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Article

Artificial Intelligence Models for Smart Traffic Management and Road Safety

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Abstract: High traffic volume, urbanization and car ownership have exacerbated traffic congestion, travel time and road accidents; these are some of the problems facing modern transportation systems. Artificial Intelligence (AI) has become a viable solution, allowing intelligent, adaptive and data-informed traffic management. This paper provides an overview of the most prominent types of AI models employed in smart traffic control and road safety, such as supervised and unsupervised machine learning, deep learning, computer vision, and reinforcement learning. It discusses their applications for traffic flow prediction, adaptive traffic signal control, vehicle and pedestrian detection, accident prediction, driver behaviour monitoring, and prioritisation of emergency vehicles. The research also covers the features of Vehicle-to-Everything (V2X) communication, connected vehicles, the Internet of Things (IoT), and Intelligent Transportation Systems (ITS), as well as their potential for enhancing transportation efficiency and road safety. In addition, the paper points out potential roadblocks for the implementation of AI such as data quality, computational complexity, cybersecurity, privacy, infrastructure cost, and model interpretability. Finally, future research directions are outlined, highlighting explainable AI, generative AI, digital twins and integration of intelligent transportation systems in smart cities for sustainable cities. Overall, the review shows that AI can revolutionize traditional transportation systems, turning them into intelligent networks that can help alleviate congestion, lower the risk of accidents, optimize traffic flow, and facilitate safer and more sustainable urban mobility.
Keywords: Artificial Intelligence (AI), Smart Traffic Management, Intelligent Transportation Systems (ITS), Road Safety, Machine Learning, Deep Learning, Computer Vision

1. Introduction

The urban population and its associated mobility needs are growing rapidly and so have the fleet of motorized vehicles and the sprawling transportation network, making traffic congestion and road safety issues a huge issue in the world. The studies on transportation around the world have shown that in urban areas there are ongoing traffic delays, higher rate of fuel usage, environmental pollution and an increasing number of road accidents because of inefficient traffic management systems. The traditional traffic control approach that mainly depends on fixed time traffic signal and manual control is not able to provide an effective response to varying traffic patterns which results in the inefficient traffic flow and slow emergency response (Nampalli, 2021; Ravish and Swamy, 2021).

Artificial Intelligence (AI) has revolutionized the field of Intelligent Transportation Systems (ITS) by allowing transportation systems to perceive, analyse, predict, and respond to traffic situations in real time. The technologies are built with the use of AI, including machine learning, deep learning, computer vision, reinforcement learning and predictive analytics that help to automate traffic monitoring, optimize signal timing, identify incidents and enhance overall road safety. The smart systems can receive and process vast amounts of data from a wide variety of sources, including surveillance cameras, sensors, connected vehicles, GPS devices, drones, and IOT platforms to inform and time traffic management decisions (Englund et al., 2021; Wu et al., 2022).

Traffic prediction models using machine learning are getting significant attention to predict traffic congestion, estimate travel times, identify hot spots for traffic accidents and forecast traffic demand. Many supervised learning algorithms are used to study traffic patterns from the past and categorise traffic congestion, for example Decision Trees, Random Forests, Support Vector Machines, and Gradient Boosting models. In the meantime, unsupervised learning methods help uncover hidden traffic behaviour patterns, anomaly detection without the need for labelled datasets. Such capabilities can help transportation authorities manage road networks more efficiently and proactively, preventing congestion from becoming a serious issue (Singh, Sharma and Kumar, 2023; Zhang et al., 2024).

Moreover, the capabilities of deep learning have improved traffic management by extracting features in complex transportation data with greater efficiency. Real-time video streams have been used to achieve outstanding performance for vehicle detection, lane detection, pedestrian recognition and classification of traffic signs with the help of Convolutional Neural Networks (CNNs). Likewise, Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks can model temporal relationships in traffic data well, which can be applied to traffic flow prediction and traffic congestion forecasting. In recent years, transformer-based models have demonstrated their effectiveness in capturing long-range interactions and processing large-scale transportation data with better accuracy and efficiency (Wang et al., 2023; Zhang et al., 2024).

Another basic AI technology that has become a key player in smart traffic management and road safety is computer vision. The advanced object detection models allow to automatically identify vehicles, pedestrians, bicycles, road signs and hazardous driving behaviours in surveillance footage. These are systems that help the traffic authorities to continually monitor the condition of the road, detect traffic offences, detect accidents and give early warnings of potentially dangerous road conditions. Automated vision-based monitoring not only minimizes the reliance on manual monitoring but also enhances the speed of detection and operational efficiency (Yang et al., 2023; Reza et al., 2021).

A significant breakthrough in the field of intelligent transportation is adaptive traffic signal control, which is possible by using reinforcement learning. Reinforcement learning agents are agents that continuously interact with traffic environments and learn optimal traffic signal control strategies that reduce congestion and vehicle waiting time compared to the conventional pre-programmed traffic signals. These adaptive techniques dynamically manipulate signal phases based on varying traffic levels, contributing to the more efficient use of intersections, fuel use, and greenhouse gas emissions. The work has been shown to achieve superior signal optimisation performance using reinforcement learning (RL) compared to fixed-time control methods under different traffic conditions (Wei et al., 2022; Bhattacharyya et al., 2026).

AI is also key to improving road safety with predictive accident analysis and intelligent driver assistant systems. AI models are used to process past accident data, weather, driver behaviour, road geometry, and traffic density to predict the likelihood of a crash and subsequent accident. These forecasting features can help transportation organizations take preventative safety action, develop infrastructure, and issue alerts to road users. In addition, AI-based driver-monitoring systems have the capacity to identify driver fatigue, distraction, over speeding, and unsafe driving habits, which helps mitigate the risk of serious accidents on the road (Zhao et al., 2023; Du et al., 2023).

The connected vehicle, autonomous driving technologies, and smart city developments have also greatly facilitated the incorporation of AI into transportation systems. Connected infrastructure facilitates real-time communication between vehicles, road side units, cloud platforms and traffic management centres, enabling AI algorithms to make coordinated decisions based on the real-time data. Edge computing also builds on these features through its ability to process traffic data locally, near the data source, to enable time-sensitive applications like prioritisation of emergency vehicles, collision avoidance, and autonomous traffic control (Zohdy and Rakha, 2022; Li and Yan, 2023).

While the progress in this field is remarkable, there are still some obstacles to the widespread adoption of AI-powered traffic management systems. However, several challenges hinder the practical implementation, such as data privacy issues, cybersecurity risks, the scarcity of high-quality labelled datasets, computational complexity, and model interpretability, as well as infrastructure expenses. Furthermore, fairness, transparency, and robustness of AI models in various traffic settings demand ongoing research and technological advancements to ensure their reliability and accuracy. Solving these problems is critical for the design of dependable, robust, and credible ITS systems that can enable future smart cities (Mazur and Borucka 2026; Patil et al. 2026).

The purpose of this paper is to give a complete review of the models of artificial intelligence that are used in smart traffic management and road safety. It explores dominant AI techniques in use in ITS, their application for the management of congestion and accident prevention, current implementation issues and potential future research trends toward creating safer, more efficient and sustainable transportation ecosystems. The paper provides a systematic overview of the latest developments and highlights the potential of AI to revolutionize traditional transportation systems, making them more intelligent, adaptive, and data-driven to meet the growing mobility needs of today's societies.

2. Literature Review

2.1 Artificial Intelligence in Intelligent Transportation Systems

Advanced communication, sensing and computing technologies are combined to enhance traffic efficiency and road safety, which is known as an Intelligent Transportation System (ITS). Fixed traffic signals and manual monitoring are typical forms of traditional traffic management and can be ineffective in a fast-changing traffic environment. With Artificial Intelligence (AI), ITS can analyse huge amounts of real-time traffic data gathered through cameras, sensors, GPS devices, connected vehicles and IoT networks to provide dynamic traffic control and inform decision-making. Traditional systems are less flexible and adaptable to new data.While traditional systems are less flexible and adaptable to new data, AI-based systems continuously learn from historical and real-time data, making them more adaptive and efficient (Englund et al., 2021; Wu et al., 2022).

Several traffic prediction methods are presented in this chapter.This chapter introduces several traffic prediction methods.

Machine Learning (ML) has emerged as an integral part of the technology in predicting traffic congestion, estimating travel time and analyzing traffic patterns. Using historical traffic data, weather information, and road characteristics, supervised learning algorithms like Decision Trees, Random Forests, Support Vector Machines, and Gradient Boosting are commonly used to classify traffic conditions and predict congestion. These models can support traffic authorities in implementing proactive traffic management measures and maximising the utilisation of the road (Singh, Sharma and Kumar, 2023).

Unsupervised learning methods are also used to discover unknown traffic patterns and recognize abnormal traffic patterns without any labeled data. Congestion Hot Spots are found using clustering algorithms and Anomaly detection models are used for detecting accidents and unusual traffic moments. In complex transportation systems, ensemble learning methods, which integrate multiple machine learning models, are also suitable for enhancing the prediction accuracy (Zhang et al., 2024).

2.2 Deep Learning in Traffic Management

In recent years, Deep learning has contributed a lot to the intelligent traffic management, which is able to extract complex features from a large amount of transportation data automatically. Convolutional Neural Networks (CNNs) are extensively used for vehicle detection, lane recognition, pedestrian identification, and traffic sign classification using surveillance images and videos. They are able to accurately process visual information under different environmental conditions, and are suitable for traffic monitoring in real time (Wang et al., 2023).

Traffic flow prediction is often done by using Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) models, which are known to be effective in identifying temporal relationships in sequential traffic data. Transformer-based models have more recently achieved improved prediction accuracy and scalability by being able to effectively capture long-range dependencies in transportation data, and thus better suited to smart city applications (Li and Yan, 2023; Zhang et al., 2024).

2.3 Computer vision for road safety

Computer vision is becoming one of the most crucial AI technologies for enhancing road safety by automating traffic monitoring.Computer vision is emerging as one of the most vital AI technologies for enhancing road safety by automating traffic monitoring. The modern vision-based systems are used to detect vehicles, pedestrians, cyclists, road sign and obstacles using real-time video streams. Such systems assist in traffic law enforcement by detecting traffic violations like speeding, red light violations, and improper lane changes, and also help in quick identification of accidents and emergency response (Reza et al., 2021).

Additionally, driver monitoring systems can help prevent accidents by monitoring driver facial expressions, eye movement, and head posture to identify when drivers are becoming fatigued or distracted. The use of these intelligent monitoring systems can help to reduce the number of accidents that occur due to human error, thereby improving the overall safety of transportation, including the safety of the drivers and passengers who depend on these systems for their journey. (Yang et al., 2023; Zhao et al., 2023)

2.4 Reinforcement Learning for Traffic Signal Optimization

Reinforcement Learning (RL) has proven to be an efficient approach to adaptive traffic signal control. RL agents continuously operate in traffic environments, learning optimal signalling strategies by maximizing traffic efficiency and minimizing vehicle waiting times, instead of fixed-time traffic signals. The systems adapt signal times dynamically depending on traffic conditions, which can lead to less congestion, shorter traffic light durations and lower fuel consumption (Wei et al., 2022).

The recent research has advanced reinforcement learning to multi-agent systems with multiple intersections working together to improve the traffic efficiency of the whole road networks in a city. Under different traffic conditions, such coordinated traffic control systems perform much better than traditional traffic control methods (Bhattacharyya et al., 2026).

2.5 Artificial Intelligence for Accident Forecast and New Developments

Artificial Intelligence also plays an important role in predicting and preventing road accidents. Accident history, traffic density, weather conditions, driver behaviour, and road characteristics are used to model risks of accidents using machine learning and deep learning models before accidents happen. These predictive systems can aid in preventive traffic management by identifying high-risk traffic accident locations and help traffic authorities take preventive steps for traffic safety (Du et al., 2023; Zhao et al., 2023).

The convergence of AI, connected vehicles, connected Vehicle-to-Everything (V2X), IoT, and edge computing has increased the potential of intelligent transportation systems. Vehicle-to-infrastructure communication can facilitate quicker decisions for traffic management, as well as collision avoidance. Yet, issues like data privacy, cybersecurity, infrastructure expenses and interpretability of models still hinder large-scale adoption. Current research tends to center on specific AI techniques, instead of systems integrating multiple AI models to handle overall traffic management and road safety. Thus, there is a need to create AI powered transportation systems that can be easily scaled, secured, and explainable, and can support future smart cities (Zohdy and Rakha, 2022; Patil et al., 2026; Bazzan, 2026; Saxena, 2024).

3. Artificial Intelligence Models for Smart Traffic Management and Road Safety

Artificial Intelligence (AI) has become the foundation of modern smart traffic management systems by enabling real-time analysis, prediction, and decision-making using large volumes of transportation data. AI models process information collected from surveillance cameras, traffic sensors, connected vehicles, GPS devices, and Internet of Things (IoT) networks to optimize traffic flow, reduce congestion, and enhance road safety. Different AI models possess unique capabilities, making them suitable for various transportation applications ranging from traffic prediction to accident prevention.

3.1 Supervised Machine Learning Models

For traffic management, supervised learning models are well suited as they utilize a set of labeled data to learn relationships among input variables and known output. Examples of classifiers used for traffic classification, travel time estimation and congestion prediction include Decision Trees, Random Forests, Support Vector Machines (SVM) and Gradient Boosting algorithms. These models process information like traffic volume, road conditions, weather elements and previous traffic patterns to deliver precise forecasts. Random Forest is one of these techniques that shows great robustness as it reduces the overfitting and also has good prediction performance in many traffic situations (Singh, Sharma and Kumar, 2023; Zhang et al., 2024).

3.2 Unsupervised Learning Models

With the unsupervised learning techniques, patterns can be detected from the transportation information without any labelled information. Road or intersection clustering algorithms (e.g., K-means, hierarchical) are used to identify groups of roads or intersections with similar traffic characteristics, which can help transportation planners identify congestion hotspots and optimize infrastructure planning. Anomaly detection methods also help identify abnormal traffic patterns, accidents, or unexpected congestion, enabling traffic management authorities to intervene quickly. These models are especially valuable for scenarios where there is a limited number of labelled transportation datasets, or when they are not available (Wu et al., 2022).

3.3 Deep Learning Models

The capability of deep learning to automatically extract complex features from high-dimensional transportation data makes it an important technology for intelligent traffic management. In images and video streams, convolutional neural networks (CNNs) are widely used for the detection of vehicles, the recognition of traffic signs, the detection of lanes, the identification of pedestrians, and traffic surveillance. They can accurately monitor in different weather and lighting conditions with their higher visual recognition ability (Wang et al., 2023).

Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks are used to analyse sequential traffic data for traffic flow prediction, traffic congestion evolution and travel demand prediction. They can model the temporal dependency which makes them very appropriate for forecasting traffic conditions over time. Recently, transformer-based architectures have been successfully applied to the field of smart city due to their ability to model long-range dependencies in large-scale transportation datasets, achieving more improved scalability and prediction accuracy (Li and Yan, 2023; Zhang et al., 2024).

3.4 Reinforcement Learning Models

Reinforcement Learning (RL) allows traffic management systems to learn optimally over time by interacting with the road environments. An RL agent monitors traffic flow, makes adjustments to traffic signals, and gets rewarded depending on traffic performance metrics like waiting time, queue length and traffic throughput. The system continuously refines its signalling strategy as it learns repeatedly without the need for rules to be designed by hand.

Multi-agent reinforcement learning takes this approach further by allowing neighbouring intersections to share and synchronize signal durations to improve overall traffic efficiency throughout the city. Previous studies have demonstrated that traffic control systems based on reinforcement learning can effectively reduce traffic congestion and increase fuel efficiency over traditional fixed-time signal systems (Wei et al., 2022; Bhattacharyya et al., 2026).

3.5 Computer Vision Models

Computer vision is among the most applicable AI technologies that can be used in traffic control and road safety. The advanced object detection models are used for live video streams to detect vehicles, pedestrians, cyclists, traffic signs, and roadway obstacles in real time. These systems can detect traffic offenses like speeding, cutting off another car and running a red light, and automatically alert the police, while also identifying accidents and idle cars. Automated visual monitoring enhances the efficiency of traffic surveillance and reduces the need for manual monitoring (Reza et al., 2021; Yang et al., 2023).

Facial expression, eye movements and head position are also analyzed using computer vision for fatigue and distraction detection in driver monitoring systems. These models can produce early warning systems that play a critical role in minimizing accidents resulting from human errors (Zhao et al., 2023).

3.6 AI Integration with Smart Transportation Infrastructure

AI models can be further enhanced by integrating with new transportation technologies including IoT, connected vehicles, Vehicle-to-Everything (V2X) communication, cloud computing, and edge computing. Traffic data is gathered in real-time by IoT sensors and connected vehicles share real-time data with road-side infrastructure. These data streams are used to optimize traffic operations, prioritize emergency vehicles, and assist in collision avoidance systems, among other uses. Edge computing allows computations to be carried out close to the data sources, which is suitable for many applications where the latency of the traffic management is crucial (Zohdy and Rakha, 2022; Englund et al., 2021).

While AI models have shown impressive capabilities in the field of intelligent transportation, certain obstacles such as data privacy, cybersecurity, computational complexity, and model interpretability pose significant challenges to their broader adoption. Solving these challenges will be crucial to creating dependable, expandable, and secure traffic control systems powered by AI that can assist smart cities in their future development (Patil et al., 2026; Mazur and Borucka, 2026).

Table 1. Comparison of Artificial Intelligence Models for Smart Traffic Management

AI Model	Primary Application	Advantages	Limitations
Decision Tree	Traffic classification	Simple, interpretable, fast training	Prone to overfitting
Random Forest	Traffic congestion prediction	High accuracy, robust to noise	Higher computational cost
Support Vector Machine (SVM)	Traffic state classification	Effective with small datasets	Limited scalability for very large datasets
Convolutional Neural Network (CNN)	Vehicle and pedestrian detection	Excellent image recognition accuracy	Requires large labelled datasets
Long Short-Term Memory (LSTM)	Traffic flow forecasting	Captures temporal dependencies	High training time
Transformer	Large-scale traffic prediction	Handles long-range dependencies efficiently	Computationally intensive
Reinforcement Learning	Traffic signal optimization	Learns adaptive traffic control policies	Slow convergence during training

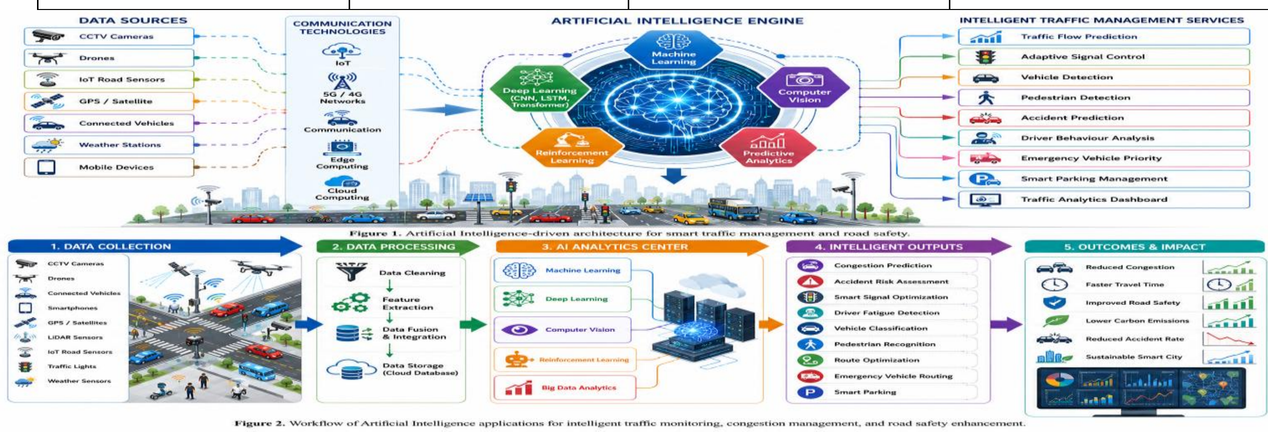

Figure 1. Artificial Intelligence framework for smart traffic management and road safety.

4. Applications of Artificial Intelligence in Smart Traffic Management and Road Safety

Artificial Intelligence (AI) has revolutionized modern transportation systems with its intelligent and data-driven solutions, resulting in more efficient traffic management and enhanced road safety. AI can be used in a variety of ways, such as congestion management, accident prevention, and more, through integrating machine learning, deep learning, computer vision, and reinforcement learning. As a result, these applications help to build safer, more sustainable, and efficient urban mobility networks.

4.1 Intelligent Traffic Signal Control

Adaptive traffic signal control is one of the most promising applications of AI. Traditional traffic signals rely on fixed time periods, which are not always suitable for varying traffic patterns. AI-driven traffic signal systems continuously process real-time data from traffic cameras, sensors, and connected vehicles to fine-tune traffic signals for maximum efficiency. Reinforcement learning algorithms dynamically control the duration of the green light based on the traffic situation at the intersection to minimize vehicle delay, congestion, and improve traffic flow. These smart systems also help to minimize fuel usage and green house gas emissions by cutting down on unnecessary idling of vehicles (Wei et al., 2022; Bhattacharyya et al., 2026).

4.2 Traffic Flow Prediction and Congestion Management

Precise traffic forecasting helps transportation systems to operate in a proactive way. These AI models incorporate historical traffic data and real-time information like weather, road occupancy, special events, and travel demand to predict future traffic conditions and congestion. Machine learning and deep learning algorithms produce short-term and long-term traffic forecasts to help with route planning, traffic diversion and infrastructure management. Congestion can be identified early and prompt solutions can be taken to improve travel time, which helps enhance the transportation system (Singh, Sharma and Kumar, 2023; Zhang et al., 2024).

4.3 Vehicle, Pedestrian, and Incident Detection (VPID)

Advancements in computer vision have greatly enhanced the ability to automatically monitor traffic, allowing for the detection of vehicles, pedestrians, bicycles and obstacles on roadways in real-time. AI surveillance systems can be used to analyse video streams and monitor traffic, flagging any violations and identifying accidents as they happen. These systems can deliver instant alerts to traffic control centres and emergency response teams, which can help to shorten response times and mitigate the impact of road incidents. The continuous automatic monitoring also contributes to a more efficient enforcement process and to a decrease of the need for manual monitoring activities (Reza et al., 2021; Wang et al., 2023).

4.4 Road Accident Prediction and Prevention

AI is one of the most critical fields of application today, with road safety being a primary focus. Predictive models can use past accident data, traffic volume, driver history, weather conditions, and road conditions to determine the likelihood of accidents happening prior to them. These forecasts are used by transportation agencies to determine which spots are likely to cause accidents, take corrective measures to prevent them and better deploy emergency resources. AI can also contribute to intelligent warning systems, alerting drivers to potential dangers such as slippery roads, low visibility, inclement weather, or high-risk intersections, which can help prevent accidents before they even happen (Du et al., 2023; Zhao et al., 2023).

4.5 Driver Behaviour Monitoring

Human factors continue to be one of the most common causes of road accidents around the world. The AI-based driver monitoring system involves real-time analysis of driver behavior, head posture, eye movement, and facial expressions, using cameras and computer vision algorithms. These systems identify unsafe driving behaviours, such as fatigue, distraction, drowsy driving, mobile phone use and more that raise the likelihood of an accident occurring. If unusual behaviour is detected, an alert is raised to promote appropriate action to prevent the set up of an unsafe situation. With this, intelligent monitoring systems have become more crucial for commercial transportation and advanced driver assistance systems (ADAS) (Yang et al., 2023).

4.6 EV Prioritization and Smart City Integration

The AI also enhances emergency response capabilities by prioritizing ambulances, fire engines, and police vehicles in the urban traffic system. AI-powered traffic control systems dynamically manage traffic signals on emergency roads, ensuring more efficient movement of priority vehicles while minimizing delays. Moreover, AI is more and more being applied to smart cities and connected vehicles, IoT, Vehicle-to-Everything (V2X) communications, and edge computing to facilitate coordinated transportation management in smart cities. The integrated systems facilitate the sharing of information between vehicles and infrastructure, enhancing the efficiency of traffic management, avoiding crashes, and boosting the reliability of transportation (Zohdy and Rakha, 2022; Englund et al., 2021).

In summary, AI has a wide range of applications that hold the promise of reshaping the traditional transportation landscape into smart systems that can facilitate mobility, alleviate traffic jams, enhance road safety, and contribute to sustainable urban growth. However, major issues such as data privacy, cybersecurity, infrastructure investment, and the reliability of models need to be addressed to ensure secure and trustworthy intelligent transportation systems (ITS) (Patil et al., 2026; Mazur and Borucka, 2026).

Table 2. Applications of Artificial Intelligence in Smart Traffic Management and Road Safety

Application	AI Technique	Expected Outcome
Traffic congestion prediction	Machine Learning	Reduced travel delays
Adaptive traffic signal control	Reinforcement Learning	Improved traffic flow
Vehicle detection	CNN	Accurate traffic monitoring
Pedestrian detection	Computer Vision	Enhanced pedestrian safety
Accident prediction	Machine Learning & Deep Learning	Reduced accident risk
Driver behaviour monitoring	Computer Vision	Detection of fatigue and distraction
Emergency vehicle prioritization	AI + IoT + V2X	Faster emergency response
Smart parking management	Machine Learning	Reduced parking search time

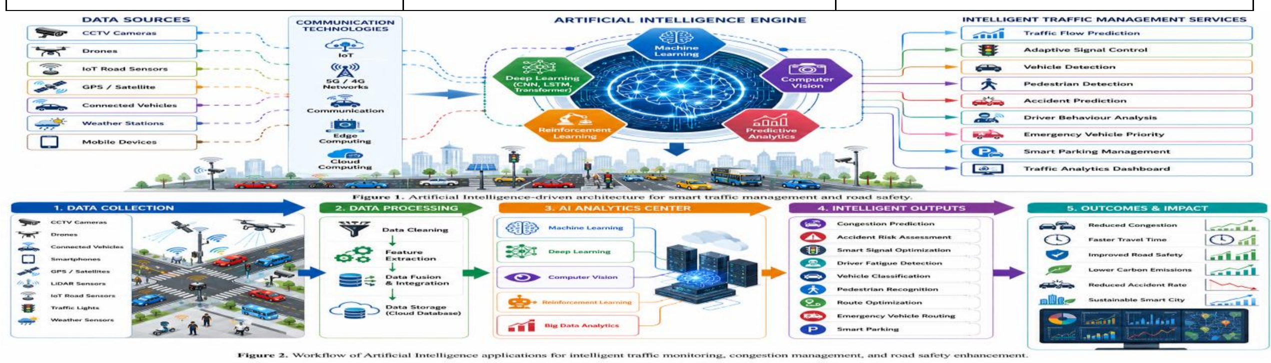

Figure 2. Workflow of Artificial Intelligence applications for intelligent traffic monitoring, congestion management, and road safety enhancement.

5. Challenges and Future Directions

Artificial Intelligence (AI) has played a pivotal role in revolutionizing smart traffic management and road safety, enhancing the efficiency, effectiveness, and safety of transportation systems. However, despite all these developments, numerous technical, operational and ethical issues remain that hinder the widespread adoption of AI-powered transportation systems. Safely and efficiently solving these problems, and taking advantage of new technologies, will prove critical to the creation of reliable, secure and sustainable ITS.

5.1 Challenges in AI-Based Traffic Management

Availability and quality of transportation data is one of the main challenges. To train and validate the AI models, extensive and varied datasets are needed, and the data must be accurate. Traffic data gathered by a camera, sensor, GPS or connected vehicles, however, are often incomplete, inconsistent or impacted by environmental factors like poor lighting, fog, and rain. Imbalanced data and small amounts of labelled data can also limit the predictive accuracy of machine learning and deep learning models, especially for detecting rare traffic incidents or accident scenarios (Patil et al., 2026).

Another major difficulty is the time complexity of computers. Thousands of sensors and surveillance systems gather data at high frequencies, which is continually processed in smart transportation systems. However, deep learning models, particularly CNNs and transformer-based architectures, demand a large amount of computational resources and memory, which limits their real-time application feasibility in resource-limited environments. Edge computing has shorted processing delays, but it remains a challenge to keep latency low while achieving high prediction accuracy (Li and Yan, 2023).

Privacy and cyber security are also a major concern in the intelligent transportation systems. A key component of AI-powered traffic systems is the ability to track and gather data about vehicle movements, traffic patterns, surveillance footage, and individual vehicle usage. Unauthorized login, cyberattacks or data breaches may lead to loss of user privacy and disruption of transportation systems. Thus, to safeguard sensitive transportation data, securing communication protocols, data encryption, and privacy-preserving AI methods are crucial (Zohdy and Rakha, 2022).

The other significant constraint is modelling interpretability. The problem is that many of the sophisticated AI systems are considered "black-box" systems, where it is hard to see how decisions are being created by transportation authorities. The lack of explainability diminishes user trust and makes accountability more difficult – especially in safety-critical applications like accident prediction and autonomous traffic control. In the future, the development of explainable AI techniques will be increasingly important for intelligent transportation systems (Bazzan, 2026).

Cost of infrastructure and implementation is a further hurdle to AI adoption, particularly in low and middle-income countries. Implementing intelligent traffic management solutions involves investing in sophisticated camera hardware, Internet of Things (IoT) sensors, communication infrastructure, cloud computing, and data analysis systems. Moreover, such systems need to be maintained and updated, and skilled workers and finance to maintain and upgrade them may be lacking (Mazur and Borucka, 2026).

5.2 Future Directions

Future studies are likely to involve the integration of several AI techniques into comprehensive intelligent transportation systems. By effectively integrating multiple AI disciplines, including machine learning, deep learning, reinforcement learning, and computer vision, instead of relying on individual algorithms, the combined approach can enhance traffic prediction, signal optimization, and overall road safety (Wu et al., 2022).

The growing adoption of connected vehicles and Vehicle-to-Everything (V2X) communication will further enhance AI-driven traffic management. V to V, V to R, and V to T communication will help to enhance the accuracy of traffic forecasting, speed up the detection of incidents and coordinate the management of traffic across urban road networks. These technologies are going to be vital to the autonomous vehicle and future smart city ecosystems (Englund et al., 2021).

Edge computing and cloud-based AI platforms are also likely to gain much greater significance. Edge AI can help process transportation information within a few seconds of its creation, minimizing delays for real-time applications like collision avoidance and emergency vehicle priority. However, cloud computing offers scalable computational resources to efficiently manage growing transportation networks for large-scale traffic analysis and model training (Zohdy and Rakha, 2022).

A further potential field of research is the creation of explainable and trustworthy AI models. For future systems, clear decision making processes should be implemented, where traffic authorities can follow the process to understand and validate the AI recommendations. By enhancing system reliability, supporting regulatory adherence, and boosting public trust in intelligent transportation systems, Explainable AI will play a pivotal role in the future of the sector.Explainable AI will be crucial for the future of the sector, as it enhances system reliability, aids in regulatory compliance, and helps build trust among the public for intelligent transportation systems.

Lastly, intelligent transportation systems will feature generative AI, digital twins, and predictive simulation models in the future. These technologies can mock traffic situations, assess infrastructure modifications and assist in strategic planning prior to implementation. When integrated with sustainable transportation measures, AI can help alleviate traffic congestion, minimise emissions, enhance road safety, and build more resilient transportation systems to address the future needs of urban mobility (Saxena, 2024; Li and Yan, 2023).

To sum up, while AI has shown tremendous promise in the field of smart traffic management and road safety, there are still a number of hurdles to overcome, including data quality, computational load, cybersecurity, explainability, and infrastructure. Ongoing research and technological advancement will lead to the realization of more adaptive, secure, efficient and intelligent transportation systems that will facilitate the changing and increasing demands of modern smart cities.

Table 3. Challenges and Future Research Directions

Challenge	Impact	Future Direction
Poor data quality	Reduced prediction accuracy	Large-scale standardized datasets
Computational complexity	Increased processing time	Edge AI and hardware acceleration
Privacy and cybersecurity	Risk of data breaches	Secure and privacy-preserving AI
High implementation cost	Limited deployment	Cost-effective smart infrastructure
Model interpretability	Low user trust	Explainable Artificial Intelligence (XAI)
Limited scalability	Difficult deployment in large cities	Cloud-edge collaborative computing
Integration complexity	Poor interoperability	Standardized Intelligent Transportation System architectures

6. Conclusion

Artificial Intelligence (AI) is a technology that has the potential to revolutionize the transportation industry by creating a smart, efficient, and safe system. The combination of machine learning, deep learning, computer vision, and reinforcement learning has enhanced the capabilities of traffic management systems in real-time data analysis, traffic forecasting, signal optimization, and accident prevention. AI-based traffic management systems continuously learn from the dynamic traffic environment, adapting quickly and accurately to improve mobility and alleviate congestion, unlike traditional methods.

The paper presented a literature review on the most common AI models in smart traffic management and road safety applications, such as supervised and unsupervised machine learning models, deep learning architectures, reinforcement learning, and computer vision models. They were pointed out to be useful in various applications such as traffic flow prediction, intelligent traffic signal optimization, vehicle and pedestrian detection, prediction of accidents, driver behaviour monitoring and prioritization of emergency vehicles. The applications showcase the potential of AI in enhancing transportation efficiency, promoting safer road environments, and supporting sustainable urban development.

While these developments hold promise for the future of transportation, there are still some obstacles that hinder the widespread adoption of these AI-driven systems.Although these are promising advancements, there are still several challenges that prevent the widespread use of AI transportation systems. Data quality, computational complexity, privacy protection, cybersecurity, costs of infrastructure and model interpretability are other issues that need to be addressed. Tackling these challenges is crucial to maintaining the reliability, transparency, and security of AI systems in practical applications ranging from engineering to the public sector and beyond.

The seamless integration of AI in the future of connected vehicles, with the Internet of Things (IoT), Vehicle-to-Everything (V2X) communication, edge computing, and cloud-based platforms will prove to be a game-changer. Advancements in emerging technologies like explainable AI, generative AI, and digital twin models will also improve traffic predictions, infrastructure planning and decision support. The developments will facilitate the progress of transportation networks to become more adaptive, autonomous, and resilient.

Finally, AI is now an essential tool for the smart traffic management of the future and for creating safe roads. Future research, technological advancement, and co-action of government, researchers and industry will play a key role in developing intelligent transportation systems that will enhance mobility, reduce accidents, limit environmental impacts, and enable the development of sustainable smart cities.

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