Ushus-Journal of Business Management
2025, Vol. 24, No. 4, *1-19*
ISSN 0975-3311|https://doi.org/10.12725/ujbm.73.1

White Paper: Artificial Intelligence In The Automotive Industry 2.0

Selvakummar V. P.*

Executive Summary

Artificial Intelligence (AI) is changing the automotive industry across the world. It is helping the industry to work in new and improved ways. This change is considered one of the most important technological developments after the invention of the internal combustion engine.

Today, AI is used in many stages of the automotive value chain. It supports vehicle design, improves manufacturing processes, and helps in quality control. AI also plays a major role in autonomous driving, smart vehicle connectivity, and customer support systems such as predictive maintenance and service recommendations.

Technologies such as machine learning, deep learning, computer vision, IoT sensors, 5G networks, and edge computing are widely used in modern vehicles. These technologies help automotive companies increase accuracy, reduce human effort, and improve overall efficiency. AI systems also help vehicles understand their surroundings, make decisions, and react to road conditions in real time.

This white paper explains the basic concepts of Artificial Intelligence used in the automotive sector. It discusses practical use cases, current challenges, and future opportunities. The paper is intended to support students, researchers, industry professionals, and policymakers who want to understand how AI can improve the future of mobility.

1. Introduction

The automotive industry is changing due to the development of Artificial Intelligence (AI). In the past, the industry mainly depended on mechanical systems and human control. Today, AI has become an important part of vehicle design, safety systems, and automated decision-making.

*Oracle, selvasami@gmail.com

Earlier, AI was only a concept used for research and experiments. Now, it is a practical technology used in many modern vehicles. AI helps improve driving safety, reduce human effort, and support advanced vehicle functions.

Several technologies are helping in the growth of AI in the automotive sector. Some of the key technologies are explained below.

Machine Learning and Deep Learning

Machine learning and deep learning systems learn from large amounts of driving data. These systems help vehicles identify objects on the road, detect lane markings, monitor driver behavior, and make quick decisions during driving.

Computer Vision

Computer vision helps us to allow vehicles to understand visual information from cameras and sensors. It helps in reading road signs, identifying pedestrians and obstacles, checking driver attention, and understanding road and weather conditions.

IoT and Sensor Fusion

Modern vehicles are equipped with different types of sensors such as LiDAR, radar, ultrasonic sensors, and telematics systems. These sensors collect large amounts of data from the vehicle and its surroundings. Sensor fusion combines data from all these sources to provide a clear and accurate understanding of the driving environment. This helps vehicles make better and safer decisions.

5G and Edge Computing

5G technology enables fast and reliable communication with very low delay. It allows vehicles to communicate with other vehicles (Vehicle-to-Vehicle) and with road infrastructure such as traffic signals (Vehicle-to-Infrastructure). Edge computing processes data closer to the vehicle, which helps in faster decision-making and reduces dependence on distant cloud systems.

AI's Expanding Role Across the Automotive Lifecycle

Artificial Intelligence is now used in many areas of the automotive industry. Some of the major applications include:

- Autonomous driving systems at different levels of automation
- Predictive maintenance and vehicle diagnostics
- Use of intelligent robots in vehicle manufacturing
- AI-based quality inspection and defect detection
- Smart infotainment systems and personalized user experience
- Fleet management and mobility-as-a-service solutions
- Cybersecurity and detection of abnormal activities in connected vehicles

These changes are transforming traditional automotive business models. AI helps companies reduce operating costs, improve vehicle safety, and create new sources of revenue. It also increases reliability and efficiency in automotive operations.

2. AI Applications in Autonomous Driving

Artificial Intelligence playing a key role in autonomous driving systems. It helps the vehicles understand their surroundings, identify their location, analyze road conditions, and make driving decisions. Autonomous vehicles use multiple AI components that work together to ensure safe and smooth operation.

These components include perception, localization, prediction, decision-making, and vehicle control. All the systems must work quickly and accurately to handle real-time driving situations. The following sections explain these components and their role in autonomous vehicle technology.

2.1 Perception Systems and Object Detection

Perception is one of the most important functions of an autonomous vehicle. It allows the vehicle to understand what is happening around it. Using AI-based computer vision and data from multiple sensors, vehicles can detect objects such as cars, pedestrians, traffic signals, and obstacles.

This system provides a complete view of the surrounding environment and helps the vehicle respond safely to different driving conditions

Multi-Modal Sensor Fusion

Autonomous vehicles use different types of sensors to understand their surroundings. Each sensor has a specific purpose and provides different information. The main sensors used are:

- Cameras, which capture color, shapes, and detailed visual information systems
- LiDAR, which creates accurate 3D maps of nearby objects in the world
- Radar, which detects objects at long distances and works well in bad weather climate
- Ultrasonic sensors, which help during low-speed movements such as parking

AI systems combine data from all these sensors using a process called sensor fusion. By combining multiple data sources, the vehicle gets a more accurate and complete view of its environment. This approach helps vehicles detect objects clearly even in poor visibility, such as during rain, fog, night-time driving, or when sensors are affected by noise.

Studies show that using multiple sensors together gives better results than relying on a single sensor, especially in complex urban areas and difficult weather conditions.

Deep Learning Models Used in Perception

Autonomous vehicles use deep learning models to identify and classify objects on the road. Some commonly used models include:

- Faster R-CNN, which provides accurate object detection
- YOLO models, which are designed for fast, real-time detection
- Transformer-based models, which use attention mechanisms to improve detection accuracy
- 3D detection models, which mainly work with LiDAR data
- These models help vehicles detect and recognize:
- Other vehicles and large machines
- Pedestrians and cyclists
- Road signs, traffic lights, and lane markings
- Moving and stationary obstacles
- Safe and unsafe driving areas

The perception system processes a large amount of sensor data every second. To ensure safe driving, the system must analyze this data very quickly. Modern vehicles use powerful hardware such as GPUs and other AI accelerators to process data in real time and support safe navigation, even at high speeds.

2.2 Localization and Mapping

Accurate localization is very important for autonomous vehicles. The vehicle must always know its exact position on the road to drive safely. This becomes difficult in places where GPS signals are weak or not available, such as tunnels, narrow streets, or dense urban areas.

AI-Enhanced SLAM (Simultaneous Localization and Mapping)

SLAM is a method used by vehicles to understand their location while creating a map of the environment at the same time. Traditional SLAM techniques are now improved using Artificial Intelligence to increase accuracy and reliability.

AI helps SLAM systems by improving:

- Detection of previously visited locations
- Identification and tracking of important features
- Removal of moving objects from maps
- Overall map stability and consistency

With the support of deep learning, vehicles can operate effectively even in new or unfamiliar areas, including crowded city roads and GPS-limited environments.

High-Definition (HD) Mapping

High-definition maps provide detailed information about roads and surroundings. AI-based mapping systems include:

- Accurate 3D representation of road lanes
- Identification of road elements such as curbs, crossings, and traffic lights
- Information about road curves and elevation
- Traffic pattern predictions

AI systems continuously update these maps using real-time sensor data. This ensures that the maps remain accurate even when there are road changes, construction work, or environmental disturbances.

Cooperative Perception and V2X Integration

Cooperative perception allows vehicles to share information with other vehicles and road infrastructure. Data can be exchanged through:

- Roadside sensors such as cameras and LiDAR, Traffic signals and infrastructure systems and nearby connected vehicles

This shared information increases the vehicle's awareness beyond its own sensors. It helps reduce blind spots and improves safety in complex traffic situations. Deep learning models are used to process shared data and provide accurate results, even when communication delays occur.

2.3 Decision-Making and Motion Planning

Decision-making is an important part of autonomous driving. In this stage, the vehicle uses information from sensors to decide how to move safely and efficiently. The AI system selects the best actions such as steering, braking, or changing speed based on road conditions and traffic situations.

Reinforcement Learning for Autonomous Control

Reinforcement learning is a method that allows autonomous vehicles to learn driving behavior through experience. The system learns by interacting with driving environments, both in simulations and real-world conditions.

By analyzing a large number of driving scenarios, reinforcement learning helps vehicles perform tasks such as:

- Changing lanes safely
- Overtaking other vehicles
- Merging into traffic
- Navigating intersections
- Avoiding obstacles on the road

This learning-based approach improves the vehicle's ability to make safe and timely driving decisions in complex traffic situations.

- Emergency braking and predictive interaction with pedestrians and other vehicles

DRL agents maximize long-term rewards based on safety, efficiency, comfort, and regulatory compliance.

Hybrid Decision Architecture: AI and Classical Control

Modern autonomous vehicles use a combination of AI and traditional control systems. This hybrid approach helps vehicles make safe and stable driving decisions. The system usually includes:

- Machine learning models to understand traffic situations and predict future events
- Classical control methods such as PID and MPC to control steering, braking, and speed smoothly
- Rule-based systems to ensure safety and follow traffic laws

This layered design allows vehicles to make many small decisions every second. It helps coordinate sensing, prediction, and control actions quickly and accurately.

Motion Planning

Motion planning is the process of deciding how a vehicle should move on the road. AI-based planning systems help vehicles:

- Create smooth and safe driving paths
- Avoid collisions with other vehicles and obstacles
- Analyze multiple possible paths in real time
- Adjust to changes in speed, road shape, and behavior of other road users
- Accurate motion planning is important to ensure passenger comfort and road safety in real-world driving conditions.

3. AI in Manufacturing and Quality Control

Artificial Intelligence is widely used in automotive manufacturing. It helps convert traditional factories into smart and automated systems. AI technologies such as machine learning, computer vision, IoT, and data analytics improve production efficiency, accuracy, and overall quality.

3.1 Predictive Maintenance

Predictive maintenance is one of the most useful applications of AI in automotive factories. AI systems analyze data from machines to predict failures before they happen. This helps reduce downtime and maintenance costs.

Machine learning models study data collected from industrial robots, conveyor belts, CNC machines, and assembly equipment to identify early signs of problems.

Key Capabilities

- Real-time monitoring: Sensors continuously measure vibration, temperature, sound, torque, and electrical load to track machine health
- Failure prediction: AI models identify anomalies and degradation patterns long before conventional thresholds are reached.
- Operational continuity: Accurate predictions reduce unplanned downtime and ensure near constant equipment availability.
- Deep learning models such as LSTM, autoencoders, and GRU are widely used in predictive maintenance. These models provide better results than traditional statistical methods like regression and time-series models. They can learn patterns from machine data and predict failures more accurately.
- Federated learning allows manufacturers with multiple factories to train shared AI models without exchanging raw data. This approach protects sensitive information while improving prediction quality across all locations.

As a result, manufacturing systems become more reliable. Machines can identify problems on their own, and maintenance activities move from reactive repair to planned maintenance. This helps reduce maintenance costs and improve overall production efficiency.

3.2 Quality Control and Defect Detection

AI-based quality control plays an important role in modern automotive manufacturing. AI-powered vision systems inspect components with high accuracy and consistency, often performing better than manual inspection.

Key Features:

- Image-based inspection: AI systems detect defects such as scratches, size errors, welding issues, surface damage, paint defects, and small cracks.
- Real-time inspection: Automated systems can check thousands of parts every minute with very high accuracy systems
- Anomaly detection: AI models can identify new or unusual defects without needing pre-labeled data present in the world
- High-speed cameras combined with AI vision models enable continuous inspection throughout the day. These systems reduce material waste, remove human errors, and maintain consistent quality in large-scale production. AI-driven quality inspection also helps meet strict automotive safety and certification standards.

3.3 Process Optimization and Design

Artificial Intelligence is changing how vehicles are designed and manufactured. It helps engineers create new designs faster, test ideas quickly, and build stronger and more efficient vehicle structures.

Generative AI in Automotive Design

Generative AI models help designers explore multiple design options automatically. These tools support:

- Designing lightweight vehicle frames and body structures
- Improving vehicle aerodynamics using AI-based simulations
- Reshaping components to increase strength and reduce material usage
- Reducing design time and the number of physical prototypes

This approach allows faster innovation while lowering development costs.

Production Process Optimization

AI and machine learning are also used to improve manufacturing processes. These models help optimize:

- Welding paths and robotic movements
- Material usage and assembly order
- Paint shop processes and drying cycles
- Energy consumption during production

As a result, manufacturers achieve faster development cycles, lower production costs, and quicker delivery of vehicles to the market. This helps companies respond effectively to customer demands and regulatory changes.

4. Electric Vehicles and Battery Management

Electric vehicles depend heavily on AI to manage energy usage, improve battery life, and ensure safety. Since the battery is the most expensive and sensitive part of an electric vehicle, it requires continuous monitoring and intelligent control.

4.1 AI for Battery State Prediction

AI models are used to estimate important battery parameters are updated below

- State of Charge (SOC)
- State of Health (SOH)
- Remaining Useful Life (RUL)

Advanced neural network models, including LSTM and hybrid CNN-LSTM architectures, provide highly accurate predictions under different driving conditions.

4.2 AI-Driven Battery Management Systems (BMS)

AI-powered battery management systems help us to learn and understand

- Control charging and discharging efficiently
- Prevent overheating and safety risks
- Extend battery lifespan
- Improve driving range
- Predicting the energy needs based on route, weather, driving habits and other possibilities

By using AI, electric vehicle manufacturers improve battery performance, reduce degradation, and enhance overall vehicle reliability and user satisfaction.

5. Supply Chain and Connected Vehicles

5.1 Supply Chain Intelligence

The automotive supply chain is large, global, and highly connected. Artificial Intelligence helps companies manage this complexity by improving visibility, planning, and efficiency at every stage of the supply chain.

How AI Improves the Supply Chain

- **Demand forecasting:** Machine learning models study past sales data, market trends, and economic conditions to predict future demand.
- **Supplier risk prediction:** AI identifies possible delays, political risks, and raw material shortages before they affect production.
- **Smart logistics:** AI-based route planning and real-time traffic analysis help deliveries reach faster while reducing fuel costs.
- **Inventory optimization:** AI ensures the right amount of stock is available, avoiding both excess inventory and production shortages.
- **End-to-end visibility:** IoT-based digital systems provide real-time updates on material movement, manufacturing status, and product delivery.

These AI-powered systems help manufacturers operate smoothly even during market disruptions, control costs better, and deliver vehicles on time.

5.2 Vehicle-to-Everything (V2X) Communication

Vehicle-to-Everything (V2X) communication allows vehicles to exchange information with their surroundings. Supported by AI, 5G networks, and edge computing, V2X plays a key role in connected and autonomous driving.

Key Types of V2X Communication

- Vehicle-to-Vehicle (V2V): Vehicles share speed, braking, and hazard alerts to reduce accidents.
- Vehicle-to-Infrastructure (V2I): Vehicles communicate with traffic lights, road sensors, and smart city systems to manage traffic flow.
- Vehicle-to-Pedestrian (V2P): Connected devices help protect pedestrians and cyclists by improving awareness.
- Vehicle-to-Network (V2N): Vehicles connect to cloud systems for map updates, traffic information, and system improvements.

AI helps process and prioritize the large amount of data generated by V2X communication. When combined with low-latency 5G connectivity, AI-powered V2X systems improve road safety, support cooperative driving, and enable advanced mobility services.

6. Manufacturing and Industry 4.0 Integration

Artificial Intelligence is helping traditional automotive factories change into smart, connected, and automated systems. This shift follows the principles of Industry 4.0 and improves productivity, safety, and efficient use of resources.

6.1 Smart Factories and Robotics

Smart factories use AI-based automation to achieve high accuracy and consistent performance. Robots supported by computer vision, sensors, and machine learning can perform complex manufacturing tasks with great precision.

How AI-Powered Robots Improve Manufacturing

- Collaborative robots (cobots): These robots work safely alongside human workers.
- Adaptive learning: Robots can adjust automatically to changes in parts, tools, or assembly conditions.
- Self-improving production lines: AI systems detect delays or inefficiencies and correct workflows in real time.
- AI-enabled robots can learn tasks by observing humans and then perform them more efficiently. These systems form the backbone of modern automotive manufacturing.

6.2 Human–Robot Collaboration

AI has changed how humans and robots work together on the factory floor. Advanced vision systems and intelligent motion planning allow robots to assist in precise assembly tasks that were earlier done only by humans.

- Benefits of Human–Robot Collaboration
- Improved safety through real-time detection of obstacles
- Higher productivity by sharing tasks between humans and robots
- Greater flexibility with fast and easy robot reprogramming
- Fewer errors due to accurate AI-based guidance

With AI support, humans and robots can work together smoothly while maintaining high safety and quality standards.

7. Challenges and Considerations

Although AI offers many advantages, using it in safety-critical automotive systems comes with challenges. These issues must be carefully addressed to ensure reliable performance, safety, and large-scale adoption in the automotive industry.

7.1 Safety and Regulatory Frameworks

Safety, Cybersecurity, and Workforce Challenges

Safety and Regulatory Compliance

Automotive AI systems must meet very high safety and performance standards. Regulations such as ISO 26262, which focuses on vehicle safety, and new AI-related laws require strict testing, validation, and regular audits.

Major Regulatory Challenges from the Government

- Proving that AI systems work reliably in real-world conditions
- Making sure safety-critical systems behave in a predictable and controlled way
- Meeting different regulations across multiple countries

Building trustworthy and safe AI systems is a top priority for vehicle manufacturers, suppliers, and regulators.

7.2 Cybersecurity

Connected and autonomous vehicles are increasingly exposed to cybersecurity risks, such as:

- Unauthorized access to vehicle networks
- Remote control or manipulation of sensors
- Attacks that try to confuse or mislead AI models
- Data leaks from cloud-connected vehicle services

AI-based intrusion detection systems can detect new types of cyberattacks, but they must be continuously updated to stay effective.

Attacks designed specifically to fool machine learning models are a growing threat and require advanced security measures.

7.3 Data Quality and Privacy

The performance of AI systems depends heavily on the quality and variety of data used for training. Automotive AI must be trained on data covering different roads, weather conditions, and traffic situations.

Key Data updated below

- High cost and complexity of labeling large datasets
- Errors, noise, or bias in sensor data
- Privacy concerns when collecting real-world driving data
- Compliance with data protection laws such as GDPR and CCPA

Manufacturers must carefully balance the need for data access with privacy and legal requirements.

7.4 Workforce Transitions

AI and automation are changing job roles in the automotive industry.

- Impact on the Workforce
- Some traditional assembly and inspection jobs may reduce over time
- At the same time, new roles are emerging that require skills in AI, data analysis, and advanced manufacturing technologies.
- New Job Roles and Workforce Skills
- New jobs are appearing in robotics management, AI model development, and data engineering.
- Training and re-training programs are important to keep people employed.
- Companies need to plan how to help their employees adapt to new roles to stay strong in the long term.
- Explainability and Transparency in AI
- Many deep learning AI systems work like "black boxes," making it hard to understand their decisions, which is risky for self-driving cars.

- Why Explainable AI (XAI) is needed:
- Regulators need clear decision paths.
- Investigations need traceable steps for accidents or incidents.
- Users and stakeholders need confidence in autonomous systems.

Tools like SHAP, LIME, and saliency maps give some insights, but AI transparency is still not complete in complex systems.

8. Emerging Technologies and Future Trends

The next 10 years in automotive innovation will be driven by AI, connectivity, and powerful computing.

8.1 Generative AI

Generative AI is changing the automotive industry by:

- Creating synthetic datasets for training self-driving car models.
- Speeding up design and improving aerodynamics.
- Offering personalized experiences inside cars.
- Simulating rare or dangerous driving situations for safer testing.

This reduces the need for expensive real-world data and makes AI models stronger.

8.2 Advanced Edge Computing

Modern cars have strong processors that can run AI in real time.

- Chips with over 2000 TOPS allow:
- Fast combination of sensor data.
- Immediate decisions without relying on the cloud.
- Better performance in areas with weak connectivity.

Edge AI is very important for keeping self-driving vehicles safe because it processes data directly inside the vehicle.

8.3 Causal AI

Traditional AI mostly learns by finding patterns and correlations.

Causal AI focuses on understanding cause-and-effect relationships. This helps by:

- Making AI decisions easier to explain to regulators
- Keeping AI models stable in new or unexpected situations
- Improving safety and reliability in critical vehicle systems

Causal AI is a big change in how AI is designed for autonomous driving.

8.4 5G and Beyond

The move toward 5G and future 6G networks enables:

- Very fast and reliable communication with almost no delay
- Real-time communication between vehicles and infrastructure (V2X)
- Cloud-based digital models to predict and analyze future situations
- AI systems shared across vehicles and smart cities

These technologies support fully connected and intelligent transportation systems.

9. Implementation Strategies and Best Practices

Companies that want to use AI in automotive systems should focus on these best practices:

Strong Data Management

Collect, check, and manage data carefully to ensure good quality and meet legal and regulatory requirements.

AI Skills and Technology Investment

Train employees, hire skilled professionals, work with universities, and partner with AI technology companies.

Fast and Flexible Development

Use quick testing, continuous updates, and real-world testing to improve AI systems faster.

Safety and Clear AI Decisions

Build AI systems that are safe, easy to understand, and follow safety standards.

Build Strong Partnerships

Work closely with suppliers, vehicle manufacturers (OEMs), governments, and research organizations to improve compatibility, standards, and innovation.

Prepare the Workforce for Change

Provide planned training and reskilling programs so employees can work effectively with AI-based systems.

10. Conclusion

Artificial Intelligence is changing the automotive industry in many ways—such as self-driving cars, smart factories, better battery performance, and connected vehicles. When AI works together with IoT, 5G, cloud and edge computing, and generative AI, it improves safety, efficiency, and environmental sustainability.

At the same time, there are important challenges to solve, including safety, cybersecurity, data management, clear AI decision-making, and employee skill development. Companies that use AI wisely and responsibly will lead the future of mobility.

The automotive industry is at a turning point. AI is moving from small experiments to large-scale use. In the next ten years, AI will be the key factor that gives companies a competitive advantage and shapes future vehicles, factories, and transportation systems.

References

Ferraa, O., & Touzi, B. (2025). AI and supply chain resilience trends in the automotive industry: A systematic literature review.

Hashmi, S. M. A., Fekete, T., & Wicaksono, H. (2024). Causal AI in the automotive industry: Impact analysis through carbon emission case study.

Hawlader, F., Robinet, F., & Frank, R. (2023). Leveraging the edge and cloud for V2X-based real-time object detection in autonomous driving.

He, X., & Lv, C. (2023). Towards energy-efficient autonomous driving: A multi-objective reinforcement learning approach.

Khawaja, Y., et al. (2023). Battery management solutions for Li-ion batteries based on artificial intelligence.

Madrid, J. A. (2023). The role of artificial intelligence in automotive manufacturing and design.

Madhavaram, C., et al. (2024). The future of automotive manufacturing: Integrating AI, ML, and generative AI for next-gen automatic cars.

Matamoros, O. M., et al. (2025). Artificial intelligence for quality defects in the automotive industry: A systemic review.

Meng, Z., et al. (2024). Traffic object detection for autonomous driving fusing LiDAR and pseudo 4D-radar under birds-eye-view.

Miraftabzadeh, S., et al. (2024). Exploring the synergy of artificial intelligence in energy storage systems for electric vehicles.

Moniz, A., Candeias, M., & Boavida, N. (2022). Changes in productivity and labour relations: Artificial intelligence in the automotive sector in Portugal.

Naz, N., et al. (2022). Intelligence of autonomous vehicles: A concise revisit.

Nogueira, C., et al. (2024). Explaining bounding boxes in deep object detectors using post hoc methods for autonomous driving systems.

Ojha, A., Sahu, S. P., & Dewangan, D. K. (2021). Vehicle detection through instance segmentation using Mask R-CNN for intelligent vehicle system.

Othman, U., & Yang, E. (2023). Human–robot collaborations in smart manufacturing environments: Review and outlook.

Rao, N. S. (2025). AI-driven predictive maintenance using IoT in automotive manufacturing.

Reddy, B. N. K., et al. (2024). Recent AI applications in electrical vehicles for sustainability.

Reddy, G. J., & Sharma, D. S. G. (2024). Edge AI in autonomous vehicles: Navigating the road to safe and efficient mobility.

Robinson, R. J., & Gorecha, V. (2024). AI adoption patterns among major OEMs in the automotive industry.

Shinde, C., & Garikapati, D. (2025). Gen AI in automotive: Applications, challenges, and opportunities with a case study on in-vehicle experience.

Siddiqui, F., Khan, R., & Sezer, S. (2021). Bird's-eye view on the automotive cybersecurity landscape and challenges in adopting AI/ML.

Song, Z., et al. (2024). Robustness-aware 3D object detection in autonomous driving: A review and outlook.

Tyagi, R. (2024). Deep learning for predictive maintenance in smart manufacturing: A review.

Vasudevan, V., et al. (2024). Certifiability analysis of machine learning systems for low-risk automotive applications.

Vinod, V. (2025). Federated deep learning approach for predictive failure detection in distributed automotive manufacturing parts.

Zhang, T., Zhao, T., Qin, Y., & Liu, S. (2023). Artificial intelligence in intelligent vehicles: Recent advances and future directions.