International Journal of Next-Generation Engineering and Technology (IJNGET)
eISSN: 3087-4319
Volume03 Issue07 | Page No: - 07-15

Received: 30 May 2026, Revised: 15 June 2026, Accepted: 28 June 2026, Published: 22 July 2026

DOI: https://doi.org/10.55640/ijnget-v03i07-02

Future of Transportation Safety: Emerging Technologies, Challenges, And Opportunities

Dr. Manish Jain [1]

[1] Professor, Department of Electronics and Communications, Mandsaur University, Mandsaur(M.P.), India

ABSTRACT: The rapid advancements in intelligent mobility, linked cars, and autonomous transportation systems have elevated transportation safety to the forefront of research priorities. When it comes to monitoring, decision-making, and road safety, traditional transport is being utterly transformed by technologies like AI, ML, the Internet of Things (IoT), V2X communications, edge computing, and autonomous cars. The present review provides an extensive overview of the key concepts of transportation safety, such as VRUs, camera-based perception, AI detection and recognition, tracking and trajectory prediction techniques. In addition, the state-of-the-art in the areas of IoT enabled transportation systems, intelligent vehicles and V2X communication frameworks is discussed to explore how these innovations enable cooperative and connected mobility. Besides that, the main challenges faced by the autonomous vehicles, especially safety and reliability issues, legal and moral concerns, infrastructure issues and human-machine interaction are considered. Moreover, the recent literature in the area of emerging transportation technologies is reviewed in order to examine the most recent trends, advancements and open problems. This analysis demonstrates how critical it is to build a trustworthy transportation ecosystem by integrating intelligent communication networks, artificial intelligence (AI), and edge computing.

KEYWORDS: Transportation Safety, Artificial Intelligence (AI), Machine Learning (ML), Internet of Things (IoT), Vulnerable Road Users (VRUs).

1. Introduction

The transformation in transportation is currently taking place at a pace never seen before thanks to the adoption of new technologies at all levels of operation, organizations, and regulation[1]. The enhancement of safety and operations of transport traffic is a global task, where the attention of researchers is drawn to improvements in both technology and strategy[2]. On the whole, scientists in the sphere of transportation are constantly looking for ways to apply new methods and technologies for enhancing the performance of transportation systems. Modern trends include new technologies aimed at solving current problems related to transportation.

The other aspect that has been gaining much attention across the globe is the Advanced Traffic Management Systems (ATMSs). Automated & connected vehicles (CAVs) are a part of the ATMSs; these vehicles use linked and autonomous vehicle technology to improve traffic management and reduce the likelihood of human mistake [3]. Additionally, there are smart traffic lights that can react to the current traffic conditions in real-time to reduce congestion and maximise safety [4]. The ITSs are a part of ATMSs as well. ITSs employ data analytics, cameras, and sensors to manage traffic conditions [5].

Roads are essential in urban design, defining the space through movement, connection, and accessibility. The layout of roads impacts the economy, environment, and street qualities. Efficient traffic management is achieved by the hierarchical planning of roadways, from minor roads to major arterials [6]. The efficient flow of traffic into and out of roadways of the same or neighbouring hierarchy level should be a goal of road planning and design [7]. Urban planners and road designers need to put new evaluation tools at their disposal if they are serious about solving the capacity and safety problems caused by lower speeds and higher traffic volumes [8]. When it comes to creating safer and more efficient road networks and promoting environmentally friendly modes of travel in this "smart" age, cutting-edge management systems and technology are paramount. Advanced technologies on freeways ensure the safe and fast movement of traffic while in urban environment they help manage complex traffic conditions[9].

The development of autonomous vehicles (AVs) [10] marks an unprecedented technological breakthrough in the field of transportation systems that holds promise to deliver safe, efficient, and sustainable transportation systems[11]. In order to comprehend how these autonomous vehicles operate in their environment, which can be very complex and involve interaction between other vehicles, agent-based modeling (ABM) [12] offers itself as a potent computational approach to model and analyze these systems[13]. AI, ML techniques, advanced sensor technologies, digital twins, and degrees of automation have been implemented into safety critical transportation systems including aviation, rail, maritime, and surface transportation.

A. Structure of the paper

The structure of the paper: Section II presents the fundamentals of transportation safety systems. Section III discusses AI-empowered methodologies an challenges for VRU safety. Section IV reviews emerging transportation safety technologies. Section V presents the literature review and research gap. Section VI concludes the paper and outlines future research directions.

2. Fundamentals of Transportation Safety Systems

Fundamentals of Transport Safety Systems rely on accident prevention, reduction in injuries severity, and provision of safe road environment for users through the use of advanced technologies, infrastructure, and regulations. Such systems encompass ITS, vehicle safety systems, traffic monitoring communications, and emergency services designed to identify dangers, assist in making rational decisions, and increase overall efficiency and safety in transport operations.

A. Definition and Vulnerable Road Users (VRUs)

VRUs represent individuals that have a high probability of being injured or killed while travelling in traffic because of their physical vulnerability and high exposure to fast moving vehicles. Although initially limited to pedestrians and cyclists, today's definition of VRUs extends its boundaries and encompasses various types of non-motorized or lightly protected road users[14] . Nevertheless, a standard definition of each particular subclass of VRUs is still missing[15].

B. Camera-Based Tasks for VRU Safety

Camera-based sensing solutions have emerged as a crucial part of transport safety because of their low cost, high deploy ability, and capability to produce highly semantic data as shown in figure 1 [16]. Camera solutions are superior to other sensing technologies like lidar or radar when it comes to producing highly visual data which is required for pose estimation. Moreover, cameras are widely deployed in cities and embedded in vehicles and thus, can serve as a robust backbone for VRU safety solutions. However, the way how cameras are configured plays an important role in their sensing capabilities.

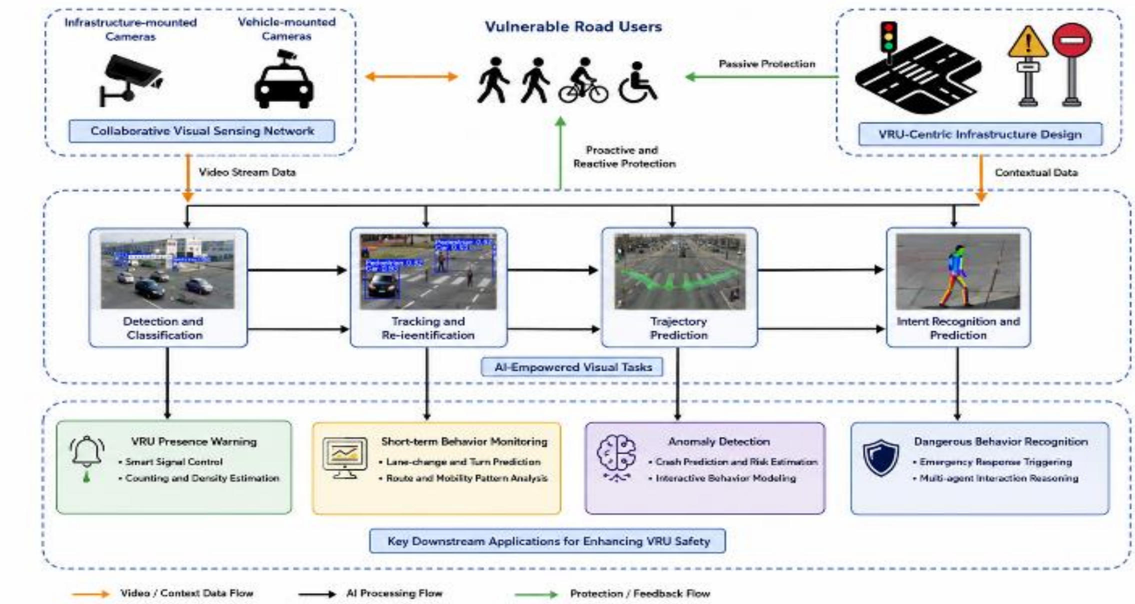

Fig. 1. Integrated Camera-Based Perception and Downstream Tasks for VRU Safety Enhancement.

3. Core Ai-Empowered Methodologies and Challenges for VRU Safety

Core AI-driven approaches to VRU safety involve computer vision, deep learning, sensor fusion and predictive analytics to detect, track and analyze pedestrians, cyclists and other vulnerable users[17]. This help achieve trajectory predictions, intent understanding, collision likelihood assessment and decision making, enhancing situational awareness and accident prevention. Core AI-driven Approaches for VRU Safety is illustrated in figure 2.

A. Detection and Classification

Transitioning from feature-based pipelines that were hand-crafted to representations based on deep learning has been a common path for both general object recognition and VRU detection. There are two main schools of thought when it comes to deep learning and the input modalities. One school of thought is RGB image-based monocular camera detection, and the other is multi-spectrum detection, which uses data from both visible and non-visible spectra (e.g., infrared or thermal cameras) to improve effectiveness in challenging environmental situations. Even though the development of VRU detection has heavily relied on advancements in general object detection, there are special problems that need to be addressed, for instance, identifying people in dense or heavily occluded scenes.

B. Tracking and Re-Identification

Tracking the motion of VRUs through video frames captured by one camera is important for knowing about the pattern of movement and being proactive about ensuring safety within the transportation system. In comparison with multiple cameras, one camera tracking is more common because it is cheaper and easier to set up, particularly onboard and roadside[18]. Nevertheless, it involves several problems, including occlusion, switching identities, and field-of-view constraints. The basis for contemporary one-camera multi-object tracking (MOT) is the detection-to-tracker framework[19]. Classic algorithms like SORT and Deep SORT are commonly used in this area.

C. Trajectory Prediction

The rise of A.I. systems in transportation has elevated VRU trajectory prediction to the status of a critical area of study. With its contributions to near-miss detection, collision prevention, and behaviour modelling, trajectory prediction is crucial to VRU protection [20][21]. Predicting VRU trajectories has so attracted a lot of interest from many research groups in recent years. Advanced surveillance systems and self-driving automobiles are two potential areas of use. It is more challenging to predict human mobility than that of any other road user [22]. This is mainly because of the following three reasons. First of all, there is less rigid dynamics involved in human motion.

D. Intent Recognition and Prediction

The ability to recognise and predict VRUs' intentions gives us a lot of information about how they act in the future. This information is closely connected to trajectory forecasting and can be learned separately or along with trajectory forecasting [23]. Intent prediction poses a difficult problem due to the large variability in VRU behaviors that depends not only on the internal state of VRUs (e.g., walking speed, attentiveness) but also on the external conditions (e.g., traffic condition, light phase, environment shape). Although most approaches focus mainly on trajectories as an input, some use additional features, like human poses[24], traffic lights, etc. Due to advances in deep learning, RNNs quickly became the most prevalent approach to learn intent.

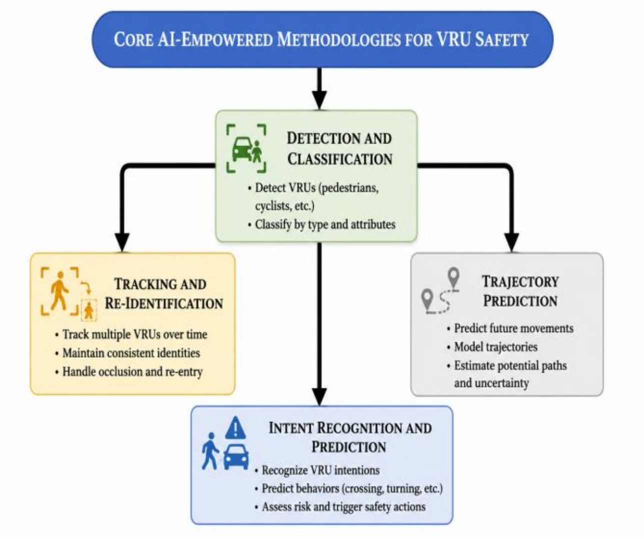

Fig. 2. Core AI-Empowered Methodologies for VRU Safety

4. Emerging Technologies for Transportation Safety

Emerging technologies are changing transportation safety via AI, IoT, autonomous vehicles, V2X communications, and advanced sensing systems. With these technologies, it becomes possible to monitor in real time, predict accidents, make traffic management intelligent, and conduct automatic decision-making. The result is increased road safety, decreased collision risk, and creation of sustainable transportation systems.

A. Internet of Things (IoT)

IoT has completely transformed the automotive industry with cars becoming more connected, intelligent and safe[25]. IoT in automotive is a complex network of interconnected devices including sensors, cameras, and GNSS which are connected with each other with help of the Internet to the cloud. This network constantly generates data which can be used to increase the efficiency of transport management.

B. Machine Learning (ML) and AI

AI plays a pivotal role in perception, prediction, and decision-making[26]. The most common AI methods used include:

- Deep Neural Networks (DNNs): Used for object detection, segmentation, and classification.

- Reinforcement Learning (RL): Train agents for complex decision-making using trial and error.

- Bayesian Networks: For probabilistic reasoning in uncertain situations.

- Generative Adversarial Networks (GANs): To augment synthetic data for perception model training.

- Federated Learning: Facilitates decentralized AI learning from fleets without the need for centralized data storage.

Larger datasets of annotated data, simulations, and edge cases need to be collected to train and validate such models.

C. Road Safety and Smart Policy Making

The risks to road safety are not the result of a single careless move by a motorist, but rather of a conglomeration of circumstances. The current academic literature has identified some of the contributing factors that impact road safety, that is road condition weather conditions road user behaviour accident hot spots traffic jamming [27], Good road condition ensure safe and better driving conditions as compared to bad road conditions where the likelihood of accidents increases. Similarly, the road user's behavior, whether the drivers and pedestrians, critical in maintaining road safety.

D. Accident detection

Some of the methods that can automatically detect accidents include the problem of road accidents resulting from population growth and increased demands of vehicles [28]. While encouraging smartphones that incorporate machine learning techniques and sensors to recognize abnormal motion of the vehicles, there are some problems in real time accuracy and sensor reliability. However, although susceptible to communication disruptions, encourage Vehicular Ad-hoc networks (VANETs).

E. Real-Time Traffic Monitoring

Through AI real-time monitoring of traffic condition can be done by collecting data from different sources like cameras on roads, sensors, vehicles that are connected, and GPS systems. Constant collection of this data helps traffic management system get a clear idea about current road conditions, volumes of traffic[29], and congested areas. Processing the data helps in making proper decisions related to any issue that might occur like identifying bottlenecks and re-routing vehicles in case of traffic accidents.

F. Key Challenges in Autonomous Vehicle Technology

The way to fully autonomous vehicles (AVs) has its own set of difficulties that have not yet been addressed successfully. Despite some advancements, there are still certain challenges that hinder the widespread use of AVs.

1) Safety and Reliability

The primary concern in developing and utilising autonomous cars is safety. The operation of an AV is required to be reliable regardless of all the different driving situations that might take place, including unexpected situations like pedestrians suddenly appearing on the road, bad weather, inadequate road markings, and building areas. It is very hard for machine learning models to predict edge cases – rare but dangerous driving situations[30]. Rule-based programming never cope with such complexity of real life. ML algorithms educated by massive volumes of data are what make AVs what they are. However, the data quality has a significant impact on the algorithm's efficacy.

2) Legal and Ethical Issues

The regulatory framework surrounding autonomous cars is yet to be fully developed. The biggest worry here is who bears the blame in case of an accident. It is yet to be decided whether the automobile company, the software maker or the car owner is at fault. This lack of clarity on the legal front acts as a major impediment to investment and deployment, especially where there are no AV laws in place. On the ethical front too, there are issues. AVs could find themselves in situations where they have to make ethical choices, such as deciding between two evils when a collision is inevitable.

3) Infrastructure Readiness

Current road infrastructures are not always ready for use with autonomous vehicles because there are many places without proper lane markings and road signs, as well as traffic management systems. Autonomous vehicles require high-resolution maps and constant connectivity, which are unavailable in rural and undeveloped regions. It also should be noted that one of the key features of AV is the V2X technology, which allows vehicles to exchange information with traffic lights, other vehicles and road infrastructure. However, the implementation of V2X infrastructures has just started in most countries.

4) Human-Machine Interaction

In transitioning from Level 2 and Level 3 autonomous cars to higher levels, the importance of human-machine interaction cannot be ignored. During these phases, the system takes care of everything but the driver needs to be vigilant to take over the controls in case of an emergency[31]. It poses a problem of cognition where the drivers get complacent or too dependent on the system, and their reaction time becomes slow during an emergency situation. Trust is the other barrier which comes in the way of using AVs. Most users are not comfortable with the machine's decision making and being controlled by machines. Communication between the car and the user plays an important role in building trust.

G. Opportunities of Future Transportation Safety

Future of transportation safety can provide many opportunities through adoption of intelligent and digital technology. Some of them are as follows:

- **Enhanced Road Safety through AI**: AI and ML are capable of making predictions about accidents, detecting dangerous situations, and enabling real-time decision-making to avoid traffic accidents.

- **Connected and Autonomous Vehicles**: V2V and V2I technology is useful for managing traffic, avoiding mistakes made by humans, and improving overall road safety.

- **Smart Traffic Management**: Management: ITS employs real-time data for traffic management, reduction of congestion, and improvement of efficiency of emergency response.

- **Predictive Maintenance of Infrastructure**: Through IoT sensors and data analysis, smart transport systems are capable of continuous monitoring of roads, bridges, and other transport infrastructure to prevent any problems with them.

- **Faster Emergency Response**: New technologies like 5G, drones, and intelligent emergency response systems allow for quick detection of an accident and efficient routing of emergency vehicles to the site of an accident.

5. Literature Review

New technological developments are revolutionizing transport safety through AI, IoT, Autonomous vehicles, and Connected Communication systems. These technologies facilitate real-time tracking, accident prediction, and intelligent decision-making. Nonetheless, there are still many obstacles such as security problems, privacy issues, infrastructure constraints, and policy problems that have to be resolved to create smart, intelligent, and sustainable future transportation systems in Table I.

M. Ameur, et al.,(2026), offers an overview of the latest developments in the area, and points out the results achieved so far, the open problems, and future perspectives of the field. This study is a valuable resource for academics and stakeholders working towards the development of smart, collaborative, and environmentally friendly transport systems by synthesising existing material and highlighting the connection between DRL and C-ITS [32].

H. Yin,(2026) introduce NavDrive, an autonomous driving framework that ensures better safety by planning through a multi-modal generation system. Namely, NavDrive integrates dispersion strategies with navigation-guided rules. Develop a DCF module to selectively highlight the regions with critical interactions between the ego vehicle and other agents in order to emphasise decision-relevant locations. Furthermore, the TDiT is employed by a safety-aware generative planner to optimise trajectory samples to viable regions [33].

B. Reddy, et al. (2025) presents RideSphere, a real time rides management application developed using the React Native and Node.js frameworks. RideSphere is developed to be used by users, drivers, and administrators in a single application and has unique features like the provision of gender-based preference of the driver such that a user can select a female driver and the provision of a rent a driver feature that enables the hiring of professional drivers who drive the car belonging to the user. RideSphere works using the Expo Go platform and it supports both Android and IOS mobile phones[34].

M. Manoj Nair (2025), examines the opportunities, limitations, and potential avenues of future research on Industry 5.0 and Society in regards to emerging technologies like Blockchain, IoT, AI, and others. The current work also examines the possible implications of AI, Blockchain, and IoT in these futuristic concepts from the point of view of transformation. In case of Industry 5.0, where technology less important and it assumed that the foundation of any development lies in the cooperation of humans and robots, there is a paradigm shift which leads to solution. Through customized products, the industrial revolution is increasing[35].

J. Xue, et al. (2024) use techniques and theories of system dynamics to create models that show how emergent technologies in the aircraft manufacturing business are changing over time, factoring in the slow but steady evolution of these technologies as identified through expert interviews. To show how the technology evolved over time, analysed and simulated data from Shaanxi Province. Analysing the simulation results reveals that new competing technologies arise during the growth phase, which in turn lowers the rate of incremental change in emerging technologies [36].

G. Javed et al., (2023) the challenges and potential benefits of technological skill enhancement in Southeast Asia and India. Call attention to the challenges that come with issues like language barriers, insufficient time, lack of enthusiasm, and inadequate access to quality training. Rising demand for trained labour and expansion of the digital economy present upskilling prospects in Southeast Asia and India. Additionally, discuss some novel, human-centered methods of skill enhancement that may be relevant to Industry 5.0 [37].

M. Georgiades and M. S. Poullas, (2023) provides an overview of the latest research on V2X communication and VEC tools for creating a long-term, sustainable IoV in the 6G age. Finding, screening, selecting, synthesising, and reporting relevant papers is achieved by the use of the PRISMA technique in this study. Finding novel technology, difficulties, possibilities, impacts, and future directions is the goal of the research [38].

TABLE I. LITERATURE REVIEW ON FUTURE OF TRANSPORTATION SAFETY: EMERGING TECHNOLOGIES, CHALLENGES, AND OPPORTUNITIES

Author(s), Year	Objective	Technology/Methodology	Advantages	Limitations
M. Ameur et al. (2026)	Reviewed the integration of Deep Reinforcement Learning (DRL) with Cooperative Intelligent Transportation Systems (C-ITS).	DRL, C-ITS, Literature Survey	Identified research trends, challenges, and future directions for intelligent transportation.	Limited practical implementation and real-world validation.
H. Yin (2026)	Proposed a safety-enhanced end-to-end autonomous driving framework (NavDrive).	Diffusion Policy, Decision-Aware Channel Fusion (DCF), Target-Prior Diffusion Transformer (TDiT)	Improved driving safety, trajectory planning, and human-aligned autonomous behavior.	High computational complexity and limited real-world deployment.
B. Reddy et al. (2025)	Developed a real-time ride management application for modern urban mobility.	React Native, Node.js, REST APIs, WebSocket, Expo Go	Real-time tracking, scalable architecture, gender-based driver preferences, user-friendly interface.	Focuses on mobility services rather than advanced transportation safety mechanisms.
M. Manoj Nair (2025)	Investigated the role of Industry 5.0 technologies in future intelligent systems.	Artificial Intelligence, IoT, Blockchain, Industry 5.0	Promotes human-centric automation, sustainability, and smart industrial transformation.	Lacks detailed implementation strategies for transportation safety applications.
J. Xue et al. (2024)	Analyzed the gradual evolution of emerging technologies in aviation manufacturing.	System Dynamics, Conceptual Modeling, Historical Data Analysis	Evaluates technology evolution and competitive growth factors.	Limited applicability to road transportation safety systems.
G. Javed et al. (2023)	Examined technology upskilling challenges and opportunities in Industry 5.0.	Human-Centric Learning, Industry 5.0 Framework	Highlights workforce development and digital skill enhancement.	Does not directly address transportation safety technologies.

Research gap: Even though considerable progress has been made in the field of AI, the IoT, autonomous cars, V2X communication, and ITS, there are still numerous gaps to be explored in the area of transportation safety in the future. It is worth mentioning that existing researches are mostly limited to individual technologies but not to the intelligent safety framework as a whole. Issues associated with cybersecurity, data protection, explainable AI, interconnectivity, regulatory requirements, and others are yet to be adequately addressed. Moreover, there is a need for better reliability of autonomous systems in complicated traffic environments and adverse weather conditions.

6. Conclusion and Future Work

The current review gives an overview of how Transportation Safety is advanced by using AI, ML, IoT, V2X communication and Autonomous Vehicles. The review outlines the basics of transportation safety, VRU safety, AI-based perception approaches, and new communication paradigms. Also, the current review covers the most important challenges associated with the use of autonomous vehicles, which include such aspects as safety, reliability, legal/ethical, infrastructure readiness, and HMI issues. Intelligent sensing, connected communication, and decision-making technologies have great potential to decrease the probability of accidents. Despite the significant accomplishments in the field, the development of safe, scalable, and interoperable transportation systems is still a crucial task to accomplish. In general, the use of emerging technologies may become a powerful base for creating smart transportation systems.

Further studies should focus on the integration of AI, V2X, edge computing, digital twin, and 6G communications to increase transportation safety. Special attention should be paid to explainability of AI, security, standardization of communication protocols, and real-world validations.

REFERENCES

1. M. Elassy, M. Al-Hattab, M. Takruri, and S. Badawi, "Intelligent transportation systems for sustainable smart cities," Transp. Eng., vol. 16, p. 100252, Jun. 2024, doi: 10.1016/j.treng.2024.100252.

2. H. K. Yadav, "Design and Implement Machine Learning Based Predictive Analytics for Road Safety and Accident Prevention," in 2026 IEEE International Conference on Interdisciplinary Approaches in Technology and Management for Social Innovation (IATMSI), Gwalior, India: IEEE, 2026, pp. 1–6, March. doi: 10.1109/IATMSI68868.2026.11465965.

3. D. Elliott, W. Keen, and L. Miao, "Recent advances in connected and automated vehicles," J. Traffic Transp. Eng. (English Ed., vol. 6, no. 2, pp. 109–131, 2019, doi: https://doi.org/10.1016/j.jtte.2018.09.005.

4. A. Talebpour and H. S. Mahmassani, "Influence of connected and autonomous vehicles on traffic flow stability and throughput," Transp. Res. Part C Emerg. Technol., vol. 71, pp. 143–163, 2016, doi: https://doi.org/10.1016/j.trc.2016.07.007.

5. A. N. A. Yusuf, A. S. Arifin, and F. Y. Zulkifli, "Recent development of smart traffic lights," IAES Int. J. Artif. Intell., vol. 10, no. 1, pp. 224–233, 2021, doi: 10.11591/ijai.v10.i1.pp224-233.

6. J. Rui and F. Othengrafen, "Examining the Role of Innovative Streets in Enhancing Urban Mobility and Livability for Sustainable Urban Transition: A Review," Sustain., vol. 15, no. 7, 2023, doi: 10.3390/su15075709.

7. T. Li, J. Klavins, T. Xu, N. M. Zafri, and R. Stern, "Identifying built environment factors influencing driver yielding behavior at unsignalized intersections: A naturalistic open-source dataset collected in Minnesota," J. Safety Res., vol. 92, pp. 331–345, 2025, doi: 10.1016/j.jsr.2024.12.006.

8. C. Yaibok, P. Suwanno, T. Pornbunyanon, C. Kanjanakul, P. Luathep, and A. Fukuda, "Improving urban intersection safety insights from simulation analysis," IATSS Res., vol. 48, no. 4, pp. 523–536, 2024, doi: https://doi.org/10.1016/j.iatssr.2024.10.005.

9. A. Ait Ouallane, A. Bakali, A. Bahnasse, S. Broumi, and M. Talea, "Fusion of engineering insights and emerging trends: Intelligent urban traffic management system," Inf. Fusion, vol. 88, pp. 218–248, 2022, doi: https://doi.org/10.1016/j.inffus.2022.07.020.

10. J. Li, Z. Wu, M. Li, and Z. Shang, "Dynamic Measurement Method for Steering Wheel Angle of Autonomous Agricultural Vehicles," Agric., vol. 14, no. 9, pp. 1–20, 2024, doi: 10.3390/agriculture14091602.

11. J. B. Mehta, "Autonomous Security Validation For Embedded Trust Chains In Connected Devices," Int. J. Adv. SIGNAL IMAGE Sci., vol. 11, no. 6s, pp. 802–812, Dec. 2025, doi: 10.29284/1th3da51.

12. P. Lin, J. Liu, P. J. Jin, and B. Ran, "Autonomous Vehicle-Intersection Coordination Method in a Connected Vehicle Environment," IEEE Intell. Transp. Syst. Mag., vol. 9, no. 4, pp. 37–47, 2017, doi: 10.1109/MITS.2017.2743167.

13. N. B. Roise Uddin Lourdu Akhila Yeruva, Deepak Singh, Swathi Suddala, "Augmented Data Management: Enhancing Cache Performance and Cybersecurity through AI and Mobile Integration," J. Comput. Mech. Manag., 2026.

14. N. S. C. NSC, "Position/Policy Statement Vulnerable Road Users," pp. 6–9, 2016.

15. Z. Zhang, C. Wei, G. Wu, and M. J. Barth, "Vulnerable Road User Detection for Roadside-Assisted Safety Protection: A Comprehensive Survey," Appl. Sci., vol. 15, no. 7, pp. 1–32, 2025, doi: 10.3390/app15073797.

16. R. M. Silva et al., "Vulnerable road user detection and safety enhancement: A comprehensive survey," Expert Syst. Appl., vol. 292, p. 128529, 2025, doi: https://doi.org/10.1016/j.eswa.2025.128529.

17. S. Chatterjee, "A Data Governance Framework for Big Data Pipelines: Integrating Privacy, Security, and Quality in Multitenant Cloud Environments," Tech. Int. J. Eng. Res., vol. 10, no. 5, 2023, doi: 10.56975/tijer.v10i5.158181.

18. A. Bewley, Z. Ge, L. Ott, F. Ramos, and B. Upcroft, "Simple online and realtime tracking," Proc. - Int. Conf. Image Process. ICIP, vol. 2016-Augus, pp. 3464–3468, 2016, doi: 10.1109/ICIP.2016.7533003.

19. N. Wojke, A. Bewley, and D. Paulus, "Simple online and realtime tracking with a deep association metric," in 2017 IEEE International Conference on Image Processing (ICIP), 2017, pp. 3645–3649. doi: 10.1109/ICIP.2017.8296962.

20. Y. Huang, J. Du, Z. Yang, Z. Zhou, L. Zhang, and H. Chen, "A Survey on Trajectory-Prediction Methods for Autonomous Driving," IEEE Trans. Intell. Veh.,

vol. 7, pp. 652–674, 2022.

21. S. Singamsetty, “AI-powered Satellite Image Processing for Global Air Traffic Surveillance Techniques Using NCNN–EGSA Optimization Techniques,” in Machine Learning Based Air Traffic Surveillance System Using Image Processing, Emerald Publishing Limited, 2026, pp. 179–197. doi: 10.1108/978-1-80592-062-520251010.

22. M. Taha, A. Zaky, H. Yamaguchi, and A. Fares, “Pedestrian trajectory and intention prediction: a comprehensive review of models, datasets, and challenges,” J. Ambient Intell. Humaniz. Comput., vol. 17, no. 2, pp. 491–523, 2026, doi: 10.1007/s12652-026-05042-1.

23. C. Zhang, J. Sprenger, Z. Ni, and C. Berger, “Predicting Pedestrian Crossing Behavior in Germany and Japan: Insights into Model Transferability,” 2024. doi: 10.48550/arXiv.2412.03689.

24. F.-G. Landry and M. A. Akhloufi, “Predicting Pedestrian Crossing Intention in Autonomous Vehicles: A Review,” Neurocomputing, vol. 618, p. 129105, 2025, doi: https://doi.org/10.1016/j.neucom.2024.129105.

25. K. Kiela et al., “Review of V2X-IoT standards and frameworks for ITS applications,” Appl. Sci., vol. 10, no. 12, 2020, doi: 10.3390/app10124314.

26. S. Nunnavath and D. Patel, “Comprehensive Review of Autonomous Vehicle Technology: Challenges, Innovations, and Future Directions,” 2025.

27. M. Eskandari Torbaghan, M. Sasidharan, L. Reardon, and L. C. W. Muchanga-Hvelplund, “Understanding the potential of emerging digital technologies for improving road safety,” Accid. Anal. Prev., vol. 166, p. 106543, Mar. 2022, doi: 10.1016/j.aap.2021.106543.

28. A. Babu, “Reviewing Innovations: Advances in Transportation, Security, and Accident Detection,” INTERANTIONAL J. Sci. Res. Eng. Manag., vol. 08, no. 03, pp. 1–5, Mar. 2024, doi: 10.55041/IJSREM29884.

29. G. Mancino, “The Role of Autonomous Vehicles and AI in Smart Transportation Systems: Enhancing Traffic Management, Route Optimization, and Predictive Maintenance,” 2022. doi: 10.13140/RG.2.2.23868.04483.

30. A. Gehlot et al., “Wpan and iot enabled automation to authenticate ignition of vehicle in perspective of smart cities,” Sensors, vol. 21, no. 21, pp. 1–24, 2021, doi: 10.3390/s21217031.

31. N. Adik, “The Rise of Open and Free Networks: A Community-Driven Paradigm for Decentralized Connectivity,” in 2025 IEEE First International Conference on Innovations in Engineering and Next-Generation Technologies for Sustainability (ICINVENTS), Coimbatore, India: IEEE, 2025, pp. 1–9, November. doi: 10.1109/ICINVENTS64613.2025.11402224.

32. M. E. L. A. Ameur, B. Brik, H. Drias, M. Ameur, S. Foufou, and A. Zomaya, “Deep Reinforcement Learning for Cooperative Intelligent Transportation Systems: A Survey on Architecture, Use Cases, and Future Directions,” IEEE Trans. Intell. Transp. Syst., pp. 1–22, 2026, doi: 10.1109/TITS.2026.3683551.

33. H. Yin, D. Tian, J. Zhou, X. Duan, D. Zhao, and D. Cao, “NavDrive: Safety-Enhanced End-to-End Autonomous Driving With Navigation-Guided Diffusion Policy,” IEEE Trans. Intell. Transp. Syst., vol. 27, no. 5, pp. 5957–5971, 2026, doi: 10.1109/TITS.2026.3650852.

34. B. Y. K. Reddy, C. Ganesh, V. V. Rao, and L. Sharmila, “RideSphere: The Future of Transportation,” in 2025 5th International Conference on Intelligent Technologies (CONIT), 2025, pp. 1–5. doi: 10.1109/CONIT65521.2025.11167586.

35. M. Manoj Nair and A. K. Tyagi, “Transformative Effects of Emerging Technologies on Industry 5.0 and Society 5.0: Current Status, Vision, Issues, Challenges, and Opportunities for Future,” in Next Generation Data Science and Blockchain Technology for Industry 5.0: Concepts and Paradigms, 2025, pp. 325–352. doi: 10.1002/9781394245215.ch13.

36. J. Xue, M. O. Esangbedo, Q. Zhang, W. Zhang, and L. Wu, “The Impact of Emerging Technologies in the Aviation Manufacturing Industry: A Case Study of the Gradual-Change Factors in Shaanxi, PR China,” IEEE Trans. Eng. Manag., vol. 71, pp. 220–232, 2024, doi: 10.1109/TEM.2021.3118709.

37. G. S. Javed, S. F. Vajrala, and G. Rasheed, “Technology Era: Opportunities and Challenges for Engineering Learning and Skills Development,” in 2023 IEEE Technology & Engineering Management Conference - Asia Pacific (TEMSCON-ASPAC), 2023, pp. 1–3. doi: 10.1109/TEMSCON-ASPAC59527.2023.10531407.

38. M. Georgiades and M. S. Poullas, “Emerging Technologies for V2X Communication and Vehicular Edge Computing in the 6G era: Challenges and Opportunities for Sustainable IoV,” in 2023 19th International Conference on Distributed Computing in Smart Systems and the Internet of

Things (DCOSS-IoT), 2023, pp. 684–693. doi: 10.1109/DCOSS-IoT58021.2023.00108.