LEVERAGING SMART TECHNOLOGIES TO ENHANCE LOGISTICS EFFICIENCY

Blen KHAN FORGU. Vytautas Magnus University Agriculture Academy, Faculty of Bioeconomy Development, email: blen.khan.forgu@stud.vdu.lt

Abstract

The integration of emerging technologies like blockchain, autonomous systems, artificial intelligence, machine learning, and the Internet of Things (IoT) is causing a significant upheaval in the logistics sector. Customer satisfaction, supply chain optimization, cost reduction, and operational efficiency have all significantly increased as a result of these developments. The use of these technologies to improve logistics operations—enabling real-time tracking, predictive analytics, route optimization, and increased transparency—is known as smart logistics, or logistics 4.0. This paper examines how various technologies affect the effectiveness of logistics, with a particular emphasis on the use of blockchain, IoT, AI, ML, and autonomous systems to enhance logistical procedures. The study discusses the difficulties of putting smart logistics into practice while highlighting its many benefits, including lower costs, quicker deliveries, and more dependable systems. These difficulties include regulatory barriers, expensive initial investment costs, data security issues, and technical constraints. The results indicate that, in spite of these obstacles, the logistics sector must continue to embrace smart technology in order to become a more customer-focused, sustainable, and efficient one. The present state of smart logistics is thoroughly examined in this study, along with the technologies' promise for the future and suggestions for removing obstacles to its effective application.

***Keywords**:* Smart Technologies, Tracking, Route optimization, artificial intelligence, machine learning.

Introduction

The use of smart technology has brought about major changes in the logistics sector, which is a vital component of the global economy. Due to the demand for faster, more affordable, and transparent services, businesses have been forced to incorporate cutting-edge technologies that can improve customer satisfaction and optimize operations. Using cutting-edge technologies like internet of things (IoT), artificial intelligence (AI), machine learning (ML), blockchain, and autonomous systems to optimize supply chains and boost overall operational efficiency is known as smart logistics, or logistics 4.0. Providing real-time visibility into logistics processes, cutting down on inefficiencies, and enabling data-driven decision-making are the main goals of smart logistics. Thanks to the Internet of Things, companies may better understand inventory levels, shipment conditions, and possible interruptions by tracking goods across the supply chain, from manufacture to final delivery. Blockchain guarantees transparency and security by permitting decentralized, unchangeable record-keeping, while AI and ML further improve this by offering predictive analytics, streamlining supply routes, and enhancing demand forecasts. Drones and self-driving trucks are examples of autonomous vehicles, which are another innovation that can assist in cutting delivery costs and times, particularly in last-mile delivery situations. With an emphasis on the fundamental areas of real-time tracking, route optimization, transparency, and automation, this article investigates how these technologies affect the effectiveness of logistics. It offers a thorough understanding of how smart logistics is revolutionizing the industry by analyzing both the benefits and the difficulties of putting these technologies into practice. The following inquiries serve as a guide for the study: How are logistics operations improved by IoT, AI, ML, blockchain, and autonomous systems? What obstacles must businesses overcome to implement these technologies? And how may these obstacles be removed to optimize smart logistics' potential?

Research Problem. The article examines the research problem of leveraging smart technologies (IoT, AI, blockchain, autonomous systems) to enhance logistics efficiency, while identifying key barriers to their adoption. Despite the proven potential of these technologies to optimize supply chains through real-time tracking, predictive analytics, and cost reduction, their implementation faces significant challenges, including high costs, regulatory constraints, technical limitations, and organizational resistance. The study addresses gaps in existing literature by providing a holistic view of how these technologies interact, rather than analysing them in isolation, and highlights practical adoption hurdles through secondary data analysis. However, the research is limited by its reliance on existing literature, which may overlook recent developments, and lacks primary validation through case studies or expert input. The findings emphasize the need for interdisciplinary approaches, policy adjustments, and further empirical research to overcome adoption barriers and fully realize the benefits of smart logistics technologies.

Research aim – This study aims to assess how smart technologies such as IoT, AI, ML, blockchain, and autonomous systems maximize supply chain efficiency, lower costs, and optimize logistics while highlighting major implementation problems. The following **objectives** have been chosen to achieve the aim:

1. To investigate the role of IoT in providing real-time visibility and enhancing operational effectiveness, while exploring how artificial intelligence and machine learning can improve demand forecasting, route optimization, and predictive analytics in smart logistics and supply chain management.
2. To assess how blockchain might help to increase responsibility, security, and openness inside logistics systems.

3. Looking at using autonomous technology, including drones and self-driving cars to lower delivery times and expenses.

4. To examine the possible obstacles and difficulties to the general acceptance of smart technology in the logistics industry.

Research Design. This study employs a systematic literature review methodology combined with thematic analysis to comprehensively examine how smart technologies enhance logistics efficiency. The research follows a structured process of identification, screening, eligibility assessment, and synthesis of relevant studies. This research looked at how smart technology might affect logistics using a mixed-methods approach. Apart from reviewing past studies. This research was carried out mainly using secondary methodology while focusing on existing literature reviews and materials like books, papers, scholarly journals, and web databases. Data is compared, trends found, and conclusions drawn using content analysis. The study looks at the advantages and challenges that smart logistics presents.

Results and Interpretive Analysis

Role of IoT in providing real-time visibility and enhancing operational effectiveness

The integration of the internet of things and artificial intelligence in logistics and supply chain management is revolutionizing operational effectiveness by providing real-time visibility and enhancing decision-making processes. IoT enables the continuous monitoring of supply chain activities, allowing for the identification of areas needing improvement and proactive management of potential disruptions, which leads to increased visibility and customer satisfaction. Artificial intelligence and machine learning further enhance these capabilities by improving demand forecasting, route optimization, and predictive analytics. These technologies allow for accurate demand predictions, optimized delivery routes, and efficient inventory management, ultimately reducing operational costs and improving responsiveness to market changes. The synergy of IoT with AI-driven analytics facilitates real-time data collection and processing, enabling logistics systems to adapt swiftly to dynamic market conditions and optimize performance. As a result, businesses can achieve greater efficiency, sustainability, and resilience in their supply chain operations, positioning themselves competitively in the evolving digital landscape (Zrelli et al., 2024).

Key Benefits of Blockchain in Logistics

Blockchain technology has the potential to significantly enhance responsibility, security, and openness within logistics systems. By providing a decentralized and immutable ledger, blockchain ensures transparency and traceability, allowing real-time visibility into the movement of goods across the supply chain. This transparency is crucial for fostering trust among stakeholders, as it reduces the risk of fraud and theft by ensuring data integrity and security (Ahmad et al., 2021). The use of smart contracts further enhances these benefits by automating transactions and ensuring compliance with predefined conditions, thereby reducing errors and administrative costs (Ugochukwu et al., 2024). Additionally, blockchain's decentralized nature eliminates the need for intermediaries, which not only streamlines operations but also minimizes delays and reduces costs. The integration of blockchain with other technologies, such as internet of things, further bolsters security by enabling real-time monitoring and secure data storage, addressing challenges related to data integrity and secure storage. Overall, blockchain technology offers a transformative approach to logistics, promoting more efficient, reliable, and cost-effective supply chain management while enhancing responsibility, security, and openness (Tijan et al., 2019).

Use of autonomous technology

The integration of autonomous technology, including drones and self-driving cars, is poised to significantly lower delivery times and expenses in logistics. These technologies offer innovative solutions for last-mile delivery, optimizing routes, reducing operational costs, and enhancing efficiency. The integration of autonomous technology, including drones and self-driving cars, is poised to revolutionize delivery systems by significantly lowering delivery times and expenses. Autonomous vehicles (AVs) and drones are transforming logistics by optimizing routes, reducing fuel consumption, and minimizing the need for human intervention, which collectively enhance efficiency and reduce costs. The use of drones in last-mile delivery, for instance, offers rapid, contactless transportation of goods, especially in challenging terrains and congested urban areas, thereby reducing delivery times (Nweje & Onuma, 2025). Additionally, the combination of drones with autonomous vehicles, as seen in the autonomous vehicle routing problem with drones (A-VRPD), optimizes operational costs and increases profits for delivery companies by efficiently scheduling routes and selecting the best AVs for specific delivery tasks. Moreover, the application of AI in dynamic route planning further enhances the efficiency of these autonomous systems by continuously adjusting delivery routes based on real-time data, such as traffic patterns and weather conditions, which helps in reducing operational disruptions and delivery times (Adeoye et al., 2025). Despite these advancements, challenges such as regulatory hurdles, infrastructure limitations, and public acceptance remain significant barriers to widespread adoption (Odumbo et al., 2025). However, the potential for cost savings and increased delivery speed makes the integration of autonomous technology a promising solution for the logistics industry, with companies like Amazon and UPS actively exploring these innovations. Overall, the adoption of autonomous technology in delivery systems represents a paradigm shift towards a more efficient and sustainable supply chain ecosystem.

Challenges & difficulties

The general acceptance of smart technology in the logistics industry faces several obstacles and difficulties that hinder its widespread adoption. One significant challenge is the technical limitations associated with the internet of things,

such as issues with radio frequency identification, wireless sensor networks, and the standardization of IoT technologies. These technical barriers are compounded by concerns over data acquisition, processing, and security, which are critical for the effective implementation of IoT in logistics (Tran-Dang et al., 2020). Additionally, the logistics industry grapples with organizational and human resource-related barriers, including resistance to change and the need for a cultural shift towards embracing smart logistics solutions. Economic factors, such as the high initial costs of implementing technologies like AI and blockchain, further complicate the adoption process, especially for smaller businesses. Moreover, regulatory and legal frameworks often lag behind technological advancements, creating uncertainties that can deter investment in smart logistics (Rathore et al., 2022). To overcome these obstacles, it is essential to foster top management support, develop robust technological infrastructures, and ensure compliance with privacy laws to build trust and reliability in smart logistics systems (Adesoga et al., 2023). Addressing these challenges is crucial for the logistics industry to fully leverage the benefits of smart technology, such as increased efficiency, cost reduction, and enhanced decision-making capabilities. Maintaining a competitive advantage and improving efficiency depend on intelligent technology in logistics. They augment tasks including production, transportation, and information management. Industry 4.0 trends encompass personalization, digitization, autonomy, and sustainable logistics. On-demand manufacturing systems and autonomous vehicles revolutionize last-mile deliveries. Intelligent technologies in logistics include decision support, identification and tracking, information distribution, and automation and robotics. Artificial Intelligence and Big Data enhance decision-making, while the Internet enables real-time monitoring and security. Cloud computing improves collaboration among logistics stakeholders, enabling firms to meet client demands more effectively. The amalgamation of information and communications technology with industrial and automation technology is driving innovation in logistics. Logistics management is crucial for a company's efficiency in supply chain production and distribution. Attaining a balance between delivery and processing time poses difficulty that might lead to increased service costs and inefficiencies. The dissemination of information is an essential element in the administration of goods and inventory. Innovative technologies, including internet of things sensors and artificial intelligence, have shown promise in enhancing efficiency and effectiveness in logistics operations. Organizations invest resources to intelligent technology to automate processes across several stages, including production, transportation, storage, and distribution. Industry 4.0 trends emphasize individualization, personalization, servitization, accessibility, autonomy, digitalization, and sustainable logistics.

Logistics management faces challenges in optimizing delivery and processing times, potentially leading to waste and increased costs if not well controlled (Strandhagen et al., 2017). Technologies like IoT sensors and AI improve logistical operations, including manufacturing and transportation (Feng et al., 2021). These technologies automate activities such as storage, dissemination, and data transport. Smart technologies can be classified into four key categories: decision-making support, identification and tracking, information distribution, automation and robotics. Artificial intelligence-driven decision-making and big data analytics enable the assessment of client demand data and inventory levels, hence permitting automated decision-making processes (Govindan et al., 2018). Big data technology extracts valuable insights from large data sets, enhancing product tracking, inventory management, and material supply efficiency. Smart technologies enhance consumer experience by providing greater convenience, transparency, and opportunities for personalization. The advent of smart logistics technology has led to a consensus on the integration and transmission of logistical information through cloud computing. Cloud technology integrates millions of sensors, cameras, displays, and communication devices within cloud data centers to leverage substantial processing and storage capabilities under centralized management.

1. Internet of Things and Immediate Awareness. With its exceptional real-time tracking and monitoring capabilities, the internet of things is crucial to contemporary logistics. Logistics firms can monitor shipments, keep an eye on inventory levels, and assess the condition of goods throughout transit by deploying IoT-enabled sensors in infrastructure, trucks, and products. This real-time visibility allows companies to anticipate potential disruptions, minimize delays, and enhance operational efficiency. Moreover, IoT data helps optimize routing, assess vehicle performance, and save maintenance expenses.

2. Exploring Artificial intelligence and machine learning for Predictive Analytics and Optimization. Through their facilitation of data-driven decision-making, artificial intelligence and machine learning have fundamentally transformed logistics. Examining large volumes of data, artificial intelligence systems enhance supply chain projections, consumer preferences, and delivery paths. Machine learning algorithms consistently integrate previous data to improve operational efficiency, allowing logistics businesses to proactively mitigate prospective challenges. By means of route optimization, artificial intelligence helps companies to avoid traffic congestion, decrease fuel consumption, and raise delivery efficiency.

3. Blockchain for Transparency and Security. Blockchain technology is being used progressively in logistics to improve security, traceability, and openness across the supply chain. Decentralized ledgers facilitate blockchain in real-time cargo monitoring, document authentication, and transaction validation without intermediaries. This transparency reduces the probability of fraud and errors, while guaranteeing that all supply chain players have accurate and current information. Blockchain significantly enhances international logistics by optimizing the customs process and minimizing documentation.

4. Unmanned aerial systems and autonomous vehicles. By reducing human error, increasing operational efficiency, and cutting costs, autonomous vehicles including drones and self-driving trucks will transform the logistics sector. Last-mile deliveries increasingly use drones, a faster and more cost-effective substitute for more conventional delivery systems. Particularly in long-distance transportation, autonomous trucks run nonstop without requiring driver

breaks, therefore reducing transportation costs and accelerating delivery times. Notwithstanding technological and legal obstacles, the spread of driverless cars is predicted to quicken noticeably in the next years.

Conclusions

The Internet of Things (IoT), artificial intelligence (AI), machine learning (ML), blockchain, and autonomous systems and their potential to revolutionize the logistics business have been investigated in this study. Following a comprehensive examination of the most recent research, it has been determined that the utilization of these technologies results in a substantial improvement in operational efficiency, a reduction in expenses, and an increase in customer satisfaction. Within the realm of logistics operations, the study highlights the significance of embracing these advances in order to enhance real-time visibility, automate procedures, and cultivate more transparency and security. Additionally, the report identifies important obstacles that stand in the way of the adoption and integration of these technologies within the logistics industry. Technical obstacles, high implementation costs, concerns about regulatory environments, and reluctance to change within businesses are some of the factors that fall under this category. The report, on the other hand, emphasizes that overcoming these obstacles is necessary to take advantage of the long-term benefits that smart technologies provide, particularly about improving corporate operations and providing greater customer service. These technologies are undergoing a process of evolution that is being driven by ongoing investment and development, which offers excellent prospects for the forthcoming logistics industry. The findings of this study provide significant new information to the expanding body of knowledge concerning the implementation of intelligent technology in the logistics industry. Logistics organizations need to overcome both technical and organizational constraints to fully exploit the potential of these innovations. Particular attention should be paid to infrastructure, data security, and the cultivation of an innovative culture because these are the most important factors. The logistics industry has the potential to pave the way for operations that are smarter, more efficient, and more sustainable if it makes efforts to promote collaboration among technology suppliers, industry stakeholders, and regulators. This will ultimately result in increased competitiveness and growth in a market that is becoming increasingly dynamic. This article proposes that for logistics organizations to successfully utilize the full potential of these technologies, it is essential for them to make investments in infrastructure, address issues regarding data security, and cultivate a culture of innovation. To establish an atmosphere that is favorable to the implementation of intelligent logistics solutions, technology providers, regulatory bodies, and industry players need to work together through collaboration. The continued development of these technologies has the potential to result in the creation of logistics systems that are more effective, environmentally friendly, and customer-focused. This would be a significant driver of innovation and competition within the sector.

References

1. Ahmad, R., Hasan, H., Jayaraman, R., Salah, K., & Omar, M. (2021). Blockchain applications and architectures for port operations and logistics management. *Research in transportation business and management*, 100620. https://doi.org/10.1016/J.RTBM.2021.100620.
2. Ugochukwu, N., Goyal, S., Rajawat, A., Verma, C., & Illés, Z. (2024). Enhancing Logistics With the Internet of Things: A Secured and Efficient Distribution and Storage Model Utilizing Blockchain Innovations and Interplanetary File System. *IEEE Access*, 12, 4139-4152. https://doi.org/10.1109/ACCESS.2023.3339754.
3. Tijan, E., Aksentijević, S., Ivanić, K., & Jardas, M. (2019). Blockchain Technology Implementation in Logistics. *Sustainability,* 11(4), 1185. https://doi.org/10.3390/SU11041185.
4. Odumbo, O., & Onuma, E. (2025). The future of autonomous vehicles and drones in supply chain delivery. *International Journal of Science and Research Archive*, 14(01), 582-602. https://doi.org/10.30574/ijsra.2025.14.1.0117.
5. Tran-Dang, H., Krommenacker, N., Charpentier, P., & Kim, D. (2020). The Internet of Things for Logistics: Perspectives, Application Review, and Challenges. *IETE Technical Review*, 39, 93 - 121. https://doi.org/10.1080/02564602.2020.1827308.
6. Adesoga, T., Ajibaye, T., Nwafor, K., Imam-Lawal, U., Ikekwere, E., & Ekwunife, D. (2024). The rise of the "smart" supply chain: How AI and automation are revolutionizing logistics. *International Journal of Science and Research Archive,* 12(02), 790–798. https://doi.org/10.30574/ijsra.2024.12.2.1304.
7. Rathore, B., Gupta, R., Biswas, B., Srivastava, A., & Gupta, S. (2022). Identification and analysis of adoption barriers of disruptive technologies in the logistics industry. *The International Journal of Logistics Management,* 3(5). https://doi.org/10.1108/ijlm-07-2021-0352.
8. Cimini, C., Boffelli, A., Lagorio, A., Kalchschmidt, M., & Pinto, R. (2020b). How do industry 4.0 technologies influence organisational change? An empirical analysis of Italian SMEs. *Journal of Manufacturing Technology Management*, 32(3), 695–721. https://doi.org/10.1108/jmtm-04-2019-0135
9. Zrelli, I., & Rejeb, A. (2024). A bibliometric analysis of IoT applications in logistics and supply chain management. *Heliyon*, 10. https://doi.org/10.1016/j.heliyon.2024.e36578.
10. Adeoye, Y., Onotole, E., Ogunyankinnu, T., Aipoh, G., Osunkanmibi, A., & Egbemhenghe, J. (2025). Artificial Intelligence in Logistics and Distribution: The function of AI in dynamic route planning for transportation, including self-driving trucks and drone delivery systems. *World Journal of Advanced Research and Reviews*, 25(02), 155-167 https://doi.org/10.30574/wjarr.2025.25.2.0214.

11. Nweje, N. U., & Onuma, N. E. P. (2025). The future of autonomous vehicles and drones in supply chain delivery. *International Journal of Science and Research Archive*, 14(1), 582–602. https://doi.org/10.30574/ijsra.2025.14.1.0117
12. Feng, B., Ye, Q. Operations management of smart logistics: A literature review and future research. *Frontiers of Engineering Management*, 8, 344-355. https://doi.org/10.1007/s42524-021-0156-2
13. Strandhagen, J. W., Alfnes, E., Strandhagen, J. O., & Vallandingham, L. R. (2017). The fit of Industry 4.0 applications in manufacturing logistics: a multiple case study. *Advances in Manufacturing*, 5(4), 344–358. https://doi.org/10.1007/s40436-017-0200-y
14. Govindan, K., Cheng, T., Mishra, N., & Shukla, N. (2018). Big data analytics and application for logistics and supply chain management. *Transportation Research Part E Logistics and Transportation Review*, 114, 343–349. https://doi.org/10.1016/j.tre.2018.03.011