The Relationship Between Emerging Technologies, Logistics Efficiency and Sustainability

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1. ABSTRACT: In the contemporary era, companies seeking to strike a balance between social responsibility, the conservation of the environment, and economic growth must prioritize sustainability. Apart from strategic alignment, the inclusion of emerging technologies and innovative practices enables the achievement of sustainability goals. Emerging technologies like artificial intelligence, blockchain, the Internet of Things (IoT), and autonomous vehicles and drones have revolutionary potential to enhance sustainability through facilitating more intelligent decision-making, resource optimization, and supply chain transparency. Nevertheless, there is still a scarcity of research investigating how technological developments influence sustainability outcomes, despite the growing interest in technology-driven sustainability. This research fills this gap by highlighting the mediating role of logistics efficiency in enhancing the relationship between emerging technologies and sustainability. Converting technological advancements into real sustainability benefits is achieved through efficient logistical activities, including optimizing transportation, inventory management, warehousing, and distribution operations. The goal of this study is to investigate the correlation between emerging technologies, logistics effectiveness, and sustainability, with logistics efficiency serving as a crucial mediator that amplifies the influence of technology adoption on achieving sustainability goals. This study adopted a narrative literature review approach to address the relationship between emerging technologies, logistics efficiency, and sustainability. Therefore, a conceptual framework was developed to fill the gap in the literature by emphasizing the mediating role of logistics efficiency, stressing the importance of effective logistics systems in the quest for sustainability achievement.

2. INTRODUCTION

Given the significant environmental, economic, and social impacts of the manufacturing sector, research on sustainability within this field has emerged as a distinguished area of study. (Kazakova & Lee, 2022). While the manufacturing processes are responsible for producing products that contribute to enhancing the quality of human life and the global economy, a sustainability perspective must be taken into consideration (Abubakr et al., 2020). The field has transformed over the past few decades from giving the closest attention mostly on environmental issues to adopting a comprehensive triple bottom line (TBL) strategy that includes social, environmental, and economic aspects (Yip et al., 2023). With manufacturing contributing around 20% of global greenhouse gas emissions and being critical for national economies, this transition reflects growing social demands for responsible production (Kazakova & Lee, 2022).

The arrival of the Fourth Industrial Revolution, also labelled Industry 4.0, marked by the revolutionary existence of innovative emerging technologies like artificial intelligence, the Internet of Things, and robotics, is transforming the manufacturing industry through automation, digitization, and data analytics (Braccini & Margherita, 2019). Industry 4.0 focuses primarily on integrating digitalization, Internet-based communication technologies, and forward-thinking intelligent manufacturing technologies to create smart systems and machines, employ smart processes, and deliver smart goods and services (Sun et al., 2022). The essence of disruptive technology in logistics is the incorporation of automation. From self-driving cars to automated storage facilities, the automation revolution focuses on refining processes and minimizing human involvement (Indradevi et al., 2024).

Emerging technologies are key enablers for improving logistics efficiency through promoting transportation routes, reducing costs, enhancing delivery times, improving real-time supply chain visibility, and strategic decision-making (Hanco-Mamani, 2024). The remarkable advancements in logistics efficiency will pave the way towards achieving sustainability through reducing energy consumption and carbon emissions, and thereby enhancing distinct aspects of sustainability. The challenges businesses confront over the next few years will be critical, but those who can adapt and discover innovative arrangements will have a great chance of success (Sabina & Kerimov, 2023).

Industry 4.0 and digital transformation are predicted to have a major impact on TBL sustainability, even if they are still in their early stages. The effects of Industry 4.0 on the TBL pillars for sustainable development, however, are not widely acknowledged. There is a lack of research on this topic, and more investigations are needed to fully understand the sustainability implications of Industry 4.0 in terms of the social, environmental, and economic effects of manufacturing digitization (Nara et al., 2021). This lack of empirical evidence motivates the research into the impact of emerging technologies on sustainability through the lens of logistics efficiency. Recent research has mostly focused on the implementation of new technologies, such as big data analytics, blockchain, artificial intelligence (AI), internet of things (IoT), and additive manufacturing, to increase the intelligence, agility, and efficiency of logistics operations (Sun et al., 2022). As an example, the adoption of IoT reduces energy consumption by 15% to 20%, with manufacturing Small and Medium Enterprises SMEs seeing the most efficient advantages (Khan et al., 2025). Firms can enhance their logistical operations in terms of sustainability by implementing digital technology for innovation, which will result in significant business improvement (Saqib & Qin, 2024).

To demonstrate the mediating role of logistics efficiency in the relationship between emerging technologies and sustainability, a narrative literature review is carried out to examine the complex connection between the emerging technological trends, logistical efficiency, and sustainability, investigating how the continuous progression in these fields can jointly lead to a more sustainable future. The available literature reviews do not pay attention to the links between the three concepts. Therefore, the guiding research question is:

How does logistics efficiency mediate the relationship between emerging technologies adoption and sustainability outcomes?

3. LITERATURE REVIEW

3.1 The Evolution of Industry 4.0 and Logistics 4.0

Industrial revolutions, which started in the 18th century with mechanization and steam power, serve as significant historical turning points driven by technological advancements. The beginning of 1980's have witnessed the Third Industrial Revolution in which personal computers and the internet have led the "Digital Revolution" (Efthymiou & Ponis, 2021). Industry 4.0 made its debut in 2011 at the Hannover Fair in Germany, with an initial emphasis on building "smart factories" that combine the real and virtual worlds by using cyber-physical systems (CPS). Despite having its origins in manufacturing, this idea has expanded to include the whole supply chain, with a focus on real-time decentralization and information transparency (Núñez-Merino et al., 2022). Logistics went through several stages in parallel: logistics 1.0 (transport mechanization), logistics 2.0 (transport system automation), logistics 3.0 (logistics management systems), and logistics 4.0 (the utilization of disruptive technologies enabled by Wi-Fi to build transparent, data-driven networks).

An important turning point in the development of smart logistics is the change from Industry 4.0 to Industry 5.0, which prioritizes sustainability, resilience, and human-centricity above a purely technological paradigm. Industry 5.0 explicitly incorporates the human element, acknowledging the crucial interaction between humans and technology in this socio-economic transition, whereas Industry 4.0 mainly concentrated on advanced automation and digital transformation to improve manufacturing efficiency. In order to promote more peaceful and productive working conditions, this fresh concept in smart logistics places a higher priority on collaboration technology like collaborative robots and human-machine systems. The implications for smart logistics are deep, causing a rethinking of how intelligent automation, devices, systems, and materials are developed and deployed to enhance functionality and performance through physical and cyber links, with increased monitoring and control. In order to meet human constraints by enhancing functional capacities through intelligent technologies, this evolution calls for giving computers and robots cognitive capabilities for decision-making and active incident prevention. In the end, Industry 5.0 seeks to advance research toward a more sustainable and human-centered logistics future by achieving industrial and technological goals without sacrificing socioeconomic and environmental performance (Jefroy et al., 2022).

The logistics industry is undergoing a fundamental transformation due to the widespread adoption of cutting-edge technology, which is improving its efficiency, transparency, and ability to adapt to changing market needs. These developments make it possible for supply chain actors to set up reliable systems for asset tracking, transaction recording, and thorough documentation management, which improves operational efficiency, lowers expenses, and improves the quality of customer service (Reznik,2024). By fostering notable improvements in operational efficiency, productivity, and automation, Industry 4.0 technologies are radically changing the contemporary logistics sector and paving the way for the creation of "smart facilities" that can quickly adapt and use resources optimally with minimal input from humans. Robotics, the Internet of Things (IoT), cloud computing, big data analytics, augmented reality (AR), artificial intelligence (AI), machine learning, digital twins, blockchain, cyber-physical systems (CPS), and additive manufacturing (3D printing) are some of the major emerging technologies (Efthymiou & Ponis, 2021).

3.1.1 The Benefits and Challenges of Emerging Technologies

The convergence of technologies such as artificial intelligence, blockchain, the Internet of Things, and robotics presents tremendous benefits as well as considerable challenges.

Artificial intelligence (AI) solutions are revolutionizing fields like intelligent warehouse automation, improved route planning, and predictive analytics for demand forecasting, enabling more responsive and flexible logistics choices (Chaudhary & Bhule, 2025). Machine learning and artificial intelligence (AI) improve forecasts, optimize route planning to lower emissions, enhance customer service with virtual assistants, and increase efficiency through AI-powered robots and drones that lower labor costs and protect security against fraud. By using data-driven routing to provide faster, more effective, and ecologically friendly delivery options, last-mile delivery innovations like drones and tiny fulfillment centers are trying to solve logistical challenges (Reznik, 2024). The adoption of AI technology has reduced the excess inventory costs by 20-35% through enhancing demand forecasting and route optimization (Vudugula, 2025).

By utilizing AI and real-time data to optimize routes and prevent traffic jams, autonomous vehicles and drones drastically shorten delivery times. Autonomous systems, in contrast to traditional logistics, can run continuously, removing downtime caused by driver rest times or human exhaustion. In particular, drones may completely avoid ground-based impediments, which might cut last-mile delivery times in isolated or crowded places by as much as 40% (Oluwole Raphael Odumbo & Enyinnaya Prince Onuma, 2025). When compared to ground fleets, drones are known for being quick and reasonably priced in terms of transportation cost per kilometer (Rejeb et al., 2023).

IoT's significantly enhanced visibility and real-time tracking capabilities are a major benefit. It provides real-time visibility, reducing logistics delays by 15–40%. (Vudugula, 2025). Businesses may drastically cut down on loss, damage, and delays by implementing smart sensors and devices across the supply chain to track the precise position and state of goods from raw materials to final delivery. By reducing overstocking and stockouts, this better insight also enables more precise demand forecasting and inventory management, which immediately reduces costs and raises customer satisfaction. Beyond tracking, IoT uses automation to enable unmatched operational efficiency. IoT-enabled solutions, for instance, can automate picking, packing, and sorting in warehouses, increasing productivity and lowering labor expenses. Additionally, the information gathered by IoT devices offers priceless insights for predictive analytics, enabling proactive maintenance of transportation equipment and vehicles to avoid expensive malfunctions and guarantee on-time delivery. By lowering carbon footprints, this data-driven strategy not only improves routes and fuel usage but also supports more environmentally friendly logistical techniques (Zrelli & Rejeb, 2024). IoT has proven to have the widest range of practical uses, particularly in enhancing smart city mobility and smart environment, as well as in reducing energy usage in energy systems (Wu et al., 2022).

Blockchain serves as a transformative solution for traceability and auditing, guaranteeing product authenticity and minimizing administrative inefficiencies (Wu et al., 2022). Blockchain technology is being used and studied in four major areas: technology, trade, trust, and traceability/transparency. Technology has immense potential for global supply chains, logistics, and transportation operations, even if it is still in the early stages of realizing its full potential. Although there are current limitations in handling high volumes of transactions and high failure rate of early blockchain projects, the "Technology" cluster explores the fundamental elements of blockchain, including its features like immutability, transparency, security, decentralization, and the role of smart contracts, which enable

automated transactions and tokenization of assets. As demonstrated by projects like the Belt and Road Blockchain Consortium, the "Trade" cluster emphasizes how blockchain technology may help with energy trading, cross-border transactions, and the usage of cryptocurrencies to lower costs and unite markets. Last but not least, the "Traceability/Transparency" cluster highlights how blockchain can improve supply chain inventory and information visibility by offering a thorough audit trail from sourcing to delivery. This is essential for maintaining environmental sustainability and tackling problems like counterfeit goods, especially in the pharmaceutical sector (Pournader et al., 2020).

Despite the incremental developments, there are still various obstacles to overcome, especially in the areas of training and development for human resources, as well as the high expense and difficulty of adopting recent technologies for small and medium-sized businesses. (Efthymiou & Ponis, 2021). High capital investment costs prevent widespread adoption of emerging technologies, especially for small and medium-sized businesses (SMEs) (Khan et al., 2025). Additionally, as systems become more interconnected, cybersecurity threats and data privacy issues become more prevalent (Sun et al., 2022).Significant obstacles still exist, though, such as problems with interoperability, data security, high investment costs, the requirement for trained personnel, and organizational opposition, all of these indicates areas that require further study and advancement (Núñez-Merino et al., 2022).

3.2 Logistics Efficiency

Logistics efficiency is a broad notion that encompasses the degree of service provided by the logistics system within a specific time frame, as well as the impact of different indicators reached while necessitating the use of the fewest resources possible. To put it briefly, logistics efficiency guarantees the quality of service while maximizing resource utilization and minimizing expenses (Wang et al., 2025). It ensures that things arrive at their destination on schedule and at the lowest possible cost. It is commonly assessed as the ratio of logistics turnover to the size of the logistics network (WANG et al., 2022).

There are various ways in which logistics efficiency affects industrial businesses. One of the biggest expenses associated with running an industrial business is logistics. Reducing needless transportation, warehousing, and general operating expenses is vital to increasing logistics efficiency. For instance, by improving loading rates, cutting down on transit losses, and optimizing transportation routes, businesses can immediately lower transportation expenses. Effective inventory management can also lower obsolescence and backlogs, which reduces inventory costs(Wang et al., 2025).

3.3 Sustainability

The definition of sustainable development, which has historically served as the foundation for the concept, is the growth that satisfies current needs without compromising the ability of future generations to satisfy their own requirements. (Sun et al., 2022) Since the introduction of sustainability as a global priority, its significance has expanded across various sectors. In the corporate realm, sustainable development typically adheres to the triple bottom line, which encompasses the three pillars of sustainability: economic, environmental, and social. The economic pillar pertains to the creation of added value and financial sustainability, including aspects such as competitiveness, job creation, cost efficiency, and long-term profitability. The environmental pillar emphasizes the effects of operations on biodiversity and natural resources, addressing issues like resource and energy consumption, waste management, emissions, and ecological integrity. Meanwhile, the social pillar focuses on the broader societal impacts, including public health, social equity, and labor rights (Gonzalez et al., 2023).

A complex task, managing organizational sustainability calls for thorough assessment and control of operational effects on the environment and society. This goes beyond simple decarbonization to include waste reduction, sustainable finance, and material flow management. The "7E model," a new, comprehensive sustainability framework that greatly extends the traditional Triple Bottom Line (TBL) approach to incorporate Economic, Environmental, Social, Ethical, Efficiency, Efficacy, and Engagement dimensions, is how this study tackles the complexity. This enlarged framework acts as a useful road map for businesses, especially small and medium-sized businesses (SMEs) with limited funding, to strategically build and improve their decarbonization and sustainability performance. The research illustrates the framework's usefulness in assessing and contrasting the economic, environmental, and social aspects of business operations through an empirical case study in the tea industries of the UK and Sri Lanka, offering a more sophisticated understanding of sustainability performance. The main contribution of the 7E model is that it provides a more thorough and useful measurement tool that goes beyond theoretical frameworks to offer concrete assistance for incorporating sustainable practices straight into corporate strategy in a variety of industries (Silva etal., 2024).

3.4 Relationship Between Emerging Technologies and Logistics Efficiency

Emerging technologies are one of the key reasons behind increasing logistical efficiency by automating processes and using digital technologies in all business operations through transforming analogue data into digital formats. As an example, attempts were made in the 1970s and 1980s to integrate technology into logistics operations for the electronic exchange of papers, which accelerated the previously time-consuming and paper-based procedures (Saqib & Qin, 2024).

IoT-enabled sensors increase facility utilization and shipment tracking accuracy, enabling businesses to manage larger volumes with fewer resources. Predictive maintenance and IoT-enabled smart sensors lower costs by up to 25% by mitigating equipment and vehicle failure (Vudugula, 2025). Moreover, delivery routes and cargo consolidation are optimized using AI-driven algorithms, which lowers fuel usage and operational delays (Qureshi et al., 2024). Additionally, warehouse automation via robotics and automated storage systems (ASRS) limits picking errors and maximizes space utilization, which immediately lowers the overall costs for flow processes (Reznik, 2024).

It is evident after reviewing the literature on new technologies that tools like IoT, AI, automation, and advanced analytics improve information visibility, coordination, and responsiveness throughout logistics operations, which improves operational performance. These results indicate that companies are more likely to attain greater levels of logistical efficiency when they integrate emerging technology. As a result, this study hypothesizes that the efficiency of logistics is significantly improved by the use of emerging technologies (H4).

3.5 Relationship Between Emerging Technologies and Sustainability

The interaction between emerging technologies and sustainability is traditionally illustrated through the Triple Bottom Line (TBL) framework:

- *Environmental Sustainability:* Technologies such as big data analytics facilitate real-time carbon footprint tracking, enabling companies to comply with international environmental regulations (Sun et al., 2022). Hydrogen-powered fleets and solar-powered warehouses are examples of renewable energy technology that can significantly reduce greenhouse gas emissions (Ibrahim et al., 2024).
- *Social Sustainability:* Digital tools enhance worker safety by using augmented reality (AR) training and monitoring hazardous conditions (Jefroy et al., 2022). With digital tools utilized to enhance working conditions, guarantee labor law compliance, and promote employee satisfaction, Industry 5.0 sets an intense focus on human empowerment (Foster & Rhoden, 2020). Emerging technologies are being deployed more frequently in the maritime industry to track the health and safety of seafarers (Wagner & Wiśnicki, 2022).
- *Economic Sustainability*: Long-term value creation is driven by digital innovation, which increases a company's competitiveness through resource efficiency and market differentiation (Mutambik, 2024). According to research on Chinese logistics companies, technology adoption and integration have a strong positive impact on economic performance (Saqib & Qin, 2024).

According to research, new technologies like automation, digital platforms, big data analytics, and artificial intelligence improve sustainability performance in social, environmental, and economic spheres. In terms of the economy, these technologies boost productivity, lower operating costs, and promote long-term competitiveness; in terms of the environment, they facilitate effective resource use, real-time monitoring, and emissions reduction; and in terms of society, they enhance workplace safety, transparency, and service dependability. According to empirical data, these advantages are related and result from advancements in logistics and operations made possible by technology. This study's hypothesis, which is based on an integrated perspective, is that the adoption of emerging technologies significantly improves overall sustainability performance, which includes social, environmental, and economic aspects (H1, H2, and H3).

3.6 Relationship Between Logistics Efficiency, Sustainability, and Emerging Technologies

The crucial bridge that transforms emerging technology into quantifiable sustainability benefits is logistics efficiency. This mediation takes place because, although the raw data and connectivity are provided by technologies like Artificial Intelligence (AI), the Internet of Things (IoT), and Blockchain, it is the subsequent optimization of logistics processes—such as route planning, inventory management, and resource minimization—that directly accomplishes environmental, economic, and social goals (Sabina & Kerimov, 2023).

Emerging technologies serve as key drivers that enhance the primary components of logistics efficiency. As an example, large volumes of multi-sourced data are processed by AI and machine learning to solve complicated scheduling and forecasting issues, enabling businesses to handle greater amounts of items with fewer resources (Wu et al., 2022). On the other hand, real-time coordination is facilitated by the IoT sensors that enhance the accuracy of shipment tracking and facility usage, minimizing logistics delays by an estimated 15% to 40% (Vudugula, 2025). Moreover, operational streamlining is enabled by optimizing space utilization and minimizing picking errors. Warehouse automation via robotics and automated storage systems (ASRS) immediately lowers the overall costs for flow processes (Reznik, 2024). Finally, through automated documentation and supplier verification, blockchain-enabled administrative transparency by using smart contracts, which cut transaction costs and administrative inefficiencies by 20% to 40% (Vudugula, 2025).

The efficiency gains in logistics caused by these technologies will have a positive impact on sustainability in all three areas (the "Triple Bottom Line") (Saqib & Qin, 2024). From an environmental perspective, logistics efficiency is characterized by the reduction of energy and fuel consumption (Sabina & Kerimov, 2023). AI enhances thermal energy storage design and operation, smart grid management, loss reduction, and forecasting, leading to more efficient use of storage and renewable energy sources (Li et al., 2023). Economically, enterprises can shorten delivery cycles and increase market competitiveness through improved logistics efficiency, which saves wasteful transportation and warehousing costs (Wang et al., 2025). Concerning social responsibility, technology minimizes human error and enhances workplace safety by improving logistical operations' precision, especially in dangerous settings (Sabina & Kerimov, 2023). Additionally, businesses can ensure compliance with labor regulations and ethical standards by taking advantage of the productivity gains from digital transformation (Saqib & Qin, 2024).

The literature indicates that the impact of new technologies is primarily realised through operational processes rather than direct effects, despite the common assumption that they directly drive sustainability outcomes. When technology adoption leads to observable increases in logistical efficiency, improvements in economic, environmental, and social sustainability are most noticeable. Thus, this study hypothesizes that the adoption of emerging technologies and economic sustainability, environmental sustainability, and social sustainability are mediated by logistical efficiency (H5 and H6).

4. CONCEPTUAL FRAMEWORK

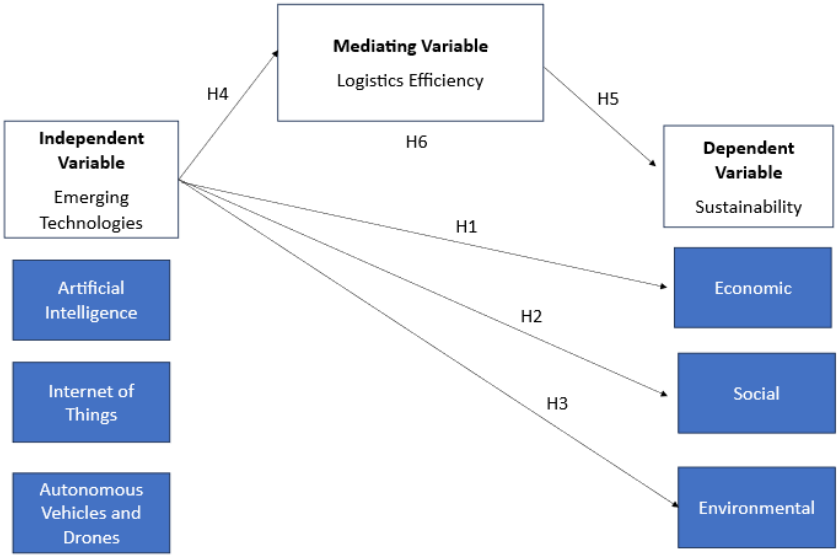

Figure1: The Mediating role of logistics efficiency in the relationship between emerging technologies and sustainability (Developed by author)

Based on the synthesis of the reviewed literature, a coherent set of hypotheses relating the adoption of emerging technologies to sustainability outcomes through the mediating function of logistics efficiency is formulated. According to previous studies, emerging technologies—like digital platforms, automation, data analytics, and intelligent logistics systems—have the potential to improve economic performance by cutting expenses and making better use of resources; strengthen social sustainability by enhancing workplace safety, transparency, and service quality; and support environmental sustainability by lowering emissions, minimizing waste, and using less energy. The study also, however, indicates that these sustainability gains are rarely attained directly; instead, they materialize through improvements in the efficiency of logistics, such as greater coordination, shorter lead times, more efficient transportation, and better inventory management. Thus, based on this information, this study puts forth a series of hypotheses suggesting that the adoption of emerging technologies has a favorable impact on environmental, social, and economic sustainability, with logistics efficiency serving as a crucial mediating factor in these connections.

4.1 Hypothesized Relationships:

H1: Emerging Technologies → Economic Sustainability

Adopting emerging technologies can lead to introducing new jobs, reducing costs, and increasing productivity.

H2: Emerging Technologies → Social Sustainability

The use of emerging technologies enhances quality of life.

H3: Emerging Technologies → Environmental Sustainability

Emerging technologies can directly impact sustainability by enabling energy-efficient operations, reducing pollution, and promoting sustainable practices.

H4: Emerging Technologies → Logistics Efficiency

Emerging technologies can enhance logistics efficiency by optimizing transportation routes, improving inventory management, and reducing waste.

H5: Logistics Efficiency → Sustainability

Efficient logistics can promote equitable labor practices by facilitating prompt payments to suppliers and employees, while also minimizing avoidable delays and interruptions. Moreover, it can lead to significant cost savings through reduced transportation costs, inventory holding costs, and warehouse expenses. Improved logistics efficiency can lead to reduced carbon emissions, less energy consumption, and minimized waste, thereby contributing to environmental sustainability.

H6: Emerging Technologies → Logistics Efficiency → Sustainability

There is a relationship between adopting emerging technologies and enhancing sustainability through the mediating role of logistics efficiency.

5. Methodology

This study adopted a narrative literature review approach to highlight the relationship between emerging technologies, logistics efficiency, and sustainability. A narrative literature review is described as a qualitative research method that combines and analyzes existing knowledge on a specific topic to provide a thorough understanding and identify theoretical and empirical gaps (Green et al., 2006). Unlike systematic reviews, which depend on strict inclusion standards, the narrative approach provides flexibility in selecting, analyzing, and connecting diverse sources, making it ideally appropriate for conceptual exploration and theory building (Baumeister & Leary, 1997).

Data from secondary sources were gathered and assessed during the review process. The secondary sources included journal articles, reports, and review papers that offered theoretical or contextual insights. To guarantee thorough coverage of the literature, information was gathered from several trusted academic databases, including Scopus, Web of Science, ScienceDirect, SpringerLink, and Google Scholar, with the use of keywords supporting the research area, such as "emerging technologies in supply chain", "sustainability", and "logistics efficiency". In order to represent the most recent developments in sustainability research and technology advancements, the search was restricted to papers from 2019 to 2025.

To guarantee the applicability, caliber, and coherence of the evaluated literature, this study used precise inclusion and exclusion criteria. Peer-reviewed journal articles and reputable conference papers that specifically explore new technologies, supply chain or logistics efficiency, and sustainability aspects (economic, social, and environmental) made up the inclusion criteria. Only research that presented solid theoretical frameworks or empirical findings and were published in English during a specific period was taken into consideration. On the other hand, non-peer-reviewed publications, such as editorials, opinion articles, industry reports that lack scientific rigor, dissertations, and studies that don't clearly connect technology adoption to logistical or sustainability outcomes, were excluded. To

preserve analytical rigor, papers that lacked methodological transparency or that concentrated only on technological elements without including logistical efficiency or sustainability consequences were also eliminated.

The integrating findings from the reviewed literature were used to build a conceptual framework that reveals the role of logistics efficiency in enhancing the relationship between emerging technologies and sustainability. This framework provides groundwork for future empirical research in which the proposed hypotheses can be empirically tested using survey data collected from relevant industry practitioners. The survey instrument is designed to capture perceptions of emerging technology adoption, logistics efficiency, and sustainability performance.

6. Findings and Conclusion

Based on the thorough assessment of the collected literature, this section illustrates the main findings derived from the narrative analysis of researched areas related to emerging technologies, logistics efficiency, and sustainability. Important links and relationships across the core variables were thoroughly identified through the narrative analysis of the reviewed literature. The analysis concluded that emerging technologies contribute to enhancing sustainability through the mediating role of logistics efficiency. By interpreting these insights, the research was able to highlight how technological advancements pave the way towards improved sustainability outcomes through enhanced logistical efficiency.

A conceptual framework has been created to demonstrate the connections between the variables analyzed. This framework supports the existence of a correlation between the variables. It not only encapsulates the combined results of earlier research but also offers a theoretical framework for future empirical studies focused on testing and verifying these connections.

In conclusion, this study aimed to reveal the existence of a correlation between emerging technologies, logistics efficiency, and sustainability. The integration of emerging technologies such as artificial intelligence (AI), internet of things (IoT), and autonomous vehicles and drones play a significant role in achieving environmental, economic, and social sustainability. The tremendous benefits of technological advancements adoption include productivity enhancements, cost reduction, lowering carbon footprint emissions, providing energy-efficient operations, and socially improving the quality of life. Those benefits are accelerated by the existence of logistics efficiency. The narrative literature review that was conducted supported the aim of the study by highlighting the existing emerging technologies and their impact on sustainable development, with the support of logistics efficiency.

7. DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES:

During the preparation of this work, the authors used ChatGPT, Consensus and Quillbot in order to identify suitable academic literature, interpret existing research on a topic, check for correct citation information and refining English grammar, spelling, and punctuation errors. After using this tool/service, the authors reviewed and edited the content as necessary and take full responsibility for the content of the publication.

8. REFERENCES

Abubakr, M., Abbas, A. T., Tomaz, I., Soliman, M. S., Luqman, M., & Hegab, H. (2020). Sustainable and smart manufacturing: An integrated approach. *Sustainability (Switzerland)*, *12*(6), 1–19. https://doi.org/10.3390/su12062280

Baumeister, R. F., & Leary, M. R. (1997). Writing Narrative Literature Reviews. In *Review of General Psychology* (Vol. 1, Issue 3).

Braccini, A. M., & Margherita, E. G. (2019). Exploring organizational sustainability of Industry 4.0 under the triple bottom line: The case of a manufacturing company. *Sustainability (Switzerland)*, *11*(1). https://doi.org/10.3390/su11010036

Chaudhary, S., & Bhule, U. (2025). The Role of Technology in Enhancing Supply Chain Integration and Logistics. *Journal of Business Logistics*, *22*(2), 1–25. https://doi.org/10.1002/j.2158-1592.2001.tb00001.x

Efthymiou, O. K., & Ponis, S. T. (2021). Industry 4.0 technologies and their impact in contemporary logistics: A systematic literature review. In *Sustainability (Switzerland)* (Vol. 13, Issue 21). MDPI. https://doi.org/10.3390/su132111643

Foster, M. N., & Rhoden, S. L. N. H. (2020). The integration of automation and artificial intelligence into the logistics sector: A Caribbean perspective. *Worldwide Hospitality and Tourism Themes*, *12*(1), 56–68. https://doi.org/10.1108/WHATT-10-2019-0070

Gonzalez, J. N., Garrido, L., & Vassallo, J. M. (2023). Exploring stakeholders' perspectives to improve the sustainability of last mile logistics for e-commerce in urban areas. *Research in Transportation Business and Management*, *49*. https://doi.org/10.1016/j.rtbm.2023.101005

Green, B. N., Johnson, C. D., & Adams, A. (2006). *Writing narrative literature reviews for peer-reviewed journals: secrets of the trade*.

Ibrahim, M. D., Pereira, M. A., & Caldas, P. (2024). Efficiency analysis of the innovation-driven sustainable logistics industry. *Socio-Economic Planning Sciences*, *96*. https://doi.org/10.1016/j.seps.2024.102050

Jefroy, N., Azarian, M., & Yu, H. (2022). Moving from Industry 4.0 to Industry 5.0: What Are the Implications for Smart Logistics? In *Logistics* (Vol. 6, Issue 2). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/logistics6020026

Kazakova, E., & Lee, J. (2022). Sustainable Manufacturing for a Circular Economy. *Sustainability (Switzerland)*, *14*(24). https://doi.org/10.3390/su142417010

Khan, M. A., Saini, P., & Alam, J. (2025). Internet of things (IOT) Enabled Sustainable Energy MANAGEMENT (SEM) for SMEs – A Review. *Journal of Electronics and Electrical Engineering*, 133–151. https://doi.org/10.37256/jeee.4220256925

Li, J., Herdem, M. S., Nathwani, J., & Wen, J. Z. (2023). Methods and applications for Artificial Intelligence, Big Data, Internet of Things, and Blockchain in smart energy management. In *Energy and AI* (Vol. 11). Elsevier B.V. https://doi.org/10.1016/j.egyai.2022.100208

Mutambik, I. (2024). Digital Transformation as a Driver of Sustainability Performance—A Study from Freight and Logistics Industry. *Sustainability (Switzerland)*, *16*(10). https://doi.org/10.3390/su16104310

Nara, E. O. B., da Costa, M. B., Baierle, I. C., Schaefer, J. L., Benitez, G. B., do Santos, L. M. A. L., & Benitez, L. B. (2021). Expected impact of industry 4.0 technologies on sustainable development: A study in the context of Brazil's plastic industry. *Sustainable Production and Consumption*, *25*, 102–122. https://doi.org/10.1016/j.spc.2020.07.018

Núñez-Merino, M., Maqueira-Marín, J. M., Moyano-Fuentes, J., & Castaño-Moraga, C. A. (2022). Industry 4.0 and supply chain. A Systematic Science Mapping analysis. *Technological Forecasting and Social Change*, *181*. https://doi.org/10.1016/j.techfore.2022.121788

Oluwole Raphael Odumbo, & Enyinnaya Prince Onuma. (2025). The future of autonomous vehicles and drones in supply chain delivery. *International Journal of Science and Research Archive*, *14*(1), 582–602. https://doi.org/10.30574/ijsra.2025.14.1.0117

Pournader, M., Shi, Y., Seuring, S., & Koh, S. C. L. (2020). Blockchain applications in supply chains, transport and logistics: a systematic review of the literature. *International Journal of Production Research*, *58*(7), 2063–2081. https://doi.org/10.1080/00207543.2019.1650976

Qureshi, K. M., Mewada, B. G., Kaur, S., Khan, A., Al-Qahtani, M. M., & Qureshi, M. R. N. M. (2024). Investigating industry 4.0 technologies in logistics 4.0 usage towards sustainable manufacturing supply chain. *Heliyon*, *10*(10). https://doi.org/10.1016/j.heliyon.2024.e30661

Rejeb, A., Rejeb, K., Simske, S. J., & Treiblmaier, H. (2023). Drones for supply chain management and logistics: a review and research agenda. *International Journal of Logistics Research and Applications*, *26*(6), 708–731. https://doi.org/10.1080/13675567.2021.1981273

Reznik, N. P. (2024). Innovative Technologies in the Logistics System. *Electronic Scientifically and Practical Journal "Intellectualization of Logistics and Supply Chain Management," 26*, 64–74.

Sabina, S., & Kerimov, B. (2023). The Significance of Using the Latest IT Technologies in Logistics. *Вестник Академии Гражданской Авиации*, *31*(4). https://doi.org/10.53364/24138614_2023_31_4_76

Saqib, Z. A., & Qin, L. (2024). Investigating Effects of Digital Innovations on Sustainable Operations of Logistics: An Empirical Study. *Sustainability (Switzerland)* , *16*(13). https://doi.org/10.3390/su16135518

Silva, D. N., Wehrmeyer, W., & Murphy, R. (2024). Development of a holistic framework for sustainability measurement: A case study of the tea sector. *Cleaner Production Letters*, *7*. https://doi.org/10.1016/j.clpl.2024.100072

Sun, X., Yu, H., Solvang, W. D., Wang, Y., & Wang, K. (2022). The application of Industry 4.0 technologies in sustainable logistics: a systematic literature review (2012–2020) to explore future research opportunities. In *Environmental Science and Pollution Research* (Vol. 29, Issue 7, pp. 9560–9591). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/s11356-021-17693-y

Vudugula, S. (2025). Sustainable Smart Supply Chains: A Review of Green Technologies and Their Impact On Logistics. *American Journal of Scholarly Research and Innovation*, *4*(01), 1–32. https://doi.org/10.63125/1fehce37

Wagner, N., & Wiśnicki, B. (2022). The Importance of Emerging Technologies to the Increasing of Corporate Sustainability in Shipping Companies. *Sustainability (Switzerland)*, *14*(19). https://doi.org/10.3390/su141912475

WANG, Y., Sui, X., Liu, D., & Li, F. (2022). Does Logistics Efficiency matter? Evidence from green economic efficiency side. *Research in International Business and Finance*, *61*. https://doi.org/10.1016/j.ribaf.2022.101650

Wang, Z., Gao, L., & Wang, W. (2025). The impact of supply chain digitization and logistics efficiency on the competitiveness of industrial enterprises. *International Review of Economics and Finance*, *97*. https://doi.org/10.1016/j.iref.2024.103759

Wu, S. R., Shirkey, G., Celik, I., Shao, C., & Chen, J. (2022). A Review on the Adoption of AI, BC, and IoT in Sustainability Research. In *Sustainability (Switzerland)* (Vol. 14, Issue 13). MDPI. https://doi.org/10.3390/su14137851

Yip, W. S., Zhou, H. T., & To, S. (2023). A critical analysis on the triple bottom line of sustainable manufacturing: key findings and implications. *Environmental Science and Pollution Research*, *30*(14), 41388–41404. https://doi.org/10.1007/s11356-022-25122-x

Zrelli, I., & Rejeb, A. (2024). A bibliometric analysis of IoT applications in logistics and supply chain management. In *Heliyon* (Vol. 10, Issue 16). Elsevier Ltd. https://doi.org/10.1016/j.heliyon.2024.e36578