The American Journal of
Engineering and Technology

ISSN 2689-0984 | Open Access

TYPE Original Research
PAGE NO. 37-43
DOI 10.37547/tajet/Volume07Issue02-07

Check for updates

Challenges and solutions in the integration of robotic systems into existing infrastructure

Pavel Sidorov

Field engineer at Swisslog healthcare, Irvine, CA, USA

OPEN ACCESS

SUBMITED 16 December 2024
ACCEPTED 18 January 2025
PUBLISHED 20 February 2025
VOLUME Vol.07 Issue02 2025

CITATION

Pavel Sidorov. (2025). Challenges and solutions in the integration of robotic systems into existing infrastructure. The American Journal of Engineering and Technology, 7(02), 37–43.
https://doi.org/10.37547/tajet/Volume07Issue02-07

Abstract: This article examines the features, challenges, and potential solutions associated with the integration of robotic systems into existing infrastructure. The relevance of this topic is driven by the widespread implementation of robotics across various sectors, including industry, logistics, agriculture, and other fields. The objective of this study is to systematize existing approaches and perspectives on integration processes, analyze key contradictions in scientific literature, and identify underexplored aspects that hinder the effective deployment of these technologies.

Discrepancies in the literature are linked to the lack of standardization in system architectures, limited real-world validation of control algorithms, and insufficient attention to legal considerations. It is concluded that successful integration requires a systematic approach encompassing standardization, the development of advanced control algorithms, adaptation of cloud technologies, and the mandatory consideration of social factors.

The author's contribution lies in structuring modern trends in integration strategies, including the shift towards modularity, scalability, active use of artificial intelligence, standardization, cloud-based solutions, and hybrid interaction systems. Additionally, research gaps are identified. The presented findings will be valuable for developers of robotic solutions, automation researchers, and enterprise managers planning the implementation of robotic systems.

Keywords: Control algorithms, system architecture, integration, infrastructure, robotics, simulation, standardization.

Introduction: Modern technological advancements have driven the rapid development of robotics, making it an indispensable and highly sought-after technology across various industries, including manufacturing, healthcare, logistics, and agriculture. However, the integration of robotic systems into existing infrastructure presents numerous challenges and obstacles, which can be attributed to technological, economic, and social determinants.

The primary objective of these integration processes is to achieve a synergistic effect, where robotic solutions not only replace or complement existing infrastructure elements but also create new opportunities for:

- Optimization of operations
- Improvement of accuracy
- Reduction of resource consumption
- Mitigation of various risks

The main challenge in the current landscape is the timely identification of barriers to robotic integration and the development of effective approaches to overcoming them. Addressing these challenges requires minimizing associated risks while maximizing the benefits of deploying robotic systems.

METHODS

The reviewed literature on the discussed topic can be categorized into the following areas: system architectures, control and planning algorithms, specialized applications of robotics, and market aspects of integration.

Studies by L. Siefke, V. Sommer, and co-authors [7] emphasize a decentralized service-oriented architecture for implementing robotic systems, enhancing the flexibility and scalability of robotic solutions. M. Marschall and colleagues [4] employ modeling and simulation methods to determine the optimal number of mobile robots required for reconfigurable modular production systems, demonstrating the significance of simulation-based approaches in system design.

Issues related to control and planning algorithms are extensively covered in the works of J. Gómez, Ch. Treesatayapun, A. Morales [2], Zh. Yu, K. Pang, Ch. Hua [10]. These studies describe identification methods based on feedback from optical sensors, which are crucial for precise positioning. Approaches to global compositional learning with constraints on tracking errors are proposed, significantly contributing to the resilience and adaptability of control mechanisms. P. Tavares and co-authors [8] examine optimal trajectory planning algorithms adapted for systems with high redundancy, addressing challenges related to spatial constraints in real-world environments.

Publications on specialized applications of robotics highlight its use in specific industries. R. Yu. Polyakov [5] explores portable aerial systems for early fire source detection, emphasizing their importance for monitoring tasks. S.K. Kota and Sh.S. Thakur [3] analyze control mechanisms based on programmable flight plans, which are relevant for autonomous logistics and aerial surveys. G.P. Vinogradov [9] studies intelligent control schemes, focusing on adaptive behavior models.

Economic aspects are discussed in the work of R. Sharma [6], who analyzes market trends and challenges in integrating robotic solutions. Additionally, in the context of cloud technologies and their role in robotics, V. Dawarka and G. Bekaroo [1] conduct a systematic analysis demonstrating their potential for improving interaction and management on a global scale.

The literature review has revealed several contradictions. While architectural solutions and decentralized approaches are actively discussed in academic research, their practical implementation requires further investigation in terms of standardization and compatibility. Algorithms, particularly those incorporating asymmetric constraints, need additional validation to confirm their effectiveness. The market availability of robotic technologies remains insufficiently linked to technical and social aspects, such as workforce training and ethical considerations.

Certain aspects, including cybersecurity challenges and legal issues of integration, remain underexplored. This results in gaps in understanding the risks associated with large-scale deployment of robots.

The study employs methods of comparative analysis, statistical evaluation, systematization, and generalization.

RESULTS AND DISCUSSION

The integration of robotic systems into existing infrastructure involves the synchronization and adaptation of robotic complexes with pre-existing elements, including:

- Technological components
- Organizational structures
- Information systems

This process encompasses their implementation in manufacturing, logistics, healthcare, construction, and other sectors to enhance efficiency, productivity, safety, and resilience [2, 8].

The global robotics system integration market was estimated at approximately $8.5 billion in 2023 and is projected to reach around $21 billion by 2032, growing at a compound annual growth rate (CAGR) of 10.7%

from 2024 to 2032 [6] (Fig. 1).

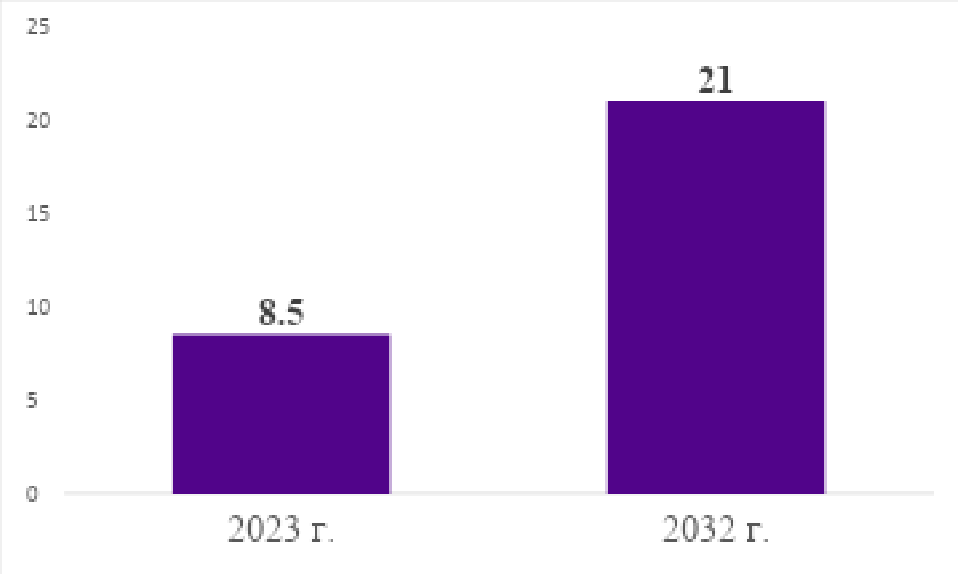

Fig. 1. Projected dynamics of the global robotics system integration market, billion US dollars (compiled by the author based on [6])

The essence of integration efforts lies in ensuring compatibility between new technological solutions and established system architectures, including:

- Equipment
- Software
- Communication protocols
- Human resource management [2, 5, 8]

It is particularly important to emphasize that this process requires not only the modernization of technical resources but also a revision of approaches to workflow organization, workforce training, and regulatory adjustments.

The analyzed integration process is influenced by key trends that reflect technological advancements, economic realities, and societal dynamics (Fig. 2). These trends define the directions for adapting robotics and the pathways for its inclusion in traditional industries.

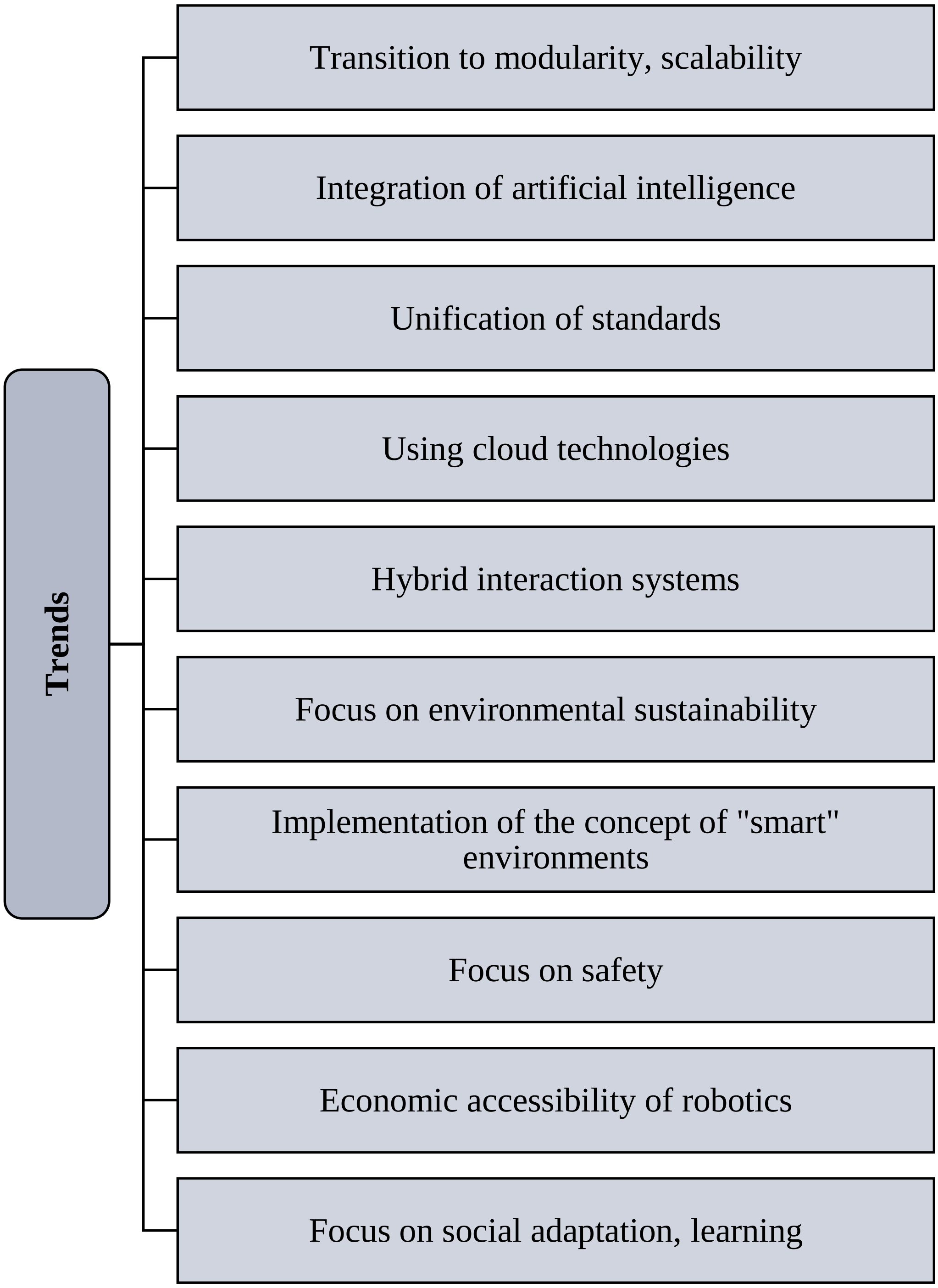

Fig. 2. Trends in the integration of robotic systems into the existing infrastructure (compiled by the author based on [1-3, 8, 10])

Modern developments are increasingly being designed with modularity principles in mind, allowing enterprises to adapt robots to existing processes. The use of standardized interfaces and modular constructions enables the expansion of functionality as needed while maintaining compatibility with legacy equipment.

The advancement of artificial intelligence contributes to increased autonomy. Machine learning and data analysis allow robots to adapt to the specifics of existing processes and interact with other systems in real-time, minimizing the need for manual configuration.

One of the most prominent trends is the development of international standards aimed at simplifying the integration of robotic solutions. This includes the unification of communication protocols, interfaces, and connection methods, reducing both time and financial costs.

The transition to cloud-based robot management platforms significantly accelerates integration steps by reducing dependence on local infrastructure. This approach provides centralized access to data, analytics, and control algorithms.

The growing popularity of hybrid systems that combine human and robotic labor highlights the importance of developing human-centered interfaces. These systems incorporate technologies such as speech recognition, gesture control, and biometric signals, facilitating smoother integration into the work environment.

The trend of using robotic solutions to achieve sustainable development goals is rapidly gaining momentum. Robots are increasingly employed to enhance energy efficiency, reduce waste, and contribute to environmentally oriented infrastructures.

The issue is also being explored in the context of smart manufacturing, cities, and buildings. In this case, multiple devices and sensors are integrated into a unified network where robots play a key role in monitoring, maintenance, and automation tasks.

Amid increasing security requirements, the integration of robotics is accompanied by the implementation of failure prevention and cybersecurity measures. This is particularly crucial for autonomous vehicles and medical robots.

The decreasing cost of robotic solutions, driven by mass production and technological advancements, expands access to integration processes. This creates additional opportunities for small and medium-sized enterprises that previously could not afford to implement such systems.

Finally, greater emphasis on training and retraining personnel facilitates integration. Programs focused on developing skills for interacting with robots are being introduced, reducing employee resistance and significantly accelerating the adoption of these technologies.

Regarding the systematization of challenges, it is appropriate to categorize them into three groups (Fig. 3).

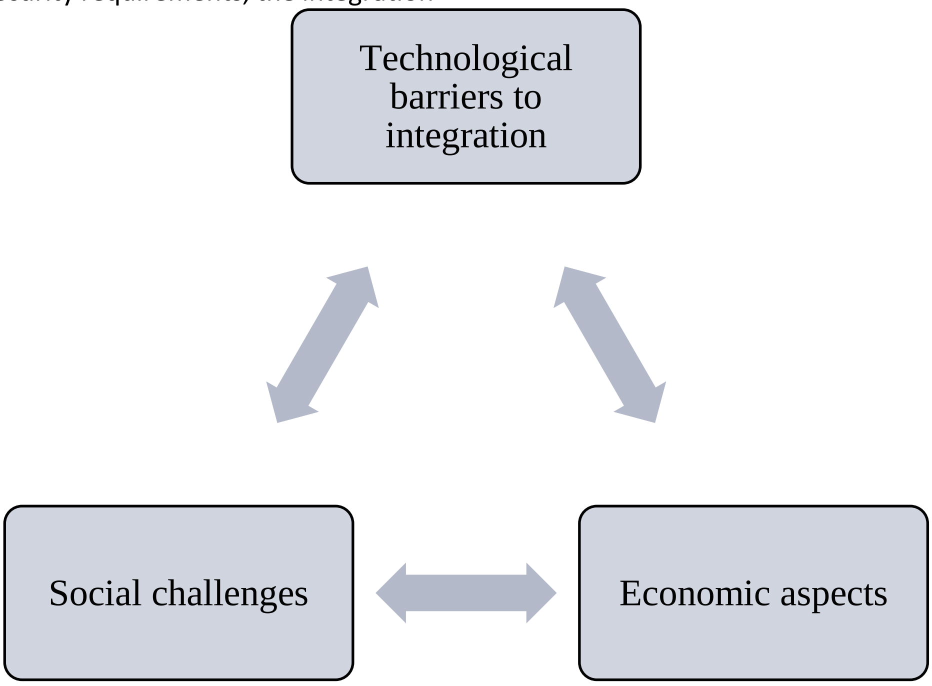

Fig. 3. Identification of groups of problems of integration of robotic systems into the existing infrastructure (compiled by the author on the basis of [3, 8, 9])

When discussing the technological aspect, one of the key challenges is the incompatibility of robotic systems with existing technical standards and equipment. Many enterprises continue to operate machinery designed decades ago, which was not intended for integration with robotic modules. This necessitates either modernization or a complete replacement of outdated systems, requiring substantial financial investment.

Another significant issue relates to software development. Robots require the integration of complex control algorithms, which are often incompatible with existing information systems. Developing universal protocols for seamless interaction between different platforms remains a highly complex task.

Additionally, reliability and safety concerns play a decisive role. The deployment of autonomous vehicles or industrial robots introduces risks of unforeseen malfunctions, which can lead to substantial financial losses or even pose threats to human life.

From an economic standpoint, the integration of robotics demands significant investment not only in equipment but also in workforce training, adaptation of production processes, and infrastructure modernization. For small and medium-sized enterprises, such expenditures are often prohibitive. Furthermore, many organizations face low profitability of robotic systems during the initial phases of implementation, which reduces motivation for adoption.

Social perception is also a central factor in integration processes. Concerns about job losses, exacerbated by low awareness of workforce retraining opportunities, lead to resistance from employees and labor unions. In some cases, this results in delays in automation projects.

Ethical and regulatory issues provoke significant debate. For instance, the use of robotic systems in medicine requires strict oversight to ensure patient rights are protected, while autonomous vehicles raise questions of liability in the event of accidents.

To address the issue of system incompatibility, the implementation of standardized protocols to unify equipment is necessary. International organizations and governmental bodies must play a key role in developing uniform standards and documentation.

A promising strategy involves the previously mentioned modular approach to robotic system design, which enables equipment to be adapted to the specific needs of businesses. The use of artificial intelligence to optimize interaction also contributes positively to increased flexibility.

Economic barriers can be overcome through subsidy programs and tax incentives for companies adopting robotics. An essential element is the development of educational programs focused on retraining personnel for automated production environments.

Social challenges can be mitigated through public awareness campaigns that highlight the benefits of robotics. It is important to emphasize that automation does not eliminate jobs but rather transforms the labor market, creating numerous new opportunities for skilled professionals.

CONCLUSIONS

The integration of robotic systems into existing infrastructure is a complex yet essential process in ensuring the sustainable development of modern industries. The transition toward modularity and scalability, active involvement of artificial intelligence, standardization, the use of cloud technologies, hybrid interaction systems, emphasis on environmental sustainability, implementation of smart environments, focus on security, economic accessibility of robotics, and social adaptation through training are all interconnected trends that reflect the global trajectory toward the widespread adoption of robotics in practical applications. These trends contribute to the formation of adaptive, resilient, and highly efficient infrastructures that meet the demands of the modern world.

Overcoming the technological, economic, and social barriers outlined in this study requires a systematic approach that relies on technical innovation, economic support, and public engagement. Only through coordinated efforts among various stakeholders can the effective implementation of robotics be achieved, leading to progress and a significant improvement in quality of life.

REFERENCES

Dawarka V. Building and evaluating cloud robotic systems: a systematic review / V. Dawarka, G. Bekaroo // Robotics and Computer-Integrated Manufacturing. – 2022. – Vol. 73.

Gómez J. Data-driven identification and control based on optic tracking feedback for robotic systems / J. Gómez, Ch. Treesatayapun, A. Morales // The International Journal of Advanced Manufacturing Technology. – 2021. – Vol. 113. – No. 5. – Pp. 1485-1503.

Kota S.K. An evaluation of flying robotic systems using software controlled flight plans in its embedded systems / S.K. Kota, Sh.S. Thakur // Technoarete Transactions on Industrial Robotics and Automation Systems. – 2022. – Vol. 2. – No. 4.

Marschall M. Defining the number of mobile robotic systems needed for reconfiguration of modular manufacturing systems via simulation / M. Marschall, M. Gregor, L. Ďurica, V. Vavrík, T. Bielik, P. Grznár, S. Mozol // Machines. – 2022. – Vol. 10. – No. 5. – P. 316.

Polyakov R.Yu. Application of portable flying robotic systems for early detection of an ignition source / R.Yu. Polyakov // Periodico Tche Quimica. – 2020. – Vol. 17. – No. 36. – Pp. 1082-1098.

Sharma R. Robotics System Integration Market Outlook / R. Sharma // URL: https://dataintelo.com/report/robotics-system-integration-market (date of request: 01/28/2025).

Siefke L. Robotic systems of systems based on a decentralized service-oriented architecture / L. Siefke, V. Sommer, B. Wudka, C. Thomas // Robotics. – 2020. – Vol. 9. – No. 4. – Pp. 1-10.

Tavares P. Optimal automatic path planner and design for high redundancy robotic systems / P. Tavares, D. Marques, P. Malaca, G. Veiga, P. Costa, A.P. Moreira // Industrial Robot. – 2020. – Vol. 47. – No. 1. – Pp. 131-139.

Vinogradov G.P. Patterns in intelligent control systems for robotic systems / G.P. Vinogradov // Studies in Systems, Decision and Control. – 2021. – Vol. 352. – Pp. 15-28.

Yu Zh. Global composite learning fixed-time control of robotic systems with asymmetric tracking error constraints / Zh. Yu, K. Pang, Ch. Hua // IEEE Transactions on Industrial Electronics. – 2023. – Vol. 70. – No. 7. – Pp. 7082-7091.