Deliberationes tudományos folyóirat
18. évfolyam 1. szám 2025/1, 81–91. oldal
Kézirat beérkezése: ,2025. április 1.
Kézirat befogadása: 2025. október 22.
DOI: 10.54230/Delib.2025.1.81

Deliberationes Scientific Journal
Vol.18; Ed.No. 1/2025, pages: 81–91
Paper submitted: 1st April 2025
Paper accepted: 22nd October 2025
DOI: 10.54230/Delib.2025.1.81

ARTIFICIAL INTELLIGENCE IN THE AUTONOMOUS VEHICLE MARKET: TRENDS AND INNOVATIONS

Máté Prorok
Faculty of Economy, Gál Ferenc University
Óbuda University, Innovation Management Doctoral School

Abstract

The application of artificial intelligence (AI) in the autonomous vehicle market has shown significant growth between 2017 and 2024. This study aims to answer the following research question through secondary data analysis: To what extent have artificial intelligence technologies—specifically machine learning, deep learning, and computer vision—contributed to trends and innovations in the autonomous vehicle market during the chosen period? I explored the role of AI technologies in the development of autonomous systems by conducting a comprehensive analysis of the IEEE, Springer and further relevant databases publications to the topic.

The results show that machine learning algorithms have significantly improved the perception and pattern recognition capabilities of autonomous vehicles, enabling accurate classification of traffic signs and reliable detection of pedestrians. Deep learning techniques have facilitated the processing of complex environmental data, supporting the development of computer vision and 3D environment modeling. Sensor fusion and AI-based real-time decision-making have played a key role in improving vehicle reliability and efficiency, contributing to market growth.

The integration of AI technologies has not only been a driver of vehicle technology development, but has also influenced industry trends, regulatory frameworks, and facilitated the emergence of intelligent transportation systems. I found that AI has significantly contributed to innovations and trends in the autonomous vehicle market between 2017 and 2024. I conclude that AI technologies will continue to be a driver of autonomous vehicle development, and I recommend further research on the integration of AI and smart city infrastructures, as well as addressing regulatory and ethical challenges.

Keywords: autonomous vehicles, machine learning, deep learning, artificial intelligence, computer vision

MESTERSÉGES INTELLIGENCIA AZ AUTONÓM JÁRMŰPIACON: TRENDEK ÉS INNOVÁCIÓK

Prorok Máté
Gál Ferenc Egyetem, Gazdasági Kar
Óbudai Egyetem, Innováció Menedzsment Doktori Iskola

Absztrakt

A mesterséges intelligencia (AI) alkalmazása az autonóm járművek piacán jelentős növekedést mutatott 2017 és 2024 között. A tanulmány a következő kutatási kérdésre kíván választ adni szekunder adatelemzés révén: Mennyire járulnak hozzá a mesterséges intelligencia technológiák – különösen a gépi tanulás, a mélytanulás , és a számítógépes látás –a trendekhez és innovációkhoz az autonóm járművek piacán a választott időszakban? A mesterséges intelligencia technológiák autonóm rendszerek fejlesztésében betöltött szerepét az IEEE, Springer és további a témához kapcsolódó releváns adatbázisok publikációinak átfogó elemzésével tártam fel.

Az eredmények azt mutatják, hogy a gépi tanulási algoritmusok jelentősen javították az autonóm járművek észlelési és mintafelismerő képességeit, lehetővé téve a közlekedési táblák pontos osztályozását és a gyalogosok megbízható észlelését. A mély tanulási technikák lehetővé tették az összetett környezeti adatok feldolgozását, támogatva a számítógépes látás és a 3D környezetmodellezés fejlesztését. Az érzékelőfúzió és az AI-alapú valós idejű döntéshozatal kulcsszerepet játszott a járművek megbízhatóságának és hatékonyságának javításában, hozzájárulva a piac növekedéséhez.

Az AI-technológiák integrációja nemcsak a járműtechnológia fejlődésének motorja volt, hanem befolyásolta az iparági trendeket, a szabályozási kereteket, és elősegítette az intelligens közlekedési rendszerek megjelenését. A mesterséges intelligencia 2017 és 2024 között jelentősen hozzájárult az innovációkhoz és trendekhez az autonóm járművek piacán. Arra a következtetésre jutottam, hogy az AI-technológiák továbbra is az autonóm járművek fejlesztésének mozgatórugói lesznek, és további kutatásokat javaslok az AI és az intelligens város integrációjával kapcsolatban. infrastruktúrák, valamint a szabályozási és etikai kihívások kezelése.

Kulcsszavak: autonóm járművek, gépi tanulás, mélytanulás, mesterséges intelligencia, számítógépes látás

Introduction

The development of autonomous vehicles has gained significant momentum over the past decade, with artificial intelligence playing a central role. AI enables vehicles to sense, interpret, and make autonomous decisions in their environment. The integration of machine learning, deep learning, and computer vision has led to a number of innovations in autonomous systems.

This study aims to answer the following research question through secondary data analysis from 2017 to 2024: To what extent have artificial intelligence technologies—specifically machine learning, deep learning, and computer vision—contributed to trends and innovations in the autonomous vehicle market during the chosen period?" During the study, I analyzed IEEE and Springer and other relevant journals available in databases to uncover the latest developments and research directions. I observed significant growth in the AI-enabled autonomous vehicle market during the analyzed period, this is why I chose exactly this period. This growth is linked to the development of AI technologies, digitalization and the increasing demand for intelligent transportation systems. The use of machine learning algorithms has enabled the efficient recognition of patterns in data, such as traffic sign classification and pedestrian detection. Deep learning has contributed to the development of computer vision, improving object recognition based on camera images and 3D modeling of the vehicle environment.

Sensor fusion and AI-based real-time decision-making are areas that have significantly contributed to increasing the reliability and efficiency of autonomous vehicles. The integration of 5G networks and V2X communication creates further opportunities for autonomous systems, facilitating the emergence of intelligent transportation infrastructures.

The role of AI in autonomous vehicles

At the heart of autonomous vehicles is artificial intelligence, which enables vehicles to sense, interpret, and also make autonomous decisions in their environment (Cunneen, 2023). The application of AI is built on integrated solutions that include a number of complementary technologies and algorithms (Fernandes & Estorilio, 2023).

Machine Learning (ML) algorithms are able to learn independently and improve their performance based on experience. The main application of ML in autonomous vehicles is to recognize patterns in data, such as classifying traffic signs or detecting pedestrians. Supervised learning allows systems to learn from specific examples, while unsupervised learning allows systems to discover hidden relationships between data. Deep learning algorithms are based on the multilayer structure of neural networks, which are particularly effective in processing large and complex databases. In autonomous vehicles, deep learning helps with computer vision, such as object recognition and classification based on camera images, and 3D models of the vehicle's environment (Cunneen et al., 2019).

Computer vision is one of the most important application areas of AI, allowing a vehicle to perceive and interpret visual data. Computer vision technology supports basic functions such as obstacle detection, path identification, and traffic sign interpretation. Sensors in autonomous vehicles such as lidar, radar, camera, ultrasonic sensors generate huge amounts of data. AI algorithms can extract useful information from this data, such as the movement patterns of objects around the vehicle or the prediction of traffic

situations (Selver et al., 2018).

The environmental perception of autonomous vehicles is based on the integrated use of different types of sensors. Sensor fusion is a technology that performs coordinated processing of data collected by sensors, thus providing a more accurate, context-rich picture of the vehicle's environment. Light Detection and Ranging, Lidar, sensors create a high-resolution spatial map using laser beams. AI systems can use this data to accurately determine obstacles, routes, and distances. Radar plays a prominent role in detecting the speed and distance of moving objects, such as other vehicles, especially in poor visibility conditions. Cameras provide accurate information about the color, shapes, and movement of the environment through computer vision algorithms. AI software integrates and analyzes information generated by sensors in real time, allowing the vehicle to respond adaptively to changing environmental factors (Blasch et al., 2021).

A key aspect of autonomous vehicle operation is real-time decision making, in which AI systems evaluate the current environment and make decisions, such as when accelerating, braking, or changing lanes (Tien, 2017). Another important thing is path planning. AI-based path planning algorithms optimize the vehicle's movement to reach a destination while taking into account traffic rules, dynamic obstacles, and traffic situations. The algorithms often use Dijkstra or A* algorithms to determine the shortest or safest path. Machine learning models can predict the movements of other road users, such as pedestrians and vehicles, thereby preventing potential accidents (Lin, 2024). Real-time adaptation is becoming more important. Autonomous vehicles are able to adapt their decisions to the current situation, for example, choosing an alternative route in case of traffic jams or adjusting their speed to bad weather conditions (Gallardo et al, 2017).

Recent developments further enhance the efficiency and reliability of autonomous systems. Federated learning means that shared learning models among autonomous vehicles allow vehicles to collectively improve AI performance without having to share raw data, thereby ensuring a high level of data protection (Zeng et al., 2022). Reinforcement learning is another branch of AI which is able to learn real-time decision-making, in which vehicles optimize their behavior based on rewards and penalties from their own experience (Hillebrand et al., 2020).

Market trends and technological development directions

The autonomous vehicle market has shown rapid growth in recent years, driven by the demand for AI technologies, digitalization, and smart transportation systems. Market players are continuously innovating to meet the ever-expanding consumer needs and regulatory expectations. AEVs, Autonomous Electric Vehicles, the rise of electric vehicles, combined with autonomous technologies, points towards a more sustainable transportation model. AEVs not only support carbon-neutral transportation, but also reduce operating costs thanks to electric propulsion and AI-based efficiency optimization

(Mallozzi et al, 2019). Models such as ridesharing and carsharing have also become significant trends in the autonomous vehicle market. AI-powered systems make these services more efficient by balancing real-time demand and supply. (Prieto et al., 2022).

Artificial intelligence has fundamentally transformed technological innovations in the autonomous vehicle market, particularly in terms of communication technologies, data processing, and enhanced safety. The role of 5G networks provides low-latency, high-bandwidth communications that enable autonomous vehicles to share data in real time and enable Vehicle-to-Everything (V2X) communication. This technology is key to vehicle-to-vehicle collaboration and the integration of intelligent transportation systems (Hasan, 2020).

Autonomous vehicles continuously generate and use large amounts of data, which are processed and stored by cloud-based systems. AI-based cloud services enable real-time analysis, for example by processing traffic patterns instantly. Autonomous vehicle data, especially sensor data and decision-making logic, contain sensitive information. The use of blockchain technology ensures its secure sharing and authenticity (Shahzad, 2022).

The widespread use of AI technology offers significant cost-effectiveness benefits in the autonomous vehicle market. The first benefit can be the reduction of manufacturing costs. AI-based robotic manufacturing processes reduce the need for human labor while increasing production efficiency. Intelligent quality control systems further reduce the rate of defective products. The other benefit can be the maintenance cost optimization. AI-powered predictive maintenance systems can predict component failure, reducing downtime and repair costs. The widespread use of autonomous vehicles is expected to reduce the number of traffic accidents, which can lead to significant cost savings in the healthcare and insurance sectors (Goriparthi, 2024).

AI-based systems in autonomous vehicles play a key role in real-time data processing and personalization of the user experience. AI systems analyze traffic data in real time, enabling congestion avoidance and optimal route selection. Technologies such as digital twins enable the simulation and optimization of transportation systems. Advanced user interfaces, like HMIs, Human-Machine Interfaces powered by AI provide passengers with real-time analysis of the vehicle environment and decisions, thereby increasing transparency and trust in the technology (Meduri et al, 2023). AI systems in autonomous vehicles can recognize user preferences, such as desired temperature, seat settings or preferred routes, thus providing a unique experience for passengers (Liao et al., 2024).

In addition to the technological development of the autonomous vehicle market, the development of the regulatory environment and infrastructure is also receiving special attention. Global developments in the field of autonomous technologies, such as regulatory harmonization in the EU and the United States, are decisive for market opportunities (von Ungern-Sternberg, 2018).

Explainable AI or XAI is important because the technologies that increase the transparency of the operation of AI systems allow the processes behind decisions to be better understood, thereby increasing user and regulatory trust (Dwivedi et al, 2023).

Social and economic impacts of AI-based autonomous vehicles

One of the most important societal impacts of autonomous vehicles is the significant reduction in the number of traffic accidents, which results from the elimination of human error. Majority of traffic accidents are caused by human error, such as fatigue, inattention or speeding. AI-based systems, such as collision avoidance systems and predictive behavior analysis, analyze traffic situations in real time, thereby minimizing the risks caused by the human factor. The more accurate perception and decision-making capabilities of AI-controlled vehicles improve reaction times and accident avoidance. For example, AI-based braking systems react to hazards in milliseconds, making it almost impossible to compete with human reflexes. Autonomous systems strictly follow traffic rules, such as speed limits, interpretation of traffic signs, and maintaining a safe distance, thereby reducing the risks of violations (Fu et al., 2021). Autonomous vehicles significantly improve the flexibility and accessibility of transportation, especially for those for whom traditional transportation options are limited. Autonomous vehicles provide personalized services that enable the elderly and people with reduced mobility to travel independently. AI-based systems use adaptive technologies such as voice control or accessible vehicle design. Ridesharing and carsharing services that use autonomous vehicles provide flexible transportation options at lower costs while reducing the need for vehicle ownership. AI-based systems' optimized route planning and real-time traffic analysis reduce congestion, improving transportation efficiency and saving time (Bongiovanni, 2022).

Autonomous vehicle technology is fundamentally transforming the economy, creating new business models and generating new industries. AI-based systems support shared mobility services, such as autonomous taxis and fleet management systems. These solutions reduce operating costs while increasing the efficiency and availability of services. Technologies related to autonomous vehicles, such as software development, sensor manufacturing, and big data analysis, have created new industries. These areas are expected to create millions of new jobs in the coming decades. Accident risks reduced by AI can result in lower insurance premiums. The data collection capabilities of autonomous vehicles enable more accurate risk analysis, which also contributes to cost-effectiveness. The widespread use of autonomous vehicles improves the efficiency of logistics chains, reduces transportation costs, and increases the availability of goods and services (Turan et al, 2020).

Autonomous vehicles contribute to the development of sustainable transport systems that have a positive impact on the environment. Optimized driving patterns of AI-based systems, such as smoother acceleration and braking, reduce fuel consumption and emissions. The proliferation of electric autonomous vehicles will further reduce the need for fossil fuels, supporting the goals of carbon neutrality. Autonomous systems

improve road use efficiency, reducing road congestion and infrastructure maintenance costs (Manavaalan et al., 2024).

One of the biggest obstacles to the widespread adoption of autonomous vehicles is the regulatory framework and the resolution of ethical dilemmas. Autonomous vehicles are being introduced in a globally diverse regulatory environment, which may hinder the development of a single market. Issues such as liability will fundamentally affect the adoption of the technology. Ethical dilemmas that arise during the operation of autonomous vehicles are generating significant debate. Social norms must be taken into account when programming the decision-making mechanisms of AI algorithms, but these may differ from region to region and culture to culture. To ensure the compatibility of autonomous systems, global standards are needed that define the interoperability of AI technologies (Fahim, 2024).

The operation of autonomous vehicles requires the collection and processing of large amounts of data, which raises a number of data protection and security challenges. Autonomous systems collect personal and sensitive data about passengers, such as location data, habits, and biometric information. Compliance with the General Data Protection Regulation (GDPR) or other similar regulations is essential to avoid data breaches. Autonomous vehicle systems are vulnerable to cyberattacks that can compromise the safety of passengers and the operation of the vehicles. The use of advanced encryption algorithms, blockchain technology, and real-time threat detection systems are key to preventing such attacks (Taeihagh, 2019).

The issue of social acceptance is based on the successful integration of autonomous vehicles depends largely on society's attitude and trust. People's trust is affected by accidents during autonomous vehicle testing and the lack of transparency in AI. Explainable AI technologies, which allow us to understand the decision-making processes of AI systems, play an important role in increasing social trust (Adnan, 2018).

For the future, the development of the autonomous vehicle market offers significant opportunities, especially in the areas of artificial intelligence and the integration of smart cities. Further advances in AI, such as increasing the efficiency of deep learning models and developing adaptive learning algorithms, will enable the precision operation of autonomous systems to be improved. The integration of smart cities and transport systems are important. Autonomous vehicles can optimize traffic flows by connecting to the transport infrastructure of smart cities. Smart traffic lights, real-time traffic control and AI-based parking systems all contribute to the efficiency of urban transport. The spread of electric self-driving vehicles contributes to environmental sustainability, while logistics optimization reduces energy consumption. The introduction of autonomous systems can lead to the realization of carbon-neutral transport models in the long term (Chehri, 2019).

Summary

In the autonomous vehicle market, the integration of AI technologies, especially machine learning, deep learning, and computer vision, has fundamentally transformed transportation systems and related industries between 2017 and 2024. According to the answer to the research question, these AI technologies have played a key role in the trends and innovations in the autonomous vehicle market, facilitating the development of vehicles' sensing, interpretation, and autonomous decision-making capabilities.

In the analysis of the IEEE, Springer and the other relevant databases to the topic, I found that the application of machine learning has enabled the efficient recognition of data patterns, which is essential for the environmental perception and interaction of autonomous vehicles. Deep learning has facilitated the processing of complex environmental information and the development of computer vision, improving object recognition and obstacle avoidance capabilities. These innovations have contributed to increasing the reliability and efficiency of autonomous vehicles, which has led to the rapid growth of the market during this period.

Future developments and research will continue to focus on integrating AI technologies, building smart city infrastructures, and addressing regulatory challenges. The widespread deployment of AI-powered autonomous vehicles offers significant benefits in terms of road safety, economic efficiency, and environmental sustainability. Overcoming barriers and continuing innovation are essential for these technologies to fully realize their potential to transform global transportation systems.

Kapcsolattartó szerző:
Prorok Máté
Gál Ferenc Egyetem
Gazdasági Kar
5600 Békéscsaba
prorok.mate@gfe.hu

Corresponding author:
Máté Prorok
Faculty of Economy
Gál Ferenc University
Bajza str. 33.
prorok.mate@gfe.hu

Hivatkozás: Prorok, M. (2025). Artificial Intelligence in the Autonomous Vehicle Market: Trends and Innovations. *Deliberationes, 18*(1), 81–91.

Bibliography

Adnan, N., Nordin, S. M., bin Bahruddin, M. A., & Ali, M. (2018). How trust can drive forward the user acceptance to the technology? In-vehicle technology for autonomous vehicle. *Transportation research part A: policy and practice*, 118, 819-836.

Blasch, E., Pham, T., Chong, C. Y., Koch, W., Leung, H., Braines, D., & Abdelzaher, T. (2021). Machine learning/artificial intelligence for sensor data fusion–opportunities and challenges. *IEEE Aerospace and Electronic Systems Magazine*, 36(7), 80-93.

Bongiovanni, C., Kaspi, M., Cordeau, J. F., & Geroliminis, N. (2022). A machine learning-driven two-phase metaheuristic for autonomous ridesharing operations. *Transportation Research Part E: Logistics and Transportation Review*, 165, 102835.

Chehri, A., & Mouftah, H. T. (2019). Autonomous vehicles in the sustainable cities, the beginning of a green adventure. Sustainable Cities and Society, 51, 101751.

Cunneen, M. (2023). Autonomous vehicles, artificial intelligence, risk and colliding narratives. In *Connected and automated vehicles: Integrating engineering and ethics* (pp. 175-195). Cham: Springer Nature Switzerland.

Cunneen, M., Mullins, M., & Murphy, F. (2019). Autonomous Vehicles and Embedded Artificial Intelligence: The Challenges of Framing Machine Driving Decisions. *Applied Artificial Intelligence*, *33*(8), 706–731. https://doi.org/10.1080/08839514.2019.1600301

Dwivedi, R., Dave, D., Naik, H., Singhal, S., Omer, R., Patel, P., ... & Ranjan, R. (2023). Explainable AI (XAI): Core ideas, techniques, and solutions. *ACM Computing Surveys*, 55(9), 1-33.

Fahim, S. (2024). Ethical Issues Related to Artificial Intelligence in Autonomous Cars. In *Ethico-Legal Aspect of AI-driven Driverless Cars: Comparing Autonomous Vehicle Regulations in Germany, California, and India* (pp. 129-154). Singapore: Springer Nature Singapore.

Fernandes, E. C., & Estorilio, C. C. A. (2023). The Impact of Artificial Intelligence Technologies in Achieving Better Levels of Maturity in Business Process Management. In F. Deschamps, E. Pinheiro De Lima, S. E. Gouvêa Da Costa, & M. G. Trentin (Eds.), *Proceedings of the 11th International Conference on Production Research – Americas* (pp. 717–725). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-36121-0_89

Fu, Y., Li, C., Yu, F. R., Luan, T. H., & Zhang, Y. (2021). A survey of driving safety with sensing, vehicular communications, and artificial intelligence-based collision avoidance. *IEEE transactions on intelligent transportation systems*, 23(7), 6142-6163.

Gallardo, N., Gamez, N., Rad, P., & Jamshidi, M. (2017). Autonomous decision making for a driver-less car. In *2017 12th System of Systems Engineering Conference (SoSE)* (pp. 1-6). IEEE.

Goriparthi, R. G. (2024). AI-Driven Predictive Analytics for Autonomous Systems: A Machine Learning Approach. *Revista de Inteligencia Artificial en Medicina*, 15(1), 843-879.

Hasan, M., Mohan, S., Shimizu, T., & Lu, H. (2020). Securing vehicle-to-everything (V2X) communication platforms. *IEEE Transactions on Intelligent Vehicles*, 5(4), 693-713.

Hillebrand, M., Lakhani, M., & Dumitrescu, R. (2020). A design methodology for deep reinforcement learning in autonomous systems. *Procedia Manufacturing*, 52, 266-271.

Liao, X., Zhao, Z., Barth, M. J., Abdelraouf, A., Gupta, R., Han, K., ... & Wu, G. (2024). A review of personalization in driving behavior: Dataset, modeling, and validation. *IEEE Transactions on Intelligent Vehicles.*

Lin, Y. (2024). Dijkstra and A* algorithms in automated vehicle driving. In *International Conference on Mechatronic Engineering and Artificial Intelligence (MEAI 2023)* (Vol. 13071, pp. 584-590). SPIE.

Mallozzi, P., Pelliccione, P., Knauss, A., Berger, C., & Mohammadiha, N. (2019). Autonomous vehicles: state of the art, future trends, and challenges. *Automotive systems and software engineering: State of the art and future trends*, 347-367.

Manavaalan, G., Gobikannan, K., Elango, S., & Kumar, P. V. (2024). Energy saving and speed control in autonomous electric vehicle using enhanced manta ray foraging algorithm optimized intelligent systems. *Journal of Power Sources*, 619, 235217.

Meduri, K., Nadella, G. S., Gonaygunta, H., & Meduri, S. S. (2023). Developing a Fog Computing-based AI Framework for Real-time Traffic Management and Optimization. *International Journal of Sustainable Development in Computing Science*, 5(4), 1-24.

Prieto, M., Stan, V., & Baltas, G. (2022). New insights in peer-to-peer carsharing and ridesharing participation intentions: Evidence from the "provider-user" perspective. *Journal of Retailing and Consumer Services*, 64, 102795.

Selver, A. M., Ataç, E., Belenlioglu, B., Dogan, S., & Zoral, Y. E. (2018). Visual and LIDAR data processing and fusion as an element of real time big data analysis for rail vehicle driver support systems. *Innovative Applications of Big Data in the Railway Industry*, 40-66.

Shahzad, A., Gherbi, A., & Zhang, K. (2022). Enabling fog–blockchain computing for autonomous-vehicle-parking system: A solution to reinforce iot–cloud platform for future smart parking. *Sensors*, 22(13), 4849.

Taeihagh, A., & Lim, H. S. M. (2019). Governing autonomous vehicles: emerging responses for safety, liability, privacy, cybersecurity, and industry risks. *Transport reviews*, 39(1), 103-128.

Tien, J. M. (2017). Internet of things, real-time decision making, and artificial intelligence. *Annals of Data Science*, 4, 149-178.

Turan, B., Pedarsani, R., & Alizadeh, M. (2020). Dynamic pricing and fleet management for electric autonomous mobility on demand systems. *Transportation Research Part C: Emerging Technologies*, 121, 102829.

von Ungern-Sternberg, A. (2018). Autonomous driving: regulatory challenges raised by artificial decision making and tragic choices. In *Research handbook on the law of artificial intelligence* (pp. 251-278). Edward Elgar Publishing.

Zeng, T., Semiari, O., Chen, M., Saad, W., & Bennis, M. (2022). Federated learning on the road autonomous controller design for connected and autonomous vehicles. *IEEE Transactions on Wireless Communications*, 21(12), 10407-10423.