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Connected Vehicle Technologies and AI-Based Road Safety Systems: A Comprehensive Review

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Abstract—**Road traffic accident is still a great concern because of increasing number of vehicles and human error and complex traffic condition. Artificial Intelligence (AI) is a technology that has shown promise in enhancing road safety by enabling intelligent monitoring, automated decision-making, and predictive analysis. This study covers the basics of connected and autonomous vehicles, Internet of Vehicles (IoV), Vehicle-to-Everything (V2X) communications and the main technologies for intelligent transportation systems. It also explores the main factors that contribute to road traffic accidents and the 5 pillars of road safety management. In addition, the latest research in the fields related to accident prediction, collision avoidance, driver behavior monitoring, traffic management, and communication systems are critically reviewed and compared. While the literature contains some successful results, the analysis reveals that most of the work is done on single applications, with scalability and interoperability issues, as well as communication delay and real-world application. The paper concludes by outlining key research gaps and highlights the need for future smart transportation systems to be integrated, intelligent, reliable, and efficient due to AI-driven connected vehicles.**

Keywords—Road Safety, Connected Vehicles, Internet of Vehicles (IoV), Intelligent Transportation Systems (ITS), Traffic Management, Artificial Intelligence (AI).

I. INTRODUCTION

The Connected Vehicle technologies (CVS) are a new generation of radio communication technologies that are transforming the transportation industry by establishing constant connections between cars, infrastructure, and other road users. Some of the other useful information that can be sent between vehicles and the transportation system is speed, location, traffic information, and information about the environment. Road safety is also very important, and CVS can help lower the number of crashes, especially those that are caused by people, by using technologies like driver aid, collision avoidance systems, and automatic braking systems [1]. By looking at the situation and letting people know about it quickly, CVS can avoid crashes and cut down on the number of jams. When it comes to fleet management, CVS refers to powerful tools that are made to get the most out of vehicles, cut costs, and boost productivity. The application of AI has revolutionized the management and monitoring of road safety in recent years [2]. Technology with AI capabilities, such as computer vision, machine learning and deep learning, enable smart analysis of traffic conditions, driver behavior, the movement of cars, and the environment around them.

These technologies can contribute to better transportation safety and efficiency, such as real-time accident prediction, collision avoidance, traffic surveillance, and automated incident detection. There are several studies that have suggested AI systems for specific applications in road safety, but the majority of current solutions are limited to specific tasks like collision avoidance, driver monitoring or traffic prediction. There is limited integration and scope in end-to-end road safety frameworks. Furthermore, the practical deployment and communication latency, scalability and interoperability are challenges for widespread adoption. To address these challenges, the paper presents an extensive discussion on recent developments of road safety systems and technologies for connected vehicles based on AI. It introduces basic concepts, enabling technologies, communication architectures, recent research advances, and challenges. The paper also identifies key research gaps and recommends future research areas for developing smart, reliable and scalable road safety solutions to address the next generation of transportation systems.

A. Paper Outline

This paper is organized as follows. Section II presents the fundamentals of connected vehicle technologies, including technologies, levels, and benefits. Section III discusses AI-based road safety systems, highlighting the significance of road safety, major causes of road traffic accidents, and the five pillars. Section IV reviews recent studies on AI-driven road safety. Section V concludes the paper with future research.

II. FUNDAMENTALS OF CONNECTED VEHICLE TECHNOLOGIES

There are a lot of problems with modern transportation that the linked vehicle apps aim to fix [3]. Design choices like real-time input sensor data, communication methods, computation location, and secure data transmission substantially impact the performance and implementation cost of these applications [4]. Autonomous cars rely on the following technologies, among the most important:

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A. Sensors

Autonomous vehicles use a variety of sensors to perceive and understand their environment, such as cameras, LiDAR sensors, radar sensors, and ultrasonic sensors. These sensors provide the car with information about the environment, such as the location and movement of vehicles, pedestrians, and objects [5].

B. Computer Vision

The information obtained from the vehicle's sensors is analysed and processed with computer vision techniques. The algorithms help the car identify and navigate objects in its environment, as well as understand their movement and behavior.

C. Artificial Intelligence (AI) and Machine Learning

The vehicle's decisions and actions are based on algorithms, which rely on AI and ML. They can, for example, guide the car to the safest path, predict the behavior of other vehicles on the road, and adapt to sudden shifts in traffic.

GPS and Maps: HD maps and global positioning systems (GPS) help the vehicle keep on track and navigate around obstacles [6].

D. Communication Systems

Self-driving cars can communicate with other cars, road infrastructure and the cloud by using several technologies, including vehicle-to-vehicle (V2V) communication, dedicated short-range communication (DSRC) and vehicle-to-infrastructure (V2I) communication.

E. Actuation Systems

Self-driving cars use various types of actuation systems to move around and perform actions like turning, accelerating, and decelerating, including electric motors, hydraulic actuators, and gas systems.

F. Power and Energy Management Systems

Autonomous cars employ multiple power and energy management systems, including batteries, fuel cells, and regenerative braking, to secure energy for operation and to optimise the use of energy [7].

G. Levels of Connected and Autonomous Vehicles (Cavs)

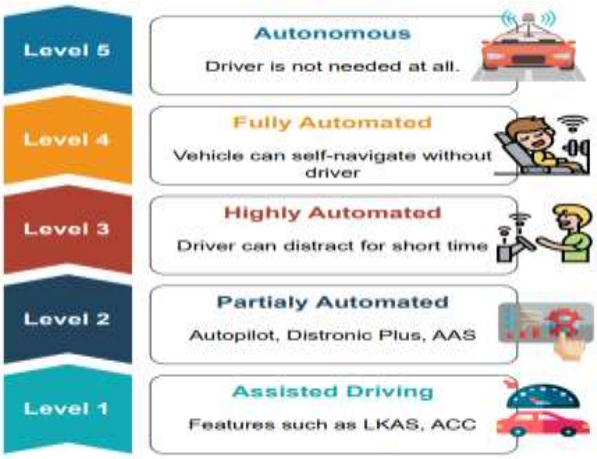

Fig. 1. Five Levels of Vehicles' Autonomy [8]

There are different kinds of self-driving cars based on how much they are automated. Typically, there are six levels of autonomy for AVs, with zero being the most basic level of control. Figure 1 shows the five levels of autonomy, excluding zero, which is not present in any AVs [9]. Fully autonomous vehicles (AVs), which operate at Level 5 autonomy, do not require a human driver. Whether there is a driver or not, the vehicle is capable of navigating any road or traffic circumstance.

1) 1" level – Assisted Driving

This level of automation is the least. In some cases, the car may include devices that temporarily aid the driver. One of the features of level 1 autonomous driving is adaptive cruise control, which keeps the car a safe distance from the one in front of it while the driver handles more complicated parts of the road, like stopping and turning [10].

2) Level 2 - partially automated

Level 2 ADAS, or advanced driver assistance systems, allow the car to partially handle the steering and speed while a human driver is still required to operate the vehicle. Because people can always take over the wheel, it can't be considered really autonomous. Level 2 autonomous vehicles are Tesla's Autopilot [11].

3) Level 3" - Highly Automated

Level 3 cars can step in if something goes wrong or the system stops working. Vehicles at Level 4 vary from those at Level 3 in this respect. While they are capable of operating autonomously, they are now restricted to a certain low-speed urban region, a feature called geo-fencing. The reason behind this is that the related laws and infrastructure need to undergo more evolution. The majority of the time, they don't need a human driver, although one is always welcome to step in and take over if needed.

4) Level 4" - Fully Automated Vehicles

The ideal of fully autonomous vehicles has finally been realized. The dynamic driving duty is completely removed from Level 5 vehicles, which completely eliminate the need for human assistance. There won't even be a steering wheel or pedals for acceleration or braking. These have the same level of control over the car as a human driver. Autonomy and freedom from geo-fencing are hallmarks of a level 4 vehicle. It some time before Level 4 vehicles are accessible to the public, while there is now a great deal of research and testing happening in many regions of the world [12].

5) Level 5" - Autonomous

Automobiles that fall under this category may operate independently, as the name suggests. They accomplish their objectives without the need for human oversight or interference, and they are highly unlikely to break any traffic laws whatsoever [13]. It is common practice to have the driver sit in the passenger seat and let them decide where to go. So, for an autonomous vehicle to function, it must be able to comprehend its surroundings, such as a ball moving front of it. Any human driver worth his salt would stop in the face of the obvious threat posed by a youngster chasing after the ball. Similarly, an autonomous vehicle has to know what other things can happen as a result of an occurrence and be ready for them.

H. Benefits of Connected and Autonomous Vehicles

The following are some of the possible advantages of highly automated technology, sometimes known as self-driving automobiles. The advantages of CAV are shown in Figure 2.

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Fig. 2. Various Benefits of CAV

- **Reduced Accidents:** The ability of CAV technology to decrease road casualties is compelling, especially considering that 94% of fatal car accidents are caused by human error. In the future, autonomous vehicles may help lower collision fatalities and injuries, especially those caused by distracted drivers.
- **Last Mile Services:** CAVs can connect commuters to public transit by providing first-mile and last-mile services. An issue with larger cities is the lack of sufficient public transit options. By enhancing public transportation, CAVs have the ability to address the first-mile-last-mile issue.
- **360° Vision:** Unlike people, who can only see side to side, CAVs can look around in all directions.
- **More Efficient Parking:** Commuters don't have to park on the streets or in lots when they use CAVs. Considering that parking takes up a third of some cities' land, CAVs have the potential to free up a lot of that area for things like parks, homes, and offices. When passengers are dropped off at their destination, personal CAVs can park themselves at an open spot, distant from the destination. Real estate expenses may go down if parking lots were to be reduced in size.
- **Societal Cost Savings:** The societal cost is one of the main considerations when assessing the advantages and disadvantages of autonomous vehicles. Society can save almost $800 billion annually thanks to CAVs, according to reports. Overall, society saves money since fewer people are hurt in automobile crashes, fewer people need medical treatment, transportation is more efficient, fuel is saved better, and more.
- **Increased Lane Capacity:** According to studies conducted by the State Smart Transportation Initiative (SSTI), the introduction of CAVs has the potential to quadruple highway capacity and more than double motorway travel speeds. A 500% increase in lane capacity is possible with CAV platooning.
- **Reduced Traffic Congestion:** The capacity of CAVs to exchange data with one another is a huge plus. Thanks to this real-time communication capability, the vehicles could drive at optimal distances from one another, greatly improving their efficiency. In addition, it can find the optimal path by removing congestion.
- **Environmentally friendly:** The steady speeds of the CAVs mean that they don't have to stop and start as often. Taking these steps helps the environment and lowers pollution [14].

I. *Network communication systems in Internet of Vehicles (IoVs)*

The IoVs aid in thorough data processing, knowledge acquisition, and security measure strengthening. The car industry was rocked to its very core by this technologically advanced breakthrough [15]. The conventional mode of vehicular communication is revolutionised into the IoVs network by intelligent cars[16], cutting-edge transportation systems, and effective communication networks. Improved and safer road travel was made possible by the IoVs. It is easy to gather data and to share it with other Internet of cars (IoV) devices and cars by connecting to a HWSN system. Furthermore, V2X can enable information flow exchange between cars, infrastructure, persons and the surrounding environment. This technology can be used for many applications, including autonomous driving and smart transportation systems, and can boost road safety and traffic efficiency [17]. It uses a special communication protocol called 802.11p and a dedicated short-range communications (DSRC) protocol to ensure that information is securely shared [18]. The network communication systems that are associated with the IoVs are illustrated in Figure 3.

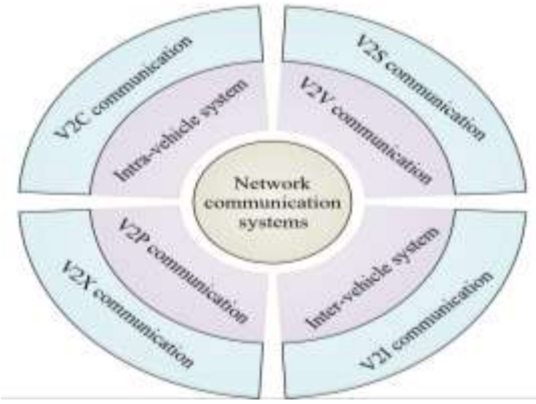

Fig. 3. Network communication systems in IoVs.

- **Intra-vehicle system (IVS):** this system includes OBUs and TPD which monitors a vehicle's internal performance.
- **Vehicle-to-vehicle (V2V) communication: The** technology lets cars talk to each other directly. This can support real time safety apps like collision avoidance and traffic coordination.
- **Vehicle-to-infrastructure (V2I) communication:** This refers to vehicles communicating with roadside units (RSUs), which can include traffic signals, road sensors, and toll booths. This allows for improved traffic management and safety.
- **Vehicle-to-pedestrian (V2PED) system:** It provides pertinent information for pedestrians, bicycle and non-drivers to keep them safe on the road.
- **Vehicle-to-cloud (V2C) system:** It gives cars access to cloud information that can be accessed via APIs[19].
- **Vehicle-to-sensor (V2S) system:** It retrieves information gathered by sensors installed in the vehicle. Several uses can benefit from this data.
- **V2X communication:** A wide variety of communication protocols fall under the V2X umbrella, including V2V, V2I, V2P, V2C, and V2S. The goal of vehicle-to-everything (V2X) communication systems is to improve efficiency and security by linking cars to their immediate environments.

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III. AI-Based Road Safety Systems

Artificial intelligence (AI) has become an important tool for making roads safer by allowing smart monitoring, making decisions in real time, and preventing accidents before they happen. Cameras, sensors, GPS devices, linked cars, and traffic infrastructure all provide data that AI-based road safety systems use to identify dangerous situations and send out timely notifications. Keeping people safe while they travel is the primary objective of road safety measures. Its goal is to ensure the safety of everyone using the road, whether they are walking, riding a bike, or using a motor vehicle. Implementing a variety of road safety measures is one approach to ensuring a safe driving environment. Solutions for road safety that are carefully planned and constructed assure the ongoing safety of cars and pedestrians. Additionally, these traffic safety technologies simply organise traffic and cars in an orderly manner while warning drivers about hazardous road conditions and accident-prone places.

Since the advent of mass-produced autos, road safety has taken centre stage. People lose their lives every year because they or others disregard different traffic safety regulations. All people may benefit greatly from and feel protected by practicing road safety measures throughout their life. When driving or walking on the road, everyone should be courteous of other people and take safety precautions for their own protection. Significant importance of road safety are:

A. *Proceedings in Court*

A collision may need consulting with an accident lawyer and navigating the legal system. It may be because are the person being sued or because the one responsible for an accident that has resulted in liability. Nobody wants to have to go to court, but accident attorneys can streamline the procedure and increase chances of success. It is still better to practise constant and careful driving safety, nevertheless.

B. *Costs of Repair*

The cost of repairs in the case of an accident is another thing to take into account when driving. Even while the majority of insurance companies help cover these costs, still responsible for paying in lost time and discomfort if not cash. Additionally, especially if work, bringing car in for repairs and even picking up a rental car may take time that don't have. Because of this, it is preferable to always drive as cautiously.

C. *Putting Life at Risk*

One of the most apparent reasons why road safety is so important is that countless lives are in danger every time a driver takes to the road. There is always a chance of serious injury or death when driving while distracted. Taking eyes off the road only takes a brief period of time. This is especially true when take into account the possibility of other drivers being distracted. It's crucial to understand that even if drive defensively, other drivers might not. Therefore, it's best if keeps an eye out for other cars that might not stop when they ought to or that might pull out of a parking lot against the rules.

D. *Major Causes of Road Traffic Accidents*

The vast majority of traffic accidents appear to be caused by human mistake. Examining operator or human variables is a crucial aspect of accident analysis. Examining the part that people play in the transportation system is essential when considering road safety concerns. Both the operator's level of expertise and the current state of traffic have a role in the likelihood of accidents. Anxieties caused by problems at home or with money can potentially contribute. People in these mental states are more likely to cause car accidents [20].

- **Careless:** Road traffic incidents in nation can be attributed, in part, to drivers' lack of care. The following are only a few instances of dangerous driving practices: talking on a phone while behind the wheel, failing to stop at red lights, not wearing a helmet, passing other cars too closely, not allowing pedestrians enough space, etc.
- **Over Speeding:** One of them is driving too fast for conditions, as the severity of injuries is in direct proportion to the speed of the accident; another is that people do not wear protective gear, which leads to the most serious and avoidable injuries that may occur in crashes.
- **Drunken Driving:** The alarming surge in road accidents is mostly attributable to drivers who are impaired by drugs or alcohol. Accidents on the road often occur when drivers are impaired by alcohol or other drugs and lose awareness of their surroundings and control of their vehicles.
- **Environmental Factors:** at last environmental variables include things like road conditions, visibility, weather, slopes and hills, and road texture, all of which contribute significantly to the occurrence of road traffic accidents.
- **Other Contributing Factors:** Age of the vehicle, safety features, driver negligence, accident location, time of day, and level of awareness are some of the additional factors that impact the number of fatalities and the severity of traffic accidents [21].

E. *Pillars of Road Safety*

The United Nations Road Safety Collaboration (UNRSC) has collaborated with stakeholders from across the globe to establish a Global Plan for the Decade of Action. This plan follows the approach suggested in Commissions 2009 report and aims to achieve this ambitious objective by identifying critical capacity building and injury prevention measures in each of five categories or pillars. All things considered, these foundational elements constitute the comprehensive Safe System strategy for road safety.

Fig. 4. Five Pillars of Road Safety Management

Indicators for each pillar are developed, mostly at the country level, with the 2013 World Health Organization Global Status Report on Road Safety serving as a reference point [22]. Each of the pillars has its own project group set up by the UNRSC. At least twice a year, these groups get together to coordinate global efforts, share knowledge, and develop new networks. Figure 4 depicts the Five Elements of the Global Plan:

- **Road Safety Management:** Supporting more effective government and law enforcement; enhancing

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operational and institutional ability to accomplish national road safety goals.

- **Safe roads and mobility:** Investment in environmentally friendly transport options and better road network planning, design, construction, and operation to protect road users.
- **Safer vehicles:** Increasing the rate of adoption of tried-and-true safety technology; raising awareness of crashworthiness and providing consumers with adequate safety information[23].
- **Safe road users:** Policy priorities should prioritise the safety of pedestrians and cyclists, encourage the use of crash helmets and seat belts, crack down on drunk driving, establish and enforce reasonable speed limits, and enhance driver education and development.
- **Post-crash response:** Facilitating better trauma treatment and emergency response; assisting victims of road accidents with rehabilitation and care; advising, supporting, and representing victims and their families in legal proceedings; and promoting third-party insurance programs to fund rehabilitation.

IV. LITERATURE REVIEW

This section reviews recent studies on AI-based road safety and connected vehicle technologies. The review identifies current advancements, highlights existing challenges, and summarizes the strengths and limitations of recent approaches.

Palanirajan et al. (2026) introduces a system that uses artificial intelligence to monitor traffic violations and improve safety for drivers and passengers via the use of IoT sensors and smart analytics. An ESP32 microcontroller is used by the system to continuously monitor the vehicle and driver data. It is connected to the MPU6050, NEO6M GPS, load cell, seat belt and eye sensors. A centralized dashboard allows real-time access to sensor data and can automatically trigger notifications in case of an accident. The experimental results have proved the high accuracy, fast response and usability of the system, which is promising for the use of the system in building smarter and safer roads for AI transportation systems [24].

RajeshKumar et al. (2025) suggest an IoT-based road information system using LoRa to help vehicles share road conditions and traffic data with the driver, allowing them to take proactive measures to avoid potential hazards. Using the simulation results, it can be concluded that the system proposal provides more timely and reliable safety alerts, thereby minimizing the number of accidents. The study demonstrates that integration of LoRa and Internet of Things can improve road safety in the development of smart transport solutions. Future research needs should concentrate on further system optimisation for wide-spread deployment and realistic tests of the system performance in real traffic conditions [25].

Miyoshi, Yamashita and Yamazaki (2025) aims to improve road safety by proposing a collision warning system that uses a location-based peer-to-peer (P2P) network and LiDAR scanning technologies. LiDAR detected road users are simulated as virtual road users, so that both networked and non-networked users can be visualised through mobile apps. The outcomes of the field tests showed that the proposed system has the potential to accurately detect and display road user identification and provide timeliness warnings of collisions. The results shown indicate the potential of the developed system to improve road and pedestrian safety through the innovative fusion of P2P and LiDAR technologies [26].

Qi (2024) conducts a thorough analysis of the causes of communication delay in the data transmission system of smart cars, identifies the key factors affecting the distance of data transmission, transmission speed, and congestion related to communication delay signals, and presents an optimisation method for cache strategies supported by popularity and location prediction. This strategy is proven from the theoretical and practical trials, validating the use of the strategy in the future advancement of the automobile network system [27].

Su et al. (2024) explored the factors affecting the ease and safety of driving an autonomous vehicle. Discovered that drivers reported wanting to monitor traffic more closely when using some automated driving technologies and reported that they worked harder thanks to the technology. The effect of driving modes on road safety and comfort can be reduced by a number of factors, such as drivers' personality traits, the complexity of the scenario, drivers' previous experience of the failure of the system, or others, including initial trust, driving experience, etc. The results of this research contribute to understanding the impact of autonomous cars on safety and comfort for drivers [28].

Bezerra and Adla (2023) offers an innovative approach to preventing vehicle collisions by predicting their trajectories using ML methods. In a CV environment, the suggested technique determines the host vehicle's TTC relative to the lead vehicle. The constructed CNN model was tested using a dataset that was chosen as realistic driving conditions. The suggested model outperforms competing techniques in terms of accuracy when it comes to predicting vehicle trajectories. When it comes to precisely estimating TTC and alerting affected cars to possible crashes, the suggested collision avoidance technology has encouraging results [29].

Du et al. (2023) provides potential uses for driving behavior-based road safety evaluation methodologies in areas including intelligent highways, road planning, and effect evaluation of road appurtenances. More than that, the article gives a rundown of a method for calculating driving behaviour indices using information gathered from cars, drivers' subjective questionnaires, and their physiological and psychological data. Lay forth in great detail an all-inclusive assessment strategy that combines all index systems. The study concludes by outlining the area's present research challenges and potential future directions for the behavior-based road safety evaluation method's growth [30].

Soto et al. (2022) Prioritise applications that enhance traffic efficiency and basic and advanced road safety, since they are vital for the development of future vehicular networks. In this paper, lay out the various cellular-related technologies that contribute to the connected vehicle's service provision, offer a taxonomy of communication types utilised in vehicular applications, and finally, utilise this taxonomy to arrange and showcase the most current findings in the field. Lastly, highlight the primary obstacles inherent in developing connected car applications using cellular technology [31].

TABLE I. SUMMARY OF RECENT STUDIES ON CONNECTED VEHICLE TECHNOLOGIES FOR ROAD SAFETY

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Authors	Objective / Application	Technology	Challenges	Future Work
Palanirajan et al. (2026)	AI-based predictive road safety and multi-violation monitoring	AI, IoT, ESP32, GPS, MPU6050, Load Cell, Seatbelt & Eyeball Sensors	Integration complexity, sensor reliability, and deployment scalability	Integrate with large-scale Intelligent Transportation Systems (ITS) and improve real-time analytics.
RajeshKumar et al. (2025)	Road condition and traffic hazard reporting	IoT, LoRa Communication	Limited real-world validation and communication reliability in dense traffic	Optimize the system for large-scale deployment and evaluate performance under real traffic conditions.
Miyoshi, Yamashita and Yamazaki (2025)	Collision warning for vehicles and pedestrians	LiDAR, Location-based P2P Network	Detecting non-connected road users under varying environmental conditions	Improve robustness and validate the system across diverse traffic scenarios.
Qi (2024)	Communication delay optimization in vehicular networks	Intelligent Vehicular Networks, Cache Strategy, Popularity & Location Prediction	Transmission delay, network congestion, and communication efficiency	Develop adaptive caching strategies for dynamic vehicular network environments.
Su et al. (2024)	Driving safety and comfort assessment in automated vehicles	Automated Driving Systems, Driver Behavior Analysis	Driver trust, workload, system failures, and varying driving scenarios	Conduct long-term real-world studies and improve human–AI interaction.
Bezerra and Adla (2023)	Vehicle collision avoidance through trajectory prediction	Machine Learning, CNN, Connected Vehicles	Generalization across diverse traffic environments and datasets	Improve prediction accuracy using larger datasets and advanced AI models.
Du et al. (2023)	Road safety evaluation using driving behavior	Driving Behavior Analysis, Multi-source Data Fusion	Lack of standardized evaluation metrics and real-time implementation	Develop unified evaluation frameworks and intelligent real-time safety assessment systems.
Soto et al. (2022)	Connected vehicle communication for road safety and traffic efficiency	Cellular V2X, Connected Vehicle Networks	Latency, scalability, interoperability, and network reliability	Enhance cellular technologies and communication protocols for next-generation connected vehicles.

Research gap: As summarized in Table I, existing studies mainly address specific road safety applications such as collision avoidance, driver monitoring, communication optimization, and traffic reporting. However, limited research has focused on developing an integrated AI-enabled connected vehicle framework that combines multimodal sensing, IoT, V2X communication, and real-time analytics for comprehensive road safety. Moreover, scalability, communication delay, interoperability and deployment issues are not sufficiently resolved, requiring the development of a solid, intelligent road safety solution.

V. Conclusion And Future Work

This study provided a high-level summary of the ways in which AI might improve road safety through the use of ITS and CVT. The article covered the fundamentals of autonomous and connected cars, the idea of IoV communication, AI-powered intelligent systems for road safety, the main causes of traffic accidents, and the five cornerstones of road safety. An extensive survey of the latest studies revealed the emerging use of AI, IoT, V2X communication, computer vision, and ML in accident prediction, collision avoidance, driver monitoring, and traffic management. While existing methods have shown good performance, they still face issues such as scalability, interoperability, communication latency, and deployment in real-world scenarios. The research scope should be expanded in the future to investigate the development of integrated AI-based connected vehicle frameworks that integrate multimodal sensing, edge intelligence, V2X communication and explainable AI for reliable real-time decision-making. These developments will help to make transportation safer, smarter, and more sustainable, and minimize road traffic accidents and enhance traffic efficiency.

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Conflicts of Interest: The author declares no conflict of interest.

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