Optimizing Supply Chain Management: A Systematic Review of Logistics 4.0 for Intelligent and Sustainable Transformation

Henry Lloclla-Salazar [1]; Ruth Zulema Puma-Flores[2]; Carlos Alexis Alvarado-Silva [3]
[1,2,3] Universidad Tecnológica del Perú, Lima, Perú, *U17302822@utp.edu.pe, 1330635@utp.edu.pe, C21629@utp.edu.pe.*

Abstract– The constant global technological evolution has driven the integration of tools such as digitalization and automation into industrial processes, marking the advent of Industry 4.0. In this context, this review on Logistics 4.0 aims to identify how these technologies enhance supply chain management efficiency, enabling companies to reduce costs, improve quality, and optimize inventory management. Method: This study is based on a Systematic Literature Review (SLR) using the Scopus database as the primary source. The PRISMA and PICO methods were employed to carry out a structured and rigorous process for identifying, selecting, and analyzing relevant studies. After applying inclusion and exclusion criteria, 42 articles were selected from an initial total of 2416 for detailed analysis. Results: The analysis revealed that technologies such as the Internet of Things (IoT), automated guided vehicles (AGV), artificial intelligence (AI), and Big Data have significantly contributed to optimizing management processes in Logistics 4.0. These tools have proven effective in improving operational and strategic efficiency in companies. Conclusion: The proper implementation of technologies in Logistics 4.0 management significantly improves processes by delivering higher quality products and services, reducing costs, and consequently increasing business profitability.

Keywords-- Internet of Things, Big Data analysis, Blockchain, Logistic 4.0.

I. Introduction

In recent years, Logistics 4.0 has revolutionized supply chain management, and the ongoing development of new tools aims to elevate the level of efficiency within the logistics chain [1]. Changes also entail responsibilities, and regarding this, [2] notes that this situation raises unresolved questions. For instance, what steps can be taken to ensure a seamless transition to the digitalization and automation of logistics processes? More importantly, what does the future hold for logistics in this new era of swift and occasionally abrupt industrial transformation? Hence, the logistics chain, an integral component of any organization, must adapt and align itself with Logistics 4.0. This adaptation promises increased efficiency, facilitating a swift response to market demand fluctuations.

Logistics processes encompass activities that entail critical factors within each phase. This is because they encompass the transportation and storage of products. According to [3], in a study on warehouse automation, there are two primary material flows within warehouses: reception and delivery. Consequently, the most time-consuming task involves product collection. Reducing the travel time and energy costs of the automated guided vehicle (AGV) system poses a significant challenge for industries. As a result, in most cases, the management of logistics processes continues to adhere to traditional methods, which leads to the loss of traceability for both internal and external products. This, in turn, results in errors in picking and inventory management.

Likewise, the surge in electronic commerce has become apparent due to the issues arising from order processing and meeting customer delivery timeframes as required in [4]. Additionally, there's a problem with inefficient space utilization, which contributes to increased wastage. Moreover, the lack of order and organization results in an inability to locate products promptly, causing delays in handling and resulting in both material losses and non-compliance with end consumers. Nevertheless, Logistics 4.0, in conjunction with the implementation of enhancement tools, strives to meet the ever-growing and complex demands of today's market [5].

Therefore, the processes rejuvenated by Logistics 4.0 promise high-quality products, swift deliveries, optimized supply chains, and informed decision-making. This, in turn, secures the profitability of companies [6]. Moreover, the technologies associated with Logistics 4.0 have delivered a positive impact on service innovation. On one hand, they've boosted the productivity and efficiency of organizations, and on the other hand, they've brought about dynamic changes in production lines and supply chain networks [7]. Digitalization also plays a significant role in innovating logistics processes. It emerges as a robust solution to confront new challenges by incorporating technologies that provide competitive advantages and mitigate risks in the value chain [8].

This review provides insight into the current landscape of Logistics 4.0, emerging as a strategic blueprint within the context of the fourth industrial revolution, harnessing intelligent technologies such as artificial intelligence (AI), the Internet of Things (IoT), and robotics to automate processes [9]. The primary goal of this review is to discern the extent to which 4.0 technology is applied in smart warehouses for the enhancement and efficient management of their logistics operations [3]. Furthermore, the analysis of Logistics 4.0 presents opportunities for an intelligent transformation of logistics, emphasizing the improvement of intelligence, connectivity, and autonomy within logistics operations [10]. Hence, we propose a comprehensive literature review that aims to stimulate research on this topic.

The document's structure is as follows: Section 2 introduces the methodology, elaborating on the approach used for the Systematic Literature Review (RSL). This section delves into technical aspects like the utilization of the PICO method, exploration of scientific literature, and the formulation of research questions. Section 3 showcases the results derived from the analysis of the selected research texts. Section 4 is dedicated to the discussion, addressing the queries arising from the results and facilitating comparisons of different authors' perspectives, approaches, and conclusions. Finally, in Section 5, we present the conclusions drawn, influenced by the limitations encountered in RSL research, and summarize the most significant findings.

II. METHODOLOGY

A. Systematic Literature Search Strategy (PICO)

The utilization of the PICO method in the research study was pivotal as it enabled the precise selection and delineation of the key research points. To achieve this, five components were taken into account to formulate the research question, which include:

Problem: This component outlines the issue that the research seeks to address. In the study, it was identified that the problem is rooted in the logistics processes of companies.

Intervention: Answer the questions of What? As? It indicates the ways to solve the aforementioned problem. The research aims to provide a solution to the identified problems through intelligent and sustainable transformation.

Comparison: The before and after the research intervention is evaluated, these must be quantifiable. The research will evaluate the innovation of traditional methods in logistics processes towards logistics with logistics 4.0.

Outcomes (Results): Indicates the scope of the investigation, in the investigation it is to obtain the results focused on the improvement of logistical processes [11].

In this way, the components of PICO for research are defined.

B. Design and Application of a Systematic Search Strategy for Scientific Literature (PICO)

The design of the strategy lies in the identification of the keywords for each PICO component. For the study, the first four components are considered, excluding the context component, because the research does not cover a specific workspace but is carried out in a general way. Likewise, once the keywords have been identified, they will have to be translated into English, in order to obtain better results in the search. In addition, synonyms that extend the search must be considered.

For its application to search for reviewed literature, the use of the Scopus database was determined, this being the only one for the queries because it has review articles that will be taken into account for the research.

A structure is established which will allow the identification of the terms used in the search; these can be clearly identified in Table 1.

TABLE I
PICO STRUCTURE

Component	Responses	Detailed description
P	Retailers	Industry, retail, traditional dealer
I	Smart and sustainable transformation	Smart, technology, intelligent
C	Logistic 4.0	Digitization, e-comerce, logistics 4.0, sustainability, supply chain mangemente
O	Process improvement	Chain, procces, six-sigma, vsm, leen manufacturing

Taking the keywords into consideration, we move on to construct the search equation. In doing so, we employ the Boolean OR operator to combine synonyms within each component, and likewise, the AND operator is utilized to connect these components. Consequently, the resulting search equation is as follows: ("industry" OR "retail" OR "traditional dealer") AND ("smart" OR "technology" OR "intelligent") AND ("digitization" OR "e-comerce" OR "logistics 4.0" OR "sustainability" OR "supply chain mangemente") AND ("chain" OR "procces" OR "six-sigma" OR "vsm" OR "leen manufacturing").

TABLE II
INCLUSION AND EXCLUSION CRITERIA

Item	Inclusion	Exclusion
1	Review articles on logistics 4.0 will be taken into account.	Studies conducted in laboratories or simulated environments.
2	The studies should incorporate management methodologies and tools aimed at enhancing the efficiency of logistics processes.	These are the types of documents that do not fall under the category of review articles: books, theses, academic papers, non-indexed materials, articles lacking a DOI, and materials not within the Scopus platform.
3	The studies were conducted within the business sector.	Studies that do not yield valuable results for research.
4	The outcomes should substantiate the utilization of the methodologies in Logistics 4.0.	Documents before 2019.

C. Inclusion and Exclusion Criteria

The inclusion and exclusion criteria considered relevant to the research are presented in Table 2.

The PRISMA methodology (preferred reporting ítems for system reviews and meta-analyses, as shown in Figure 1), is a crucial tool in systematic reviews, aiding in the justification of the research. This methodology facilitates information collection and subsequent filtering based on the required criteria to acquire the most suitable articles for the research [12]. To ensure the system's excellence for the reader, authors must conduct a horough analysis that identifies and selects appropriate studies, and also incorporates the results of the meta-analysis [13].

It should also be noted that this methodology, in scoping reviews, is a type of knowledge synthesis that follows a systematic and methodical approach to establish the validity of an argument and identify significant meanings, hypotheses, principles, and areas with limited understanding [14].

III. Results

After applying the PRISMA method, a total of 42 review articles were obtained and subsequently filtered based on various inclusion and exclusion criteria. These articles were excluded because they were not pertinent to the PICO question of the ongoing research. An essential requirement was the publication period, allowing an analysis of the publication trends over the years, as depicted in Figure 2.

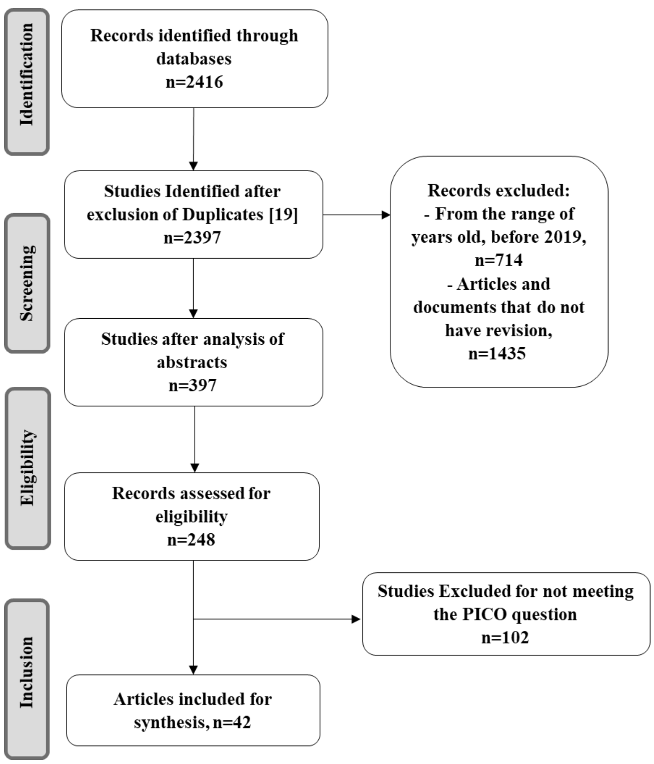

Fig. 1 PRISMA flowchart.

The analysis revealed a notable growth in publications throughout 2022, indicating a clear development of technologies aligned with Industry 4.0, particularly in the domains of logistics and supply chain, with a global emphasis on Warehouse 4.0. Numerous publications emerged in 2022 [15].

However, Figure 2 illustrates that in the current year, 2023, there is a decline in the trend, suggesting that fewer new publications are expected for the remainder of the year.

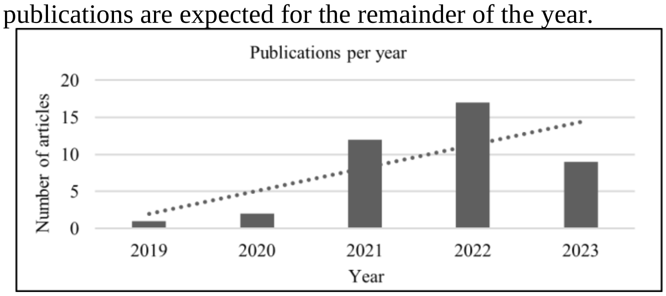

Fig. 2 Publications per year.

To delineate the key focal points within the realm of Logistics 4.0 research, an analysis of the keywords from the 42 research texts used in this study was imperative. This analysis was conducted by extracting data from the Scopus database and subsequently employing VOSviewer software to construct and illustrate bibliometric networks. These networks were created based on the analysis of keyword co-occurrence, the proximity of nodes, and the level of association among keywords [16].

Through this analysis, 351 keywords were extracted from the database, and the total strength of link occurrences with other keywords was calculated. Subsequently, the keywords exhibiting the highest link strengths were selected. The co-occurrence network is depicted in Figure 3.

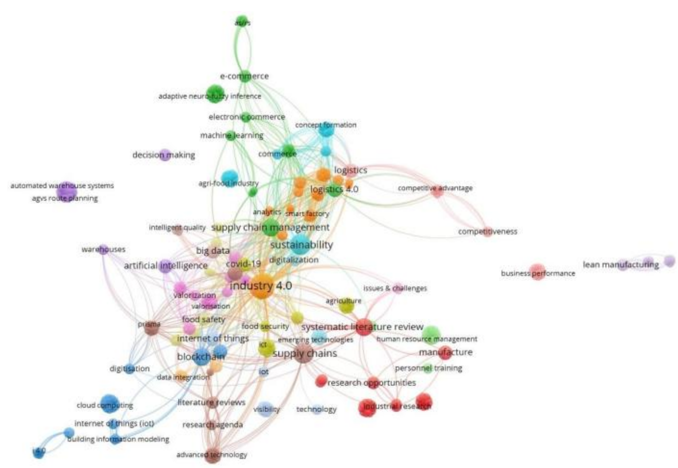

Fig. 3 Keywords.

The analysis conducted in VOSviewer facilitated the creation and visualization of bibliometric networks, primarily based on the examination of bibliographic coupling among countries. As illustrated in Figure 4, we can discern that India exhibits a more pronounced degree of association compared to other countries. This association aligns with India's global commitment to innovation, which places significant emphasis on enhancing organizational productivity while simultaneously reducing human effort and advocating for ongoing improvement. Furthermore, India adopts a comprehensive approach to Lean Manufacturing implementation, which includes ecological and sustainability initiatives [17].

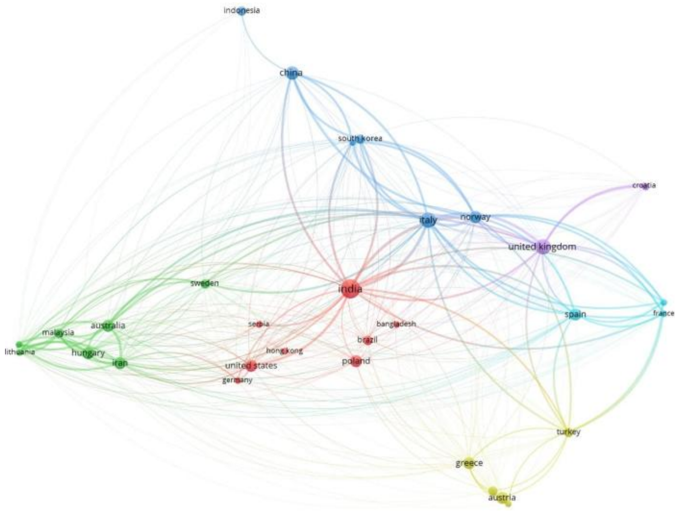

Fig. 4 Bibliographic coupling of countries.

The analysis reveals the distribution of texts by year concerning the detailed fields in Figure 5. In the inaugural article published in 2020, the authors concentrate on the aerospace, shipbuilding, and automotive sectors, collectively identified as part of the transportation domain. In their work, they define the supply chain as a complex set of activities and processes extending from the acquisition of raw materials to the eventual production and delivery of the product or service to end customers.

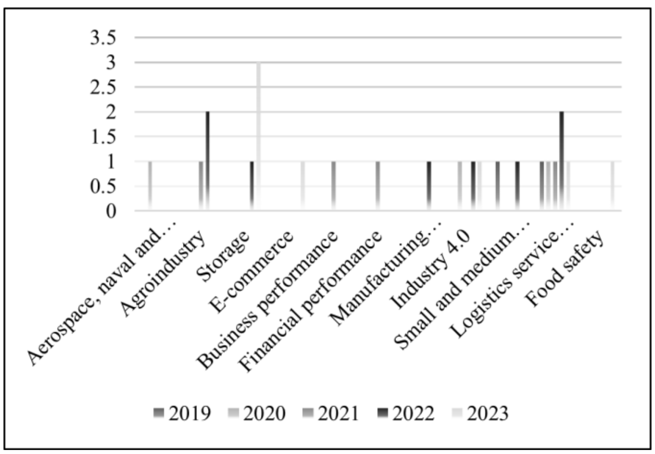

Fig. 5 Fields of Study in Logistics 4.0.

This system is often referred to as a supply network and comprises customers, suppliers, manufacturers, and transporters, all collaborating to perform these activities. The flexibility to tailor all processes to meet client needs and the adaptability to technological advancements are crucial for sustaining competitiveness in the market [18].

Conversely, various other authors have demonstrated the relevance of their research in areas such as agribusiness, warehousing, and electronic commerce [19-22].

Within the articles, various authors highlight the diverse range of fields in which Logistics 4.0 is being applied. These implementations of new technologies aim to enhance efficiency and boost profitability within companies [23-25]. Among the technologies considered pivotal by these authors are Artificial Intelligence (AI) [22,26,28], Sensors, Automatic Guided Vehicles (AGV) [26-27], and Big Data and the Internet of Things (IoT). By incorporating these technologies, they have been able to achieve their objectives in optimizing the supply chain. Consequently, Logistics 4.0 represents a potential revolution for companies seeking growth through technological advancements [22]. Notably, the most frequently implemented technologies are Big Data and Artificial Intelligence, as illustrated in Table 3.

Within the systematic literature review, methodologies aimed at enhancing efficiency in logistics processes are thoroughly examined. This consideration is of significant importance as these methodologies provide the means to achieve results that enable the identification of deficiencies in processes, facilitating corrective actions.

The Lean Manufacturing (LM) methodology is exemplified, showcasing its integration with other domains like Industry 4.0 and Six Sigma. This integration enables the adoption of Lean Manufacturing practices from an environmental, sustainable, and organizational performance standpoint, particularly within developing countries [23].

TABLE III
TECHNOLOGY IN LOGISTICS 4.0.

Authors	Artificial intelligence	Sensors	AGV	Big Data	IoT
R. Nour [29]	-	-	-	√	-
B. Ramkumar, V. Harish. [23]	-	-	-	-	-
S. Tampubolon and H. H. Purba. [30]	-	-	-	√	-
Y. Li, R. Zhang, and D. Jiang, [22]	√	-	-	√	-
S. Sader, I. Husti, and M. [31]	-	-	-	√	-
M. Dieste, R. Panizzolo [24]	-	-	-	-	-
M. Dieste, R. Panizzolo. [25]	-	-	-	√	-
Z. Zhang, J. Chen. [26]	√	-	√	-	-
M. Kim and Y. Kim [27]	√	√	√	-	-
A. Hassoun et al., [28]	√	-	√	√	-
A. A. Tubis and J. Rohman, [19]	√	-	-	√	-
G. Contini and M. Peruzzini, [32]	-	-	-	√	√
P. Morella, M. P. Lambán. [33]	-	-	-	√	√
K. Hartl, M. Sorger. [34]	-	-	-	-	-
A. Rejeb, K. Rejeb, A. [21]	√	-	-	√	√
M. Ramirez-Peña, P. F. Mayuet. [18]	-	-	√	√	√
O. K. Efthymiou and S. T. Ponis, [35]	√	√	-	√	√
A. Galkin, Y. Popova.30] [36]	-	-	-	-	-
P. Golinska-Dawson. [37]	√	-	√	√	√
I. K. A. Hamdan. [38]	-	-	-	-	-
X. Sun, H. Yu, and W. D. Solvang, [39]	√	-	-	-	√

Similarly, the Six Sigma methodology is employed within Industry 4.0 to enhance processes, ultimately leading to increased profitability [30]. Additionally, it is posited that the enhancement of financial performance will be realized through the effective implementation of Just-in-Time (JIT) and Total Quality Management (TQM) practices [24]. Figure 6 illustrates the methodologies that authors have taken into account in their research.

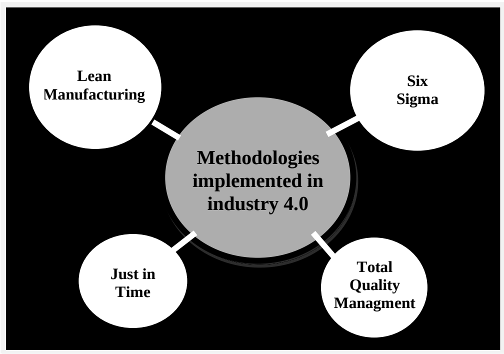

Fig. 6 Methodologies Implemented in Industry 4.0.

In Industry 4.0, technologies have been identified as the driving force behind the transformation of warehouses. Research texts define this phenomenon as the advent of a new era in logistics, leveraging network-based technologies, sensors, and devices to create intelligent warehouses capable of monitoring and controlling operations.

Conversely, Logistics 4.0 involves the integration of technologies that utilize fifth-generation 5G internet, incorporating robots and cyber collaboration to overhaul traditional processes [42]. Technologies such as response codes, RFID, and communication networks are also harnessed to optimize inventory management and reduce supply chain errors [43]. Table 4 enumerates the types of technologies explored in various articles. A majority of the articles emphasize the significance of Big Data analysis technology, which involves the analysis and interpretation of vast data sets, primarily geared towards demand planning and route optimization [44].

TABLE IV
ARTICLES IN THE TECHNOLOGY CATEGORY

Technology	Citation
Big data analysis	[20], [21], [25], [29], [45], [46]
Artificial intelligence	[21], [27], [35], [45], [46]
internet of things	[20], [21], [35], [39]
RFID	[21], [27]
Platforms	[22], [28], [31]
Autonomous Vehicle	[26], [39]
Real time location system	[19]
Blockchain	[20], [21], [39]
Digital twin	[20]
Digitization Work Environment	[18], [26]
Robots	[27]
GPS	[27]

Due to the adoption of various technologies in Logistics 4.0, the Systematic Literature Review (RSL) managed to provide a comprehensive analysis, offering insights into both qualitative and quantitative outcomes, with a limited number of results from the latter category. Nonetheless, the application of these technologies in certain domains can be intricate due to various barriers that hinder their complete implementation [47]. Furthermore, it's important to acknowledge that the implementation of these technologies can pose a substantial challenge for companies, particularly in terms of managing cultural change and fostering acceptance of new working methods [48]. Table 5 presents the key findings extracted from eight articles.

TABLE V
QUALITATIVE AND QUANTITATIVE RESULTS OF TECHNOLOGY APPLICATION

Article	Quantitative Result	Qualitative Result
[29]	58% increase in annual income	-
[30]	30% improvement in the process capacity	-
[28]	-	Improves the quality and safety of fishing products.
[49]	-	Increases efficiency in company operations.
[20]	-	Reduction of food waste.
[21]	-	Increases efficiency in the food area.
[48]	-	Increases efficiency in logistics.
[39]	-	Minimize installation costs.

IV. DISCUSSION

In the studies scrutinized within the systematic literature review, the application of intelligent technologies has been shown to enhance the efficiency of logistics processes, resulting in improvements ranging from 30% [30] to a substantial 50% [50]. These gains represent significant enhancements for companies that adopt and implement technology-driven solutions in their logistics management to refine their processes. Similarly, these advancements correlate with cost reductions spanning from 40% to 70%.

However, it's worth noting that not all authors uniformly advocate for the same technologies to achieve efficiency improvements. Their preferences vary depending on the specific company model (e.g., manufacturing, service, or e-commerce) they operate, aligning their technology choices with their specific requirements. This discrepancy highlights the importance of adapting technology to individual needs.

Furthermore, it has been observed that technology implementation is not uniform across all companies due to varying policies and the unique organizational cultures within each. This resistance to change is one of the challenges faced.

The results obtained from this analysis reveal key areas of focus, including the utilization of technologies like the Internet of Things (IoT), Big Data analysis, and Blockchain. These areas have triggered discussions on the implementation of technologies within the supply chain.

A. Use of IoT

The concept of the Internet of Things (IoT) has expanded the horizon, endowing the supply chain with intelligent technologies capable of data-driven communication via the internet [46]. Within the supply chain, IoT encompasses two primary aspects: the interconnection of intelligent management and the facilitation of customer inquiries that rely on IoT [51]. Moreover, IoT is characterized as a diverse range of equipment fitted with integrated systems connected to the telecommunications network, enabling them to autonomously generate and transmit information without human intervention [46].

Implementation results from technologies such as RFID have demonstrated a remarkable reduction in inventory costs, ranging from 40% to 70%. This cost reduction is attributed to the enhanced visibility and stability of information achieved through RFID usage, underscoring the essential role of IoT in achieving greater visibility [52].

Logistics 4.0 is geared towards enhancing the efficiency of logistics teams through the utilization of real-time decision-making facilitated by real-time data analysis techniques. Additionally, within the domain of Logistics 4.0, IoT is dedicated to ensuring privacy through the development of software and system support platforms [53]. Furthermore, it can be delineated that, within the scope of Logistics 4.0, the primary focus is on supply chain processes and supply chain performance concerning both buyers and suppliers, where technology is intricately intertwined with information management and the Internet of Things (IoT) [54].

B. Use of Big Data analysis

Big data analysis is an automation process grounded in data-driven decision-making, sometimes aided by artificial intelligence. It's important to note that it should also complement human decision-making [55]. Big data represents an optimized approach addressing pre-emptive shipping issues that anticipate customer requirements, aiming to propose analytical models for distribution while factoring in costs and transportation, all accomplished through predictive analysis. The utilization of automatic predictive analysis resulted in a significant increase of over 60%, thanks to applications for demand forecasting [56].

Big Data Analytics facilitates enhanced data accessibility, improving engagement among all parties within the supply chain through the utilization of physical data flows [57]. Within supply chain management, it becomes feasible to monitor and analyze movements across the entire chain, thereby enhancing traceability and reducing security incidents like wastage [58]. The efficacy of Big Data Analytics and IoT in logistics processes has been demonstrated [57]. The actions derived from data analysis result in increased productivity and sustainability across the entire value chain, spanning the entire product life cycle [59].

C. Use of Blockchain

Blockchain is a digital ledger that records transactions in an immutable manner, serving to manage intricate data within the supply chain. This technology enables stakeholders, including suppliers, manufacturers, distributors, etc., to transparently gather data from all their sources and distribute it digitally for universal accessibility [60]. It facilitates data exchange among supply chain participants [58]. Consequently, it proves invaluable for traceability and supply chain management, functioning as a consolidated database that furnishes insights into supply chain operations [61].

According to the World Economic Forum, the combination of blockchain, AI, sensors, and IoT has the potential to reduce food waste by up to 85 million tons by 2030 [58]. Blockchain leverages technologies such as RFID (Radio Frequency Identification) tags, NFC (Near Field Communication), GPS (Global Positioning System), IoT-enabled devices, barcodes, and QR codes to compile comprehensive data relevant to the supply chain [60].

D. Key technologies used in logistics 4.0.

Advanced technologies like sensors, mobile networks, and real-time remote tracking systems enable the gathering of real-time data, enhancing planning and programming in a more agile and flexible manner [53]. These technologies have been applied in predictive demand analysis, resulting in a notable reduction of forecast errors by 30% to 50% [6]. Additionally, the adoption of IoT technologies has led to organizations achieving a 55% improvement in operational efficiency, a 51% enhancement in safety conditions, and a 50% increase in employee productivity [62].

To optimize warehouse inventories and track item movements in and out of the warehouse, various models such as RFID tags, barcodes, Quick Response (QR) codes, and NFC are employed. Machine learning algorithms are also leveraged to analyze data and generate forecasts. Furthermore, sensors and information technologies are harnessed to optimize management processes [62].

E. Limitations and barriers

Despite the widely recognized benefits of Logistics 4.0, its implementation faces several real-world barriers within business environments. Key challenges include high initial investment costs in technological infrastructure, organizational resistance to change, a lack of skilled personnel, and the complexity of integrating new technologies with legacy systems. These obstacles hinder the uniform adoption of intelligent solutions across supply chains, particularly among small and medium-sized enterprises. To deepen the understanding of these limitations, it is essential to complement the systematic review with real-world case studies that illustrate how different organizations have addressed these challenges. For instance, leading logistics companies have adopted gradual implementation strategies, continuous workforce training, and partnerships with technology providers as mechanisms to overcome resistance and technical difficulties. Including such practical experiences would strengthen the connection between theory and application, offering readers a more actionable and context-sensitive perspective on the transition toward Logistics 4.0.

About the methodology, While the application of PRISMA and PICO provides a structured and transparent approach to conducting systematic literature reviews, it is important to recognize and compare alternative methodologies that may offer complementary strengths. For example, the SALSA framework (Search, Appraisal, Synthesis, and Analysis) emphasizes an iterative synthesis process and is particularly useful for mapping broad research landscapes, while the SPIDER tool (Sample, Phenomenon of Interest, Design, Evaluation, Research type) is more suitable for qualitative evidence synthesis. Compared to these methods, PRISMA is more rigid but excels in transparency and replicability, especially in reviews focused on quantitative data. Incorporating a brief comparative analysis of these methodologies would enrich the study by demonstrating why PRISMA and PICO were the most appropriate choices and acknowledging the trade-offs involved. Such reflection not only strengthens methodological rigor but also guides future researchers in selecting review frameworks aligned with their research objectives.

F. *Implications of Logistics 4.0*

The findings of this review have several practical, social, and environmental implications. From a practical standpoint, the integration of Logistics 4.0 technologies enables companies to improve efficiency, reduce operational errors, enhance real-time traceability, and optimize inventory and transportation systems. These improvements can lead to significant cost savings and more agile responses to market demands. On a social level, however, the digital transformation of logistics processes introduces both opportunities and challenges. While new technologies create demand for highly skilled workers and foster innovation, they may also widen the digital skills gap, displace certain labor segments, and require substantial investments in employee training. Environmentally, the adoption of smart logistics tools contributes positively by reducing fuel consumption through route optimization, minimizing material waste, and enabling more sustainable supply chain practices. Thus, the implementation of Logistics 4.0 not only enhances business performance but also influences broader societal and ecological outcomes, making it a critical area for multidisciplinary research and policy support.

G. *Future Research Directions*

While this systematic review provides a comprehensive overview of the technologies and benefits associated with Logistics 4.0, several avenues for future research remain open. First, more empirical studies are needed to evaluate the real-world effectiveness of smart logistics technologies, particularly in small and medium-sized enterprises (SMEs) and in developing countries, where implementation conditions may differ significantly from large corporations in industrialized nations. Second, future research should focus on the long-term impact of Logistics 4.0 adoption on organizational performance, workforce transformation, and supply chain resilience, especially under disruptive conditions such as pandemics or geopolitical conflicts. Third, there is a need to explore the integration of sustainability metrics into Logistics 4.0 systems, including how digital tools can support environmental, social, and governance (ESG) goals. Lastly, further investigation is required into the ethical and regulatory challenges associated with data privacy, cybersecurity, and algorithmic decision-making in digital logistics networks. Addressing these research gaps will help build a more holistic, inclusive, and sustainable vision for the future of supply chain management in the Industry 4.0 era.

V. CONCLUSIONS

This study conducted a systematic literature review to explore how logistics efficiency can be improved through the integration of smart technologies. The findings indicate that technologies such as artificial intelligence, the Internet of Things (IoT), and Big Data hold significant potential to enhance operational performance by increasing efficiency and reducing costs. While Logistics 4.0 is widely recognized as a transformative approach for modern supply chains, its full-scale implementation remains uneven across industries due to several persistent limitations.

Emerging technologies are fundamentally reshaping the competitiveness of organizations by replacing traditional logistics practices with intelligent, data-driven systems. The Logistics 4.0 paradigm promotes cost reduction, process optimization, and real-time decision-making, thereby fostering measurable improvements in day-to-day operations. As industrial processes become increasingly automated, human intervention is being minimized, enabling organizations to respond more swiftly and accurately to dynamic market demands.

However, the transition to Logistics 4.0 presents notable challenges. High implementation costs, the need for specialized personnel, and the complexity of integrating physical infrastructure with autonomous technologies act as barriers, particularly for small and medium-sized enterprises. Moreover, sustaining such initiatives requires continuous investment in monitoring and support systems. These factors contribute to the limited availability of implementation data in certain regions, underscoring the need for further empirical research and case-based evidence to guide effective adoption.

ACKNOWLEDGMENT

The authors would like to acknowledge the Universidad Tecnológica del Perú (UTP) for funding the Article Processing Charge (APC) for the publication of this research.

REFERENCES

[1] R. Nour, "Enhancing the Logistics 4.0 Firms through Information Technology," Sustainability (Switzerland), vol. 14, no. 23, 2022, doi: 10.3390/su142315860.

[2] O. K. Efthymiou and S. T. Ponis, "Industry 4.0 technologies and their impact in contemporary logistics: A systematic literature review," Sustainability (Switzerland), vol. 13, no. 21. 2021. doi: 10.3390/su132111643.

[3] Z. Zhang, J. Chen, and Q. Guo, "Application of Automated Guided Vehicles in Smart Automated Warehouse Systems: A Survey," CMES - Computer Modeling in Engineering and Sciences, vol. 134, no. 3. 2023. doi: 10.32604/cmes.2022.021451.

[4] Y. Li, R. Zhang, and D. Jiang, "Order-Picking Efficiency in E-Commerce Warehouses: A Literature Review," Journal of Theoretical and Applied Electronic Commerce Research, vol. 17, no. 4. 2022. doi: 10.3390/jtaer17040091.

[5] S. Tampubolon and H. H. Purba, "Lean six sigma implementation, a systematic literature review," International Journal of Production Management and Engineering, vol. 9, no. 2. 2021. doi: 10.4995/IJPME.2021.14561.

[6] M. Simonetto, F. Sgarbossa, D. Battini, and K. Govindan, "Closed loop supply chains 4.0: From risks to benefits through advanced technologies. A literature review and research agenda," Int J Prod Econ, vol. 253, 2022, doi: 10.1016/j.ijpe.2022.108582.

[7] K. Aravindaraj and P. Rajan Chinna, "A systematic literature review of integration of industry 4.0 and warehouse management to achieve Sustainable Development Goals (SDGs)," Cleaner Logistics and Supply Chain, vol. 5, 2022, doi: 10.1016/j.clscn.2022.100072.

[8] A. Rejeb, K. Rejeb, A. Abdollahi, S. Zailani, M. Iranmanesh, and M. Ghobakhloo, "Digitalization in food supply chains: A bibliometric review and key-route main path analysis," Sustainability (Switzerland), vol. 14, no. 1, 2022, doi: 10.3390/su14010083.

[9] T. Obradović, B. Vlačić, and M. Dabić, "Open innovation in the manufacturing industry: A review and research agenda," Technovation, vol. 102, 2021, doi: 10.1016/j.technovation.2021.102221.

[10] X. Sun, H. Yu, and W. D. Solvang, "Towards the smart and sustainable transformation of Reverse Logistics 4.0: a conceptualization and research agenda," Environmental Science and Pollution Research, vol. 29, no. 46. 2022. doi: 10.1007/s11356-022-22473-3.

[11] A. Marchenko and A. Temeljotov-Salaj, "A systematic literature review of non-invasive indoor thermal discomfort detection," Applied Sciences (Switzerland), vol. 10, no. 12, 2020, doi: 10.3390/APP10124085.

[12] J. J. Yepes-Nuñez, G. Urrútia, M. Romero-García, and S. Alonso-Fernández, "The PRISMA 2020 statement: an updated guideline for reporting systematic reviews," Rev Esp Cardiol, vol. 74, no. 9, 2021, doi: 10.1016/j.recesp.2021.06.016.

[13] J. J. Yepes-Nuñez, G. Urrútia, M. Romero-García, and S. Alonso-Fernández, "The PRISMA 2020 statement: an updated guideline for reporting systematic reviews," Rev Esp Cardiol, vol. 74, no. 9, 2021, doi: 10.1016/j.recesp.2021.06.016.

[14] A. C. Tricco et al., "PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation," Annals of Internal Medicine, vol. 169, no. 7. 2018. doi: 10.7326/M18-0850.

[15] A. A. Tubis and J. Rohman, "Intelligent Warehouse in Industry 4.0—Systematic Literature Review," Sensors, vol. 23, no. 8, 2023, doi: 10.3390/s23084105.

[16] N. Jan van Eck and L. Waltman, "VOSviewer Manual," 2023.

[17] B. Ramkumar, V. Harish, S. D. Renuka, and R. Srinivasaiah, "Lean manufacturing: A bibliometric analysis, 1970-2020," Journal of Scientometric Research, vol. 10, no. 1, pp. 63–73, 2021, doi: 10.5530/JSCIRES.10.1.8.

[18] M. Ramirez-Peña, P. F. Mayuet, J. M. Vazquez-Martinez, and M. Batista, "Sustainability in the aerospace, naval, and automotive supply chain 4.0: Descriptive review," Materials, vol. 13, no. 24, pp. 1–23, 2020, doi: 10.3390/ma13245625.

[19] A. A. Tubis and J. Rohman, "Intelligent Warehouse in Industry 4.0—Systematic Literature Review," Sensors, vol. 23, no. 8, 2023, doi: 10.3390/s23084105.

[20] P. Morella, M. P. Lambán, J. Royo, and J. C. Sánchez, "Study and analysis of the implementation of 4.0 technologies in the agri-food supply chain: A state of the art," Agronomy, vol. 11, no. 12, 2021, doi: 10.3390/agronomy11122526.

[21] A. Rejeb, K. Rejeb, A. Abdollahi, S. Zailani, M. Iranmanesh, and M. Ghobakhloo, "Digitalization in food supply chains: A bibliometric review and key-route main path analysis," Sustainability (Switzerland), vol. 14, no. 1, 2022, doi: 10.3390/su14010083.

[22] Y. Li, R. Zhang, and D. Jiang, "Order-Picking Efficiency in E-Commerce Warehouses: A Literature Review," Journal of Theoretical and Applied Electronic Commerce Research, vol. 17, no. 4. 2022. doi: 10.3390/jtaer17040091.

[23] B. Ramkumar, V. Harish, S. D. Renuka, and R. Srinivasaiah, "Lean manufacturing: A bibliometric analysis, 1970-2020," Journal of Scientometric Research, vol. 10, no. 1, pp. 63–73, 2021, doi: 10.5530/JSCIRES.10.1.8.

[24] M. Dieste, R. Panizzolo, and J. A. Garza-Reyes, "A systematic literature review regarding the influence of lean manufacturing on firms' financial performance," Journal of Manufacturing Technology Management, vol. 32, no. 9. 2021. doi: 10.1108/JMTM-08- 2020-0304.

[25] I. Ghalehkhondabi, E. Ahmadi, and R. Maihami, "An overview of big data analytics application in supply chain management published in 2010-2019," Production, vol. 30. 2020. doi: 10.1590/0103-6513.20190140.

[26] Z. Zhang, J. Chen, and Q. Guo, "Application of Automated Guided Vehicles in Smart Automated Warehouse Systems: A Survey," CMES - Computer Modeling in Engineering and Sciences, vol. 134, no. 3. 2023. doi: 10.32604/cmes.2022.021451.

[27] M. Kim and Y. Kim, "Parcel Classification and Positioning of Intelligent Parcel Storage System Based on YOLOv5," Applied Sciences (Switzerland), vol. 13, no. 1, 2023, doi: 10.3390/app13010437.

[28] A. Hassoun et al., "Use of industry 4.0 technologies to reduce and valorize seafood waste and by-products: A narrative review on current knowledge," Curr Res Food Sci, vol. 6, 2023, doi: 10.1016/j.crfs.2023.100505.

[29] R. Nour, "Enhancing the Logistics 4.0 Firms through Information Technology," Sustainability (Switzerland), vol. 14, no. 23, 2022, doi: 10.3390/su142315860.

[30] S. Tampubolon and H. H. Purba, "Lean six sigma implementation, a systematic literature review," International Journal of Production Management and Engineering, vol. 9, no. 2. 2021. doi: 10.4995/IJPME.2021.14561.

[31] S. Sader, I. Husti, and M. Daroczi, "A review of quality 4.0: definitions, features, technologies, applications, and challenges," Total Quality Management and Business Excellence, vol. 33, no. 9–10. 2022. doi: 10.1080/14783363.2021.1944082.

[32] G. Contini and M. Peruzzini, "Sustainability and Industry 4.0: Definition of a Set of Key Performance Indicators for Manufacturing Companies," Sustainability (Switzerland), vol. 14, no. 17, 2022, doi: 10.3390/su141711004.

[33] P. Morella, M. P. Lambán, J. Royo, and J. C. Sánchez, "Study and analysis of the implementation of 4.0 technologies in the agri-food supply chain: A state of the art," Agronomy, vol. 11, no. 12, 2021, doi: 10.3390/agronomy11122526.

[34] K. Hartl, M. Sorger, and M. Stockinger, "The Key Role of Laser Ultrasonics in the Context of Sustainable Production in an I 4.0 Value Chain," Applied Sciences (Switzerland), vol. 13, no. 2, 2023, doi: 10.3390/app13020733.

[35] O. K. Efthymiou and S. T. Ponis, "Industry 4.0 technologies and their impact in contemporary logistics: A systematic literature review," Sustainability (Switzerland), vol. 13, no. 21. 2021. doi: 10.3390/su132111643.

[36] A. Galkin, Y. Popova, E. Chuprina, and D. Shapovalenko, "Interaction of logistics 4.0 and consumer oriented marketing using ICT," in Proceedings of the 33rd International Business Information Management Association Conference, IBIMA 2019: Education Excellence and Innovation Management through Vision 2020, 2019, pp. 6751–6760.

[37] P. Golinska-Dawson, K. Werner-Lewandowska, K. Kolinska, and A. Kolinski, "Impact of Market Drivers on the Digital Maturity of Logistics Processes in a Supply Chain," Sustainability (Switzerland), vol. 15, no. 4, 2023, doi: 10.3390/su15043120.

[38]I. K. A. Hamdan, W. Aziguli, D. Zhang, and E. Sumarliah, “Machine learning in supply chain: prediction of real-time e-order arrivals using ANFIS,” International Journal of System Assurance Engineering and Management, 2023, doi: 10.1007/s13198-022-01851-7.
[39]X. Sun, H. Yu, and W. D. Solvang, “Towards the smart and sustainable transformation of Reverse Logistics 4.0: a conceptualization and research agenda,” Environmental Science and Pollution Research, vol. 29, no. 46. 2022. doi: 10.1007/s11356-022-22473-3.
[40]K. Tsolaki, T. Vafeiadis, A. Nizamis, D. Ioannidis, and D. Tzovaras, “Utilizing machine learning on freight transportation and logistics applications: A review,” ICT Express. 2022. doi: 10.1016/j.icte.2022.02.001.
[41]A. A. Tubis and K. Grzybowska, “In Search of Industry 4.0 and Logistics 4.0 in Small- Medium Enterprises—A State of the Art Review,” Energies, vol. 15, no. 22. 2022. doi: 10.3390/en15228595.
[42]K. Aravindaraj and P. Rajan Chinna, “A systematic literature review of integration of industry 4.0 and warehouse management to achieve Sustainable Development Goals (SDGs),” Cleaner Logistics and Supply Chain, vol. 5, 2022, doi: 10.1016/j.clscn.2022.100072.
[43]S. Guruswamy et al., “Toward Better Food Security Using Concepts from Industry 5.0,” Sensors, vol. 22, no. 21, 2022, doi: 10.3390/s22218377.
[44]A. Z. Abideen, V. P. K. Sundram, J. Pyeman, A. K. Othman, and S. Sorooshian, “Food Supply Chain Transformation through Technology and Future Research Directions—A Systematic Review,” Logistics, vol. 5, no. 4, 2021, doi: 10.3390/logistics5040083.
[45]S. K. Yevu, A. T. W. Yu, and A. Darko, “Digitalization of construction supply chain and procurement in the built environment: Emerging technologies and opportunities for sustainable processes,” J Clean Prod, vol. 322, 2021, doi: 10.1016/j.jclepro.2021.129093.
[46]K. Wójcicki, M. Biegańska, B. Paliwoda, and J. Górna, “Internet of Things in Industry: Research Profiling, Application, Challenges and Opportunities—A Review,” Energies, vol. 15, no. 5. 2022. doi: 10.3390/en15051806.
[47]A. Rejeb, K. Rejeb, A. Abdollahi, S. Zailani, M. Iranmanesh, and M. Ghobakhloo, “Digitalization in food supply chains: A bibliometric review and key-route main path analysis,” Sustainability (Switzerland), vol. 14, no. 1, 2022, doi: 10.3390/su14010083.
[48]O. K. Efthymiou and S. T. Ponis, “Industry 4.0 technologies and their impact in contemporary logistics: A systematic literature review,” Sustainability (Switzerland), vol. 13, no. 21. 2021. doi: 10.3390/su132111643.
[49]G. Contini and M. Peruzzini, “Sustainability and Industry 4.0: Definition of a Set of Key Performance Indicators for Manufacturing Companies,” Sustainability (Switzerland), vol. 14, no. 17, 2022, doi: 10.3390/su141711004.
[50]V. S. Yadav, A. R. Singh, A. Gunasekaran, R. D. Raut, and B. E. Narkhede, “A systematic literature review of the agro-food supply chain: Challenges, network design, and performance measurement perspectives,” Sustain Prod Consum, vol. 29, pp. 685–704, 2022, doi: 10.1016/j.spc.2021.11.019.
[51]B. Debnath, M. S. Shakur, F. Tanjum, M. A. Rahman, and Z. H. Adnan, “Impact of Additive Manufacturing on the Supply Chain of Aerospace Spare Parts Industry—A Review,” Logistics, vol. 6, no. 2, 2022, doi: 10.3390/logistics6020028.
[52]S. Ahmed et al., “Towards supply chain visibility using internet of things: A dyadic analysis review,” Sensors, vol. 21, no. 12, 2021, doi: 10.3390/s21124158.
[53]C. Jandl, M. Wagner, T. Moser, and S. Schlund, “Reasons and strategies for privacy features in tracking and tracing systems—a systematic literature review,” Sensors, vol. 21, no. 13, 2021, doi: 10.3390/s21134501.
[54]A. A. Khan and J. Abonyi, “Information sharing in supply chains – Interoperability in an era of circular economy,” Cleaner Logistics and Supply Chain, vol. 5, 2022, doi: 10.1016/j.clscn.2022.100074.
[55]A. A. Tubis and J. Rohman, “Intelligent Warehouse in Industry 4.0—Systematic Literature Review,” Sensors, vol. 23, no. 8, 2023, doi: 10.3390/s23084105.
[56]K. Tsolaki, T. Vafeiadis, A. Nizamis, D. Ioannidis, and D. Tzovaras, “Utilizing machine learning on freight transportation and logistics applications: A review,” ICT Express. 2022. doi: 10.1016/j.icte.2022.02.001.
[57]P. Golinska-Dawson, K. Werner-Lewandowska, K. Kolinska, and A. Kolinski, “Impact of Market Drivers on the Digital Maturity of Logistics Processes in a Supply Chain,” Sustainability (Switzerland), vol. 15, no. 4, 2023, doi: 10.3390/su15043120.
[58]A. Hassoun et al., “Use of industry 4.0 technologies to reduce and valorize seafood waste and by-products: A narrative review on current knowledge,” Curr Res Food Sci, vol. 6, 2023, doi: 10.1016/j.crfs.2023.100505.
[59]K. Hartl, M. Sorger, and M. Stockinger, “The Key Role of Laser Ultrasonics in the Context of Sustainable Production in an I 4.0 Value Chain,” Applied Sciences (Switzerland), vol. 13, no. 2, 2023, doi: 10.3390/app13020733.
[60]A. Raja Santhi and P. Muthuswamy, “Pandemic, War, Natural Calamities, and Sustainability: Industry 4.0 Technologies to Overcome Traditional and Contemporary Supply Chain Challenges,” Logistics, vol. 6, no. 4, 2022, doi: 10.3390/logistics6040081.
[61]A. Pakseresht, A. Yavari, S. A. Kaliji, and K. Hakelius, “The intersection of blockchain technology and circular economy in the agri-food sector1,” Sustain Prod Consum, vol. 35, pp. 260–274, 2023, doi: 10.1016/j.spc.2022.11.002.
[62]K. Wójcicki, M. Biegańska, B. Paliwoda, and J. Górna, “Internet of Things in Industry: Research Profiling, Application, Challenges and Opportunities—A Review,” Energies, vol. 15, no. 5. 2022. doi: 10.3390/en15051806Velásquez-Henao, J. D., Rueda-Mejía, V. M. and Franco-Cardona, J. D. Electricity demand forecasting using a SARIMA-multiplicative single neuron hybrid model, DYNA, 80 (180), pp. 4-8, 2013.