INTERNATIONAL JOURNAL OF EDUCATIONAL AND SCIENTIFIC RESEARCH FINDINGS, MARCH, 2026, ISSN: 2749-7481 VOL. 8 NO.1, GERMANY

AN EVALUATION OF THE NEED FOR A ROBOT TO HANDLE REAL-WORLD DRIVING: STUDYING THE STRATEGIES AND WHAT IT TAKES

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ABSTRACT

This study focused on the need for robots in handling real-world driving by discussing the strategies, benefits, challenges, and technological requirements involved in autonomous driving systems. The study explained that robotics and artificial intelligence have become important innovations in modern transportation because of the growing demand for safer, faster, and more efficient mobility systems. Real-world driving involves operating vehicles under normal traffic, weather, and road conditions, which often expose human drivers to errors caused by fatigue, distraction, and poor judgment. The study revealed that robotic driving systems equipped with artificial intelligence, machine learning, sensors, LiDAR, radar, and computer vision technologies can improve road safety, reduce traffic congestion, and enhance transportation efficiency through intelligent decision-making and continuous environmental monitoring. The study further identified important strategies for adopting robots in real-world driving, including sensor fusion, smart transportation infrastructure, testing and simulation, legal regulations, and public awareness programs. However, challenges such as cybersecurity threats, perception degradation, edge-case scenarios, and the black-box nature of deep learning systems were also identified as major limitations affecting the widespread adoption of autonomous vehicles. The study concluded that despite these challenges, continuous technological advancement, improved safety systems, and effective regulatory frameworks can support the successful integration of robotic systems into real-world driving environments for safer and more sustainable transportation systems. One of the recommendations made was that Governments and transportation authorities should invest more in smart road infrastructure, intelligent traffic systems, and vehicle-to-everything (V2X) communication technologies to support the effective operation of autonomous robotic vehicles in real-world driving environments.

KEYWORDS: Robot, Real-World Driving, Strategies.

INTRODUCTION

Robotics and autonomous driving technologies have become important innovations in modern transportation systems due to the increasing need for safer and more efficient road transportation. A robot is a programmable machine designed to perform tasks automatically through the use of artificial intelligence, sensors, and computer systems. According to Zhang Lee and Park (2023), modern robots are now designed to interact intelligently with humans and adapt to changing environments through advanced decision-making systems. In transportation, robots are increasingly applied in autonomous vehicles where they assist in navigation, obstacle detection, traffic monitoring, and road safety improvement. The integration of artificial intelligence, machine learning, and computer vision has further improved the ability of robotic systems to operate effectively in complex driving environments (Umofia & Okorie, 2026).

Real-world driving refers to vehicle operation under normal road conditions involving traffic congestion, weather changes, pedestrians, and unpredictable driving situations. Unlike laboratory testing, real-world driving provides accurate information about vehicle performance and driving behavior in natural environments. According to Zhu (2021), real-world driving helps researchers understand how vehicles perform under everyday transportation conditions. The increasing complexity of transportation systems has created the need for robotic driving technologies capable of reducing accidents caused by human error such as fatigue, distraction, and poor judgment. Autonomous vehicles equipped with sensors, cameras, radar, and LiDAR technologies can monitor road conditions continuously and make intelligent driving decisions faster than humans (Grigorescu, 2020).

The need for robots in real-world driving is becoming more significant because of their ability to improve road safety, traffic management, and transportation efficiency. Autonomous robotic systems help reduce accidents, minimize traffic congestion, and support smart transportation systems. According to Pagale (2024), intelligent transportation systems are developed to enhance road safety and improve mobility through automated driving technologies. Despite these benefits, challenges such as cybersecurity threats, sensor failures, and environmental uncertainties still affect the adoption of robotic driving systems. Therefore, evaluating the strategies, benefits, and challenges of using robots in real-world driving is essential for the development of reliable and sustainable autonomous transportation systems.

Concept of Robots

A robot is a programmable machine designed to automatically carry out a complex series of actions. It can perceive its surroundings, process that information, and take physical or automated actions. The concept of robots is multi-dimensional, encompassing mechanical design, computational intelligence, human-robot collaboration, and ethical considerations. This understanding reflects a dynamic and evolving field where robotics continues to integrate technological, cognitive, and social perspectives.

According to Zhang, Lee, & Park (2023), advancements in robotics technology have increasingly focused on collaborative robots, or "cobots," which are designed to work alongside humans safely and efficiently. These robots represent a change in the conceptual understanding of robotics from isolated machines to interactive agents in socio-technical systems, emphasizing human-robot interaction, autonomy, and context-aware decision-making. The integration of AI into business operations is still in its early stages, and success will depend on embracing and implementing these technologies while balancing automation with human expertise (Amuzat, 2025).

According to Alimisis (2020), robots can be classified based on their functionality, mobility, and application domains, including industrial, service, medical, and social robots. Industrial robots. These robots are defined as any autonomously operated devices that replace human labor, regardless of whether they resemble humans or perform tasks in a human-like manner. Consequently, robotics is the branch of engineering that deals with the planning, building, and use of robots. Computer Vision helps systems interpret visual data, and Robotics allows machines to perform autonomous tasks (Umofia & Okorie, 2026).

Concept of Real World Driving

Real-world driving (RWD) refers to the operation of vehicles under actual traffic, environmental, and behavioral conditions encountered in everyday transportation systems, rather than under controlled laboratory or test-track environments. The idea is frequently applied in transportation engineering, automotive technology, environmental studies, and autonomous vehicle research to assess how well vehicles function in real-world scenarios with changing road conditions, weather, traffic congestion, driver behavior, and infrastructure quality. Real-world driving provides more accurate and reliable data regarding vehicle emissions, fuel consumption, safety performance, and driver interactions because it reflects natural driving patterns and unpredictable road dynamics (Zhu, 2021).

With the advancement of autonomous driving technology, electric vehicles, and intelligent transportation systems, the idea has grown in significance. To comprehend actual vehicle behavior and environmental effects, researchers employ real-world driving data gathered by sensors, telematics devices, onboard diagnostics (OBDs), and GPS. Unlike standardized laboratory driving cycles, such as the New European Driving Cycle (NEDC) or the Worldwide Harmonized Light Vehicles Test Procedure (WLTP), real-world driving captures acceleration, deceleration, idling, road gradients, and human driving styles that significantly influence vehicle performance and emissions (Fontaras, 2021).

Real-world driving is also crucial for assessing Advanced Driver Assistance Systems (ADAS) and autonomous vehicle decision-making processes in contemporary automotive research. These technologies have to adjust to changing real-world scenarios with bikes, pedestrians, traffic lights, and unforeseen impediments. Consequently, governments and environmental agencies increasingly rely on real-world driving emission (RDE) testing to establish more realistic vehicle regulations and sustainability policies (Chen, 2023). Overall, the idea of real-world driving improves the precision of transportation research and aids in the creation of mobility systems that are safer, cleaner, and more effective.

The Necessity of Robot in real World Driving

Real-world driving has become increasingly complex due to rising traffic density, unpredictable human behavior, and the demand for safer transportation systems. Traditional human-driven vehicles are limited by fatigue, distraction, emotional decision-making, and delayed reaction time, which collectively contribute to road accidents globally.

- **Safety improvement as a major necessity of robotic driving systems**

One of the strongest arguments for the necessity of robots in real-world driving is the improvement of road safety. Autonomous vehicles are designed to minimize accidents caused by human limitations such as intoxication, fatigue, speeding, and distraction. Robotics-driven systems use continuous environmental scanning and predictive algorithms to detect obstacles faster than human reflexes. These systems also communicate with other vehicles through vehicle-to-everything (V2X) technology, allowing coordinated movement and accident prevention. Research has shown that autonomous vehicles can significantly reduce collision rates by maintaining consistent drivin The Necessity of Robot in real World Driving behaviour and adhering strictly to traffic rules. As noted by Pagale. (2024), autonomous driving technologies are developed specifically to reduce traffic congestion and enhance safety through intelligent transportation systems (ITS) integration.

- **Efficiency and traffic management benefits of autonomous driving robots**

In addition to safety, robotic driving systems are essential for improving traffic efficiency and reducing congestion in modern cities. Human driving patterns are often inconsistent, leading to unnecessary braking, traffic bottlenecks, and inefficient fuel consumption. Autonomous vehicles, however, are programmed to maintain optimal speed, safe distance, and coordinated lane movement, which improves overall traffic flow. AI-powered driving systems can also analyze real-time road data and adjust routes dynamically to avoid congestion. As noted by Wang et al. (2026), automated vehicles are increasingly being integrated into urban mobility systems where they support ride-sharing, logistics, and smart traffic coordination, helping cities manage transportation more effectively.

- **Technological advancement and real-world adaptability of robotic vehicles**

Robotic systems in driving are also necessary due to their adaptability to complex and changing environments. Unlike human drivers who may struggle with unfamiliar roads or adverse conditions, autonomous vehicles rely on machine learning models that continuously improve through data collection and experience. These systems are capable of operating in harsh weather, night driving conditions, and highly congested urban environments. Advances in deep learning, sensor fusion, and real-time computing have made autonomous driving more reliable and scalable. As noted by De Vincenzi. (2026), modern AI-defined vehicles are designed to evolve over time through continuous learning, making them increasingly capable of handling real-world driving complexities.

- **Economic and societal necessity of autonomous driving robots**

Beyond safety and efficiency, robotic driving systems also have significant economic and societal importance. Autonomous vehicles can reduce transportation costs by lowering fuel consumption, minimizing accident-related expenses, and optimizing logistics operations. In the logistics and delivery sector, autonomous trucks and vehicles reduce dependency on human labour while improving productivity and operational consistency. When robotic process automation (RPA) and artificial intelligence (AI) are integrated, businesses may decrease human error, boost production, and increase speed (Umofia & Okorie 2026). This shift is especially important in addressing driver shortages in transport industries worldwide.

The Roles of Robot in real World Driving

Through the development of driver-assistance technology, autonomous vehicles, and intelligent transportation systems, robots have a major impact on contemporary real-world driving systems. In the automobile sector, robots are combined with sensors, cameras, radar, artificial intelligence (AI), and machine learning algorithms to allow cars to sense their surroundings, make judgments, and navigate roadways with little assistance from humans. These robotic driving systems increase the effectiveness of transportation, lessen human error-related accidents, and promote the growth of smart cities.

- **Autonomous navigation**

Autonomous navigation is one of the main functions of robots in real-world driving. Self-driving cars to recognise traffic lights, road signs, pedestrians, and surrounding automobiles use robotic technology, such as LiDAR and computer vision systems. According to Grigorescu (2020), autonomous driving robots rely heavily on deep learning and sensor fusion techniques to interpret complex road environments and make safe driving decisions. Companies including Tesla, Waymo, and Toyota have adopted robotic driving systems that can conduct lane-keeping, automatic parking, adaptive cruise control, and collision avoidance.

- **Improving road safety**

Enhancing road safety is another crucial responsibility. Fatigue, distraction, and intoxicated driving are examples of human error that contribute significantly to traffic accidents globally. By paying close attention and responding to emergencies more quickly than people, robotic driving systems lower these dangers. Research by Yurtsever. (2020) explained that autonomous robotic vehicles can significantly reduce accident rates through real-time environmental monitoring and predictive decision-making systems. Robotic applications such as emergency braking and blind-spot monitoring are examples of advanced driver assistance systems (ADAS) that are already utilized in contemporary automobiles.

- **Logistics and commercial transportation**

Additionally, robots help in commercial transportation and logistics. The usage of delivery robots and autonomous vehicles is growing in order to lower operating costs and move items more effectively. Through intelligent route planning and vehicle-to-vehicle communication, robotic vehicles in smart cities help control traffic and lessen congestion. Additionally, robotic driving technologies help people with disabilities and the elderly by giving them more freedom and movement.

The Strategies of Adopting Robot in real World Driving

The strategic integration of cutting-edge technologies, infrastructure development, regulatory backing, and public acceptability is all-necessary for the use of robots in real-world driving. To produce safer and more effective transportation systems, autonomous driving systems integrate robots, artificial intelligence (AI), machine learning, sensors, and communication technology. A growing number of governments, automakers, and tech firms are putting policies in place that facilitate the effective integration of autonomous driving systems into contemporary society.

- **Integration of artificial intelligence and sensor fusion technologies into vehicles**

The incorporation of sensor fusion and artificial intelligence into automobiles is a key tactic. Robotic systems including cameras, LiDAR, radar, GPS, and ultrasonic sensors are necessary for autonomous cars to recognize and analyses road conditions. According to Kuutti (2021), combining multiple sensing technologies improves vehicle perception accuracy and enhances safe decision-making in complex traffic conditions. Robots can also learn driving patterns, identify impediments, and forecast road behavior in real time thanks to deep learning algorithms.

- **Development of smart transportation infrastructure**

The creation of intelligent transport infrastructure is another crucial tactic. By facilitating constant connection between cars and road infrastructure, smart roads, intelligent traffic lights, and vehicle-to-everything (V2X) communication systems enable robotic driving. Yurtsever. (2020) emphasized that intelligent transportation systems improve the efficiency and reliability of autonomous vehicles by reducing traffic congestion and enhancing situational awareness. To get cities ready for robotic transport systems, governments in a number of nations are funding smart city initiatives.

- **Testing and simulation**

Adopting robots in real-world driving also requires testing and simulation techniques. To lower safety hazards, autonomous driving systems are extensively tested in controlled situations and virtual simulations prior to deployment. Robotic systems can be trained in a variety of weather, traffic, and emergency circumstances thanks to simulation technologies. Additional tactics for enhancing system dependability and shielding autonomous cars from cyberattacks include regular software updates and cybersecurity precautions.

- **Public awareness and legal regulation**

Legal regulation and public awareness are equally crucial tactics. To control the use of autonomous robotic cars, numerous nations are creating laws, moral standards, and safety regulations. Road users are more likely to trust and accept autonomous driving technologies because of public education initiatives. Innovation and adoption are also accelerated when governments, academic institutions, and private businesses work together.

The Challenges of Adopting Robot in real World Driving

Deploying robots and autonomous vehicles (AVs) into real-world driving environments is one of the most complex engineering and societal challenges of the modern era. While laboratory settings and closed-course simulations allow robots to operate flawlessly, the open, chaotic world introduces several compounding friction points. The primary challenges of adopting robots in real-world driving can be categorized into four major themes.

- **Multi-Sensor Fusion and Severe Perception Degradation**

A self-driving robot relies heavily on a complex array of vision sensors, including cameras, LiDARs, and radars, to build an accurate 3D understanding of its surroundings (Chen et al., 2024). The fundamental challenge lies in multi-sensor fusion—reconciling divergent data streams that possess entirely distinct perspective views, coordinate spaces, and data densities (such as 2D camera pixels vs. 3D LiDAR point clouds). Furthermore, real-world deployment introduces severe weather and environment fluctuations (e.g., heavy downpours, blinding snowstorms, dense fog, or sudden lens flare). These adverse conditions lead to data distribution shifts that degrade neural network accuracy, resulting in catastrophic perception errors where the robot might fail to detect structural obstacles or vulnerable road users.

- **Safety of the Intended Functionality (SOTIF) & Edge Cases**

Traditional automotive safety focuses on Functional Safety (ISO 26262), which prevents accidents caused by hardware or system malfunctions. However, real-world robotic driving has birthed a much steeper challenge known as Safety of the Intended Functionality (SOTIF / ISO 21448).SOTIF deals with accidents that occur without any hardware failing, but rather due to inherent technological limitations or unexpected environmental triggers (Hu et al., 2025). In the open world, robots are constantly confronted with "long-tail" edge cases—unforeseen, rare events that were completely absent from their training data (such as a pedestrian wearing a bizarre costume jaywalking, or an overturned white truck blending into a bright, cloudy sky). Because deep learning models often struggle to generalize outside their training boundaries, these edge cases trigger unpredictable, unsafe vehicle actions.

- **Real-Time Combinatorial Decision-Making and Behavior Planning**

Driving is a highly dynamic social interaction. A robot driver must execute real-time behavior decision-making (reacting to sudden pedestrian crossings or erratic drivers) while simultaneously computing continuous motion trajectories (Hu., 2025).The mathematical challenge stems from the fact that the road environment is highly interactive and non-deterministic. To drive smoothly, the robot cannot just calculate its own path; it must dynamically predict the intents and future trajectories of every neighboring agent. Balancing aggressive progress with absolute safety creates a massive computational burden. If the system's rule-based parameters or game-theoretic models are too conservative, the vehicle suffers from "freezing robot syndrome"—becoming paralyzed at busy intersections or merging lanes because it cannot find a mathematically "perfect" risk-free gap.

- **The "Black Box" Problem and the Lack of Interpretability**

Modern autonomous driving relies heavily on deep learning and monolithic, end-to-end neural network architectures. While these AI architectures yield incredible performance gains over traditional approaches, they operate fundamentally as black boxes. When a robotic vehicle suddenly makes an erratic maneuver or brakes dangerously on a highway, it is incredibly difficult for engineers to trace back the exact neurons or causal mechanisms that triggered the failure (Chen et al., 2024).

The Mitigating Strategies to the Challenges of Adopting Robot in real World Driving

To overcome the severe perception, safety, planning, and validation roadblocks of deploying robots in real world driving, the autonomous vehicle (AV) industry has shifted away from brittle, purely rule-based frameworks. Instead, modern research heavily favors hybrid architectures, generative data expansion, and multi-modal alignment. The following are the primary mitigation strategies designed to address the core challenges of real-world robotic driving:

- **Cross-Modal Transformers & Foundation Models**

To solve the challenge of reconciling vastly different sensor formats (such as 2D camera images and sparse 3D LiDAR point clouds) and overcoming harsh weather degradation, researchers have developed Cross-Modal Transformer Networks and adapted Vision-Language-Action (VLA) Foundation Models (Chen., 2024).Rather than performing early or late data fusion—which often discards crucial geometric or contextual data—modern systems utilize attention mechanisms to align camera and LiDAR features within a unified, high-dimensional Bird's-Eye-View (BEV) space.

- **Predictive Driver Monitoring and Automated Fail-Safe Safety Maneuvers**

This hazardous transition phase is mitigated by embedding proactive, multi-modal human-machine interfaces (HMIs) backed by continuous, real-time driver monitoring systems (DMS) that track operator gaze, cognitive load, and readiness metrics to predictively adjust the handover window duration (Aliane, 2026). By utilizing advanced gaze-tracking and cabin-facing infrared cameras, the vehicle can verify the human's situational readiness before executing a control transfer; if the driver is detected to be distracted or unresponsive during a critical boundary event, the vehicle automatically bypasses the manual handover request and executes a fail-safe risk mitigation maneuver, such as slowing down and steering safely to the hard shoulder.

- **Multi-Layered Cryptographic Authentication and Cross-Layer Consensus Validation**

To safeguard vehicles against remote exploitation, manufacturers deploy a multi-layered cyber-physical security architecture consisting of continuous, consensus-based validation networks and automated vehicle-integrated intrusion detection systems (IDS) (Lippi., 2025;). This proactive framework enforces strict cryptographic authentication across all inbound V2X wireless packets, while simultaneously running cross-layer sanity checks within the vehicle's internal bus network to immediately identify, isolate, and override any anomalous command signals—such as a sudden, unauthenticated steering or braking prompt—before it can manipulate physical actuation components (Lippi, 2025).

CONCLUSION

In conclusion, the evaluation of the need for robots in handling real-world driving has shown that autonomous robotic systems are becoming essential in modern transportation due to their ability to improve road safety, traffic efficiency, and intelligent mobility. Through the integration of artificial intelligence, sensors, machine learning, and intelligent transportation systems, robotic vehicles can reduce human errors such as fatigue, distraction, and poor decision-making that often lead to road accidents. Although challenges such as cybersecurity risks, sensor limitations, environmental uncertainties, and ethical concerns still exist, continuous technological advancements and strategic development are improving the reliability and adaptability of autonomous driving systems. Therefore, the adoption of robots in real-world driving has the potential to create safer, smarter, and more efficient transportation systems for future societies.

RECOMMENDATION

1. Governments and transportation authorities should invest more in smart road infrastructure, intelligent traffic systems, and vehicle-to-everything (V2X) communication technologies to support the effective operation of autonomous robotic vehicles in real-world driving environments.
2. Public awareness programs and proper legal regulations should be established to educate road users about robotic driving technologies while ensuring that safety standards, ethical guidelines, and operational policies are properly enforced.
3. Automobile companies and technology developers should continue improving artificial intelligence, sensor fusion, and cybersecurity systems in autonomous vehicles to enhance safety, reliability, and protection against system failures and cyber threats.

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