International Journal of Economics, Politics, Humanities & Social Sciences
Vol: 8 Issue: 4 e-ISSN: 2636-8137 Summer 2025

Industry 4.0 and Digitalization: New Technological Trends in Logistics*

Maide Betül Aksoy[1], Burcu Yengil Bülbül[2]

DOI: *10.59445/ijephss.1681131*

Atıf / Cite: Aksoy, M. B., Yengil Bülbül, B. (2025). Industry 4.0 and digitalization: New technological trends in logistics, *International Journal of Economics, Politics, Humanities & Social Sciences*, 8(4), 357-367, https://doi.org/10.59445/ijephss.1681131

Araştırma Makalesi / Research Article

Makale İlk Gönderim Tarihi / Recieved (First): 25.04.2025 **Makale Kabul Tarihi / Accepted:** 04.06.2025

Abstract

Technological advancements and the production of knowledge, which began with the First Industrial Revolution and have rapidly accelerated since, have significantly influenced businesses across various sectors. For the logistics sector to remain competitive, it must adapt to new technologies and embrace digital transformation. In order to provide faster, cheaper, more reliable, traceable, and sustainable services, technologies such as big data, artificial intelligence, the Internet of Things (IoT), augmented reality, and wearable sensors are already being implemented in logistics, with many more expected to be adopted in the near future. This study highlights the effects of digitalization in the logistics sector through applied and up-to-date examples. It demonstrates how digital technologies have addressed sector-specific challenges through recent collaborations such as UPS–Fast Radius, SkyCell, and DHL–Volkswagen. Furthermore, the Logistics Trend Radar 6.0 and 7.0 reports are analyzed from an academic perspective, and the roles of big data, IoT, augmented reality, and robotic automation in the sector are explained. By discussing both the advantages and disadvantages of digitalization, the study provides a unique contribution to the literature by addressing the lack of practice-oriented, example-based research in the field.

Keywords: Digitalization, Industry 4.0, Logistics, Technological Trends.

* This article is the revised and edited version of the unpublished conference presentation entitled "Industry 4.0 and Digitalization: New Technological Trends in Logistics", orally delivered by Maide Betül Aksoy at the 5th International Conference on Future of Business, Management and Economics, 2023, Rome, Italy.

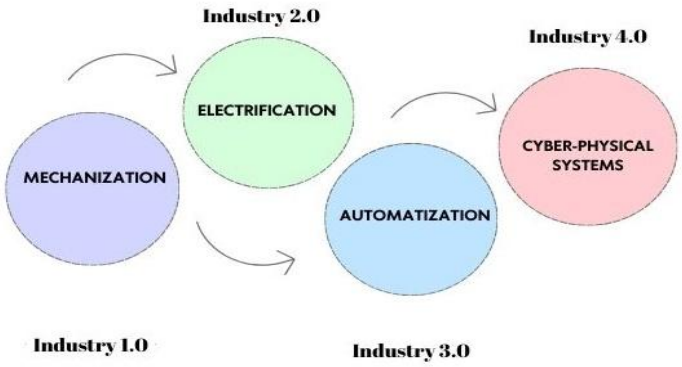
[1] Arş. Gör. / *Res. Assist.*, Gaziantep Üniversitesi, İktisadi ve İdari Bililer Fakültesi, Uluslararası Ticaret ve Lojistik Bölümü / *Gaziantep University, Faculty of Economics and Administrative Sciences, Department of International Trade and Logistics*, Gaziantep, Türkiye, betulaksoy@gantep.edu.tr, ORCID: https://orcid.org/0000-0001-6805-1099.

[2] **Sorumlu Yazar / Corresponding Author,** Arş. Gör. / *Res. Assist.*, Gaziantep Üniversitesi, İktisadi ve İdari Bililer Fakültesi, Uluslararası Ticaret ve Lojistik Bölümü / *Gaziantep University, Faculty of Economics and Administrative Sciences, Department of International Trade and Logistics*, Gaziantep, Türkiye, byengil@gantep.edu.tr, ORCID: https://orcid/0000-0001-9338-2172.

1. Introduction

Industries and their subsystems have experienced three major industrial revolutions before the Industry 4.0 Revolution. The First Revolution, led by England, greatly changed people's lives due to the use of steam power. The Second Industrial Revolution began under the leadership of Germany. The use of electricity during this era redefined the production processes of sectors such as chemistry, petroleum, and steel and accelerated the processes by switching from traditional production to automation. Subsequently, under the leadership of the United States of America and East Asia, the Third Industrial Revolution took place. In this revolution, developments in fields such as information technology, biotechnology, nanotechnology, and others emerged, leading to profound changes in industrial work culture. The Fourth Industrial Revolution, which is very advanced in terms of technology, can process big databases within seconds with cost and time efficiency. Industry 4.0 is based on the advancement in information and communication technologies. It has made it possible to adapt advanced production technology processes to manufacturing systems and utilize technologies such as the Internet of Things, big data, and cloud computing for business automation (Bag et al., 2021). Industry 4.0 involves radical changes, especially in the current operations of production systems (Tjahjono et al., 2017), and includes computer technologies and automation Technologies (Pereira et al., 2017). Industry 4.0 can be described as a series of technologies that enable the production of smart products in smart factories through the integration of digital and physical processes, and their distribution using smart logistics systems. Due to the holistic approach of Industry 4.0 and its assistance in enabling companies to work more efficiently and create problem detection and prediction models, all firms are striving to adapt to the 'digitalization' process (Aylak et al., 2020).

Figure 1: Industrial Revolutions



Source: Created by Author

Digitalization, initiated with Industry 4.0, is defined as one of the significant trends reshaping both society and the business world in the short and long term (Tihinen et al., 2016) by offering ways for manufacturers to adapt their production systems to meet evolving and rapidly changing market demands (Stoldt et al., 2018). Digitalization, in its most basic expression, involves replacing existing resources with digital products to achieve the highest level of efficiency with the lowest physical effort (Bardakçı, 2020). For example, documents that were previously printed and archived after the relevant processes were completed, began to be stored in external memories or virtual storages called 'Cloud', after digitalization.

With the rapid growth of the global economy and advancements in science, the logistics and transportation sector has become a fundamental pillar of modern economies (Hirschinger et al., 2015). It cannot be denied that we are facing a digital transformation process in virtually all services of the globalized economy (Hitpass et al., 2019). Just like every other sector, the logistics sector has entered the digitalization

process by keeping up with the constantly developing and digitalizing world. Digitalization is closely associated with cost reduction and environmental improvements in logistics and transportation processes. For example, in road transportation, autonomous driving is closely related to economic, social, and environmental efficiency.

Businesses are introducing innovations to meet market demands, ensure customer satisfaction, and compete with rivals. In the logistics sector, implementing IT solutions is necessary for managing orders, vehicles, warehouses, or inventory. The increase in companies operating in the economy, the increase in product diversity, and the ability to access information faster and with less effort have increased competition all over the world. Companies that embrace digitalization and follow new technology trends gain a competitive edge in the market. Through digitalization, firms can increase profitability and efficiency while reducing costs. For example, companies optimize their supply chains with technology and digitalization to ensure the fast and accurate management of goods shipments, preventing vehicles from being underutilized. They also determine profitable routes to achieve fuel savings. Depot optimization is carried out to place products more efficiently and expedite shipments. In pursuit of these goals, digital systems have been developed to manage orders, vehicles, inventory, and storage in logistics. Digitalization also contributes to the improvement of customer services. For instance, when there are no delays in delivering goods to the warehouse, sending them to the customer, etc., products can be swiftly delivered to the end user. This is made possible by business digitalization, ensuring full control over every stage of the supply chain. Despite the many benefits, organizations face obstacles when it comes to adopting and implementing new technologies. The major challenge is the lack of preparedness in understanding and redefining automation systems. Organizations also encounter challenges in identifying and selecting suitable technologies for their processes. Another difficulty is dispelling the fear of job loss among the workforce and enhancing their knowledge and skills to cope with automated systems. Organizations are also making efforts to develop concrete policies for the future workforce. Additionally, organizations may need to address significant issues such as high implementation costs, hardware requirements, and cybersecurity threats.

The technologies used in logistics processes are highly diverse. This study explores these technological processes and the technological advancements that can fundamentally impact the logistics sector. It offers a perspective supported by academic studies and industry observations, addressing the multidimensional dynamics of the digitalization of the logistics sector. The primary aim of this study is to examine the digitalization process within the logistics industry, discuss its advantages and disadvantages, and highlight various digital trends through concrete examples. Moreover, while most existing studies in the literature employ bibliometric analyses, some focus solely on specific technologies, analysing their contributions to the logistics sector. Therefore, this article holds significance as it encompasses a wide range of technological trends and consolidates real-world examples from the industry within a single study.

2. Literature Review

The impact of digitalization on supply chain and logistics practices has been emphasized by Ivanov et al. (2019). Hofmann & Rüsch (2017) explored the significant opportunities presented by Industry 4.0 in the logistics sector. Barreto et al. (2017) examined the essential factors required by organizations to effectively implement Industry 4.0 within the logistics industry. Wang et al. (2016) and Sanders (2014) examined and categorized strategies for the utilization of Big Data in logistics and supply chain management within the literature. Müller et al. (2019) addressed the forest industry in their study. They showcased digitalization efforts and trends in the forest supply chain while describing the benefits obtained. Özdemir & Özgüner (2018), extensively examined the Industry 4.0 revolution and discussed the innovations it would bring to the logistics sector. Miscevic et al. (2018) examined in detail concepts such as mobile logistics, digital twins, autonomous vehicles, drones, and blockchain technology, which are vital for competitiveness. In the conceptual article published by Demiral (2021), technologies affecting the development of logistics are categorized as mature, growing, developing and exponential technologies, and are explained and exemplified under subheadings. Sekkeli & Bakan (2018) gave information about the basic features of

Industry 4.0 and Logistics 4.0, which emerged as a new concept, and discussed their potential effects. Some recently published scientific studies have mentioned the features, benefits and disadvantages of industry 4.0 and its technologies (Maryniak, 2020; Abdirad & Krishnan, 2020; Sapper et al., 2021). The review by Rahman et al. (2022) aims to systematically examine the adoption of Industry 4.0 technologies in the logistics industry in the Gulf Cooperation Council (GCC) region. El Hamdi & Abouabdellah (2022), conducted a study focusing on the digitalization of manufacturing companies to unearth the connection between the last industrial revolution and the evolution of logistics. Bigliardi et al. (2021) contributed to the current situation by analyzing 131 articles in the scientific literature on the application of Industry 4.0 to the logistics industry.

3. Innovations And Technological Trends in Logistics

For logistics companies to remain competitive, it is insufficient to only address processes physically. The future of logistics will be based on automation, technological advancements, innovation, and digitalization. While concepts like efficiency and low cost were important in logistics before, now flexibility, agility, lean production, flexible operations, customized packaging, just-in-time delivery, and continuous innovation have become crucial. These concepts can be offered to customers by adapting to the latest technologies. Some of these technologies include IoT, big data analysis, edge computing, artificial intelligence, robotic process automation, etc.

Logistics trends are dynamic, meaning that from year to year, some trends may decline while new trends can emerge and become popular thanks to globalization and advancing technology. The impact of some trends on logistics can be significant, and over time, this impact can either increase or decrease. These trends and their effects are shaped by variables such as the demographic structure of countries, government policies, customer demands, and so on.

DHL has discussed the new trends in the industry with The Logistics Trend Radar. DHL has categorized these trends into two categories: social and business trends, and technology trends. Within this scope, the most common technology trends used in the logistics sector are explained by utilizing DHL's Logistics Trend Radar 6.0 and Logistics Trend Radar 7.0.

3D Printing: 3D printers, also known as additive production, were developed and patented in the 1980s and are used in the production of various objects and materials in many sectors, especially in manufacturing (Çelik et al., 2020). 3D printers have features such as not requiring special equipment during production, reducing labor force, being able to affect the quality characteristics of the product, and being able to easily adjust the content of raw materials used (Sun et al., 2015), reducing production waste, high quality at low weight, adapting to individual orders (Wieczorek, 2017) are shown as the main reasons that gave rise to this interest. Using 3DP, it is possible to supply the right resources to production facilities "on-the-spot", reducing delivery costs without extending the delivery time. An example is the collaboration between UPS and Fast Radius. Fast Radius produces parts using industry-standard technology by installing 3D printers at strategic locations near UPS's global aviation hub. In these locations, products are printed on the same day and delivered to the destination within the United States on the following day (Berman, 2016).

Big Data Analytics: It analyzes massive datasets obtained from various sources to examine and interpret reliable and valuable information for improved decision-making (Pacchini et al., 2019). It is concerned with both data storage and data access, as well as understanding and analysing data. Logistics providers use it to predict delivery times based on factors such as weather conditions, traffic congestion, vehicle specifications, etc. Manufacturers respond to fluctuations in demand, and retailers adjust their sales levels accordingly. For example, in 2012, the Swiss start-up SkyCell designed containers for medical transport using Big Data Analytics. These containers collect data about vibrations, humidity, and temperature levels. At the same time, this data is uploaded to the SkyCell database. This enables almost real time visibility of the shipment status and conditions, and an alarm function is activated in case the shipment is at risk and requires intervention from a relevant stakeholder. Reports are generated to prove that medical materials are transported under safe conditions.

Internet of Things (IoT): It is a technology that connects machines to humans and allows remote control of machines from distant locations (Ahuett-Garza et al., 2018). IoT sensors provide 100% real-time visibility of the supply chain. Thanks to this technology, companies can more efficiently monitor the technical condition of vehicles, closely track shipments and deliveries, and maintain control over storage conditions. DHL company developed the Smart Truck solution in 2018 to solve the problem of logistics costs. The company equipped its trucks with IoT sensors that collect data on weather conditions, traffic congestion, road accidents, etc. Smart Trucks reduced empty mileage by 15%, resulting in millions of gallons of fuel savings and a reduction in CO2 emissions. Another example is DB Schenker using a millimeter-sized tag for tracking technology. The Sensos tag is so small and lightweight that it can be used for loads of any size. Together with DB Schenker's IoT solution connect2track, it provides optimal visibility and status tracking for shipments, significantly improving the current offerings to customers, and making tracking more flexible, and secure.

Cloud Computing: It provides the ability to store large volumes of data in an external environment and ensures quick access and retrieval when required (Zhong et al., 2017). Thanks to cloud computing, businesses can access their data from anywhere they want at any time through computers via the internet, rather than relying on computers or data centers. It supplies businesses with information technology resources such as servers, storage, software and networks on-demand (Zhang et al., 2012). Cloud computing bestows logistics companies with flexibility and scalability they have never had before. With cloud computing, companies can expand or reduce their scope of operations based on demand.

Robotic Process Automation (RPA): It encompasses Automated guided carts, outdoor autonomous vehicles, drones, indoor mobile robots, self-driving trucks and cars, etc. RPAs are robots with artificial intelligence that have a decision-making mechanism by understanding commands and can interact with humans (Li et al., 2017). These robots can solve problems based on past experiences (Modayil et al., 2008). These robots with machine learning also can adapt to changes when necessary. Autonomous mobile robots can move goods along predetermined routes for shipping and storage. Drones can accurately count inventory and input the data into inventory management systems. Self-driving cars and trucks, which are smart vehicles, will help alleviate the driver shortage issue and reduce the number of accidents.

Digital Twins: With this technology, experts design a virtual replica of a real object or process. Logistics companies create 3D models of warehouses to test their planning strategies and determine how to arrange inventory on-site for quick retrieval and loading onto vehicles. For instance, Ericsson and Italy's Port of Livorno have developed a digital twin to facilitate faster shipment of goods. They created a digital analogue of the port area using a 5G network, IoT sensors, LiDAR, and cameras (Ericsson, 2020). Digital twins can monitor product storage conditions, vehicle technical statuses, and driving behaviors, while also optimizing other operations within the supply chain. The digital twin generates value through visualization, diagnostics, analysis, forecasting, simulation, and optimization without requiring direct interaction with its physical counterpart.

Next Generation Connectivity: It covers various technologies such as LPWAN and Wi-Fi 6. It is the development and application of wireless communication technologies and the infrastructures that support them. The number of IoT devices is increasing rapidly along with the amount of data produced. New generation wireless communication will enable much faster transfer of this data. It creates a huge opportunity for many industries to improve their services, especially those dealing with large amounts of data, such as bulk logistics. This trend helps connect everyone and everything, everywhere.

Edge Computing: This trend signifies the transition of IT architecture towards a decentralized structure. Edge computing processes data closer to sensors and other sources at the network's edge, reducing reliance on distant cloud servers and data centers. This approach minimizes long-distance data transmission between clients and servers, decreasing processing time and enabling faster responses to environmental changes. Additionally, storing data closer to its source enhances security, especially for sensitive information. Edge computing optimizes the volume of detailed data an organization can handle, allowing companies to

gain insights and learn faster than ever before. For example, instead of constantly broadcasting data about the oil level in a car's engine, a sensor could periodically send summary data to a remote server.

Next-Generation Packaging: This trend refers to changes in the materials used for packaging and the added technology. Additionally, it includes new packaging materials that are reusable, recyclable, and biodegradable, aligning with sustainability principles. Intelligent packaging systems track the internal conditions of products and provide quality-related information during transportation and storage. An example of new-generation packaging is active packaging. Active packaging contains additives that help maintain product quality and extend shelf life. These types of packaging are designed to respond to both internal and external environmental changes. The systems that monitor the packaging's condition work in conjunction with hardware components such as time-temperature indicators, freshness sensors, RFID, and other labels. Within logistics and supply chain operations, it provides better protection with real time monitoring while reducing the risk of theft, last-mile delivery diversion, fraud, and other crimes. An example of this is The Box, developed by a start-up company LivingPackets. They have developed a smart packaging solution equipped with sensors to monitor temperature, humidity, and shock during transportation. Since The Box features a digital display, traditional paper labels are no longer necessary. The screen utilizes e-ink technology, which consumes no energy. By making the box reusable, it presents a sustainable smart packaging solution.

Interactive Artificial Intelligence: This trend involves artificial intelligence algorithms capable of processing user inputs like text and speech to deliver meaningful responses. It can understand different writing styles and accents, engage in intricate conversations, and demonstrate the ability to create empathy with human users. Emerging from the broader field of artificial intelligence, interactive AI covers a wide range of applications, including geolocation and navigation, facial detection and recognition, chatbots, digital assistants, speech-to-text translation, and e-payment systems. In the logistics industry, artificial intelligence is essential for tackling complex operational issues, such as optimizing routes and making accurate capacity and demand predictions. Within logistics and supply chain operations, interactive artificial intelligence not only brings greater efficiency to these processes but also makes daily activities for workers less manual, ultimately providing a more automated customer experience.

Quantum Computing: Quantum computers are millions of times faster than supercomputers. It can process complex logistics algorithms and optimize the supply chain process in real time. It has computing power that allows the simulation of product and service models so that the supply chain can perform better. In late 2019, Portugal hosted the world's first pilot project using a quantum computer for traffic optimization. Volkswagen, in collaboration with the public transport provider Carris in Lisbon, calculated the fastest route in real-time for each of the 9 participating buses with 26 stops (Volkswagen-group, 2019). This initiative helped passengers avoid traffic congestion as soon as it occurred. Beyond dynamic route optimization, quantum computing has been identified as a key technology for efficiently packing millions of loads across thousands of trucks and planes, detecting energy and product losses at a micro level, adjusting to delayed shipments and canceled orders, and optimizing seamless re-planning and re-allocation.

4. Wearable Technological Developments in Logistics

Wearable Sensors: The wearable sensor trend involves sensors attached to or worn near the body to track movements or monitor basic physiological functions. Depending on the type of data to be captured, different sensors like gyroscopes and accelerometers are integrated into a variety of wearable devices, ranging from badges and wristbands to smart glasses and clothing.

The Exoskeletons: This trend encompasses wearable devices developed that are placed on the user's body to enhance, strengthen, or restore human performance. It's also known as support robots. These robots have a support structure that reduces the load on the body with mechanical support and reduces the risk of injury. Musculoskeletal disorders, affecting 1.7 billion people globally, are among the most prevalent work-related health issues. Exoskeletons, originally developed in the healthcare and military sectors, were

introduced for industrial use in logistics several decades ago to help reduce the onset and impact of musculoskeletal disorders in the workplace. Both active and passive devices, typically classified based on the body regions they support, have seen improvements in usability, form factor, and performance over the past two years. Although the Exoskeletons trend is anticipated to have a relatively small impact on efficiency improvements in supply chain operations, it is recognized that the technology will positively affect employee health and safety. Stuttgart Airport is the first airport in Europe to use exoskeletons for baggage handling. The smart suit aims to ease the physical burden on baggage handling personnel and keep their employees healthy in the long term.

Augmented Reality: It means providing real-life experiences with virtual objects to better understand the future and make decisions (Vaidya et al., 2018). Real area and human activities are imitated using computer equipment. For example, Head-mounted Displays (HMDs) are rapidly evolving hardware that places both the physical world and the images of virtual objects into the user's field of view. Through this system, employees can see their digital picking lists within their field of view, allowing them to follow the best path or the most efficient route. Additionally, it can guide the employee in quickly locating the correct item on the shelf using automatic barcode scanning features. To exemplify the use of augmented reality in the logistics sector, Audi employs Augmented Reality technology in its logistics processes. The software, a combination of the words "Layout" and "Augmented Reality," visualizes all logistics structures and objects such as shelves, conveyor belts, and boxes in a production area as three-dimensional holograms and reflects them in real size within the actual environment. All the generated visuals are simultaneously displayed on multiple AR devices through synchronization, allowing users to manipulate, rotate, or alter objects in this space. All changes made are seen in real time (Audi MediaCenter, 2020).

Extended Reality (XR): The extended reality (XR) trend encompasses various technologies such as augmented reality (AR), virtual reality (VR), and mixed reality (MR). XR's first major application began in 2014 with the release of Google Glass, which allowed users to view virtual objects placed in their surroundings through an AR lens. In 2018, Oculus launched the first VR standalone headset displays for consumers. VR's capability to deliver a fully immersive experience through headsets has led many industries, including logistics, to explore the potential of 360° virtual content for worker training and engagement. With the advancements in AR and VR, mixed reality has begun to emerge in recent years. Unlike AR, MR not only overlays virtual content onto the real world but also incorporates elements from the physical environment to contextualize and interact with virtual content. For instance, virtual products could appear to move on a real conveyor belt in a warehouse. MR technology enables users to not only view virtual objects but also interact and collaborate with them, creating a wide range of potential applications yet to be fully explored.

5. Challenges of Digitalization in the Logistics Sector

Digitalization has radically changed the competitive dynamics of sectors, including the logistics sector (Hofmann and Osterwalder, 2017). The reviewed literature shows that digitalization brings not only opportunities and advantages but also risks and obstacles that need to be taken into account, such as data abuse, data misuse, data breach, cyber-attacks and some job losses for the sector (Bendel, 2015; Sen, 2016). The installation and infrastructure costs required for digitalization are significant and cannot be ignored. The substantial initial investments required to adopt advanced technologies constitute a significant obstacle, especially for small and medium-sized companies (Hollaway, 2024). The lack of technical knowledge and shortage of qualified personnel create challenges in adopting digital technologies and integrating them with existing systems (Cichosz et al. 2020). Another important aspect is the changing characteristics of workforce dynamics in digitally transformed supply chains. Automation and AI-enabled technologies have transformed traditional employment positions, reducing the need for physical labor and offering the opportunity to position the workforce in tasks that cannot be performed by machines (Malagón-Suárez, 2023). However, this transition has led to a skills gap that requires specialized training programs and workforce development activities. In businesses with traditional practices, organizational resistance to change hinders the process of

adopting new technologies (Durgut et al., 2020). The growing reliance on real-time data exchange and network-based systems makes businesses more vulnerable to cyber threats and requires strong protection measures to ensure the security of sensitive information. At this point, data security and privacy—representing the vulnerable infrastructure of digitalization—have become critical issues in the digital transformation of supply chains (Kalaycı, 2023). Ensuring interoperability and cooperation between stakeholders among supply chain members, each of whom uses different systems, platforms and technologies, is of great importance (Malagón-Suárez, 2023).

6. Conclusion

The evolving new technologies and digital systems demonstrate that businesses must embrace digitization in their logistics operations to gain a competitive advantage. The concept of digitization can significantly transform production processes and related logistics processes. Some of the advantages that digitization brings to the logistics sector include enhanced information visibility and connectivity, along with fast and reliable delivery options through a physical network. This, in turn, enhances logistics productivity and efficiency while reducing adverse environmental effects. Automation and real-time control can prevent delays in warehouse operations and cargo deliveries. In addition to providing cost efficiency to businesses, it can also foster loyal customer relationships. By making potential risks in logistics processes visible, digitization allows for real time monitoring of material flows and enables to plan healthier for the future. Logistics managers who invested in digitalization aimed to achieve a flexible structure, reduce logistics costs and eliminate supply risks with this change (Schmidt et al., 2015). The use of new technologies in conjunction with digitization also provides logistics businesses with flexibility and agility, ultimately increasing profitability and efficiency (Strange et al., 2017). In this study, the impacts of digitalization, which facilitates our lives, on the logistics sector have been examined, considering both its advantages and disadvantages. It also emphasizes the significance of logistics trends for businesses and highlights current examples from around the world.

For long-term success, it is essential to modernize all touchpoints in the supply chain from start to end. Those who embrace, scale, and rapidly develop workforce skills in new technologies will have a significant competitive advantage in the market. The appropriate integration and use of digital technologies to enhance logistics performance have the potential to promote competitive advantages that drive economic development. Future studies may examine the impacts of technological trends such as 3D printing, cloud technologies, big data, IoT, and extended reality on the efficiency, cost management, and sustainability of logistics processes.

Competing Interests

The authors declare that they have no competing interests.

Fundings and Acknowledgments

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethical Statement

It is declared that scientific and ethical principles have been followed while carrying out and writing this study and that all the sources used have been properly cited.

Authors' Contributions

The authors have contributed equally to the study.

KAYNAKÇA / REFERENCES

Abdirad, M., & Krishnan, K. (2021). Industry 4.0 in logistics and supply chain management: a systematic literature review. *Engineering Management Journal, 33* (3), 187-201.

Ahuett-Garza, H., & Kurfess, T. (2018). A Brief Discussion on the Trends of Habilitating Technologies for Industry 4.0 and Smart Manufacturing. *Manufacturing Letters, 15*, 60-63. https://doi.org/10.1016/j.mfglet.2018.02.011

Audi MediaCenter (2020). Audi is using augmented reality to increase efficiency in logistics planning, Retrieved 22.11.2024 from https://www.audi-mediacenter.com/en/press-releases/audi-is-using-augmented-reality-to-increase-efficiency-in-logistics-planning-13441

Aylak, B. L., Kayıkcı, Y., & Taş, M. A. (2020). Türkiye'de Lojistik Sektöründe Faaliyet Gösteren İşletmelerin Dijital Trendlerinin İncelenmesi. *Yaşar Üniversitesi E-Dergisi, 15* (57), 98-116. https://doi.org/10.19168/jyasar.569599

Bag, S., Yadav, G., Dhamija, P., & Kataria, K. K. (2021). Key resources for industry 4.0 adoption and its effect on sustainable production and circular economy: An empirical study. *Journal of Cleaner Production, 281*, 125233.

Bardakçı, H. (2020). Benefits of Digitalization in International Logistics Sector. I*nternational Journal of Social Science and Economic Research*, *5* (06), 1476-1489.

Barreto, L., Amaral, A., & Pereira, T. (2017). Industry 4.0 Implications in Logistics: An Overview. *Procedia manufacturing, 13*, 1245-1252.

Bendel, O. (2015). Die Industrie 4.0 aus ethischer Sicht. *HMD Praxis der Wirtschaftsinformatik, 52* (5), 739-748. DOI 10.1365/s40702-015-0163-z

Berman, J. (2016). UPS rolls out plan for full-scale on-demand 3D printing manufacturing network. *Logistics Management*.

Bigliardi, B., Casella, G. & Bottani, E. (2021). Industry 4.0 in the logistics field: A bibliometric analysis. *IET Collaborative Intelligent Manufacturing, 3* (1), 4-12. https://doi.org/10.1049/cim2.12015

Çelik, F. B., Topçu, E., & Onursal, F. S., (2020). Pandemi Sonrası Yeni Dünya Düzeninde Teknoloji Yönetimi Ve İnsani Dijitalizasyon. *Lojistik ve Dijitalleşme, Chapter 17*, 391-414.

Cichosz, M., Wallenburg, C. M., & Knemeyer, A. M. (2020). Digital transformation at logistics service providers: barriers, success factors and leading practices. *The International Journal of Logistics Management, 31* (2), 209-238.

Demiral, D. G. (2021). Endüstri 4.0'ın lojistik boyutu: Lojistik 4.0. *IBAD Sosyal Bilimler Dergisi, 9*, 231-251. https://doi.org/10.21733/ibad.838751

DHL, The Logistics Trend Radar 6.0. Retrieved 05.10.2024 from https://www.dhl.com/tr-en/home/innovation-in-logistics/logistics-trend-radar.html

DHL, The Logistics Trend Radar 7.0. Retrieved 19.12.2024 from https://www.dhl.com/global-en/home/insights-and-innovation/insights/logistics-trend-radar.html

Durgut, İ. A., Ayaz, İ. S., & Kasapoğlu, E. B. Barriers to Digitalization in Business Processes: A Research On Third Party Logistics Service Providers. Conference Paper.

El Hamdi, S., & Abouabdellah, A. (2022). Logistics: Impact of Industry 4.0. *Applied Sciences, 12* (9), 4209.

Ericsson (2020). Future Network Trends. Retrieved 10.01.2025 from https://www.ericsson.com/4ac6aa/assets/local/reports-papers/ericsson-technology-review/docs/2020/technology-trends-2020.pdf

Hirschinger, M., Spickermann, A., Hartmann, E., Gracht, H. & Darkov, I. (2015). The Future Of Logistics in Emerging Markets–Fuzzy Clustering Scenarios Grounded in Institutional And Factor-Market Rivalry Theory. *Essays on supply chain management in emerging markets*, 73-93.

Hitpass, B., & Astudillo, H. (2019). Editorial: Industry 4.0 Challenges For Business Process Management and Electronic-Commerce. *Journal of Theoretical and Applied Electronic Commerce Research, 14* (1), 1-3.

Hofmann, E., & Osterwalder, F. (2017). Third-party logistics providers in the digital age: towards a new competitive arena*?*. *Logistics, 1* (2), 9. https://doi.org/10.3390/logistics1020009

Hofmann, E., & Rüsch, M. (2017). Industry 4.0 And The Current Status As Well As Future Prospects On Logistics*.* *Computers in Industry, 89*, 23-34. https://doi.org/10.1016/j.compind.2017.04.002

Holloway, S. (2024). Digital Transformation in Supply Chain Management: A Systematic Literature Review of Trends and Applications.

Ivanov, D., Dolgui, A., & Sokolov, B. (2019). The Impact of Digital Technology and Industry 4.0 On The Ripple Effect And Supply Chain Risk Analytics. *International journal of production research, 57* (3), 829-846.

Kalaycı, N. (2023). Dijitalleşememe ve Dijital Eşitsizlik. *Scientific Journal of Space Management and Space Economy, 2* (1), 43-52.

Li, G., Hou, Y., & Wu, A. (2017). Fourth Industrial Revolution: Technological Drivers, Impacts and Coping Methods. *Chinese Geographical Science, 27*, 626-637.

Malagón-Suárez, C. P., & Orjuela-Castro, J. A. (2023). Challenges and trends in logistics 4.0. *Ingeniería, 28*.

Maryniak, A., & Bulhakova, Y. (2020). *Benefits of the technology 4.0 used in the supply chain-bibliometric analysis and aspects deferring digitization*. In Business Information Systems Workshops: BIS 2020 International Workshops, Colorado Springs, CO, USA, June 8–10, 2020, Revised Selected Papers 23 ,73-183. Springer International Publishing.

Miscevic, G., Tijan, E., Žgaljić, D., & Jardas, M. (2018). *Emerging trends in e-logistics. In 2018 41st international convention on information and communication technology, electronics and microelectronics* (MIPRO),1353-1358.

Modayil, J., & Kuipers, B. (2008). The Initial Development of Object Knowledge by a Learning Robot. *Robotics and autonomous systems, 56* (11), 879-890.

Müller, F., Jaeger, D., & Hanewinkel, M. (2019). Digitization in wood supply–A review on how Industry 4.0 will change the forest value chain. *Computers and Electronics in Agriculture, 162,* 206-218.

Özdemir, A., & Özgüner, M. (2018). Endüstri 4.0 ve lojistik sektörüne etkileri: Lojistik 4.0. *İşletme ve İktisat Çalışmaları Dergisi, 6*(4), 39-47.

Pacchini, A. P. T., Lucato, W. C., Facchini, F., & Mummolo, G. (2019). The Degree of Readiness for the Implementation of Industry 4.0. *Computers in Industry, 113,* 103125.

Pereira, A. C., & Romero, F. (2017). A review of the meanings and the implications of the Industry 4.0 concept. *Procedia manufacturing, 13,* 1206-1214.

Rahman, N. S. F. A., Hamid, A. A., Lirn, T. C., Al Kalbani, K., & Sahin, B. (2022). The adoption of industry 4.0 practices by the logistics industry: A systematic review of the gulf region. *Cleaner Logistics and Supply Chain*, 100085.

Sanders, N. R. (2014). *Big Data Driven Supply Chain Management: A Framework for Implementing Analytics And Turning Information Into Intelligence*. Pearson Education.

Sapper, S., Kohl, M., & Fottner, J. (2021). *Future competency requirements in logistics due to industry 4.0: a systematic literature review.* In 2021 10th international conference on industrial technology and management (ICITM), 94-105.

Schmidt, B., Rutkowsky, S., Petersen, I., Klötzke, F., Wallenburg, C. M., & Einmahl, L. (2015). *Digital supply chains: increasingly critical for competitive edge*. European AT Kearney, WHU Logistics Study.

Sekkeli, Z. H., & Bakan, İ. (2018). Endüstri 4.0'ın Etkisiyle Lojistik 4.0. Journal of Life Economics, 5(2), 17-36.

Sen, R. (2016). Cyber and information threats to seaports and ships. *Maritime Security*, 281-302.

Stoldt, J., Trapp, T. U., Toussaint, S., Süsse, M., Schlegel, A., & Putz, M. (2018). Planning For Digitalisation in Smes Using Tools of the Digital Factory. *Procedia College International pour la Recherche en Productique, 72*, 179-184.

Strange, R., & Zucchella, A. (2017). Industry 4.0, global value chains and international business. *Multinational Business Review, 25* (3), 174-184.

Sun, J., Peng, Z., Zhou, W., Fuh, J. Y., Hong, G. S., & Chiu, A. (2015). A review on 3D printing for customized food fabrication. *Procedia Manufacturing, 1*, 308-319.

Tekin, M., Etlioğlu, M., & Tekin, E. (2017). Inovatif Lojistik. *The International New Issues in Social Sciences, 5* (5), 81-104.

Tihinen, M., Kääriäinen, J., Ailisto, H., Komi, M., Parviainen, P., Tanner, H., Tuikka, T. & Valtanen, K. (2016). The Industrial Internet in Finland: on route to success. *VTT Technical Research Centre of Finland, 278*, 1-84.

Tjahjono, B., Esplugues, C., Ares, E., & Pelaez, G. (2017). What does industry 4.0 mean to supply chain? *Procedia manufacturing, 13*, 1175-1182.

Vaidya, S., Ambad, P., & Bhosle, S. (2018). Industry 4.0–a Glimpse. *Procedia manufacturing, 20*, 233-238.

Volkswagen-group (2019). Volkswagen optimizes traffic flow with quantum computers. Media Information no.373/2019. Retrieved 25.12.2024 from https://www.volkswagen-group.com/en/press-releases/volkswagen-optimizes-traffic-flow-with-quantum-computers-16995.

Wang, G., Gunasekaran, A., Ngai, E. W., & Papadopoulos, T. (2016). Big Data Analytics in Logistics And Supply Chain Management: Certain Investigations for Research and Applications. *International journal of production economics, 176*, 98-110.

Wieczorek, A. (2017). Impact of 3D printing on logistics. *Research in Logistics & Production, 7* (5), 443-450.

Zhang, L., Luo, Y., Tao, F., ve Liu, Y. (2012). Cloud manufacturing: A new manufacturing paradigm. *Enterprise Information Systems, 8* (2), 167-187.

Zhong, R. Y., Xu, X., Klotz, E., & Newman, S. T. (2017). Intelligent manufacturing in the context of industry 4.0: A Review. *Engineering, 3* (5), 616-630.