

(REVIEW ARTICLE)



## Impacts of industry 4.0 on supply chain management of logistics providers: A methodical review

Anthony O. O<sup>1</sup>, Olabanji O. M<sup>2,\*</sup> and Rameshwar D<sup>1</sup>

<sup>1</sup> Logistics and supply chain management department, University of Hall, United Kingdom.

<sup>2</sup> Department of Mechanical Engineering Federal University of Technology Akure, Ondo State in Nigeria.

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### Abstract

The arrival of Industry 4.0 transformed and reshaped manufacturing, and the logistics industry is not excluded. As such, there is a need to explore the influence of this latest technological innovation on industries with a focus on logistics providers; this research examines the impact of Industry 4.0 on logistics providers' supply chain management. Using qualitative analysis of secondary sources, this research identifies the key relevance of Industry 4.0 technologies to logistics providers while assessing their adoption and exploring their impact on supply chain performance. Through the series of examination of secondary sources, it was revealed that Industry 4.0 components such as IoT enable real-time tracking, reducing lead times and improving customer service. AI, on the other hand, helps optimize routing and scheduling while also enhancing efficiency. Nevertheless, the industry 4.0 implementation into the logistics provider supply chain is not without challenges; the challenges evidenced through the research include data security, interoperability, and workforce skills. This study recommends investments in technology and skills, data security measures, collaborative organizational structures, agility, change management, and benchmarking to navigate the transformative landscape of Industry 4.0 in logistics supply chain management.

**Keywords:** Industry 4.0; Internet of things; Supply Chain Management; Logistics Provider; Artificial Intelligence; Manufacturing Industries

### 1. Introduction

The rapid advancement of technology in various industries, including logistics and supply chain management, has led to the emergence of Industry 4.0, which encompasses cutting edge technologies such as the Internet of Things (IoT), artificial intelligence (AI), cloud computing, big data analytics, and robotics. Industry 4.0 has the potential to revolutionize traditional manufacturing and logistics processes by integrating digital technology, automation, and data analytics (IBM, n.d.). The Internet of Things (IoT) plays a pivotal role in Industry 4.0, enabling the real-time tracking and monitoring of goods, vehicles, and equipment (Barreto et al., 2017). While Industry 4.0 represents a significant shift in technological paradigms with the promise of optimizing production, improving efficiency, and enhancing decision-making capabilities (Marr, 2018), its impact on logistics providers' supply chain management remains underexplored. Logistics service providers play a vital role in the movement and management of goods across the supply chain, making their adoption of Industry 4.0 technologies and practices highly relevant (NetSuite, 2023).

Despite the potential benefits of Industry 4.0 integration in logistics and supply chain management, there is a need to comprehensively investigate the extent of its influence on logistics providers' supply chain operations. This need necessitates an in-depth examination of how Industry 4.0 technologies and practices impact logistics providers' supply chain management, encompassing both positive and negative aspects. Understanding this influence is essential for

\* Corresponding author: Olabanji O. M

logistics providers seeking to leverage Industry 4.0 to enhance supply chain operations, improve efficiency, and gain a competitive advantage in a rapidly evolving industry (Abdirad & Krishnan, 2020). The core research issue addressed in this article is the understanding of the influence of Industry 4.0 on logistics providers' supply chain management. By addressing this problem, this research aims to bridge the knowledge gap, identify key technologies and practices relevant to logistics providers, assess adoption levels, evaluate the impact on supply chain performance, and uncover challenges and opportunities associated with Industry 4.0 integration.

In recent times, Industry 4.0 is the latest ideal for every industry as it is a total shift from the regulars, i.e., the regular form of technological machinery. It is created in such a way that it will optimize production, improve efficiency, and enhance decision-making capabilities through its advanced technologies (Marr, 2018) since it is a combination of various improved digital technologies. Industry 4.0 differs from industry to industry; in the logistics and supply chain industry, implementing Industry 4.0 can be of great input and impact. According to Ghadge *et al.*, (2020), Industry 4.0 can enhance demand forecasting, route optimization, and prediction and help improve overall performance. In logistics and supply chain management integrating Industry 4.0 technologies in logistics and supply chain management will have significant implications for the industry. Logistics service providers play a crucial role in the movement and management of goods across the supply chain (NetSuite, 2023).

Implementing Industry 4.0 technologies and practices in logistics operations can substantially improve efficiency, visibility, and responsiveness (Barreto et al., 2017). For instance, IoT sensors and real-time tracking systems enable monitoring and optimization of transportation and warehousing activities, resulting in reduced lead times, lower costs, and improved customer service (Jirsak, 2018). Logistics service providers can leverage IoT devices and real-time tracking systems to enhance visibility and provide real-time updates to customers regarding the status and location of their goods (Barreto et al., 2017). This level of visibility and responsiveness will improve customer satisfaction and allow logistics providers to optimize their operations, reduce costs, and minimize disruptions in the supply chain (Abdirad & Krishnan, 2020). Furthermore, the integration of AI in logistics operations enables logistics providers to optimize routing, scheduling, and inventory management, leading to improved efficiency and reduced costs (Mahdavisarif et al., 2022). In view of this it is necessary to provide a knowledge on how much influence Industry 4.0 has on the supply chain management of logistic service providers, including how this influence plays out in Logistics Providers' Supply Chain Management; as such, this article aims to examine the influence of Industry 4.0 on logistics providers' supply chain management. This will provide information on how logistics providers can leverage Industry 4.0 technologies and practices to enhance their supply chain operations, improve efficiency, and gain a competitive advantage. This article will contribute to the existing body of knowledge by providing insights into the challenges and opportunities associated with adopting Industry 4.0 in logistics and supply chain management (Abdirad & Krishnan, 2020).

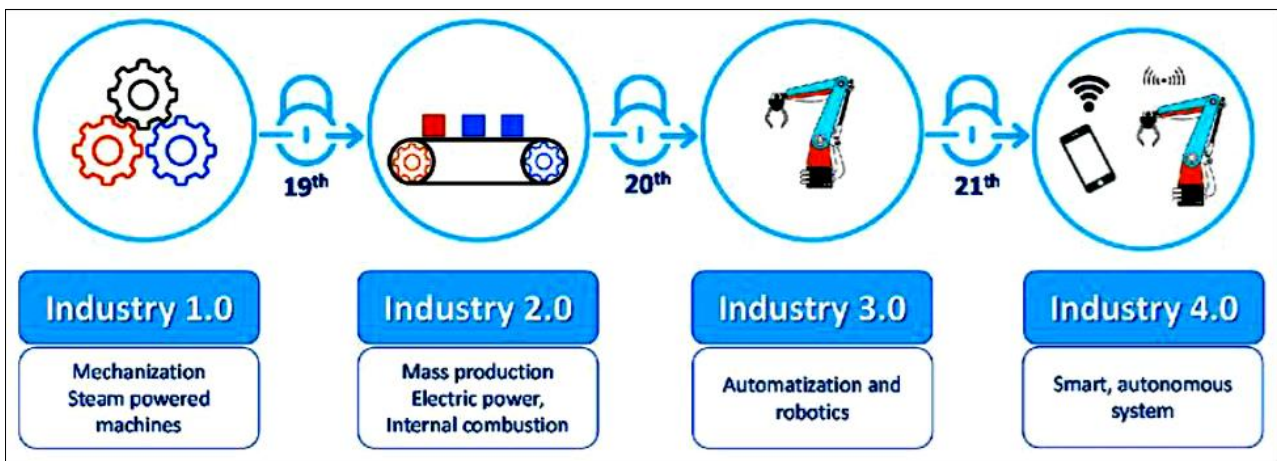


Figure 1 Industry 1.0 to 4.0

The Industry 4.0, also known as the Fourth Industrial Revolution, is a concept that has evolved, reflecting the ongoing transformation of the manufacturing and logistics industries. Historically, it is rooted in the progression of industrial revolutions. Desoutter's source provides a broad perspective, tracing the evolution from the first industrial revolution (Industry 1.0) to the present Industry 4.0 (Desoutter, n.d.) Figure 1. This historical continuum underscores the significance of Industry 4.0 as the latest stage in a series of transformative industrial shifts. A more detailed historical perspective is presented by Dima (2021), who notes that Industry 4.0 originated in the year 2011 as part of the Fourth

Industrial Revolution (Dima, 2021). This specific starting point in the early 21st century marks a crucial juncture in the development of Industry 4.0, signaling a departure from previous industrial eras. It highlights the accelerated pace of technological advancements and their impact on logistics providers' supply chain management.

Klingenberg, Borges, and Antunes (2022) offer a historical framework to understand the phenomenon of Industry 4.0. They emphasize that this revolution did not arise abruptly but rather evolved through the convergence of various technological advancements. Their work provides valuable insights into the gradual process that culminated in Industry 4.0 and helps contextualize its historical background. Michelsen (2020) further contributes to the historical underpinnings of Industry 4.0 by providing an overview of Industry 4.0 in retrospect and the context of its technical, economic, and societal effects on manufacturing. This work helps us understand the evolution of Industry 4.0 in terms of its impact on different aspects of the manufacturing sector. Examining the effects reveals how the revolutionary changes of Industry 4.0 have influenced supply chain management for logistics providers. IBM's resource (2022) contributes to our understanding of Industry 4.0 by providing a concise and scholarly definition. According to IBM, Industry 4.0 represents a paradigm shift characterized by the integration of digital technologies, data analytics, and automation into manufacturing and logistics processes (IBM, 2022). This definition underscores the pivotal role of technology and data-driven decision-making, which have profound implications for supply chain management. Rojko (2017) offers a comprehensive background and overview of the Industry 4.0 concept. Rojko (2017) delves into the key technologies and principles underpinning Industry 4.0. Rojko (2017) is of immense contribution to this body of research as it underpins the fact that foundational knowledge is essential to grasping the historical development and significance of this revolution in transforming traditional manufacturing processes and logistics operations. In essence, the review on the historical background of Industry 4.0 is shaped by a gradual process of technological advancements and convergence, as Klingenberg et al. (2022), Michelsen (2020), and Rojko (2017) provide essential historical frameworks, insights into the effects, and a comprehensive overview of the concept, respectively.

On the other hand, Müller and Kazantsev (2021) extended the discussion by focusing on implementing Industry 4.0 in small and medium-sized enterprises (SMEs) worldwide. Their study emphasizes the global scope of this revolution and highlights how it has penetrated various industries and organizational sizes. Understanding the adoption of Industry 4.0 by SMEs is crucial to logistics providers' supply chain management, as SMEs often play a significant role in the supply chain ecosystem. Furthermore, Tilak, Pune, and Singh (2018) discuss the impact of Industry 4.0 on employability and the existing education system. This work sheds light on the broader socio-economic implications of the revolution, particularly concerning the workforce. As logistics providers are part of a vast workforce, this aspect of Industry 4.0's influence is significant to consider while examining its effects on supply chain management. (Müller & Kazantsev, 2021) and its impact on employability and education (Tilak et al., 2018) have revealed the widespread influence of Industry 4.0 across industries and socio-economic aspects.

Immerman (2019) delves deeper into the concept by emphasizing the transformative nature of Industry 4.0. Immerman describes it as a shift from traditional manufacturing to smart manufacturing, emphasizing the importance of data connectivity and real-time insights (Immerman, 2019). This transformation has a direct bearing on logistics providers, who need to adapt to this new landscape to optimize their supply chain operations. Defined within the context of logistics and supply chains, Industry 4.0 integrates digital technologies, automation, and data analytics into manufacturing and logistics processes (IBM, n.d.). It represents the fourth industrial revolution and encompasses key technologies such as the Internet of Things (IoT), artificial intelligence (AI), cloud computing, big data analytics, and robotics (Abdirad & Krishnan, 2020). These technologies enable real-time data collection, analysis, and utilization to optimize operations and enhance decision-making capabilities (Makris et al., 2019). Furthermore, Industry 4.0 involves the development of cyber-physical systems that connect physical processes with digital information networks, leading to increased connectivity and intelligence in production and supply chain management (Barreto et al., 2017). McCabe (2016) provides a historical perspective on the Fourth Industrial Revolution, elucidating its significance in the context of Industry 4.0. This perspective helps us appreciate the broader societal and economic changes that have led to the development of Industry 4.0 (McCabe, 2016). It underscores that Industry 4.0 is not just a technological change but a fundamental shift in the way industries and logistics operate. McKinsey & Company (2022) elaborates on the Fourth Industrial Revolution, emphasizing its global impact and the concept's interconnection with Industry 4.0. This interconnectedness highlights the relevance of Industry 4.0 beyond a mere technological upgrade; it encompasses broader economic and social dimensions (McKinsey & Company, 2022). As logistics providers are integral to these economic and social systems, understanding these dimensions becomes crucial. These scholarly works offer valuable insights into the historical context and multifaceted implications of Industry 4.0, making them highly relevant to the present.

## 2. Impacts of Industry 4.0 on Supply Chain

Logistics 4.0, which represents the application of Industry 4.0 principles and technologies in the logistics sector, has garnered significant attention due to its potential to transform supply chain management. Various scholarly works have explored the impact of Industry 4.0 on supply chains, shedding light on the implications of adopting advanced technologies in logistics operations. Ghadge et al. (2020) delve into the overall impact of Industry 4.0 implementation on supply chains. Ghadge et al. (2020) believed that implementing Industry 4.0 technologies profoundly impacts supply chains as it enables greater visibility, efficiency, and responsiveness in supply chain operations. This review provides insights into how logistics providers can leverage emerging technologies to enhance their operations. Jirsak (2018) further this position when he highlights how different components of Industry 4.0 can make their impact; for example, IoT sensors and real-time tracking systems facilitate accurate monitoring and optimization of transportation and warehousing activities, resulting in reduced lead times and lower costs, and improved customer service. Integrating AI and advanced analytics enables predictive maintenance, demand forecasting, and risk management, leading to better decision-making and operational performance (Mahdavisarif et al., 2022).

Furthermore, Industry 4.0 enables the implementation of smart and agile supply chain strategies, allowing organizations to quickly adapt to changing customer demands and market conditions (Zhang et al., 2022).

Moreover, Koskin, Thuy, and Nguyen (2021) explore the broader impact of Industry 4.0 on supply chains, shedding light on how logistics providers can optimize their operations and improve efficiency through technological integration. Although the reviews above do not focus on Logistic 4.0, their work provides valuable insights into the potential benefits of Logistics 4.0 for supply chain management, which can be relevant to the current research's examination of Industry 4.0's influence on logistics providers. Nevertheless, the concept of Industry 4.0 has pros and cons. According to Pfohl et al. (2015), implementing Industry 4.0 technologies in supply chain operations presents both challenges and opportunities for logistics providers. One of the challenges is the need for significant investments in technology infrastructure and workforce training. Organizations must ensure compatibility and integration among various systems and technologies to achieve seamless data flow and interoperability (Corrêa et al., 2020). Moreover, the complexity and security risks associated with data management and cybersecurity require careful attention (El Hamdi & Abouabdellah, 2022).

However, adopting Industry 4.0 technologies also brings several opportunities for logistics providers. It enables them to optimize supply chain processes, improve resource utilization, and reduce operational costs (Politecnico et al., 2021). Furthermore, Industry 4.0 facilitates enhanced collaboration and information sharing among supply chain partners, improving coordination and performance (Kunrath et al., 2023). Advanced analytics and AI-driven technologies can enable data-driven decision-making, enhancing supply chain agility and responsiveness (Rad et al., 2022). In essence, the literature review on Logistics 4.0 (Industry 4.0 in Logistic Provider) reveals the diverse range of scholarly works exploring the impact of Industry 4.0 on supply chain operations. These works offer valuable insights into the opportunities, challenges, and potential benefits of adopting advanced technologies in the logistics sector. However, the majority of the reviewed works emphasize the positive impact of Industry 4.0 on supply chain management.

The majority of it needs to be more logistic provider-focused. Moreover, some gaps exist in research, particularly in region-specific studies and in-depth analyses of logistics providers' experiences with Logistics 4.0 implementation.

### 2.1. Opportunities and Challenges Associated with Industry 4.0 Adoption in Logistics

Industry 4.0 technologies offer a range of benefits to logistics providers, but they also come with challenges and require critical success factors for successful implementation. Industry 4.0 represents a transformative wave of technological advancements that offer substantial opportunities for logistics providers. Abdelmajied (2022) highlights that Industry 4.0 brings about new concepts and opportunities for supply chain optimization, such as real time data analytics, predictive maintenance, and enhanced visibility across the entire logistics network (Abdelmajied, 2022). These capabilities have the potential to revolutionize logistics operations, improving efficiency and customer satisfaction. Rad et al. (2022), conducted a systematic literature review on 11 core technologies of Industry 4.0 and identified several benefits, challenges, and critical success factors. The benefits of Industry 4.0 technologies include increased efficiency, productivity, and quality through automation and optimization (Rad et al., 2022). Real-time data analytics and AI-driven technologies enable better decision-making, improved forecasting accuracy, and enhanced risk management (Makris et al., 2019). Additionally, Industry 4.0 technologies enable greater visibility and traceability throughout the supply chain, supporting demand-driven and customer-centric approaches (Ghadge et al., 2020).

Barreto, Amaral, and Pereira (2017) offer an overview of the implications of Industry 4.0 in logistics. They emphasize the potential for automation and the integration of cyber-physical systems, which can lead to improved decision-making and resource allocation in logistics operations (Barreto et al., 2017). These advancements align with the need for logistics providers to streamline their supply chain management processes, reduce costs, and meet evolving customer demands. However, alongside the opportunities, there are formidable challenges associated with the adoption of Industry 4.0 in logistics. Ghadge et al. (2020) shed light on the impact of Industry 4.0 implementation on supply chains, emphasizing the need for significant investments in technology, infrastructure, and employee training (Ghadge et al., 2020). These investments can be financially demanding and require logistics providers to carefully assess their readiness for Industry 4.0 adoption. Industry 4.0 has also been recognized as producing some substantial investments in technology infrastructure, data security and privacy concerns, and the requirement for skilled personnel (Pfohl et al., 2015). Organizations must address interoperability issues, standardization, and integration of various systems and technologies (Corrêa et al., 2020).

Furthermore, the cultural change and workforce adaptation necessary to embrace new technologies can be challenging (El Hamdi & Abouabdellah, 2022). Ilin, Simi, and Sauli (2019) delve into the challenges and opportunities presented by the logistics industry in the context of Industry 4.0. They emphasize the need for logistics providers to address cybersecurity concerns, data privacy issues, and the integration of legacy systems with new technologies (Ilin et al., 2019). These challenges highlight the complex nature of implementing Industry 4.0 in logistics, which requires a holistic approach to ensure the security and interoperability of systems. In a study focusing on the Gulf Region, Shaiful Fitri Abdul Rahman et al. (2022), conducted a systematic review of Industry 4.0 adoption in the logistics industry. They found that one of the challenges faced by logistics providers is the need for cultural and organizational changes to align with the new technological landscape (Shaiful Fitri Abdul Rahman et al., 2022). This highlights the importance of change management strategies to successfully transition into Industry 4.0.

Moreover, Sun et al., (2021) conducted a systematic literature review on the application of Industry 4.0 technologies in sustainable logistics. They identified the challenge of ensuring sustainability while implementing Industry 4.0 practices, emphasizing the need for responsible and environmentally conscious logistics operations (Sun et al., 2021). Sustainability concerns are increasingly important for logistics providers as they seek to minimize their environmental footprint. Toyin and Siaminwe (2023) provide a case study highlighting the challenges of implementing Industry 4.0 in a less facilitated environment, such as manufacturing industries in Zambia. This underscores that Industry 4.0 adoption may face unique challenges in different regions and industries, necessitating context-specific strategies (Toyin and Siaminwe, 2023). Vijay Prakash Sharma et al. (2023) investigate the challenges to the adoption of Industry 4.0 technologies in logistics management for last-mile delivery. They emphasize the importance of addressing issues related to the scalability of technology solutions and the integration of diverse systems in logistics management (Vijay Prakash Sharma et al., 2023). Scalability is crucial for logistics providers to adapt to changing demands and expand their operations efficiently.

The above scholarly resource evidences that the adoption of Industry 4.0 technologies in logistics presents significant opportunities for supply chain optimization and enhanced decision-making. However, these opportunities come hand-in-hand with challenges related to financial investments, cybersecurity, data privacy, cultural changes, sustainability, regional disparities, and scalability. Logistics providers must navigate these complexities to harness the full potential of Industry 4.0 in their supply chain management. Critical success factors for implementing Industry 4.0 technologies in logistics include strong leadership commitment, clear strategic objectives, effective change management, and collaboration with supply chain partners (Rad et al., 2022). Organizations need to develop a robust technology roadmap, conduct pilot projects, and continuously assess the impact and effectiveness of implemented technologies (Ghadge et al., 2020). Furthermore, investing in training and upskilling employees to leverage the potential of Industry 4.0 technologies is crucial (Pfohl et al., 2015).

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### 3. Industry 4.0 Technologies and Practices

Industry 4.0, often called the fourth industrial revolution, has ushered in a new era of technological advancement that integrates various cutting-edge technologies into different industries (IBM, n.d.). This transformative trend encompasses the Internet of Things (IoT), artificial intelligence (AI), cloud computing, big data analytics, and robotics, all of which have significant implications for logistics and supply chain management (Rojko, 2017). Integrating these technologies into manufacturing and logistics processes is the cornerstone of Industry 4.0, enabling increased automation, data-driven decision-making, and enhanced efficiency (IBM, n.d.). The Internet of Things (IoT), a critical component of Industry 4.0, involves interconnected devices and objects that collect and exchange data (Barreto et al., 2017). In logistics and supply chain management, IoT devices such as sensors and RFID tags are crucial in tracking and monitoring goods, vehicles, and equipment (Abdirad & Krishnan, 2020). This real-time visibility allows organizations

to improve operational efficiency, cut costs, and enhance customer service. For instance, logistics providers can optimize their transportation and warehousing activities through IoT sensors and real-time tracking systems, which leads to reduced lead times, cost savings, and improved customer satisfaction (Jirsak, 2018). Such technological advancements allow logistics service providers to offer real-time updates on the status and location of goods to their customers, thereby elevating customer satisfaction (Barreto et al., 2017).

Furthermore, integrating artificial intelligence (AI) into logistics operations enables providers to optimize various aspects of their supply chains, including routing, scheduling, and inventory management (Mahdavisharif et al., 2022). AI's analytical capabilities help make more accurate demand forecasts and route optimizations, improving overall performance (Ghadge et al., 2020). However, despite the substantial potential benefits of Industry 4.0 technologies in logistics and supply chain management, there has been limited scholarly exploration of their impact on logistics providers' supply chain management (Abdirad &

Krishnan, 2020). The logistics and supply chain industry stands to gain significantly from the adoption of Industry 4.0 technologies and practices. Logistics service providers play a pivotal role in the seamless movement of goods across the supply chain (NetSuite, 2023). These advanced technologies can substantially enhance logistics operations' efficiency, visibility, and responsiveness (Barreto et al., 2017). This enhanced visibility allows logistics providers to offer real-time updates to customers regarding the status and location of their goods, thereby improving customer satisfaction. Integrating AI further refines routing, scheduling, and inventory management, leading to efficiency gains and cost reductions (Mahdavisharif et al., 2022).

### **3.1. Adoption of Industry 4.0 Technologies**

The adoption of Industry 4.0 technologies within the logistics sector has garnered significant attention due to its potential to revolutionize operations and enhance overall performance. Industry 4.0 represents the fusion of various digital technologies, including the Internet of Things (IoT), artificial intelligence (AI), cloud computing, big data analytics, and robotics, aimed at integrating automation and data analytics into manufacturing and logistics processes (IBM, n.d.). These technologies offer transformative opportunities for logistics providers, enabling real-time monitoring, enhanced decision-making, and optimized supply chain management.

Szczupak, (2022) delves into the profound impact of Industry 4.0 technologies on logistics companies' operations. The study highlights the shift in the traditional logistics landscape and emphasizes the trends and patterns of adoption. This aligns with the observations of Khiem (2018), who explicitly investigates the adoption of Industry 4.0 within the Vietnamese logistics industry. These studies collectively underline the global nature of the adoption phenomenon and emphasize the need for both developed and developing economies to harness the benefits of these technologies. Industry 4.0's integration of IoT devices like sensors and RFID tags plays a pivotal role in logistics by offering real-time visibility of goods, vehicles, and equipment (Barreto et al., 2017). The result is improved efficiency, reduced costs, and enhanced customer service.

Furthermore, the integration of AI in logistics operations, as highlighted by Mahdavisharif et al. (2022), enables logistics providers to optimize routing, scheduling, and inventory management, thereby significantly improving efficiency and reducing costs. However, despite the potential advantages, adopting Industry 4.0 technologies in logistics is challenging. Abdirad and Krishnan (2020) emphasize that multiple factors influence adoption, including organizational culture, resources, and technological readiness. The authors highlight the need for organizations to overcome these barriers to fully leverage the benefits of Industry 4.0. The research presented by da Silva, Frederico, and Garza-Reyes (2023) sheds light on the gap in understanding the influence of Industry 4.0 on logistics providers' supply chain management. This study recognizes the limited scholarly exploration of this vital connection and emphasizes the importance of investigating how Industry 4.0 can enhance logistics operations and contribute to competitive advantage. These insights are particularly significant as they contribute to addressing the existing gap in the literature.

### **3.2. Supply Chain Performance Enhancement**

Industry 4.0, often called the fourth industrial revolution, has profoundly transformed various industries, including logistics and supply chain management. This revolution is characterized by the integration of technologies such as the Internet of Things (IoT), artificial intelligence (AI), cloud computing, big data analytics, and robotics (IBM, n.d.). As the logistics and supply chain industry relies heavily on the movement and management of goods across various stages, integrating Industry 4.0 technologies can significantly enhance supply chain performance in terms of efficiency, responsiveness, and cost-effectiveness.

Industry 4.0's integration of digital technology automation and data analytics into manufacturing and logistics processes has led to a paradigm shift in logistics operations (IBM, n.d.). The Internet of Things (IoT) is at the core of Industry 4.0, enabling the interconnection of devices and objects that gather and exchange data (Barreto et al., 2017). This interconnectedness has profound implications for logistics and supply chain management, enabling real-time tracking of goods, vehicles, and equipment through IoT devices such as sensors and RFID tags (Barreto et al., 2017). This real-time visibility not only enhances the efficiency of operations but also reduces costs and improves customer service by providing accurate updates on the status and location of goods (Abdirad & Krishnan, 2020).

Moreover, integrating Industry 4.0 technologies in logistics and supply chain management brings many benefits. Logistics service providers play a critical role in the efficient movement of goods, and adopting Industry 4.0 technologies can significantly enhance their operations (NetSuite, 2023). Real-time tracking systems and IoT sensors enable optimal management of transportation and warehousing activities, leading to reduced lead times, lowered costs, and improved customer satisfaction (Jirsak, 2018). Furthermore, incorporating AI facilitates efficient routing, scheduling, and inventory management, reducing costs and improving overall performance (Mahdavisarif et al., 2022). While the potential benefits are substantial, the literature reveals limited empirical evidence on the extent of Industry 4.0's influence on the supply chain management of logistics service providers (Abdirad & Krishnan, 2020). Therefore, the current research aims to investigate the impact of Industry 4.0 on logistics providers' supply chain management, focusing on how these technologies can be leveraged to enhance efficiency and gain a competitive edge (Abdirad & Krishnan, 2020). This research seeks to fill the existing knowledge gap by shedding light on the challenges and opportunities of adopting Industry 4.0 in logistics and supply chain management.

### **3.3. Challenges and opportunity of integrating industry 4.0**

Integrating Industry 4.0 technologies presents challenges and opportunities for logistics providers in their supply chain operations. Industry 4.0, often called the fourth industrial revolution, encompasses a range of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), cloud computing, big data analytics, and robotics. These technologies can potentially revolutionize logistics and supply chain management by enhancing efficiency, visibility, and responsiveness (IBM, n.d.). As Pfohl et al. (2015) point out, integrating Industry 4.0 into supply chains presents challenges that stem from the complexity of the technologies, including data security and privacy concerns, interoperability issues, and the need for workforce upskilling. However, despite these challenges, logistics providers can gain competitive advantages by harnessing the potential benefits of Industry 4.0. Radivojević and Milosavljević (2019) discuss the challenges and opportunities of Logistics 4.0, emphasizing the transformation of logistics operations by integrating digital technologies. The shift towards Logistics 4.0 involves using real-time data and predictive analytics to optimize various aspects of logistics, including demand forecasting, route optimization, and inventory management. This can significantly improve operational efficiency and cost reduction (Ghadge et al., 2020). Additionally, integrating AI and machine learning allows logistics providers to make more accurate predictions and decisions, ultimately enhancing customer service and satisfaction (Mahdavisarif et al., 2022).

Mirando et al. (2021) delve into the benefits, challenges, and critical success factors of Industry 4.0 technologies in supply chain management. The benefits of adopting Industry 4.0 technologies in logistics and supply chain management are manifold. Real-time tracking systems enabled by IoT devices enhance visibility and traceability of goods, reducing lead times and improving customer service (Jirsak, 2018). The integration of AI enables logistics providers to optimize routing and inventory management, contributing to enhanced efficiency and reduced costs (Mahdavisarif et al., 2022). Furthermore, adopting Industry 4.0 technologies can enable logistics providers to offer value-added services, such as real-time updates on the status and location of goods to customers (Barreto et al., 2017).

However, the successful implementation of Industry 4.0 technologies requires overcoming various challenges. Abdirad and Krishnan (2020) emphasize that logistics providers must address data privacy and security issues, as the increased connectivity and data exchange inherent to Industry 4.0 can expose vulnerabilities. Interoperability of different systems and technologies also poses challenges, as logistics providers may need to integrate legacy systems with new Industry 4.0 technologies (Corrêa et al., 2020). Furthermore, adopting Industry 4.0 requires a skilled workforce capable of operating and maintaining these advanced technologies (Radivojević & Milosavljević, 2019).

Nevertheless, despite the evident benefits, there are limited scholarly studies concerning the influence of Industry 4.0 on the supply chain management of logistics service providers (Abdirad & Krishnan, 2020). This research gap underscores the need for more comprehensive investigations into the actual impact of these technologies on logistics operations. By examining this topic, researchers aim to uncover ways logistics providers can harness Industry 4.0 technologies to their advantage, enhancing their supply chain processes and gaining a competitive edge (Abdirad & Krishnan, 2020).

## 4. Industry 4.0 Technologies and Practices in Logistics Supply Chain Management

The research findings highlight the significance of Industry 4.0 technologies in transforming logistics and supply chain management. Industry 4.0 is characterized by the integration of cutting-edge technologies such as the Internet of Things (IoT), artificial intelligence (AI), cloud computing, big data analytics, and robotics into various industries (IBM, n.d.). These technologies are reshaping how logistics providers manage their supply chains, offering opportunities to enhance efficiency, visibility, and responsiveness. IoT: IoT devices, including sensors and RFID tags, play a critical role in the real-time tracking and monitoring of goods, vehicles, and equipment (Abdirad & Krishnan, 2020). This real-time visibility enables logistics providers to optimize transportation and warehousing activities, reducing lead times and improving customer service (Barreto et al., 2017).

Artificial intelligence: Integrating AI into logistics operations enables providers to optimize routing, scheduling, and inventory management (Mahdavishtarif et al., 2022). AI's analytical capabilities help make more accurate demand forecasts and route optimizations, improving overall performance (Ghadge et al., 2020). The findings reveal that Industry 4.0 technologies like IoT and AI are transforming logistics and supply chain management. These technologies offer real-time tracking, data-driven decision-making, and enhanced operational efficiency. The integration of these technologies holds immense potential for logistics providers to optimize their supply chain operations, but further research is needed to understand their impact and address challenges comprehensively. As logistics and supply chain management evolve, embracing Industry 4.0 is crucial for staying competitive.

### 4.1. Extent of Adoption of Industry 4.0 Technologies

The adoption of Industry 4.0 technologies among logistics providers has ushered in a transformative era of technological advancement with the integration of cutting-edge technologies such as the Internet of Things (IoT), artificial intelligence (AI), cloud computing, big data analytics, and robotics (IBM, n.d.). The Internet of Things (IoT) is a cornerstone of Industry 4.0, allowing for the interconnectivity of devices that gather and exchange data (Barreto et al., 2017). This interconnectedness provides real-time tracking and monitoring capabilities, improving operational efficiency and reducing costs (Abdirad & Krishnan, 2020). For instance, IoT sensors and RFID tags enable logistics providers to track goods, vehicles, and equipment in real-time, reducing lead times, cost savings, and improving customer service (Jirsak, 2018).

This real-time visibility also enhances customer satisfaction by providing accurate updates on the status and location of goods (Barreto et al., 2017). The integration of AI further amplifies these benefits by optimizing various aspects of supply chain management, including routing, scheduling, and inventory management (Mahdavishtarif et al., 2022). AI-driven analytics enhance demand forecasting accuracy, improving overall performance (Ghadge et al., 2020). However, despite the potential benefits, there's a need for more comprehensive research to fully understand the impact of Industry 4.0 on logistics providers' supply chain management (Abdirad & Krishnan, 2020). This integration is crucial as it enables increased automation, data-driven decision-making, and enhanced operational efficiency (IBM, n.d.). As a critical player in the movement of goods, the logistics and supply chain industry stand to benefit significantly from these advancements (NetSuite, 2023).

### 4.2. Impact, Opportunities and Challenges in Implementing Industry 4.0 Technologies

Integrating Industry 4.0 technologies into logistics providers' supply chain operations presents a transformative shift with substantial opportunities and notable challenges. Industry 4.0, often referred to as the fourth industrial revolution, encompasses advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), cloud computing, big data analytics, and robotics (IBM, n.d.). These technologies can revolutionize logistics and supply chain management by enhancing efficiency, visibility, and responsiveness. The opportunities tied to Industry 4.0 in logistics are profound. Real-time tracking and monitoring of goods, vehicles, and equipment through IoT devices such as sensors and RFID tags enhance visibility and traceability (Barreto et al., 2017). This reduces lead times and costs and improves customer service (Abdirad & Krishnan, 2020). The integration of AI further refines these advantages, facilitating efficient routing, scheduling, and inventory management (Mahdavishtarif et al., 2022). Furthermore, Industry 4.0 empowers logistics providers to offer value-added services, such as real-time updates to customers about the status and location of their goods (Barreto et al., 2017).

However, the journey towards implementing Industry 4.0 in logistics is accompanied by notable challenges. Ensuring data security and privacy in an interconnected environment is critical (El Hamdi & Abouabdellah, 2022). Interoperability issues arise as logistics providers may need to integrate legacy systems with new Industry 4.0 technologies (Corrêa et al., 2020). The transformation also necessitates a skilled workforce capable of operating and maintaining these advanced technologies (Radivojević & Milosavljević, 2019). Moreover, organizational culture and



business processes must adapt to fully leverage the benefits of these technologies (Klingenberg et al., 2022). Research on the impact of Industry 4.0 on logistics providers' supply chain management is pivotal in understanding and addressing these challenges while capitalizing on opportunities. While the benefits are clear, there is limited empirical evidence to fully grasp the extent of

Industry 4.0's influence in this context (Abdirad & Krishnan, 2020). Researchers aim to bridge this gap by exploring how logistics providers can utilize Industry 4.0 technologies to enhance efficiency and gain a competitive edge (Abdirad & Krishnan, 2020).

Integrating Industry 4.0 technologies into logistics providers' supply chain management offers transformative efficiency, responsiveness, and cost-effectiveness benefits. IoT devices, sensors, AI capabilities, and real-time tracking systems enhance operational visibility and decision-making. At the same time, challenges such as data security and organizational change need to be addressed. As logistics providers continue to embrace these technologies, they stand to reshape their industry and deliver enhanced customer value, as the unique challenges and opportunities of Industry 4.0's implementation in the logistics and supply chain domain are underscored by the intricate web of interconnected activities in these industries. While Industry 4.0 promises efficiency improvements and increased visibility, its successful implementation requires substantial organizational transformation, requiring collaboration and coordination among various stakeholders (Barreto et al., 2017). This interdependence underscores the significance of addressing challenges collectively to harness the full potential of these technologies.

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## 5. Conclusion and Outlook

The research findings unveiled a comprehensive narrative that highlights the profound and transformative impact of Industry 4.0 technologies on the landscape of logistics providers' supply chain management. The findings evident that the integration of cutting-edge technologies like the Internet of Things (IoT), artificial intelligence (AI), cloud computing, big data analytics, and robotics into logistics operations has ushered in a new era of possibilities. These technologies collectively serve as catalysts for change, offering logistics providers an array of substantial opportunities aimed at bolstering the very core of their supply chain management. At the forefront of this revolution is the Internet of Things (IoT), a linchpin of Industry 4.0 that facilitates the interconnectivity of devices and objects, thereby enabling real-time tracking and monitoring of goods, vehicles, and equipment. IoT devices such as sensors and RFID tags have emerged as invaluable assets in the logistics realm, introducing an unprecedented level of visibility into the intricacies of supply chain operations. These devices allow logistics providers to optimize transportation and warehousing activities with unparalleled precision. By constantly relaying crucial data regarding the location and status of goods, the IoT empowers logistics providers to reduce lead times, minimize operational costs, and elevate customer service standards. The result is a supply chain that operates with enhanced efficiency, armed with the capability to make data-driven decisions promptly.

Additionally, artificial intelligence (AI) has emerged as another cornerstone of Industry 4.0, redefining the paradigms of logistics operations. Through the integration of AI, logistics providers can embark on a journey of optimization across various facets of supply chain management. This includes the ability to fine-tune routing, scheduling, and inventory management with an unprecedented level of precision. AI-driven analytics and algorithms have the power to revolutionize demand forecasting, enabling logistics providers to make more accurate predictions and ultimately enhancing the overall performance of their supply chains. The result is a logistics landscape that operates with heightened efficiency, where resources are allocated optimally and costs are minimized.

However, amidst the promise of these remarkable benefits, it becomes increasingly evident that a multitude of challenges accompany the adoption of these advanced Industry 4.0 technologies. These challenges serve as a stark reminder that the path to realizing the potential of Industry 4.0 in logistics is not without obstacles.

First and foremost, data security and privacy concerns loom large on the horizon. As logistics providers dive headfirst into the interconnected environment fostered by Industry 4.0, they must grapple with the critical task of safeguarding the sensitive data generated and transmitted by their IoT devices and AI-driven systems. Ensuring the confidentiality and integrity of this data becomes paramount to maintaining the trust of customers and partners. Interoperability emerges as another significant hurdle. As logistics providers seek to integrate their legacy systems with the cutting-edge technologies of Industry 4.0, they must navigate

the complex landscape of compatibility and seamless data exchange. Bridging the gap between old and new systems without disruption becomes a formidable challenge. Furthermore, the journey towards Industry 4.0 necessitates a significant cultural shift within logistics organizations. Traditional business processes and organizational cultures must

adapt to fully embrace the transformative potential of these technologies. A shift in mindset, coupled with a commitment to reimagining established workflows, becomes imperative for success.

The logistics industry also faces a pressing need for a skilled and adaptable workforce capable of operating and maintaining these advanced technologies. The implementation of Industry 4.0 demands a workforce equipped with the necessary skills to harness the full potential of IoT, AI, and related technologies. Evidence from the research underscores the pivotal role of Industry 4.0 technologies in redefining logistics providers' supply chain management. The transformative potential of these technologies, driven by IoT and AI, offers unprecedented opportunities for efficiency, visibility, and responsiveness. However, the path to realizing these benefits is not without its share of challenges. Navigating data security concerns, addressing interoperability issues, fostering cultural change, and developing a skilled workforce are integral components of successfully incorporating Industry 4.0 into supply chain operations. It becomes abundantly clear that embracing Industry 4.0 is not merely a technological endeavor but a strategic imperative, demanding careful planning, investment, and alignment with broader organizational goals. Only by surmounting these challenges can logistics providers unlock the full potential of Industry 4.0 and usher in a new era of logistics excellence.

Integrating Industry 4.0 technologies into logistics providers' supply chain management represents a pivotal opportunity to enhance operational efficiency, customer service, and competitiveness; however, challenges have been seen to exist. Based on the research findings, the following recommendations are essential for proper implementation and utilization of opportunity presented by industry 4.0 by logistic providers while mitigating and avoiding the challenges involved.

- **Investment in Technology and Skill Development:** Logistics providers should allocate resources for investing in advanced technologies and the necessary skill development for their workforce. Training programs and upskilling initiatives can empower employees to operate and maintain Industry 4.0 technologies effectively.
- **Data Security and Privacy Measures:** Given the interconnected nature of Industry 4.0 technologies, logistics providers should prioritize robust data security and privacy measures. Implementing encryption, secure communication protocols, and compliance with data protection regulations is crucial to safeguard sensitive information.
- **Collaborative Organizational Structure:** Industry 4.0 implementation often requires collaboration with various stakeholders, including technology vendors, partners, and customers. Logistics providers should establish collaborative ecosystems to share insights and best practices and jointly address challenges.
- **Agility and Flexibility:** As technology evolves rapidly, logistics providers should maintain agility and flexibility in their strategies. This involves staying informed about emerging technologies and their potential applications in logistics.
- **Change Management and Organizational Culture:** Successful integration of Industry 4.0 requires a shift in organizational culture. Logistics providers should prioritize change management initiatives that facilitate the adoption of new technologies and promote a culture of innovation.
- **Benchmarking and Performance Evaluation:** Logistics providers should establish metrics to evaluate the performance impact of Industry 4.0 technologies. Regular benchmarking against key performance indicators can help identify areas of improvement and measure the return on investment.

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## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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