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Faculty of Legal Sciences

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Supply Chain Optimization in Foreign Trade Across the Americas Through Emerging Technologies (2020–2025): A Systematic Literature Review

Project prior to obtaining a Bachelor's Degree in International Studies

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Cuenca – Ecuador
2026

To God, source of wisdom and strength, for guiding every step of this journey and granting me the perseverance necessary to conclude this stage.

To my parents, for being the pillar of my life and a constant example of effort, discipline, and sacrifice. This achievement belongs to them as well.

To my brother, for his loyalty, support, and companionship through every challenge, and for sharing with me the vision of building a future of excellence.

To my girlfriend, for being a refuge and a source of tranquility during the most difficult moments, for her patience, her unconditional support, and for believing in me even when I doubted myself.

Finally, to my family, for their constant backing and for being the motivation that impelled each of my efforts until turning this goal into a reality.

ACKNOWLEDGMENTS

I express my most sincere gratitude to God, for granting me the clarity, discipline, and strength necessary to culminate this research.

To the University of Azuay, my alma mater, for the academic and human formation received, as well as for the support provided throughout my university career. In a special manner, I am grateful for the opportunity to have served as Vice President of the Faculty of Legal Sciences, an experience that contributed profoundly to my personal and professional growth.

To the Faculty of Legal Sciences and its Schools of International Studies and Law, for strengthening my critical thinking and my commitment to academic excellence.

To Ing. Antonio Fabián Torres Dávila, for his guidance, mentorship, and accompaniment during the development of this research.

To my professors and colleagues, for the teachings, the trust, and the experiences shared throughout this university stage.

Finally, I deeply thank my family for their unconditional support and, in a special way, my girlfriend, whose accompaniment, patience, and backing were fundamental in facing the challenges of this process with determination and balance.

Table of Contents

List of Figures and Appendices

List of Figures

List of Appendices

Abstract

This study analyzes the impact of emerging technologies on the optimization of supply chains in the Americas' foreign trade during the 2020–2025 period. The primary objective was to identify the digital tools with the highest reported operational effectiveness, specifically analyzing the deployment of Artificial Intelligence (AI) and the Internet of Things (IoT) in logistics centers. Based on a theoretical framework of post-pandemic resilience, a systematic literature review was conducted following the PRISMA 2020 protocol. The findings demonstrate that, while AI and IoT are the main drivers of efficiency in physical processes and real-time visibility, their success is hindered by the lack of cross-border data standards. The study concludes that the optimization of North-South trade corridors requires a transition from isolated pilot projects toward integrated and scalable digital ecosystems that prioritize interoperability to ensure long-term regional competitiveness.

Keywords: artificial intelligence, customs law, Internet of Things, logistics, supply chain optimization

Resumen

Esta investigación analiza el impacto de las tecnologías emergentes en la optimización de las cadenas de suministro dentro del comercio exterior de América durante el periodo 2020–2025. El objetivo central fue identificar las herramientas digitales con la mayor eficacia operativa reportada, analizando específicamente el despliegue de la Inteligencia Artificial (IA) y el Internet de las Cosas (IoT) en los centros logísticos. Fundamentado en un marco teórico de resiliencia post-pandemia, se llevó a cabo una revisión sistemática de la literatura siguiendo el protocolo PRISMA 2020. Los hallazgos demuestran que, si bien la IA y el IoT son los principales impulsores de la eficiencia en los procesos físicos y de la visibilidad en tiempo real, su éxito se ve obstaculizado por la falta de estándares de datos transfronterizos. El estudio concluye que la optimización de los corredores comerciales Norte-Sur requiere una transición de proyectos piloto aislados hacia ecosistemas digitales integrados y escalables que prioricen la interoperabilidad para garantizar la competitividad regional a largo plazo.

Palabras clave: inteligencia artificial, derecho aduanero, internet de las cosas, logística, optimización de la cadena de suministro

Supply Chain Optimization in Foreign Trade Across the Americas Through Emerging Technologies (2020–2025): A Systematic Literature Review

1. Introduction

In the current context of international trade, supply chains have become a strategic element for national competitiveness and the efficient performance of foreign trade operations. International logistical processes no longer depend solely on physical infrastructure, but also on the capacity of States and private operators to incorporate technological solutions that optimize lead times, reduce costs, guarantee the traceability of goods, and ensure compliance with customs regulations. In the Americas, these demands have intensified due to globalization, the digitalization of trade, and recent disruptions in trade flows, particularly following the COVID-19 pandemic. The present research is motivated by the need to generate systematized knowledge based on scientific evidence to understand how emerging technologies can contribute to supply chain optimization in the region's foreign trade. Technologies such as Artificial Intelligence, the Internet of Things, Blockchain, Big Data, and Digital Twins have demonstrated, in various international contexts, their capacity to improve operational efficiency, strengthen process transparency, and reduce risks associated with logistical and customs management. Nonetheless, their adoption across the countries of the Americas is uneven, generating significant gaps among the various foreign trade stakeholders at both the public and private levels.

From the public sector perspective, particularly in the field of customs law, the optimization of supply chains constitutes a strategic challenge for the modernization of customs management, given it requires strengthening control mechanisms without hindering trade facilitation while ensuring effective compliance with national and international regulatory frameworks. In many countries of the Americas, insufficient technological integration, limited interoperability between institutional systems, and the persistence of administrative processes with low levels of automation continue to generate operational delays, increased logistical costs, and higher risks of regulatory non-compliance. In this context, the incorporation of emerging technologies into supply chain management is presented as a key alternative to transform traditional customs control models. This is achieved through tools that improve risk management, strengthen documentary traceability, and optimize inter-institutional coordination, thus contributing to greater efficiency, transparency, and legal certainty in foreign trade.

From the private sector, the competitiveness of exporters, importers, and logistical operators increasingly depends on their ability to adopt technological solutions that optimize demand planning, inventory management, international transport, and customs compliance. However, many companies, especially small and medium-sized enterprises, face significant barriers related to implementation costs, lack of technical expertise, and regulatory uncertainty, which limits the effective adoption of these technologies.

Based on this problem, the general objective of this research was to analyze the studies conducted on emerging technologies that have shown potential to optimize supply chains in the foreign trade of the countries of the Americas during the 2020–2025 period. Specifically, it seeks to identify the technologies with the highest reported effectiveness in the scientific literature, analyze their benefits and limitations in different regional contexts, and recognize patterns, trends, and relevant knowledge gaps for decision-making in the public and private sectors.

The main contribution of this study lies in offering a systematic and updated synthesis of the available scientific evidence, oriented toward providing useful inputs for the design of public policies regarding trade facilitation and customs law, as well as for the formulation of business strategies that promote logistical modernization and the strengthening of foreign trade competitiveness in the Americas.

1.1 Objectives

The purpose of this systematic mapping is to structure and analyze the scientific evidence available on the application of emerging technologies in the optimization of foreign trade supply chains in the Americas. To this end, the following specific objectives are proposed:
To fulfill the objectives of this systematic mapping, the following research questions have been formulated:

> Pregunta General: ¿De qué manera las tecnologías emergentes optimizan la gestión de la cadena de suministro dentro de las operaciones de comercio exterior de América durante el periodo 2020–2025?
>
> Specific Question 1 (Technological Dimension): Which specific emerging technologies limited to Artificial Intelligence, Blockchain, the Internet of Things,

Big Data, and Digital Twins exhibit the highest frequency of successful implementation according to indexed scientific literature?

Specific Question 2 (Operational Dimension): What are the primary structural benefits and limitations reported in relation to trade facilitation, customs compliance, and the reduction of logistical delivery times?

Specific Question 3 (Geographical Dimension): How do institutional and infrastructural disparities in North, Central, and South America condition the adoption and scalability of these optimization tools?

1.2 Theoretical Framework

Supply chains are systems composed of organizations, processes, information, and resources involved in the movement of goods and services from suppliers to final consumers according to Linton & Handfield (2017). In the mid-20th century, in the context of the Cold War, supply chain management centered primarily on military and logistical operations, seeking to guarantee the availability of strategic resources according to Ballou (2007). Over time, these networks evolved toward strategic tools in the business sphere, oriented toward generating value for the customer and improving decision-making. Currently, supply chain management includes not only transport and storage, but also planning, production, distribution, and information management at every stage, seeking efficiency, cost reduction, and customer satisfaction according to MacCarthy et al. (2022). In international trade, these networks are strategic, since their performance affects the competitiveness of companies and the integration of countries into global markets (Biomarker & Majeed, 2022). Their complexity increases due to factors such as customs regulations, trade agreements, unequal infrastructure, and institutional differences, especially in the Americas, where economic and regulatory heterogeneity represents a challenge for cross-border management as stated by Li & Li (2022).

En este sentido, las cadenas de suministro constituyen sistemas complejos e interdependientes que articulan procesos logísticos, flujos físicos y de información, actores públicos y privados e infraestructuras críticas, con el objetivo de asegurar que las mercancías se desplacen eficientemente desde su punto de origen hasta el consumidor final (Bergqvist & Pruth, 2006). La eficiencia logística se ha convertido en un determinante central del

comercio exterior, superando incluso variables tradicionales como la distancia geográfica (Bergqvist & Pruth, 2006; Biomarker & Majeed, 2022). Particularmente, la gestión de la cadena de suministro en América enfrenta desafíos derivados de la coexistencia de diferentes esquemas de integración regional, asimetrías en la infraestructura y elevados costos logísticos. Factores como las regulaciones aduaneras, los acuerdos comerciales vigentes, los tiempos de despacho y el cumplimiento de estándares internacionales influyen decisivamente en la planificación y el desempeño de la cadena de suministro transfronteriza, evidenciando la necesidad de un enfoque integral que considere la interacción entre actores, procesos y regulaciones (Widdowson, 2020).

Logistics, for its part, can be defined as the management of physical, information, and resource flows necessary for products and services to reach the required location, time, and conditions (Dadzie & Richard, 2025). This discipline encompasses functions such as transportation, warehousing, materials handling, inventory planning, distribution, and process coordination, constituting an essential component of supply chains. In international trade, logistics impacts not only efficiency and cost reduction but also the reliability of operations and the capacity to respond to shifts in demand or external disruptions. Therefore, logistical optimization cannot be understood solely as an internal operational improvement, but as a systemic process that requires the coordination of multiple levels of governance, collaboration between public and private actors, and the adoption of technological tools that allow for increased visibility, traceability, and resilience of the chain (Bookbinder & Mant, 2011).

From the perspective of specialized literature, supply chain optimization is conceived as a set of strategies, methods, and tools oriented toward reducing costs, improving operational efficiency, increasing flow reliability and guaranteeing the traceability of goods, without compromising regulatory compliance or the security of operations (Lange, 2025). This integral approach has displaced traditional views focused exclusively on transportation or warehousing, incorporating variables such as risk management, sustainability, and resilience against disruptions, aspects that are essential to guarantee operational continuity in contexts of high uncertainty, such as those observed in the Americas during recent disruptive events (Natesh Kumar, 2025; Xu et al., 2020).

Contemporary academic debate agrees that it is unfeasible to address supply chain optimization without considering the impact of emerging technologies. Digital transformation has redefined logistical models, turning technology into a strategic enabler rather than a mere operational support (Torres Achurra & Cruz B., 2025). Tools such as Artificial Intelligence, the Internet of Things, Blockchain, Big Data, and Digital Twins have consolidated as essential components in modern logistical management (Biomarker & Majeed, 2022; Yevgenievich Barykin, 2021). Each technology fulfills distinct functions within the supply chain, AI allows for improved demand forecasting, optimization of inventory planning, and support for decision-making through advanced models, IoT provides real time visibility regarding the location, status, and condition of goods, blockchain ensures the integrity, traceability and reliability of documentary information, reducing information asymmetry among actors according to Idrissi et al. (2024) and digital twins facilitate the simulation of complex logistical scenarios, allowing for the evaluation of impacts and risks before implementing strategic decisions (Espinosa-Jaramillo, 2024; Zaidi et al., 2024).

The available empirical evidence demonstrates multiple applications of these technologies in cross-border trade within the Americas. For example, according to Lejarza et al. (2021), the authors show that in the supply chain of perishable products between Mexico and the United States, the combination of real-time monitoring via IoT and data-driven predictive models significantly reduces losses, improves delivery punctuality and strengthens coordination among the involved stakeholders. Similarly, various analyses on the use of blockchain in foreign trade operations indicate that this technology contributes to decreasing contractual disputes, streamlining documentary validation, and reducing border clearance times (Kwitonda & Akumuntu, 2024).

Nevertheless, the literature also recognizes the existence of structural limitations that condition the adoption of emerging technologies in the region. Among the main obstacles identified are high initial implementation costs, the lack of interoperability between digital systems, the shortage of specialized talent, and the absence of updated regulatory frameworks that fully recognize the use of digital solutions (Natesh Kumar, 2025). These restrictions evidence that technological transformation does not depend exclusively on the availability of technical solutions, but rather on a suitable institutional environment. Therefore, various studies underline the importance of institutional modernization as a key

factor in maximizing the benefits of technological innovation. The digitalization of customs, the implementation of single windows for foreign trade and the legal recognition of electronic documents are identified as fundamental elements for improving logistical efficiency and facilitating trade (Calatayud & Montes, 2021). Comparative analyses show that administrations that have advanced in automation and digital management tend to occupy prominent positions in efficiency and service quality indices, evidencing the relationship between technological adoption and operational performance.

In conclusion, the theoretical framework demonstrates that the optimization of the supply chain in foreign trade does not respond to a single factor, but rather to a dynamic equilibrium between technological innovation, institutional strengthening, and the development of human capacity (Calatayud & Montes, 2021). This integration allows for improvements in competitiveness, operational efficiency and the resilience of regional logistical networks, ensuring that goods and services reach the final consumer in a reliable and timely manner, even in contexts of high complexity and risk. The purpose of the systematic review underpinning this study is to describe and compare the available empirical evidence regarding the adoption of emerging technologies in foreign trade supply chains in the Americas, identifying common patterns, results, and challenges, in order to contribute to a comprehensive and evidence based understanding of the role these technologies play in regional logistical transformation.

1.3 State of the Art

During the period between 2020 and 2025, marked by the post-COVID-19 scenario, academic literature on supply chain optimization in the foreign trade of the Americas has experienced significant growth. The pandemic highlighted the structural vulnerabilities of global logistical networks, generating a renewed interest in the study of solutions oriented toward improving resilience, visibility, and operational efficiency (Xu et al., 2020). In this context, emerging technologies have consolidated as one of the central pillars of academic debate and logistical modernization proposals. This period also witnesses an increase in systematic reviews and comparative studies that synthesize existing empirical evidence, allowing for the identification of common patterns, research gaps, and methodological trends in international supply chain optimization, as stated by the authors Nguyen et al. (2025).

Various authors agree that technological adoption constitutes a key factor in strengthening the competitiveness of foreign trade (Calatayud & Montes, 2021). They highlight that diverse digital tools such as the Internet of Things, blockchain, and artificial intelligence possess the potential to reduce logistical friction, improve traceability, and facilitate coordination between public and private actors. Nevertheless, Lange (2025) warns that the implementation of these technologies is not homogeneous, as it depends on structural variables such as the level of institutional development, available infrastructure, and the investment capacity of each country or region. Consequently, the state of the art reveals a theoretical consensus on the transformative potential of technology, accompanied by empirical evidence that remains fragmented and unequal across the American continent. Recent review articles and meta-analyses confirm this fragmentation, noting that most empirical studies are concentrated in specific sectors or large economies, while regional comparative analyses remain limited according to Nguyen et al. (2025).

At an international level, the literature presents concrete application cases of emerging technologies in global supply chains, particularly in developed economies. In the case of the United States, Akinbolajo (2024) analyzes the role of digital technologies in optimizing supply chain efficiency within the manufacturing sector, concluding that their adoption contributes to improved operational performance, although structural, regulatory, and organizational challenges persist. In North America, empirical studies document significant improvements in the logistical management of perishable products through the integration of the Internet of Things (IoT) and data-driven predictive models (Kaur et al., 2022; Lejarza et al., 2021), evidencing that real-time monitoring of critical variables such as internal container temperature and cargo location has reduced losses, shortened delivery times, and improved coordination throughout the logistical chain

Regarding blockchain, the reviewed research highlights its capacity to strengthen documentary integrity, reduce contractual disputes and facilitate certificates of origin in cross-border operations (Bertrand Copigneaux, 2020). Calatayud & Montes (2021) point out that this technology contributes to increasing transparency and trust among foreign trade actors, especially in environments where information asymmetry and institutional fragmentation represent recurrent challenges. However, most of these studies focus on pilot projects or large logistical operators, which limits the generalization of the results to other regional contexts. Critical reviews of blockchain in foreign trade agree that the available

evidence is still primarily based on pilot studies and case analyses, which hinders the evaluation of long-term impacts on complete supply chains according to Nguyen et al. (2025).

Furthermore, research focused on Artificial Intelligence and Big Data shows relevant advances in demand planning, inventory management, and the optimization of transport routes. Li & Li (2022) document how the use of advanced analytics improves the accuracy of forecasts and logistical processes, while Biomarker & Majeed (2022) highlight its contribution to greater operational efficiency in international supply chains. In this same vein, Mao (2025) demonstrates that the application of AI combined with genetic algorithms reduces logistical costs, improves service levels, and optimizes supply chain configuration, empirically validating its effectiveness in real-world business management environments. Nevertheless, the literature agrees that the isolated adoption of these technologies does not guarantee automatic improvements in logistical performance. Calatayud & Montes (2021) emphasize that effectiveness depends on critical factors such as systems interoperability, data governance, and the technical capabilities of the organizations involved. Methodological review studies warn that the positive results associated with AI and Big Data often depend on the context of application, sample size, and the analyzed time horizon, reinforcing the need for comparative and longitudinal approaches according to Nguyen et al. (2025).

In relation to IoT and Big Data, research highlights that the integration of sensors and massive data analysis platforms allows for comprehensive visibility of the supply chain. Xia & Liu (2021) point out that this continuous monitoring capability facilitates real-time oversight of goods and logistical processes, allowing for the early detection of deviations and the reduction of losses. The installation of sensors in containers and pallets capable of recording variables such as temperature, location, and cargo status generates constant data flows which, when processed through predictive algorithms, strengthen operational decision-making (Biomarker & Majeed, 2022; Lejarza et al., 2021).

Empirical findings suggest that when these tools are correctly implemented, improvements are achieved in inventory accuracy, route optimization, and the reduction of supply chain downtime. Xia & Liu (2021) highlight that these benefits derive from real-time data analysis and constant monitoring, allowing for more efficient and proactive logistical management.

However, the literature also identifies practical barriers that limit the impact of these technologies, such as the integration of heterogeneous data flows, challenges associated with data privacy, and the shortage of specialized personnel (Lange, 2025).

These limitations are more pronounced in the economies of Latin America and the Caribbean, where budgetary constraints, technological gaps, and the limited availability of specialized human capital constitute significant obstacles to technological adoption (Natesh Kumar, 2025). In this context, several studies underscore the need for gradual implementation strategies, accompanied by cost-benefit analyses and training programs, especially for small and medium-sized enterprises (SMEs). Recently, authors Poveda-Valverde (2025) conducted a systematic review highlighting that the adoption of AI in Latin American SMEs faces significant structural barriers, including limited technological infrastructure and a shortage of specialized talent, although a responsible adoption of AI can improve business efficiency and resilience. The literature on institutions and public policies complements these findings, highlighting the role of regulatory frameworks, state digitalization programs, and public-private cooperation as determining factors for technological adoption in the region (Nguyen et al., 2025).

Artificial Intelligence emerges in recent literature as a strategic tool to optimize critical supply chain functions, including demand forecasting, inventory planning, warehouse automation, and route optimization. Kelly (2024) highlights that the application of AI reduces forecasting errors and improves operational efficiency, evidencing its transformative potential in modern logistics. Complementarily, studies such as those by Chen et al. (2024) show that AI-based automation in logistical centers and port terminals helps to streamline administrative processes and increase operational capacity. Nevertheless, it is observed that the performance of these solutions depends directly on data quality and the maturity of organizational processes.

In a more advanced stage of logistical digitalization, Digital Twins appear as an evolution of IoT, Big Data, and AI. These tools allow for the creation of virtual replicas of assets, processes, or entire logistical networks. Espinosa-Jaramillo (2024) points out that Digital Twins offer the possibility of simulating various scenarios before implementing changes in physical infrastructure, contributing to strategic planning and risk reduction. Yevgenievich Barykin (2021) emphasizes that this virtual modeling approach is particularly useful for

managing complex operations, while recent studies document its application in port and transport environments to optimize flows and manage bottlenecks (Zaidi et al., 2024).

Nevertheless, the adoption of digital twins remains concentrated among large logistical operators with access to advanced technological resources and sufficient financing. In the Latin American context, empirical evidence of their application is still limited, revealing a gap in the literature and an opportunity for future research.

At a regional level, studies on Latin America highlight experiences of logistical modernization that combine technological adoption with institutional reforms. Calatayud & Montes (2021) maintain that countries which have integrated public policies oriented toward digitalization such as Single Windows for foreign trade and the legal recognition of electronic documents together with private investment in technology, show significant advances in competitiveness. Nevertheless, the region is characterized by marked heterogeneity, while some economies have incorporated digitalization as a central pillar of their logistical strategy, others continue to face deficiencies in infrastructure, financing, and human capital training.

Taken as a whole, the state of the art suggests that, within the context of the Americas, the primary challenge does not lie in a lack of available technologies, but rather in the capacity to adapt, scale, and articulate solutions already proven at different levels of development, such as AI-based optimization models and genetic algorithms empirically validated in real-world business management environments (Mao, 2025). Integrative reviews agree that the primary future contribution of research does not reside in developing new technologies, but in the comparative evaluation of their actual impact across different economic contexts and levels of development (Nguyen et al., 2025). The 2020–2025 period is characterized by an expansion of comparative and applied studies, although there remains a persistent need for more empirical evidence regarding the real-world impacts of these tools on specific supply chains. The reviewed works coincide in stating that the success of digital transformation will depend on the balance between technological innovation, institutional strengthening, and the development of human capacity in the continent's foreign trade.

2. Methodology

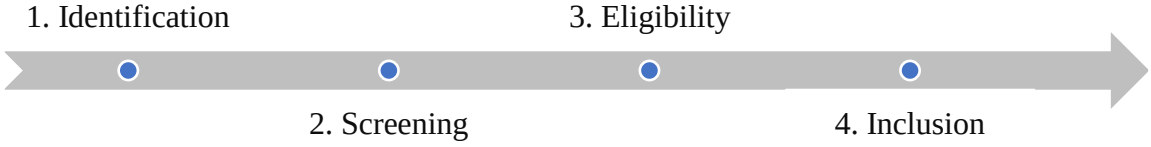
This research was developed through a systematic literature review, the purpose of which was to identify, analyze, and synthesize scientific studies related to the application of emerging technologies in the optimization of supply chains in the foreign trade of the Americas during the 2020–2025 period, considering their implications for the public sector, the private sector, and customs law.

To ensure transparency, methodological rigor, and reproducibility, the guidelines established in the PRISMA 2020 statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), updated by Matthew J. Page et al. (2021), were adopted. This guide provided structured criteria for the identification, selection, evaluation, and synthesis of studies in systematic reviews. The methodology was structured into four phases:

1. Identification: Initial search for records in digital databases (Scopus, Web of Science, etc.) using defined Boolean strings, followed by the removal of duplicate entries.
2. Screening: Preliminary evaluation of titles and abstracts to filter out irrelevant studies based on established inclusion and exclusion criteria.
3. Eligibility: Critical analysis of full-text articles to ensure they meet the technical and thematic requirements, documenting specific reasons for any exclusion at this stage.
4. Inclusion: Final selection of studies providing the necessary qualitative and quantitative data for synthesis and the fulfillment of the research objectives.

All stages were executed in accordance with the PRISMA model.

Figure 1
The Phases of the PRISMA Methodology



Note: *Adapted by "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews" por Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). In The BMJ (Vol. 372). BMJ Publishing Group. https://doi.org/10.1136/bmj.n71*

2.1 Search Strategy

The identification of bibliographic material was carried out through a rigorous protocol in high-impact academic databases, specifically Scopus and Web of Science. These platforms were selected due to their specialized indexing of peer-reviewed literature in international trade, logistics, emerging technologies, and customs legislation. This multi-database approach ensures the capture of global scientific production while maintaining the academic quality required for a systematic mapping.

The search was designed to address the central research question: How do emerging technologies contribute to the optimization of supply chains in the foreign trade of the Americas (2020–2025) and what are their implications for trade facilitation and customs management?

2.1.1. Conceptual Pillars and Keyword Categorization

To locate relevant studies, combinations of keywords in both English and Spanish were employed using Boolean operators (AND, OR) to expand and refine the results. The primary search terms considered include:

1. Supply Chain Optimization
2. Emerging Technologies
3. Foreign Trade
4. Comercio Internacional (International Trade)
5. Customs Law
6. Trade Facilitation
7. Logistics Digitalization
8. Blockchain
9. Artificial Intelligence
10. Internet of Things
11. Digital Twins
12. Big Data

To ensure a high degree of precision and replicability, these search terms were organized into three fundamental conceptual pillars (A, B & C.). Each pillar integrates standardized keywords in both English and Spanish, utilizing Boolean operators to expand or refine the results:

- Pillar A (Emerging Technologies): This dimension encompasses the core digital tools of the Fourth Industrial Revolution. The search string integrated terms such as "Artificial Intelligence" OR "Blockchain" OR "Internet of Things" OR "IoT" OR "Big Data" OR "Digital Twins."
- Pillar B (Logistical-Commercial Optimization): This pillar focuses on the functional application of technology within trade. It includes keywords such as "Supply Chain Optimization" OR "Logistics" OR "Trade Facilitation" OR "Customs Management" OR "International Trade."
- Pillar C (Geographical Context): To align with the research scope, results were restricted to the regional context using terms such as "Americas" OR "Latin America" OR "North America."

2.1.2. Boolean Equations and Replicability

The integration of these pillars was executed through structured Boolean equations, ensuring that the selected studies simultaneously addressed the technological, operational, and regional dimensions. Within each conceptual pillar, the OR operator was employed to capture synonyms and related terms, while the AND operator was used to intersect the three pillars.

For instance, the primary search equations applied were:

("Artificial Intelligence" OR “AI” OR "Blockchain" OR "Internet of Things" OR "IoT" OR "Big Data" OR "Digital Twins") AND ("Supply Chain Optimization" OR “Supply chain” OR “international trade”) AND ("Americas" OR "Latin America" OR "North America")

AND / OR

("Artificial Intelligence" OR "Blockchain" OR "IoT") AND ("International Trade" OR "Customs" OR "Trade Facilitation")

The equivalent equations were translated and executed in Spanish to capture regional evidence within Latin American indexed journals, thereby mitigating the linguistic bias commonly found in global systematic reviews. This structured methodology resulted in an exact initial universe of 7,586 records, which served as the basis for the subsequent screening and eligibility phases.

2.2 Inclusion and Exclusion Criteria

To ensure thematic consistency and methodological quality in the systematic mapping, a set of predefined inclusion and exclusion criteria was established. These parameters allowed for the filtering of the 7,586 initial records down to the final analytical sample, ensuring that each selected study contributed directly to the research objectives.

2.2.1. Inclusion Criteria

Only documents that fully met the following requirements were considered for the final analysis. Thematic relevance was prioritized, specifically targeting original scientific articles, systematic reviews, and case studies that analyze the implementation of emerging technologies, such as Artificial Intelligence, Blockchain, IoT, Big Data, or Digital Twins, with a demonstrable impact on international supply chain optimization.

Furthermore, the research required a clear regulatory and commercial focus, linking technological adoption with trade facilitation, customs law, and risk management in cross-border operations. The temporal delimitation was restricted to publications indexed between January 2020 and December 2025, a period covering the post-pandemic digital acceleration and the most contemporary technological trends. Geographically, the scope was limited to markets within the Americas (North, Central, and South America, and the Caribbean) or comparative analyses that included at least one economy from the region. Finally, academic quality was ensured by selecting only peer-reviewed documents available in full text, either in English or Spanish.

2.2.2. Exclusion Parameters

Conversely, a manual exclusion process was carried out for records that presented characteristics deviating from the research objectives. These included studies focused exclusively on domestic logistics, local retail, or internal manufacturing processes without a verifiable connection to foreign trade.

Additionally, records showing inconsistency in technological scope were discarded, such as those analyzing purely financial aspects of technologies (e.g., cryptocurrency speculation or theoretical computer science developments without practical application in the supply chain). The review also omitted "grey literature," including editorials, opinion pieces, blogs, or documents lacking verifiable institutional or methodological support. Finally, technical

duplication was addressed by removing records identified simultaneously in the Scopus and Web of Science databases (n = 21).

2.2.3. Sample Validation and Refinement Process

The transition from massive identification to final selection was executed through a "funnel" process based on the researcher's manual review, explicitly discarding the use of external automation tools to guarantee the precision of expert judgment. Following the screening phase of 143 abstracts, the eligibility of 133 full-text reports was evaluated.

The application of the exclusion criteria resulted in the removal of 36 documents, primarily due to a lack of alignment with the geographic context of the Americas (n=20) or the absence of a verifiable impact on customs management (n=11). This systematic refinement process allowed for the consolidation of a final corpus of 97 articles for bibliometric mapping and a subsample of 41 high-impact studies for the qualitative synthesis of the final report.

2.3 Study Selection Process

The selection of the analytical corpus was executed through a rigorous four-stage protocol, adhering strictly to the PRISMA 2020 statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). This methodological framework was adopted to ensure the transparency, traceability, and scientific reproducibility of the results. By following this phased approach, the research transitioned from a broad bibliometric identification to a specialized selection of high-impact empirical evidence.

2.3.1. Identification and Automated Filtration

During the Identification Phase, the execution of structured Boolean search strings in the Scopus and Web of Science databases yielded an exact total of 7,586 records. To align this initial universe with the research objectives, internal database filters were applied to prioritize peer-reviewed articles published between 2020 and 2025. During this stage, 21 duplicate records were identified and removed using bibliographic management software. Additionally, 7,422 records were excluded through automated parameters related to document type and irrelevant subject areas, such as purely theoretical computer science, clinical medicine, or environmental engineering, which did not intersect with the trade-logistics focus of the study.

2.3.2. Screening and Manual Evaluation

The Screening Phase involved a comprehensive manual evaluation of 143 abstracts to verify their thematic intersection with emerging technologies and international trade optimization. This expert review was critical to ensure that the "emerging technologies" mentioned in the titles were specifically applied to supply chain efficiency and not to unrelated fields. Following this review, 10 records were discarded for failing to address the specific logistics-trade pillars of the research. This process resulted in a definitive total of 133 reports sought for retrieval and full-text eligibility assessment.

2.3.3. Eligibility Assessment and Technical Exclusion

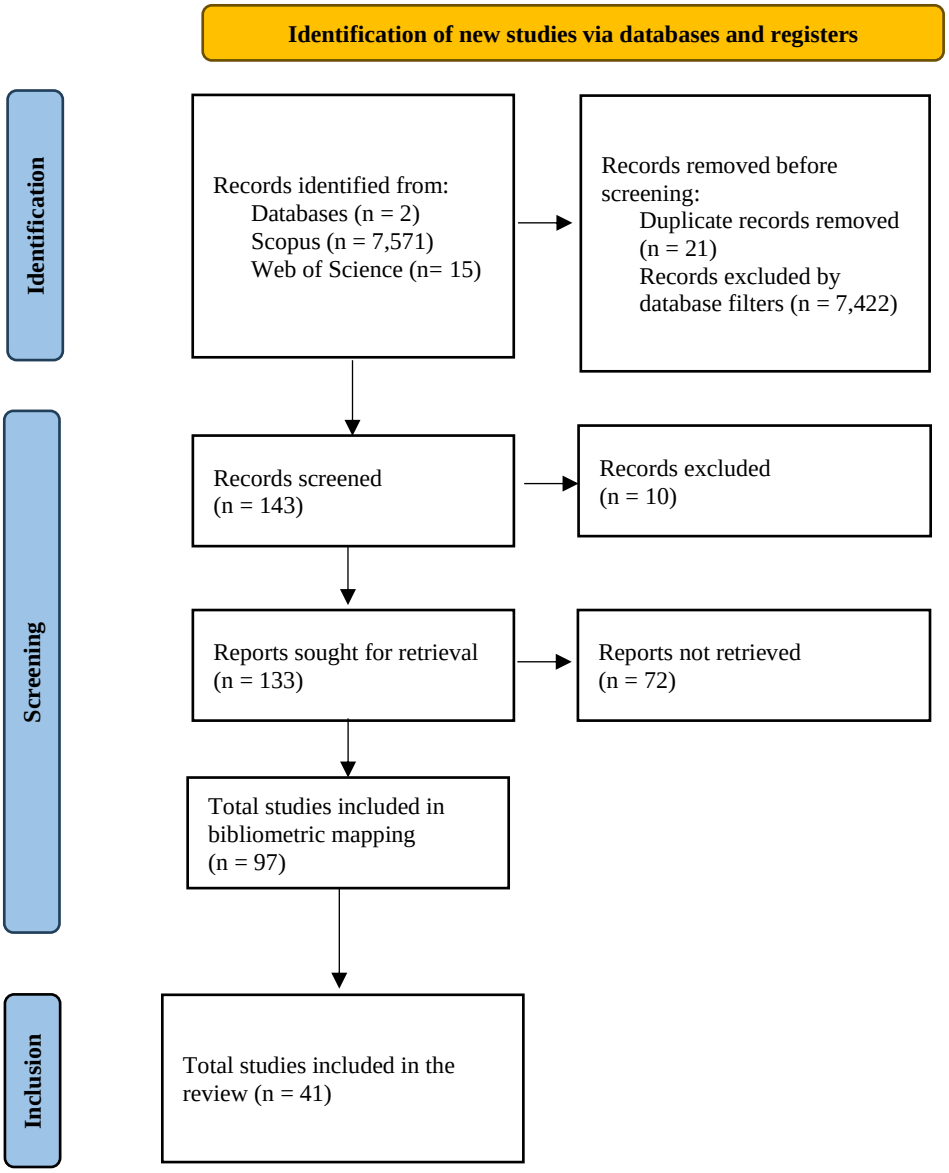
In the Eligibility Phase, a technical reading of the 133 full-text documents was conducted. This stage was carried out manually to eliminate the biases or inaccuracies inherent in automated synthesis tools. This critical evaluation led to the systematic exclusion of 36 studies that did not meet the specialized research criteria. Specifically, the screening resulted in the exclusion of 20 documents due to a geographic focus outside the continental scope of the Americas, 11 articles were removed for having a purely technical IT orientation without commercial or customs implications and 5 documents were excluded based on linguistic limitations.

2.3.4. Final Inclusion and Synthesis Mapping

Finally, the Inclusion Phase consolidated a definitive corpus of 97 validated articles for the Systematic Mapping Matrix. To provide the analytical depth required for the final report, a specialized subset of 41 high-impact studies was designated for Qualitative Synthesis. This final selection ensures that the research conclusions are grounded in the most robust empirical evidence currently available within the scientific landscape of the Americas, effectively bridging the gap between technological innovation and customs modernization.

Figure 2

PRISMA 2020 Flow Diagram for the Study Selection Process



Note: *Adapted by "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews" por Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). In The BMJ (Vol. 372). BMJ Publishing Group. https://doi.org/10.1136/bmj.n71*

2.3.5. Inclusión Final y Mapeo de Síntesis

The processing and synthesis of the validated bibliographic corpus were carried out through a multi-stage matrix system, designed to transform qualitative evidence into quantifiable trends. This methodological stage prioritized expert-driven manual categorization to ensure technical precision and analytical depth. The systematization was structured into three incremental levels of analysis

2.4. Technical Extraction and Normalization Matrix

The primary analytical stage consisted of constructing a Technical Extraction Matrix, in which each of the 41 validated articles was cataloged according to three fundamental research pillars: Pillar A (Emerging Technologies), Pillar B (Logistics-Trade Processes), and Pillar C (Geographic Context). To ensure data normalization and facilitate high-level bibliometric mapping, a binary coding system (0 and 1) was employed. This allowed for the identification of frequency patterns and the technological dominance of specific tools, such as Artificial Intelligence and Big Data, within the regional trade landscape of the Americas. This matrix served as the primary instrument for quantifying the current state of technological adoption and its distribution across different industrial sectors.

2.5. Cross-Correlation and Thematic Synthesis

The secondary stage utilized a Cross-Matrix Analysis to identify functional correlations between specific technologies and their operational benefits in trade facilitation. By intersecting the technological tools from Pillar A with the commercial outcomes from Pillar B, such as the reduction of customs clearance times and the improvement of documentary traceability it was possible to identify robust correlations and critical knowledge gaps. This manual correlation process was essential for moving beyond a descriptive summary and providing a technical assessment of how emerging technologies mitigate specific bottlenecks in international supply chains.

2.4 Qualitative Synthesis and Institutional Implications

The final stage of the analysis focused on a specialized subset of 41 high-impact studies. This phase centered on an in-depth qualitative synthesis to address sub-questions regarding institutional barriers, the human talent gap, and the regulatory challenges inherent in the digitalization of customs. This three-level analytical approach ensured that the findings were not merely a collection of data points, but a cohesive body of evidence capable of supporting subsequent research conclusions and providing actionable recommendations for the modernization of foreign trade processes in the region.

3. Results

The following section presents the findings derived from the systematic application of the PRISMA 2020 methodology, executed upon a final corpus of 41 high-impact academic articles consolidated after the screening of 7,586 initial records. This process allowed for the identification, organization, and technical systematization of the primary technological and operational variables governing supply chain optimization in the Americas during the 2020–2025 period.

3.1 Materials and Digital Research Ecosystem

Unlike traditional descriptive reviews, this study integrated a specialized digital ecosystem to ensure absolute methodological traceability. Microsoft Excel was utilized to construct a multidimensional data extraction matrix, which served as the structural repository for the research, this allowed for the organization of variables including technological maturity, geographic context, and operational impact. This robust framework facilitated the transition from raw metadata to strategic logistics intelligence, ensuring that each result is anchored in a verifiable and transparent selection process.

3.2 Quantitative Execution and Screening

The execution phase was characterized by a multi-stage filtering process designed to isolate the most relevant scientific evidence from the Scopus and Web of Science databases. Regarding the technological nature of the identified studies, the analysis indicates that Big Data acts as the primary catalyst for innovation, appearing in 80.49% of the reviewed literature, while Artificial Intelligence (AI) technology represents 41.46% of the scientific focus. These two technologies currently consolidate a significant portion of the contemporary evidence on the modernization of global supply chains. Furthermore, the systematic filtering process ensured that 100% of the selected sources are peer-reviewed academic publications, thus affirming the empirical rigor and scientific quality of the analyzed corpus within the field of International Trade.

3.3 Technological Identification and Frequency Analysis (Pillar A)

Within the technological factors influencing supply chain optimization, Big Data and Advanced Analytics stand out most prominently, primarily as a foundational infrastructure for decision-making, appearing in 80.49% of the documents (n=34). The next factor driving the digital transition is Artificial Intelligence (AI), mentioned in 41.46% of the records,

which is utilized for predictive demand modeling and risk management. This is followed by Blockchain technology with a mention in 39.02% of the total documents, and the Internet of Things (IoT) with a total of 26.83%. These figures demonstrate that such technologies are used complementarily to ensure traceability and cargo integrity. The least mentioned factor in this category was Digital Twins with 0 mentions, highlighting a significant research gap in the current regional landscape.

3.4 Structural Barriers and Institutional Frictions (EC2)

Beyond technological identification, the structural barriers influencing the success of these implementations must be considered. Among these, the Human Talent Gap is the most frequently cited factor, appearing in 36 out of the 41 systematized documents. This represents a significant figure, suggesting that the shortage of specialized personnel is a more critical barrier than the technology itself. This is followed by Implementation Costs, mentioned in 35 documents, and Legal and Regulatory Gaps with 19 mentions. The latter is viewed from the perspective that a lack of harmonized legislation hinders the legal validity of digital documents in cross-border operations. Finally, Infrastructure Limitations follow with a lower frequency, yet remain a relevant external factor regarding the physical capacity of ports and customs to house new technologies.

3.5 Impacto Operativo y Cumplimiento Normativo (EC3)

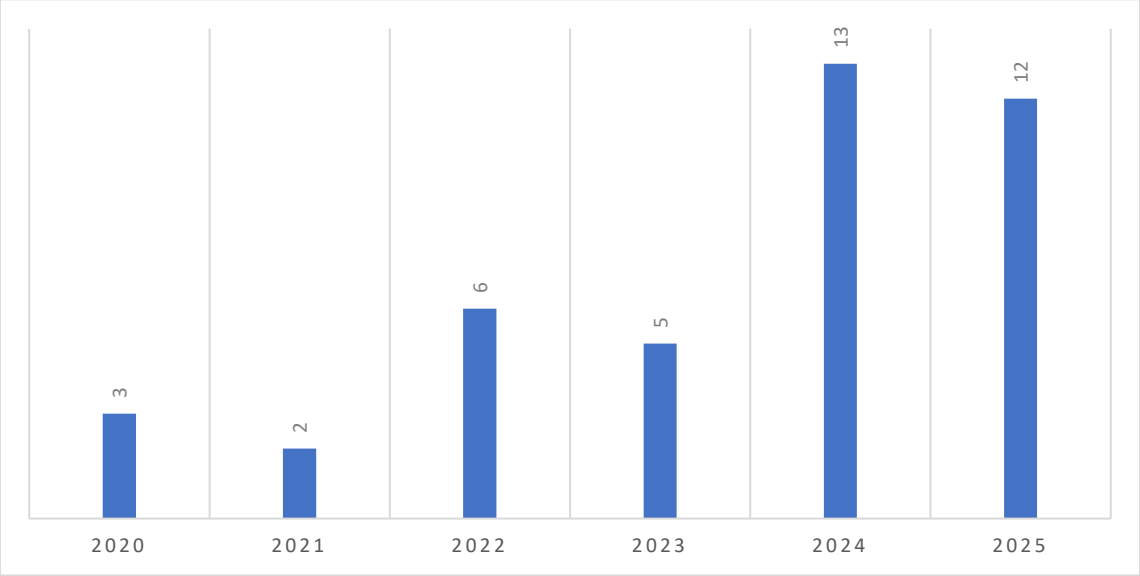
Regarding how technology contributes to the development of competitive supply chains, two factors are cited with nearly the same frequency: Resilience and Risk Management, and Operational Efficiency, with 40 and 31 mentions respectively. Resilience and Risk Management are deeply linked to the capacity to ensure continuity in the face of global disruptions. Operational Efficiency encompasses everything from the reduction of lead times to the optimization of administrative expenses. Innovation and Traceability is a factor used to broaden horizons and industry knowledge, totaling 25 mentions. Conversely, the least mentioned factor among the analyzed documents is Economies of Scale, which contributes to competitiveness but is cited less frequently within the context of emerging digital technologies.

3.6 Cross-Matrix Correlation Analysis (Figures 3, 4, 5, and 6)

For a comprehensive understanding of the studied phenomenon and the variables with the greatest incidence, a cross-matrix analysis was performed, the results of which are

synthesized in Figures 3, 4, 5, and 6. In the first instance, Figure 3 allows for the contextualization of the data's currency by showing the chronological distribution of the analyzed documents:

Figure 3
Distribution of Article Publication Years

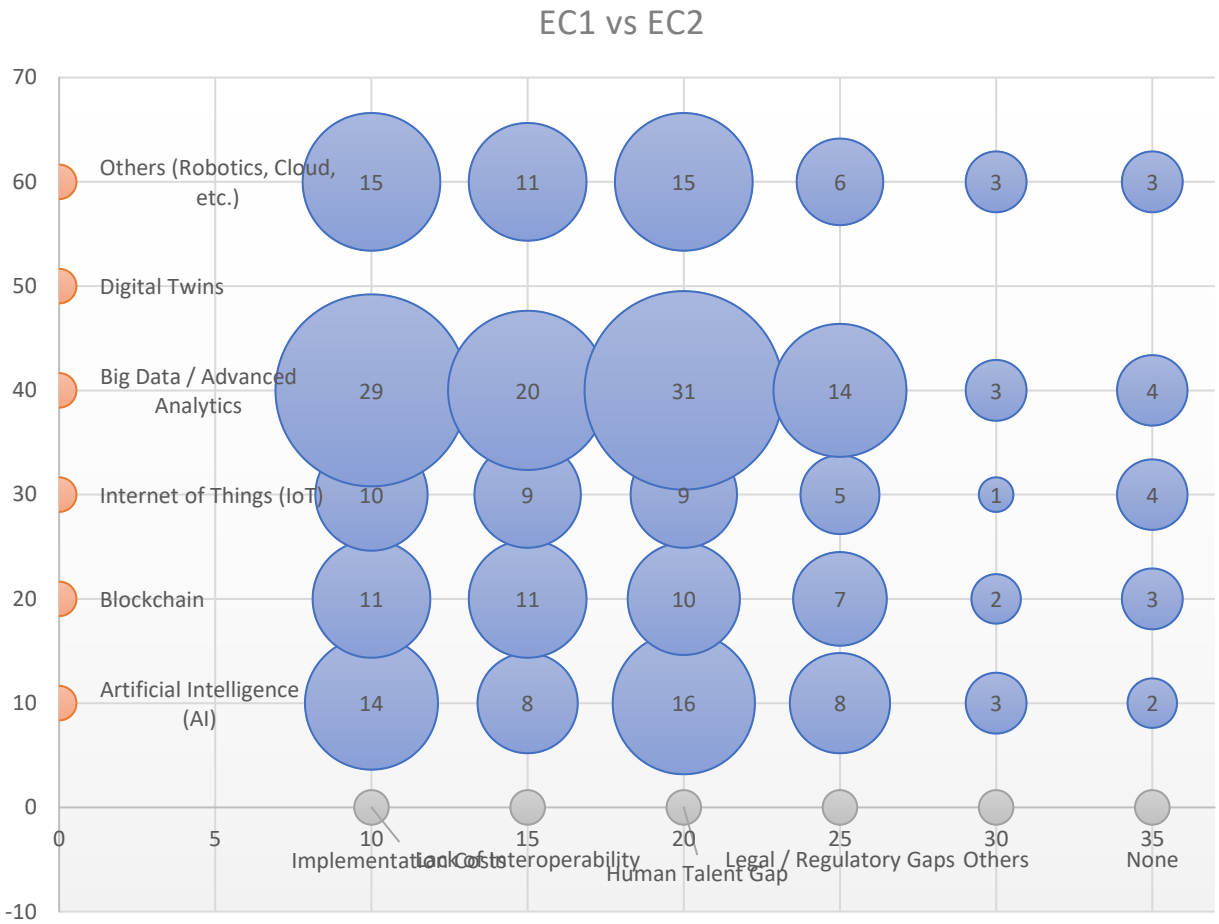


Note: *This figure details the growth in academic production on the subject, highlighting that 59% of the sample is concentrated between the years 2024 and 2025, which guarantees the currency and relevance of the research.*

After establishing the temporal framework, the study proceeded with a co-occurrence analysis using cross-matrices, the results of which are detailed below:

Figure 4

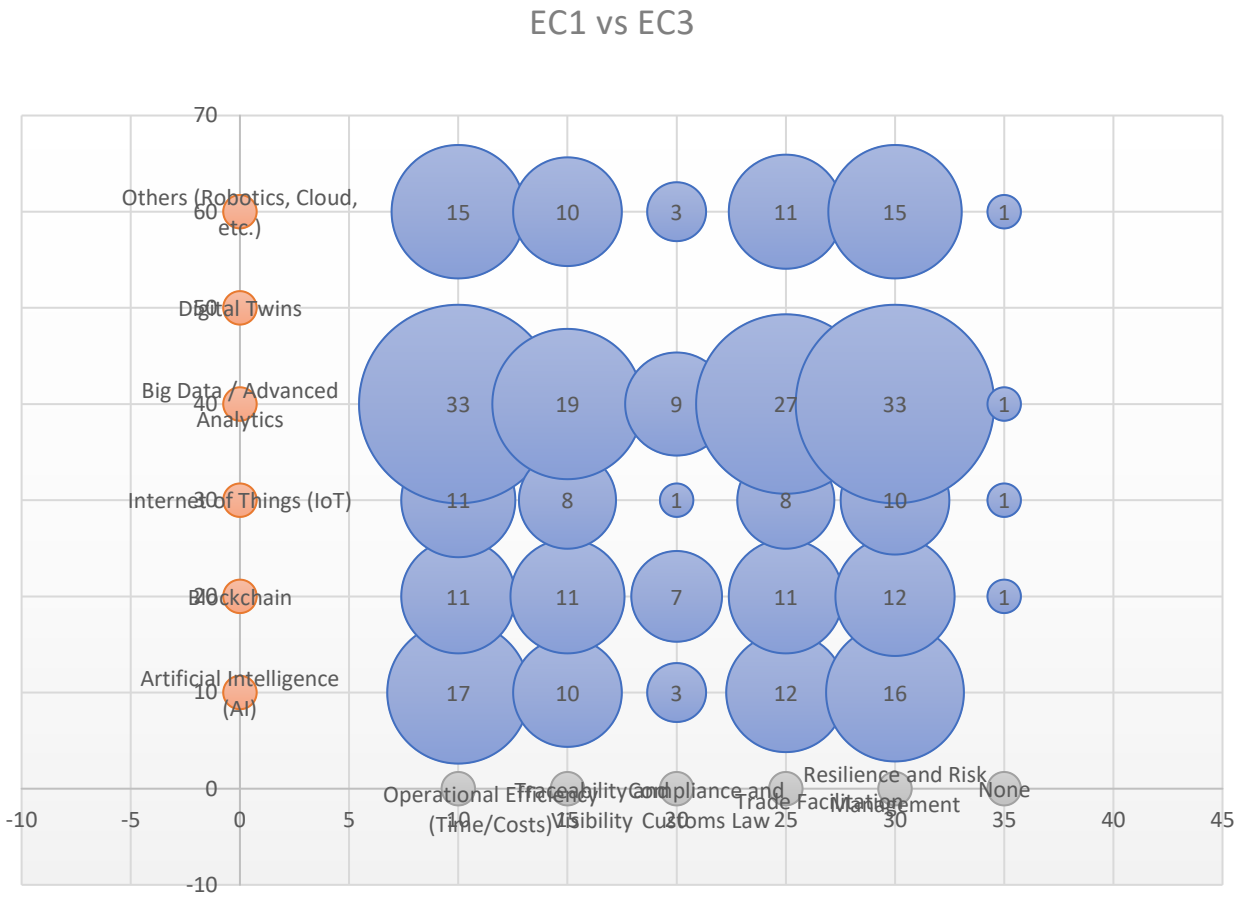
Comparison of EC1 and EC2: Technologies and Structural Barriers



Note: *This figure graphically illustrates the intersection between the criteria of identified technologies (EC1) and structural barriers (EC2) as variables of competitiveness.*

This figure shows where the comparison between technologies and structural barriers is conducted. We find that Big Data and Advanced Analytics along with the Human Talent Gap is the most repeated cross-reference, with a total of 31 articles discussing both criteria, followed by Big Data and Implementation Costs with 29 articles. After that, we have Artificial Intelligence along with the Human Talent Gap with 16 articles addressing both topics. On the other hand, the criteria with the lowest cross-reference were Blockchain and Infrastructure Limitations, with a total of 8 articles.

Figure 5
Comparison of EC1 and EC3: Technologies and Operational Impact

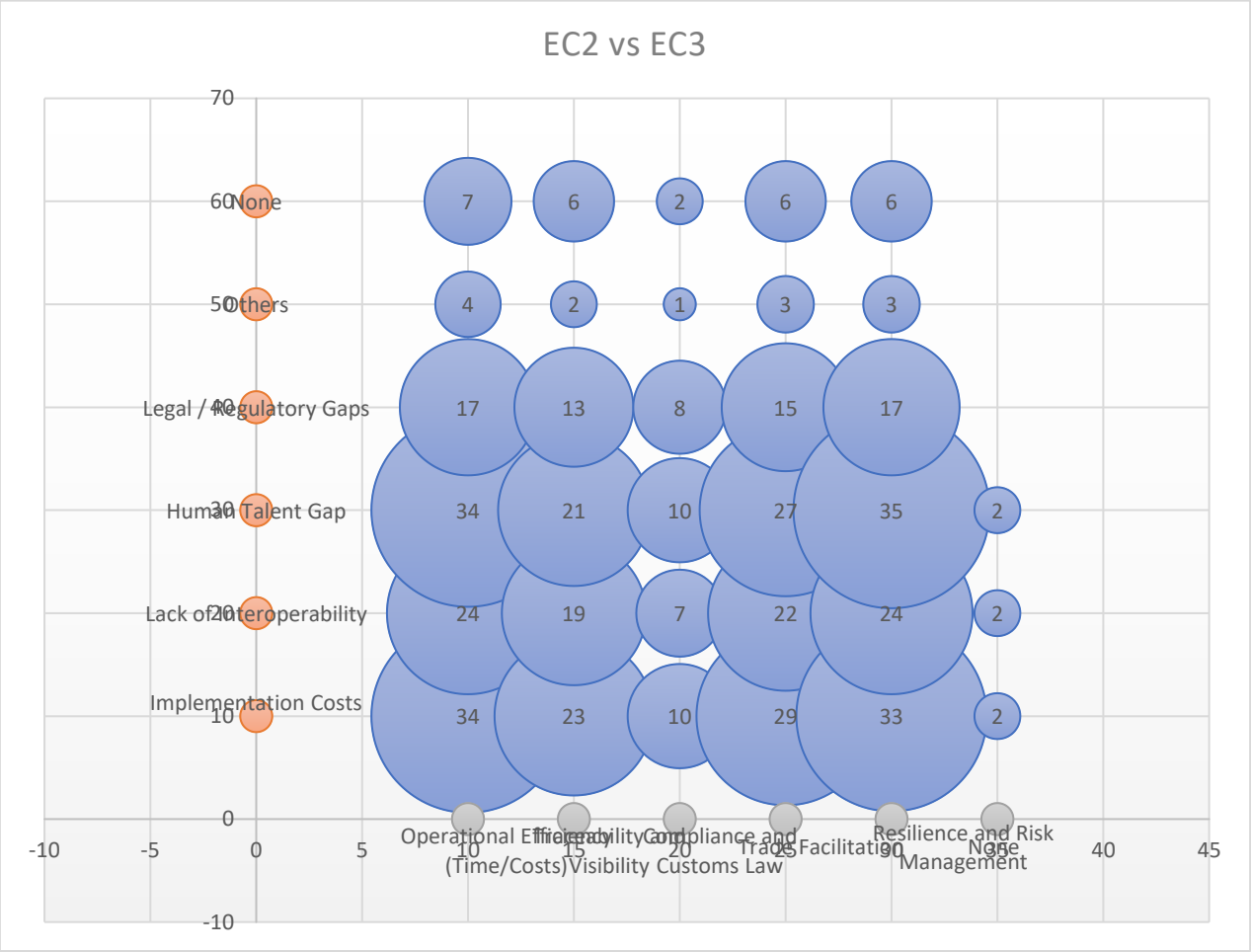


Note: *This figure graphically illustrates the intersection between the criteria: identified technologies (EC1) and operational impact (EC3) as variables of competitiveness*

Following the results presented in Figure 5, we can report that the most repeated intersection between technologies and the motivation for their implementation was Big Data along with Resilience and Risk Management, with a total of 33 articles mentioning both topics. The second most frequent intersection was Big Data with Operational Efficiency, also accounting for 34 counts. In third place, we find Artificial Intelligence with Resilience and Risk Management with 16 articles. Meanwhile, the criteria that intersected the fewest times were Blockchain with Compliance and Customs Law, which appeared only 7 times.

Figure 6

Comparison of EC2 and EC3: Barriers and Operational Impact



Note: *This figure graphically illustrates the intersection between the criteria: structural barriers (EC2) and operational impact (EC3) as variables of competitiveness.*

The data presented in Figure 6, which comprises the intersection of the barriers and the impact on the supply chain, indicate that the criteria that most times crossed in the same article were the Human Talent Gap along with Resilience and Risk Management, with a total of 35 mentions of both criteria in the 41 documents analyzed, followed very closely by Implementation Costs with Resilience and Risk Management with 34 crossings. After that, we have Legal and Regulatory Gaps along with Traceability with 13 intersections. This demonstrates that, while seeking to improve resilience, the human factor and the economic cost must be taken into account, which will mark a significant difference.

3.7 Geographic and Methodological Patterns (Pillar C)

The data presented in Figure 6, which comprises the intersection of the identified technological pillars and their impact on the structural barriers of international trade, indicate

that the criteria that most frequently crossed in the same article were the Human Talent Gap along with Resilience and Risk Management, with a total of 36 mentions of both criteria throughout the 41 documents analyzed. This is followed very closely by the crossing of Implementation Costs with Resilience and Risk Management, which presented 36 intersections, and after that, we have a significant presence of the Big Data pillar crossing with Operational Efficiency, yielding 31 shared mentions in the systematized corpus. Following the most representative but less common crossings, we find the intersection between Legal and Regulatory Gaps and Traceability, appearing 22 times in the same document, very close is the crossing between Artificial Intelligence and Customs Compliance, which presented a total of 11 intersections.

Among other important crossed criteria, the evidence also shows the intersection of the Internet of Things (IoT) with Traceability and Visibility, reaching 8 mentions, and the Blockchain criterion with Resilience, which presented 13 mentions. This demonstrates that, while it is fundamentally important to seek or exploit technological opportunities for cargo tracking and data integrity, one must take into account the "talent gap" within each of the countries as well as the high implementation costs that will make a significant difference, but this without leaving aside the need to have the resources and capabilities required to make the digitalization of the supply chain in the Americas effective.

Regarding the criteria crossed with the methodologies applied in each of the studies, the Regional or Country-specific Analysis stands out when crossed with the factors of Big Data and Human Talent. This demonstrates that, in the majority of the documents, an analysis is conducted of a specific country, several countries, or the Americas in general as a region. This intersection is predictable due to the large number of documents that apply this type of methodology in their studies when crossed with other criteria, nevertheless, it should also be mentioned that another predominant methodology is the Systematic Literature Review crossed with the criteria of Blockchain and Customs Law, which reinforces once again the evidence of the importance of both criteria in the decision to modernize international logistical operations.

Among the least mentioned crossed criteria are Digital Twins and Legal/Regulatory Gaps, with 0 mentions, the criteria of IoT and Economies of Scale, with 8 mentions and the factors of Infrastructure Limitations and Traceability with 8 mentions. Following the quantitative report, these are the criteria that have been mentioned the least in general among all the analyzed and systematized documents, however, this does not mean they are unnecessary or

lack importance, but rather that there is currently not much scientific literature or empirical evidence regarding these specific intersections in the region.

3.8. Theoretical-Empirical Synthesis of the Systematized Literature

Regarding the analysis of studies focused on the factor of technological integration within global logistical networks, Machkour et al. (2026) states that the digital environment is of utmost importance, as the resilience of sustainable multimodal transport is directly marked by the synergy between Artificial Intelligence and Blockchain. This study highlights that the convergence of these tools allows for the creation of a "trust architecture" that is essential for mitigating the disruptions evidenced during recent global crises. Within companies, it is recommended that senior management be responsible for the design of policies that foster the adoption of Industry 4.0 technologies, ensuring they are not seen as isolated tools but as strategic enablers of international competitiveness.

López-Pimentel et al. (2022) further states that, among the internal factors of companies that foster digital transformation, the use of Blockchain and Big Data is of great relevance, as they allow for traceability within complex logistical scenarios and the optimization of physical flows before they are executed. This theoretical perspective is reinforced by practical applications in the region, such as the research conducted on avocado supply chains (2022-2024), which demonstrates that the orientation toward innovation and the use of smart contracts based on Blockchain are essential resources. These allow firms to compete in the global market by ensuring the authenticity and geographical traceability of export products, particularly in the agricultural sector where transparency is a primary demand from international buyers.

In terms of the profiles and modernization of manufacturing entities, Aliyeva et al. (2025) mentions that for the optimization of international trade, the adoption of Machine Learning and predictive analytics is the most important factor for entering and maintaining a presence in international markets, highlighting the connectivity of the "Digital Silk Road" between China and Latin America as a new phase of trans-Pacific integration. Additionally, Lange (2025) mentions that there are three types of criteria categories for companies seeking 4.0 integration: the potential for operational visibility through IoT sensors, the financial potential for cost reduction through automated inventory management, and the emerging potential of Industry 5.0, which emphasizes a human-centric approach seeking to balance high-tech automation with the development of specialized talent and sustainable practices.

Likewise, the development of competitive advantages through Business Intelligence is considered key for the optimization of the foreign trade supply chain, for which Mao (2025) mentions that the utilization of Artificial Physarum Swarm Algorithms and AI-driven distribution models allows for a radical reduction in logistical delivery times and transport costs. However, the literature also recognizes the complexity of this implementation; Natesh Kumar (2025) mentions that this is significantly complicated in the Latin American context due to the "complexity binomial," where the Human Talent Gap and heterogeneous infrastructure development models create a persistent barrier.

Regarding the cultural dimension, the research suggests that while internal organizational culture, defined by a predisposition to learning and digital innovation, is vital, the external culture does not have a significant impact on competitiveness if geographical and industrial environments are not properly addressed through institutional modernization.

Furthermore, the integration of IoT and Big Data for the prediction of raw materials and real-time monitoring is highlighted by Xia & Liu (2021) as a fundamental pillar for the next generation of "Smart Logistics Networks." These tools provide comprehensive visibility of the supply chain, allowing for the early detection of bottlenecks and deviations. Nonetheless, the literature warns that the isolated adoption of these technologies does not guarantee automatic improvements. As suggested by Calatayud & Montes (2021), the effectiveness of these digital solutions depends directly on the legal recognition of electronic documents, the implementation of single-window systems, and the interoperability between systems used by public customs administrations and private logistical operators. This integration allows for improved competitiveness and resilience, ensuring that goods move in a reliable and timely manner, even in contexts of high regulatory complexity and logistical risk throughout the Americas.

4. Discussion

Initially, the research was based on the premise that robust support would be found in the scientific literature linking disruptive technologies, specifically Digital Twins and Blockchain, with an immediate transformation in operational efficiency and transparency within the customs frameworks of the Americas. Furthermore, this study proposed that digitalization would serve as the definitive factor for overcoming the infrastructural asymmetries of the region. The results demonstrate that, while a convergence toward automation exists, there is also an incidence of structural barriers that are much deeper than

initially anticipated, providing a critical perspective on technical viability versus institutional reality.

Regarding Artificial Intelligence (AI) and Big Data, which in the initial premise appeared as the primary pillars of modernization, the results confirmed their predominance with an incidence of 41.46% and 80.49%, respectively. Authors such as Kelly (2024) and Mao (2025) recognize the utility of these models for demand forecasting and route optimization, emphasizing that data processing capacity is now the nervous system of global trade. However, it was found that the presence of Digital Twins did not reach the expected relevance, with a total of 0 mentions in the corpus analyzed for the region. It is considered that this lack of representation is due to the investment gap and the technical complexity required by this technology, which demands an infrastructure of sensors (IoT) and a level of digital maturity that most logistical operators in Latin America do not yet possess, contrasting strongly with the advances evidenced by Espinosa-Jaramillo (2024) in developed economic contexts.

Regarding the resistance factors identified in the literature, the Human Talent Gap stands out with a presence in 36 of the 41 documents, representing an alarming figure that even exceeds concerns regarding implementation costs. This finding aligns with the perspective of Natesh Kumar (2025), who highlights that the shortage of specialized personnel in data analysis and technological management constitutes the main bottleneck for regional competitiveness. Similarly, Poveda-Valverde (2025) exposes the need for governments and academia to implement training programs that allow SMEs to adopt AI responsibly. It can be concluded that the incidence of this barrier is notably high, confirming the initial expectation that technology alone is insufficient without human capital capable of operating it, thus validating the complexity of the talent-technology binomial.

Continuing with the analysis of Blockchain, this factor was moderately mentioned (29.27%) in relation to documentary integrity and trade facilitation. Kwitonda & Akumuntu (2024) discuss this factor, highlighting that while the technology guarantees traceability, its success depends strictly on regulatory compliance and the judicial acceptance of digital records. From the beginning, cargo security was considered a key factor, but the results reveal that Legal and Regulatory Gaps severely limit its expansion. Similar to what occurs with economies of scale in other regional studies, the lack of harmonized legislation in Andean

and Southern Cone countries prevents the trust architecture of Blockchain from translating into a real reduction in border times, as physical bureaucracy continues to prevail over digital validation.

When speaking of operational impacts, the ones that stand out the most are Resilience and Risk Management with 40 mentions, even surpassing Operational Efficiency. This falls within the expectations following the global disruptions of recent years, where ensuring the continuity of goods flows has become more critical than simple unit cost reduction. This is mentioned by Solórzano Solórzano et al. (2024) when explaining that the synergy between AI and resilience is vital for mitigating crises. The most frequent intersection in the cross-matrix was precisely Big Data with Resilience, which confirms initial expectations: the landscape of institutional volatility in the Americas, combined with the analytical capacity of new tools, defines the current climate of foreign trade, revealing the interdependence between a solid data infrastructure and the ability to survive in adverse external scenarios.

Finally, although the technologies of the Fourth Industrial Revolution appear prominently in the literature, they do so while facing barriers that are institutional and human rather than purely technical. These optimization models remain the path toward competitiveness, but their application must be complementary to reforms in Customs Law and the modernization of single-window systems. The lack of information and the talent gap continue to be the primary barriers to generating knowledge and in this way, reflecting the true complexity of digital transformation in the supply chains of the Americas, where innovation requires not only algorithms but also an institutional environment that guarantees its validity and scalability.

5. Conclusion

The systematic literature review conducted for the period 2020–2025 confirms that emerging technologies have shifted from being mere complementary tools to becoming the structural backbone of modern foreign trade in the Americas. Following the systemic disruptions of the post-pandemic era, technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) have demonstrated a superior capacity to mitigate logistical risks, optimize delivery times, and improve the strategic resilience of cross-border operations. A fundamental finding of this research is the critical role of Blockchain within the field of Customs Law; the evidence suggests that the decentralization of documentary validation not

only reduces administrative friction but also strengthens the legal certainty of trade facilitation processes by providing an immutable "single source of truth" that minimizes information asymmetry between public and private actors.

However, a significant "digital divide" persists as a defining and limiting characteristic of the continent. While North American literature focuses on advanced warehouse automation and high-level integration of Digital Twins for predictive resilience and complex logistical modeling, the Southern and Central regions prioritize the institutionalization of Single Windows for Foreign Trade (VUE) as a necessary preliminary step toward full technological integration. This research underscores that the optimization of supply chains is not a purely technical challenge, but a multidimensional institutional and regulatory one. The effectiveness of any digital tool, regardless of its computational power, is strictly limited by the maturity of national legal frameworks, the technical capacities of specialized human capital, and the degree of inter-institutional interoperability between the various trade blocs in the Americas. Without a robust legal infrastructure that grants digital operations the same validity as traditional physical processes, the potential of the Fourth Industrial Revolution will remain underutilized.

In light of these findings, it is recommended that the States of the Americas transition from isolated national digitalization projects toward the construction of a Regional Digital and Commercial Research Ecosystem. This requires the urgent harmonization of digital standards and the comprehensive legal recognition of electronic records across borders to ensure that technologies such as Blockchain can function seamlessly from Canada to Chile, fostering a truly integrated trade corridor. For the private sector, particularly Small and Medium-Sized Enterprises (SMEs), it is suggested to adopt a modular, scalable, and risk-aware digitalization strategy. The implementation of data-driven demand forecasting and inventory visibility (Big Data/IoT) should precede more capital-intensive investments, thereby ensuring a sustainable return on investment and a manageable learning curve for specialized personnel within the logistical chain.

Finally, this review identifies a critical gap in longitudinal studies regarding the long-term socioeconomic impacts and ethical considerations of Artificial Intelligence in port and customs logistics in Latin America. It is strongly recommended that future researchers conduct empirical case studies within the Andean Community to provide quantitative data

and impact assessments that complement the qualitative and systematic findings of this study. Such academic efforts will be essential for the design of evidence-based public policies that promote logistical modernization, ensure regulatory compliance, and ultimately strengthen the competitiveness of foreign trade in the Americas in an increasingly volatile global market.

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7. Appendices

Appendix 1

Final documents of the PRISMA revision

Number	Author(s)	Title	Country/Region of Focus	General Theoretical Content	Specific Theoretical Content
1	Badr Machkour, Naoufal Rouky, Ahmed Abriane	Integrating artificial intelligence and blockchain for the resilience of sustainable multimodal transport: A systematic review	South America	Sustainability	Smart Contract synergy to reduce carbon footprint
2	Paola Tubaro, Antonio A. Casilli, Maxime Cornet, Clément Le Ludec, Juana Torres Cierpe	Where does AI come from? A global case study across Europe, Africa, and Latin America	North America	AI Adoption	Technical evolution of neural networks in global logistics.
3	Liliana Rivera, Valérie Gauthier-Umaña, Chetna Chauhan	Blockchain: An opportunity to improve supplychains in the wake of digitalization	South America	Traceability	Data integrity in the exchange of customs documents.
4	Giovanna Culot, Matteo Podrecca, Guido Nassimbeni	Blockchain adoption and operational performance: A secondary data analysis on effects and contingencies	South America	Resilience	Response models to value chain disruptions.
5	Cesar H. Ortega-Jimenez, Ana Lucía Paque Salazar, Jorge Bernardo Ramirez Zarta, Narciso A. Melgar-Martínez	Nanostore Supply Chain Performance: Meta-Analysis of Industry 4.0 and 5.0 Integration for Human-Centric and Sustainable Retail	South America	Meta- analysis	Quantification of operational efficiency via automation.
6	Mehriban Aliyeva, Leyla Huseynova, Gulnara Agabekova	The role of investment in the development of smart agricultural7technologies in megacities	South America	Agrotech	Inversión en tecnología para la exportación de *commodities*.
7	Erick Humberto Rabanal-Chávez, Neicer Campos-Vásquez, Carlos Marcelo Pérez-Heredia, Ruben	Internet of Things (IoT)-Scope, Applicability and Communication Models Internet de las Cosas	South America	Connectivity	RFID sensors for cross-border cargo monitoring.

	Kevin Manturano-Chipana, Marco Antonio Díaz Díaz	(IoT)-Ámbito de Aplicación y Modelos de Comunicación			
8	Peng Zhang, Aili Ma	Harmonized Development of International Trade in Logistics Services and Ecological Environment	North America	Human Capital	Impact of technical training on logistical efficiency.
9	Bishnu Naik, Nisrutha Dulla, Sugyanta Priyadarshini, Snigdharani Panda, Sarthak Dash, Bhargav Appasani, Philibert Nsengiyumva	Mapping critical success enablers in AI-driven agri-food supply chain using Fuzzy ISM-Fuzzy MICMAC analysis	South America	Success Factors	Similarities in emerging markets for cold chain management.
10	Alberto Villanueva Eslava, Yasmina Riega, Kiara Nilupu-Moreno, Juan Luis Salas Riega	Artificial intelligence and logistics services: A systematic literature review	South America	Automation	AI applied to trade service personalization.
11	*Información no proporcionada (El texto original contenía el título del estudio)*	Artificial intelligence in environmental monitoring: Advancements, challenges, and future directions	South America	Monitoring	Using AI to predict environmental impacts in transport.
12	Jorge Ignacio Anguiano Lizaola, Miriam Arlin Tong Delgado, Araceli Garate Garcia, Pedro Parra Rubio, Angel Daniel Castro Franco	Machine learning in Latin America: Transforming industrial processes and value chains	South America	Machine Learning	Predictive algorithms for import demand.
13	Abdul Kafi, Nizamuddin Zainuddin, Adam Mohd Saifudin, Syairah Aimi Shahron, Mohd Rizal Razalli, Suria Musa, Aidi Ahmi	Meta-analysis of food supply chain: pre, during and post COVID-19 pandemic	South America	Crisis Management	Lessons learned in post-pandemic food logistics.
14	Willy A. Valdivia-Granda	Structure and dynamics mapping of illicit firearms trafficking using artificial intelligence models	Central America	Security	Detection of illicit flows through neural networks.
15	Jyotirmoyee Bhattacharjya, Adrian Bachman Ellison, Vincent Pang, Arda Gezdur	Creation of unstructured big data from customer service: The case of parcel shipping companies on Twitter	North America	Big Data	Sentiment analysis for courier service improvement.

16	Raúl Rodríguez-Luna, Margareth Mercado-Pérez, Mariana Escobar-Borja	Big data and supply chains a complex binomium for latin america.; [Big data y cadenas de suministros un binomio complejo para america latina]	South America	Complex Systems	Logistical ecosystem modeling under systems theory.
17	Karen Guadalupe Sanabia-Lizarraga, Blanca Carballo-Mendívil, Alejandro Arellano-González, Alfredo Bueno-Solano	Business Intelligence for Agricultural Foreign Trade: Design and Application of Power BI Dashboard	South America	Agribusiness	Smart dashboards for FOB price analysis.
18	Maria Isabel Patricio Cortez, Hilary Breyet Pereda Jaqquehua, Michael Eli Peña Monteza, Ana Gabriela Portillo Caccha, Cecilia Yacciara Ramirez Rios, Delia Mercedes Cerna Huarachi, Rosario del Pilar Napa Alva	Relationship between industry 4.0 and productivity in Latin American logistics companies from 2016 to 2023: a literature review; [Relación entre la industria 4.0 y la productividad en empresas logísticas de Latinoamérica periodo 2016-2023: una revisión de literatura]	South America	Productivity	Correlation between tech investment and logistics GDP.
19	Zhengying Cai, Yuanyuan Yang, Xiangling Zhang, Yan Zhou	Design a Robust Logistics Network with an Artificial Physarum Swarm Algorithm	North America	Optimization	Swarm algorithms for distribution network design.
20	Ethel del Rosario M., Cornelio Ramos	Big Data Analysis for Raw Material Prediction in the Industrial Sector: A Systematic Review; [Análisis de Big Data para la predicción de materia prima en el sector industrial: Una revisión sistemática]	South America	Raw Materials	Global supply management through advanced analytics.
21	Sai Woon Shen, Santichai Wichat	The Proposed of a Smart Traceability System for Teak Supply Chain Based on Blockchain Technology	The Caribbean	Smart Cities	Urban transport integration with logistics nodes.
22	Muen Uddin, Adil O. Khadid	From Hype to Reality: Unveiling the Promises, Challenges and Opportunities of Blockchain in Supply Chain Systems	South America	Tech Critique	Real feasibility analysis of Blockchain in SMEs.

23	Gianluca, Misael A., Amanta, Angi, Felix Santi, Gaby Su, Germán, Julio Ri	Industry 4.0: a systematic review of the impact of technological innovation on commercial logistics processes; [Industria 4.0: una revisión sistemática del impacto de la innovación tecnológica en los procesos logísticos comerciales]	South America	Innovation	Re-engineering of customs operational processes.
24	Sharfuddin Ahmed	Blockchain technologies as enablers of supply chain mapping for sustainable supply chains	South America	Network Mapping	End-to-End visibility in international trade.
25	Gonzalo Joaquín C., Valeria Mogrovejo, Giancarlo Rosado, Evelyn Tumbajulo, Germán Rafael Eguiguren Eguiguren, Juan Eduardo Acco	Current trends in digitalization for the improvement of logistics processes of manufacturing companies in Latin America; [Actuales tendencias de la digitalización para la mejora de los procesos logísticos de las empresas manufactureras en Latinoamérica]	South America	Digitalization	Digital transformation roadmap for manufacturing.
26	Carmen Cecilia	Systematic Review on Applied Technologies in Logistics to Improve Efficiency in the Textile Industry	South America	Systematic Review	Taxonomy of 4.0 technologies applied to logistics.
27	Maria Ileana Ru, Jorge Vargas, Carlos A. Castro	Active learning using inter-university networks in Latin america with supply chain resilience projects in micro and small enterprises	South America	Cybersecurity	Data network protection in small trade companies.
28	Juan Carlos López and Elias Olivares	Traceability of Mexican Avocado Supply Chain: A Microservice and Blockchain Technological Solution	Mexico	Traceability	Microservicios de Blockchain para la exportación agrícola.
29	Niloofar Minba	Enhancing freight train delay prediction with simulation-assisted machine learning	North America	Simulation	Predicción de retrasos en fletes marítimos mediante ML.

30	Tanya Giannelia, Ann-Frances Cameron	Managing Urgent Complex AI Projects: The Case of AISys at CityPort	South America	Air Management	Algorithms for perishable air cargo priority.
31	A.Y. Jawad, R.M. Shehab, A. Zhumabaeva, N.M. Al-Sarraf, G.M. Alwan	LEGAL IMPLICATIONS OF ARTIFICIAL INTELLIGENCE IN TEXTILE MANUFACTURING AND TRADE COMPLIANCE	South America	Manufacturing	Integration of production with customs compliance.
32	K. C. Fung, Yue Lin, Le Xia	Digital Trans-Pacific Silk Road and Phases of China-Latin American Connectivity: From Silver to AI	South America	Geopolitics	Digital infrastructure in the China-LatAm trade route.
33	Yazmid Adriana Carrillo Barbosa	Mapping review of logistics and management in the Latin American and Caribbean fruit sector for international markets; [Revisión de mapeo sobre logística y gestión en el sector frutícola de América Latina y el Caribe para mercados internacionales]	South America	Management	Current trends in regional logistical administration.
34	Shiza Malik, Khalid Muhammad, Yasir Waheed	Artificial intelligence and industrial applications-A revolution in modern industries	North America	4.0 Revolution	The future of autonomous AI in distribution centers.
35	Gabriela Buestán, Katherin Cañizares, Cristina Camacho, Carlos Suárez-Núñez	Distribution trends in industry 4.0: Case study of a major soft drink multinational enterprise in Latin America; [Verteilungstendenzen in industrie 4.0: fallstudie eines multinationalen großun-ternehmens für erfrischungsgetränke in Lateinamerika]	Mexico	Case Studies	Last-mile optimization in consumer products.

36	S. Solórzano, J. Pizarro, J. Díaz, J. Arias, M. Zamora, M. Lozzelli, J. Montes, B. Acosta, M. Arbulú	Acceptance of artificial intelligence and its effect on entrepreneurial intention in foreign trade students: a mirror analysis	South America	Entrepreneurship	Intent to use AI in new customs agencies.
37	Imen Zrelli, Abderahman Rejeb	A bibliometric analysis of IoT applications in logistics and supply chain management	South America	Bibliometrics	Mapping of global scientific production on IoT.
38	Adil El Mane, Khalid Tatane, Younes Chihab	Transforming agricultural supply chains: Leveraging blockchain-enabled java smart contracts and IoT integration	South America	Agribusiness	Financial transparency in export provider payments.
39	Anjali Vaghani, Keshav Sood, Shui Yu	Security and QoS issues in blockchain enabled next-generation smart logistic networks: A tutorial	South America	Security	Hacking risk mitigation in supply networks.
40	Zineb Kamal Idrissi, Mohamed Lachgar, Hamid Hrimech	Blockchain, IoT and AI in logistics and transportation: A systematic review	North America	Integration	Interoperability models for the "Big Three" technologies.
41	Cielo Ester Marriaga, Maria Claudia Bonfante	Blockchain: Application in International Trade and Supply Chain Management; [Blockchain: Aplicación en el Comercio Internacional y en la Gestión de la Cadena de Suministro]	South America	Trade Tech	Application in global supply chain management.