Schemes," IETE Technical Review, 40(4) 574–590 (2023). doi:10.1080/02564602.2022.2136271

131) Kumar, S., Upadhyay, T., & Gupta, O. H., "Power Quality Improvement and Signal Conditioning of PV Array and Grid Interfaced Off-Board Charger for Electric Vehicles with V2G and G2V Capabilities," Chinese Journal of Electrical Engineering, 9(4) 132–143 (2023). doi:10.23919/CJEE.2023.000027

132) Lenka, R. K., Panda, A. K., & Senapati, L. "Grid integrated multifunctional EV charging infrastructure with improved power quality", Journal of Energy Storage, 76(1) 109-137 (2024). doi: 10.1016/j.est.2023.109637

133) Mukherjee, S., Roy, S., Maity, S., De, S., & Chaklader, S. D., "A Review on Smart Charging Infrastructure for Electric Vehicles", International Journal of Engineering Research and Applications, 14(7) 37–46 (2024). doi: 10.9790/9622-14073746

134) Raza, A., Baloch, M. H., Ali, I., Ali, W., Hassan, M., & Karim, A., "Artificial Intelligence and IoT-Based Autonomous Hybrid Electric Vehicle with Self-Charging Infrastructure," 2022 International Conference on Emerging Technologies in Electronics, Computing and Communication (ICETECC), 1(1) 1–6 (2022). doi: 10.1109/ICETECC56662.2022.10069346

135) Trabelsi, Y., Touaiti, B., & Azza, H. ben., "Technologies and Configuration of Charging Infrastructure for Battery Electric Vehicles-An Overview," 2023 IEEE Third International Conference on Signal, Control and Communication (SCC), 1(1) 1–6 (2023). doi: 10.1109/SCC59637.2023.10527632

136) Van den bergh, O., Weekx, S., De Cauwer, C., & Vanhaverbeke, L., "Locating Charging Infrastructure for Shared Autonomous Electric Vehicles and for Vehicle-to-Grid Strategy: A Systematic Review and Research Agenda from an Energy and Mobility Perspective," World Electric Vehicle Journal, 14(3) 56-75 (2023). doi: 10.3390/wevj14030056

137) Wadi, M., Elmasry, W., Jouda, M., Shahinzadeh, H., & Gharehpetian, G. B., "Overview of Electric Vehicles Charging Stations in Smart Grids," 2023 13th International Conference on Computer and Knowledge Engineering (ICCKE),13(7) 540–546, (2023). doi: 10.1109/ICCKE60553.2023.10326265

138) Zhang, Z., Liu, J., Bastidas, J. P., & Jones, S., "Charging infrastructure assessment for shared autonomous electric vehicles in 374 small and medium-sized urban areas: An agent-based simulation approach", Transport Policy, 155(8) 58–78 (2024). doi:10.1016/j.tranpol.2024.06.017