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Research

Challenges and Trends in Logistics 4.0

Retos y tendencias de la Logística 4.0

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Abstract

Context: Due to the technological breakthrough in worldwide productive systems generated by the 4.0 revolution, it has become necessary to make sweeping changes to logistics in order to allow supply chains to enhance their performance and response times. Hence, the concept of *Logistics 4.0* was born. Although many developed countries have implemented the principles of Logistics 4.0, there is still a breach in its study and application worldwide. This article explores the challenges and trends in the implementation of Logistics 4.0.

Method: Articles published from 2015 to 2021 in the Scopus, Science Direct, Taylor and Francis, and Google Scholar databases were analyzed via a systematic literature review.

Results: A conceptualization of Logistics 4.0 was proposed which includes a definition, objectives, characteristics, and the most representative technologies in its implementation. Likewise, the main challenges and trends facing industries in the implementation of Logistics 4.0 within supply chains were identified.

Conclusions: *Logistics 4.0* is a novel term that has aroused the interest of researchers, governments, and companies worldwide, which is due to its promising benefits in reducing response times and increasing flexibility and collaboration in supply chains. However, the lack of a common framework for its study and adoption has hindered its integration in companies and supply chains, especially for those facing technical, social, economic, and legal barriers for the implementation of Logistics 4.0.

Keywords: Logistics 4.0, Industry 4.0, Supply chain

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Resumen

Contexto: Debido a los avances tecnológicos en los sistemas productivos globales generados por la revolución 4.0, se ha vuelto necesario hacer cambios profundos a la logística para que las cadenas de suministro puedan mejorar su desempeño y tiempos de respuesta. De ahí nace el concepto de *Logística 4.0*. Aunque muchos países desarrollados han implementado los principios de la Logística 4.0, aún hay brechas en su estudio y aplicación alrededor del mundo. Este artículo explora los retos y tendencias de la implementación de la Logística 4.0.
Método: Se analizaron artículos publicados entre 2015 y 2021 en las bases de datos Scopus, Science Direct, Taylor and Francis y Google Scholar, mediante una revisión sistemática de la literatura.
Resultados: Se propuso una conceptualización de la Logística 4.0, que incluye una definición, objetivos, características y las tecnologías más representativas en su implementación. Asimismo, se identificaron los retos y tendencias principales que afrontan las industrias en la implementación de la Logística 4.0 en el ámbito de las cadenas de suministro.
Conclusiones: *Logística 4.0* es un término novedoso que ha despertado el interés de los investigadores, los gobiernos y las compañías alrededor del mundo. Esto, debido a sus prometedores beneficios en la reducción de tiempos de respuesta y el incremento de la flexibilidad y la colaboración en las cadenas de suministro. Sin embargo, la falta de un marco común para su estudio y adopción ha limitado su integración en las compañías y las cadenas de suministro, especialmente en aquellas que enfrentan barreras técnicas, sociales, económicas y legales para la implementación de la Logística 4.0.

Palabras clave: Logística 4.0, Industria 4.0, Cadena de suministro

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1. Introduction

The increased demand for individualized products (1, 2), the shortening of product lifetimes (3, 4) and innovation cycles (5, 6), the increased demand for shorter lifespans and better service levels (4, 5), larger supply chains and shorter batch sizes (7), and the volatility of markets (8), (9, 10) have challenged the field of logistics. Today, logistics processes must deal with more complex material and information flows (11–13), while the traditionally used techniques and tools fail to provide the sufficient agility and flexibility that supply chains (SCs) need in order to respond to the new requirements of markets (14). One alternative to improve results of SCs is integrating the technologies and principles of the fourth industrial revolution to their processes (15).

The term *fourth industrial revolution* was adopted in the Hannover Fair of 2011 to name the German government's high-technology strategy to promote the automation and digitalization of manufacturing processes (16). This term has been used to describe the inclusion of technological trends in industrial manufacturing, such as cyber-physical systems, the Internet of Things, and Big Data, among others (17). This fourth revolution has changed the way in which people and companies buy, produce, manage, sell, and deliver their products worldwide, making logistics a competitive driver (rather than a cost-centered one) for online stores and retailers (18).

Therefore, Logistics 4.0 seems to be a solution to the slow change that logistics activities have undergone in recent years. This term is used to describe the adoption of technologies and concepts of the Industry 4.0 in the field of logistics (10). Logistics 4.0 aims to achieve the '8RS Factors', which means that logistics is responsible for the delivery of the right product, at the right time, in the right place, with the right quality and quantity, ecologically right, and with the right information (5). *Logistics 4.0* seeks to improve the effectiveness and efficiency of entire supply chains. Nevertheless, authors often confuse the term Logistics 4.0 with the use of digital technologies in the logistics activities, since there is still no consensus around the definition and the characteristics of this term (3), which makes it a difficult matter to investigate and implement.

This article aims to propose a common definition for and characterize Logistics 4.0 through a systematic review of the literature. Section 2 explains the data collection methodology used. In section 3, a bibliometric analysis is conducted in order to identify the patterns in publications on Logistics 4.0. In section 4, the definition, technologies, and attributes that should be associated with Logistics 4.0 are established. Section 5 analyzes the role of Logistics and the Industry 4.0 in SCs. Finally, sections 6 and 7 describe trends and barriers in the implementation of Logistics 4.0.

2. Methodology

Through a systematic review, the attributes and elements commonly accepted among authors and experts on the subject were identified, allowing for the elaboration of a common conceptual framework for Logistics 4.0. To this effect, the procedure described by (19) was followed in order to answer the following research questions: (i) what is Logistics 4.0?, (ii) what is the influence of the Industry 4.0 in the current context of logistics?, (iii) what are the most representative technologies in Logistics 4.0?, and (iv) what is the role of Logistics 4.0 in SCs, as well as the barriers and opportunities of its implementation?. Table I contains a description of each phase of the review.

Table I. Phases of the systematic review of the literature

Phases	Description	Results
Search protocol and strategy	Databases used: ScienceDirect, Taylor and Francis, Scopus, and Google Scholar. Search terms: ((“logistics 4.0”) OR (“supply chain 4.0”) OR (“industry 4.0” AND (“logistics” OR “supply chain”))) and ((“blockchain” OR “IoT” OR “Cyber Physical Systems” OR “Big Data”) AND “logistics”) in title, abstract, and keywords.	797 publications were found
Review and selection criteria	Review of publications on titles, keywords, and abstracts in order to determine their pertinence with the research topic. Inclusion criteria: articles related to smart logistics, supply chain 4.0, and applications of digital technologies in logistics. Exclusion criteria: publications before 2015.	127 publications were selected according to the criteria
Data extraction	Filling out the analysis matrix. Information was extracted from the articles based on the analysis variables: definition, objectives, attributes, technologies, benefits, and implementation challenges.	Review of the 127 selected publications
Data synthesis and report	Synthesis of the contributions of authors in the analysis matrix. Identification of points of convergence and opposition between authors. Drafting of the report text.	

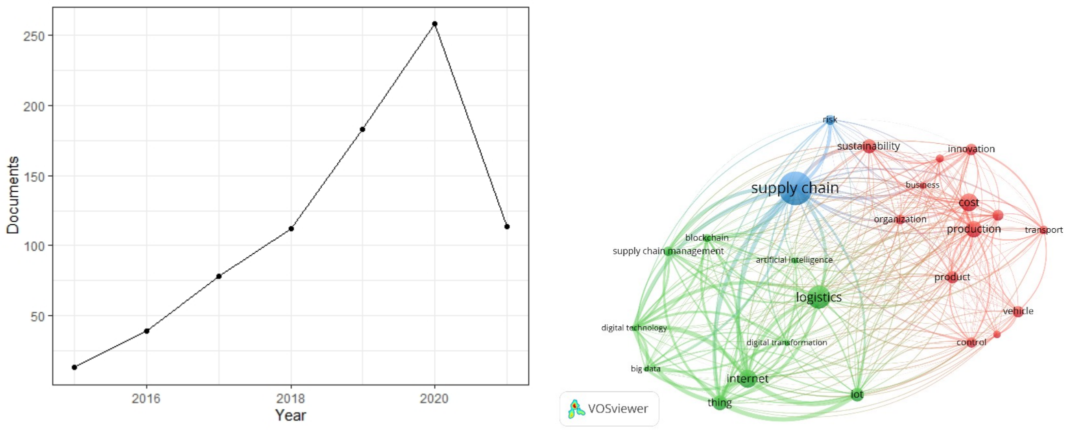
Source: adapted from (20)

Additionally, a bibliometric analysis was conducted in order to determine the new emerging trends in publications related to Logistics 4.0. This analysis was made in VOSViewer, a software used to build and visualize bibliometric networks. Furthermore, seminal publications were found using Hazing, a software that determines the number of citations of the most relevant articles on a topic.

3. Bibliometric analysis

Publications on Logistics 4.0 started to appear in 2015, four years after the 2011 Hannover Fair, when the term *Industry 4.0* was first proposed. Fig. 1 illustrates the annual number of publications on Logistics 4.0 in the Scopus database. The figure shows a growing trend for the number of publications, which could be an insight to the increasing importance gained by Logistics 4.0 in academia. Most papers are reviews and maturity models of European countries, which indicates a lack of Logistics 4.0 applications in industries, given the novelty of the term.

Due to the wide diffusion of this concept in Europe, the most cited authors on logistics in the Industry 4.0 come from Germany, Italy, Poland, the United Kingdom, and France, with around 75 % documents being from the continent. This is a consequence of the growing interest by the European Commission in developing competitive advantage through the research and implementation of digital technologies and Industry 4.0 in companies. These efforts have fostered the creation of Horizon 2020, an initiative aimed at securing Europe’s global competitiveness by funding research and innovation (21). Together with the European Commission, these are



[a] [b]

Figure 1. Behavior of publications on Logistics 4.0: a) documents related to Logistics 4.0 in Scopus by year; b) Logistics 4.0 bibliometric network including the top 25 most used words in the title and abstract of 689 articles published between 2015 and 2020 in the Dimensions database

largest sponsors worldwide in research and application related to the Industry 4.0 in logistics, accounting for 13 % of the published documents.

Through the Hazing software, seminal publications on Logistics 4.0 were found, with the following articles being the most cited of the reviewed publications (Table II).

Table II. Top 5 most citated publications on Logistics 4.0

Cites	Authors	Publication	Year
1057	(13)	Industry 4.0 and the current status as well as future prospects on logistics	2017
862	(22)	A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises	2016
707	(23)	Global logistics and supply chain management	2016
480	(14)	Industry 4.0 implications in logistics: an overview	2017
331	(24)	Intuitionistic fuzzy based DEMATEL method for developing green practices and performances in a green supply chain	2015

Then, a bibliometric analysis was conducted to identify the main trends and areas of application of the publications found in the Dimensions database. Fig. 1b shows the bibliometric network of the top 25 most used words in titles and abstracts of publications on Logistics 4.0 between 2015 and 2020. In the network, it is possible to identify three main clusters: the first is related to blockchain, IoT, Big Data analytics, and artificial intelligence, which are the main technologies related to Logistics 4.0; the second shows the application of Logistics 4.0 as a driver for supply chain management (SCM) and mitigating risks in SCs; and the third gives insights into the areas and activities in which Logistics 4.0 could be a driver for innovation processes, transportation, sustainability, and vehicle control.

Logistics 4.0 could drive the success of companies in the new technological revolution, enabling the creation of new competitive advantages in competitive markets. Nevertheless, its implementation in academia and industry is still in its early stages. Although *Logistics 4.0* is a novel term, some European countries have focused their interest in order for its development to be at the forefront of technology.

4. Towards the conceptualization of Logistics 4.0

Logistics is defined as the SC process of planning, executing, and controlling efficient material and information flows, from the origin to the consumption point, in order to satisfy the customer's requests (25). This term arose in the military field in times of the ancient roman empire, but it became important in 50s due to the concern in the army about the efficient flow of military equipment and food during wars (26). Logistics was later adopted by companies to manage material flows, and it was integrated as a part of the supply chain (25). Given the emergence of new technologies, logistics had to adapt its operations in order to respond to the new needs of the market. This happened in four phases: Logistics 1.0 focused on the mechanization of transportation, Logistics 2.0 on the automation of cargo systems, Logistics 3.0 on the use of information systems, and Logistics 4.0 on the automation of material and information flows (27,28).

Logistics 4.0 is defined as the combination of the traditional logistics activities and the innovations and technologies of the Industry 4.0, mainly cyber-physical systems (CPS). Furthermore, it is defined as the implementation of the Industry 4.0 in the field of logistics (29), as a response to the changes generated by manufacturing processes in the Industry 4.0, improving operations in SCs. There are three types of Logistics 4.0: instrumented logistics (the use of technologies to improve materials handling within companies); interconnected logistics (enabling the connection between two or more logistics devices, thus improving tracking and traceability); and intelligent logistics (the ability to communicate and share information throughout the organization) (30).

On the other hand, Logistics 4.0 is described as the union of the Internet of Things, high performance sensors, information technologies, and robots with logistics activities, which allows the interconnection of SCs (31). The use of technologies in logistics improves the flow of materials and information among participants in SCs, creating value in each step. This, due to the fact that customers play an important role as active stakeholders in the value creation process (32). Although Logistics 4.0 is mainly associated with the implementation of digital technologies, its implementation should also include changes in all related processes (33).

Nowadays, the importance of green logistics, circular economies, inverse logistics, and green supply chains, among others, has increased in both academia and the industry, seeking to respond to the concern about the impact of logistics activities on the environment. The purpose of these trends is to make processes along SCs more sustainable. Sustainability is defined as the responsible utilization of resources that guarantees the well-being of current and future generations (34), which includes economic, social, and environmental aspects. Logistics 4.0 embraces this concern by including the management of materials and information during the whole product's life-cycle, *i.e.*, until its final disposal (35).

Considering the above-mentioned definitions, a definition of Logistics 4.0 that combines the identified elements and parameters of the definitions given by the literature would be as follows:

> *Logistics 4.0 is the management of the flow of materials and information along the supply chain from the point of extraction to the end of the product's life cycle and its final disposal, which includes the creation of value in each echelon of the supply chain, by implementing the innovations and technologies of the Industry 4.0.*

The main objective of Logistics 4.0 is to increase the overall efficiency and effectiveness of SCs through the creation of networking and the synchronizing processes for different partners (28, 36, 37). Networking is made possible by the integration of information and communication technologies between companies (38). Long-term integration in SCs generates efficiency and competitive advantages that allow companies to perform better in the market (1, 39). Moreover, the adoption of ICTs facilitates communication and data sharing among companies, which could improve the information and material flows of SCs (4, 14, 40). These improvements, generated by Logistics 4.0, help companies to provide end customers with products under the conditions described by the 8Rs (5, 8, 27). On the other hand, better information and material flows make logistics systems more flexible, thus allowing them to respond quickly to the changes in market demand (28, 41). This is a key factor in transportation and distribution systems (42).

Besides, integration among participants could reduce costs and emissions (35), which could be reflected on the performance of the entire SC (1, 4, 27, 33). These benefits will not always be evidenced in the performance of each individual company, but in the overall performance of the SC (35, 43). For that reason, clear agreements between partners become crucial in the implementation of Logistics 4.0, in which it is important to clarify issues related to data protection, possession, handling, intellectual property, and security (44). In conclusion, the main objectives followed by Logistics 4.0 are cost reduction, increased SC performance and flexibility, and compliance with the 8Rs. These objectives are usually achieved by improving intercompany and intracompany material and information flows.

4.1. Technologies

Most of the technologies of the Industry 4.0 could be implemented in the field of logistics, given the close work between manufacturing and logistics and the extensive possibilities offered by the use of digital technologies, which allows ensuring completeness and interoperability between interorganizational functions. Furthermore, digitization in logistics could represent an increase in effectiveness and competitiveness for both industries and countries (45). As shown in the previous section, the key technologies that drive Logistics 4.0 are IoT (2), CPS (28), Big Data analytics (6), blockchain (44), and cloud computing (12). Each of the main drivers is listed below, and a taxonomy of related technologies is presented.

Internet of Things (IoT):

It is defined as a network that interconnects physical objects, such as products, machines, and processes, which are capable of collecting information (46). Through the IoT, different objects can send and share large amounts of information in real time. The IoT could be implemented with RFID, cloud computing, and wireless sensor networks (WSN), thus enhancing traceability, allowing for faster decision making, and increasing accuracy and flexibility in logistics (47). The adoption of the IoT is affected by company size, as large companies are used to having the necessary competences to facilitate the implementation of these technologies (48).

Big Data analytics:

Big Data analytics refers to the collection, processing, and analysis of large amounts of information that cannot be managed in real time (49). Big Data is characterized by the four Vs: volume, velocity, variety, and veracity (50). Big Data can bring great benefits in SC operations and activities by facilitating the creation of data-driven strategies, allowing to make better, faster, and more informed decisions (51,52), achieving reductions in delivery time and costs in SCs (53), and optimizing business operations by analyzing valuable information (54). Moreover, it helps in lean, agile, resilient, and green supply chains (55). For instance, Big Data helps to improve forecasting methods through its integration with data science and machine learning in aviation logistics (56). On the shop floor, Big Data could be useful to visualize the logistics trajectory and evaluate the performance and efficiency of logistics operators (52). In the transportation sector, Big Data helps companies to understand and explore patterns in freight activities (57), especially when it is combined with tracking and geolocation services (58). To achieve the benefits of Big Data in logistics, it is necessary to gather heterogeneous, homogeneous, and dynamic SC data in the shortest possible time (59).

Cyber-physical systems (CPS):

These are defined as interconnected systems of digital and physical objects that communicate and interact with each other, as in a social network of physical objects (60), thus allowing to make decentralized decisions (61). The main benefit of implementing CPS is the improvement of data exchange between business partners and multiple collaborating companies along the value chain (62). CPS enable monitoring, coordination, and horizontal and vertical integration of IT systems in SCs (63, 64), thus contributing to cooperation and communication frameworks between processes in an effective and low-cost way (14).

Some of the advantages of CPS integration in logistics are the reduction of operation costs and production cycle times (65). CPS work with scanners, readers, QR and RFID codes, GPS, and mobile applications for the automatic recognition and processing of the location (66), condition, and status of products (67). CPS have been used in the design a Logistics 4.0 model for the inventory management process of a cold chain (68). Furthermore, CPS have been applied to intra-logistics for scheduling self-guided vehicles in warehouses while considering orders, vehicles, and the status of each product in the production process (69).

Blockchain (BC):

BC has become one of the most widespread technologies in terms of security and digital confidentiality. In 2016, the World Economic Forum predicted that blockchain could store around 10 % of the global GDP by 2027, as it is a technology that will change society in the following years (70). It was created as a security mechanism for exchange of cryptocurrencies, but it is now used in areas such as public administration, business, transport, and logistics (71). BC is composed of different features such as a decentralized structure, a storage mechanism, a consensus algorithm, smart contracts, and encryption (72). This technology allows creating and sharing copies of records in the form of time-stamped blocks of information from a database between different SC actors in real time, thus preventing the alteration or deletion of information (73). There are three types of blockchain: public, private, and federated platforms, depending on the permissions given to users (74).

Some benefits of BC adoption in SCs could be improved transparency and response times (72), disintermediation and enabling trust (75), mitigating the bullwhip effects (71), reporting on environmental and social sustainability, facilitating payments and contract arrangements (76), reducing the risks of cyberattacks, and increased information security, a key success factor in the implementation of Logistics 4.0 (44). In humanitarian logistics, blockchain could improve collaboration among the actors in disaster relief and enhance supply chain resilience (77), as well as improving effectiveness and efficiency in humanitarian assistance by facilitating partnerships (78).

Cloud computing:

Another technology is cloud computing, which allows companies to access to infrastructure components, architecture, and an economic model, where virtualization, hosting, and Software as a Service (SaaS) converge (79).

Due to the large number of different technologies related to Logistics 4.0, different taxonomies were found which seek to create common frameworks for aggregation. Some taxonomies classify technologies based on the area of implementation (36), while others do it by functionality (80). For example, technologies could be classified in categories such as *connecting* (cloud computing, 5G, IoT, and digital twins), *collaborating* (digital platforms and ecosystems), *capitalizing* the adoption of emerging technologies by enhancing existing competencies (IoT, AI, Big Data, and analytics), or *building* new competencies (blockchain) (81).

This review proposes a new taxonomy based on functionality which includes the areas of cybersecurity, traceability, and process automation. Fig. 2 shows the proposed taxonomy of Logistics 4.0 technologies, with three macro-groups: those related to automation (RFID and QR codes, robots, *etc.*), real-time control (location technologies such as GPS and SMART sensors of pressure, temperature, humidity, and other conditions of cargo), and information management (CPS, Big Data, blockchain, *etc.*).

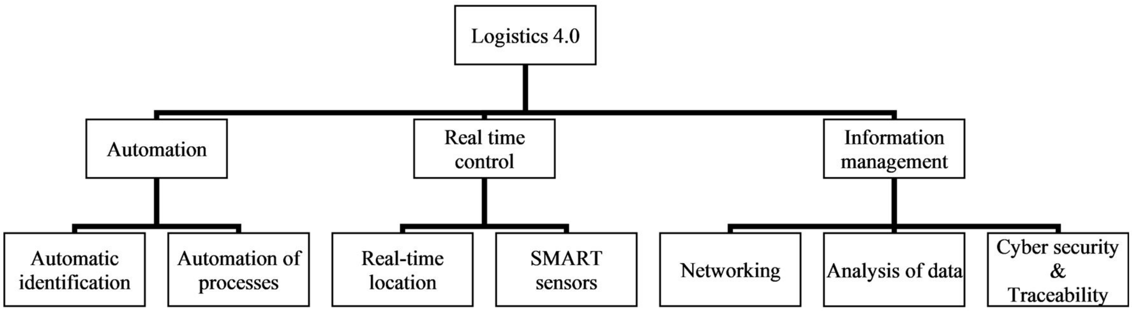


Figure 2. Taxonomy of Logistics 4.0 technologies

4.2. Attributes

Although Logistics 4.0 is mainly characterized by the implementation of digital technologies in logistics activities (37, 44, 66), other attributes include integration and networking (4, 35, 68). Integration occurs through the networking of customers, parts and components, and technical systems that communicate their status and work with others (82) and could provide SCs with competitive advantages (28). There are two types of integration: vertical and horizontal. The difference between both is that vertical integration implies the synchronization between different areas and functional departments in the same company, while horizontal integration links different companies in a SC (64). In the consolidation of integration and networking, collaboration and transparency among participants are fundamental (27). Therefore, it is necessary to break business barriers and work closely with customers, suppliers, and other organizations, thus improving productivity (83).

Networking describes any type of organizational structure where two or more geographically dispersed processes, business units, or companies frequently work in interaction (84). When networking is applied between SC stakeholders, it becomes a differentiating element of Logistics 4.0 (3). The combination of integration and networking is an essential requirement for the emergence of interoperability, defined as the ability to share and exchange information between different entities, as well as to utilize the functionalities of some parts of the network (84).

Another attribute of Logistics 4.0 is its focus on value creation through SCs. This trend increases the value generated through the disruptive improvement of management and the increase in flexibility, visibility, and transparency in SCs (44). Moreover, Logistics 4.0 increases the geographic and temporal accessibility of end customers to products, helping to provide products and services to customers at any time and any place, removing the historical barriers that traditional logistics has faced (35).

5. Benefits and challenges of SCs in Logistics 4.0

Some of the most important technologies related to logistics are the Internet of Things (IoT) (36), cyber-physical systems (CPS) and cloud computing (61, 82). The idea behind Logistics 4.0 is to implement self-regulating processes that improve SC transparency and achieve flexibility, process automation, decentralized decision-making, increased productivity, and cost reductions (38). In addition, in SCs, Logistics 4.0 enhances the visibility of inventory and operational movements (85); makes planning efficient and helps to respond quickly to the changes in sources, suppliers, capacity, and demand (33); and enables on-demand production and delivery according to just-in-time principles (86). Overall, Logistics 4.0 turns traditional SCs into open and flexible supply networks (80). To achieve these benefits, SCs should address some key challenges, such as managing implementation costs, creating cooperation models between stakeholders, achieving levels of knowledge absorption, and creating an appropriate strategic orientation.

Although the benefits of Logistics 4.0 are desirable for all companies, the costs associated with its implementation are high. Therefore, companies should first identify their key organizational processes and evaluate their technological needs in order to determine in which technology and when they should invest (44). In some cases, companies choose to implement 4.0 technologies in just one logistics process, giving rise to terms such as *Warehousing 4.0* (87). One example is the use of augmented reality in warehouse processes via smart glasses, which allows operators to identify easily the products and objects to pick (46), enabling the collaboration between digital and physical objects and the user, decreasing task completion times and errors, and making the working environment safer and more productive (88). Other technologies such as robots and automated guided vehicles (AGV) could also be applied in warehousing, helping to pick, place, palletize, and assemble materials and products (89).

Another challenge is the cooperation of all stakeholders (37), including logistics service providers (LSPs), who should implement Logistics 4.0 based on their knowledge management (42). Some of the technologies that benefit the operation of LSPs are Big Data analytics, IoT, business intelligence, simulation, real-time connectivity, and product life cycle management software (90). Collaboration could lead to significant cost reduction and reduced greenhouse gas emissions in shipping activities (91). Moreover, in the context of a pandemic, extensive communication and collaboration across SCs could minimize a lockdown's impact on operations and performance by means of designing alternative plans and supply allocations (92).

The successful implementation of Logistics 4.0 depends on companies' ability to absorb knowledge, not only on the integration of cutting-edge technology (63, 93). Therefore, the purchase of technologies alone will not provide benefits, but it should result in efficient processes (1). The use of the new technologies must be combined with the knowledge provided by highly trained personnel (94).

In addition, an appropriate strategic orientation is needed in order to overcome barriers and be sustainable over time (86). A successful process to implement Industry 4.0 in SCs included the following steps (95): (i) creating a cross-functional team, (ii) preparing a data integration process between functional areas, (iii) determining the desirable state in terms of customer experience and the optimal state of the 8Rs, (iv) evaluating of the current state of the Industry 4.0, (v) implementing and analyzing internal weaknesses, and (vi) creating an action plan. In addition, financial indicators were proposed in order to evaluate the impact of the implementation of Logistics 4.0, such as the absolute change in depreciation, amortization, and personnel costs; the change in profitability; and the substitution of personnel costs for depreciation and amortization over sales (96).

6. Implementation trends

Logistics 4.0 applications can be found in different business sectors. Fig. 3 shows which fields commonly use some technologies related to Logistics 4.0.

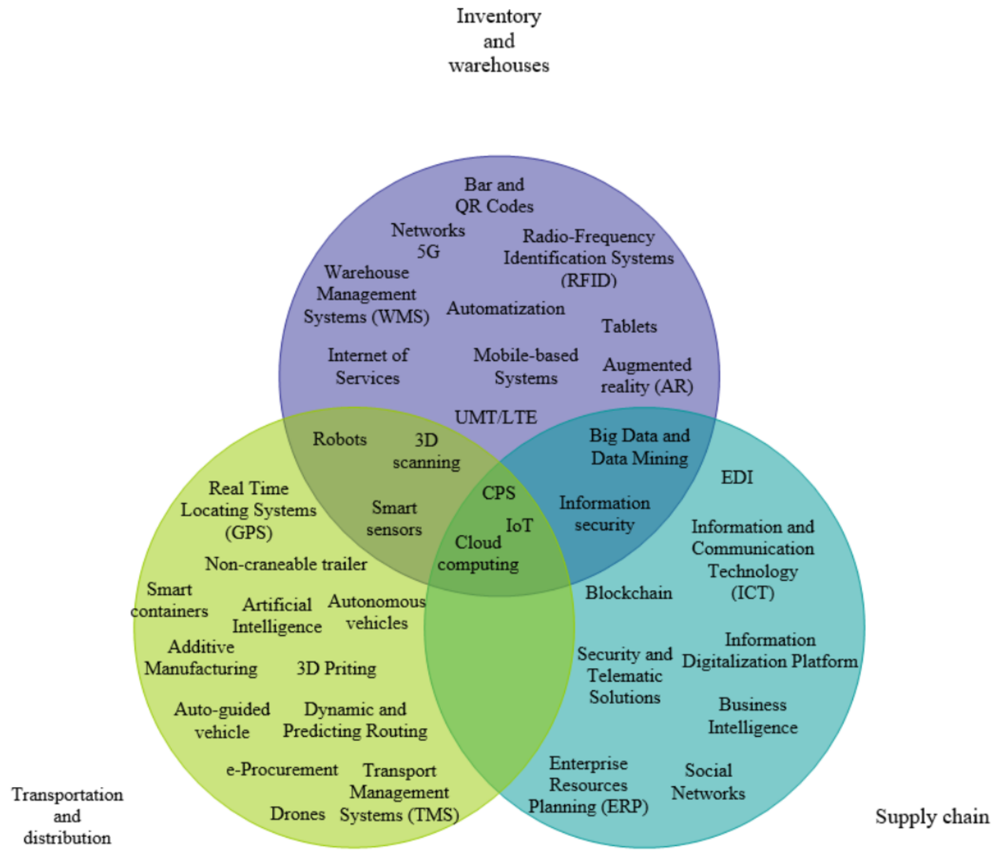


Figure 3. Grouping of Logistics 4.0 technologies based on the field of application

In 2015, Chinese company Changing Precision Technology became the first factory operated entirely by robots, which perform the processes of storage, production, and transportation (97). Bosch has integrated the operation of multiple factories by implementing RFID and using a centralized database-driven logistics systemin order to automate the flow of materials and information (98). Moreover, worldwide delivery services companies such as DHL, FedEx, and UPS have included barcoding, RFID, online tracking, and freight tracing, creating efficient logistics systems (23).

In the agri-food sector, Ali Cloud and ZhongAn Technology implemented blockchain in the chicken SC in order to improve the traceability and transparency of logistics and cold chain information among stakeholders (99). Similarly, a blockchain-based framework was designed for the traceability of agri-food chain products to ensure food safety (100). In the German logistics solutions sector, the use of smart containers equipped with cameras that autonomously monitor, determine, and transmit the load level via radio signals has been implemented (101). To improve collaboration, the CAR2SHARE project was created by the German Daimler business group, which seeks to become a transportation service provider (102). Such developments require a robust communication system in order to enable vehicles to communicate directly with each other, which is already being publicized by the marketing departments of commercial vehicle manufacturers (103). In recent years, initiatives have been carried out in public institutions, as is the case of the Colombian National Customs Department (DIAN), which unified multiple information systems between control agencies in order to reduce inspection times in ports (104). Table **III** shows examples of 4.0 technologies applied to different logistics processes and the advantages expected from their implementation.

One of the most applied technologies in logistics is blockchain, which promises to drive the development of SCs and society in the following years (70). This technology enables the cybersecurity of information, increases transparency and traceability in SCs, and allows integrating smart contracts between partners (72, 76). The second most important technology is Big Data analytics, which allows companies to identify patterns in their activities, mainly in mobility, as well as to make informed decisions (121). Finally, the IoT together with smart sensors could automate logistics activities in transport and warehousing (112).

7. Implementation barriers

The barriers and risks associated with the implementation and adoption of Logistics 4.0 can be classified into four groups: technical and technological, financial, legal and regulatory, and social (44). In the following subsections, every barrier will be explained in detail.

Technical and technological barriers:

The current lack of technologies in most SCs complicates the adoption of new machines into operations in the context of a 4.0 revolution (122). This has generated a low level of technification

Table III. Application of digital technologies in logistics

Author	Technology	Field	Results
(105)	IoT and Big data	Transport	• Analysis of real-time traffic status • Increasing the efficiency of logistics management
(106)	Data mining	Transport	• Optimizing the location and service area of dry ports in a large-scale transportation system
(107)	IoT and cloud computing	Transport	• Improving delivery planning and scheduling of perishable food (which requires different temperatures) in e-commerce
(108)	IoT, BLE (Bluetooth Low Energy), cloud service, and mobile applications	Indoor parking systems	• Enabling indoor parking vehicle tracking in a practicable, scalable, and cost-effective way • Reducing the vehicle searching time and regularizing parking behavior, logistics delay, and congestion in the parking floor
(109)	IoT	Reverse logistics	• Capturing real-time information of product returns • Maximizing the life cycle of products • Maximizing the flow of materials of the returned product at the plant location
(110)	Augmented reality (AR) and WSM	Warehousing	• Upgrading the work experience within the warehouse • Decreasing the learning curve for new employees • Enhancing the flexibility and smartness of logistics processes
(111)	Collaboration	Transport	• Increasing port efficiency and reducing energy-utilization costs • Increasing environmental efficiency throughout SCs • Helping terminal operators to extend their service
(112)	IoT	Urban logistics	• Reducing the use of fossil fuels, pollution, noise, traffic congestion, human errors, and accidents • Speeding up the handling of orders • Enhancing control and real-time knowledge of the delivery status of orders
(113)	Autonomous vehicles	Transport	• Enhancing capacity utilization via truck sharing • Reducing fuel costs • Increasing overall efficiency
(114)	RFID and Big Data	Maritime logistics	• Contributing to the sustainability of sea transport real-time monitoring to prevent pollution and protect the environment • Improving the transparency and security of international intermodal traffic • Reducing waiting times and costs, as well as optimizing process flow • Identifying the legal or illegal opening of containers
(115)	Blockchain	Supply chain	• Improving the milk quality, animal welfare, and milk safety • Decreasing food fraud, increasing rural development, ensuring coordination between stakeholders, and reducing waste and loss of food
(116)	Information Technologies (IT)	Urban logistics	• Improving mobility patterns • Influencing the structure and number of resources in mobility
(117)	Blockchain	Logistics	• Providing security to customers' personal information in logistics models • Increasing the traceability of logistics information
(118)	Blockchain (smart contracts)	Urban logistics	• Enabling data to evaluate customer satisfaction • Providing transparency • Ensuring the authenticity of information and improving decision making
(120)	IoT and smart sensors	Agri-food supply chain	• Reducing the gap between demand and supply • Improving quality and food safety • Improving sustainability in SCs

and innovation in SCs (33, 123), and a slow adoption of automation systems by stakeholders, which constitutes a disadvantage for companies in the market.

On the other hand, the implementation of Logistics 4.0 technologies such as blockchain requires enormous computing power and high-bandwidth internet connections (124), which are not available in all geographies and companies. In order to solve these problems, companies must create an agenda for the deployment of new technologies, which must include the following steps: identifying the technology that could benefit the SC, developing a digital technology roadmap for the SC, and updating information systems (125). Additionally, the wide availability of data and information sharing in networks increase the vulnerability of information systems to cybernetic attacks (44). This fact hinders the consolidation of trust and transparency in relationships between logistics partners and SC stakeholders (40).

Financial barriers:

The main barriers of Logistics 4.0 implementation are related to its high investment costs, which cannot be assumed by all companies (4,36,41). Some companies have difficulties to access funding and technological investments, and they do not have the required initial capital (122). Moreover, when companies have enough resources to buy new technologies, the long playback period is an aspect that limits the investment in the field. To reduce the financial risks of Logistics 4.0 implementation, it is a priority to perform a detailed analysis of the investment methods and select the one that best suits the company's economic situation (44).

Legal barriers:

The lack of standardization and the creation of public policies to regulate emerging technologies is a challenge that governments will have to overcome (73) by creating standards that enable interconnectivity between companies at national and international levels (67). Although there are still gaps in the field of regulations, some standards have been created to guide the adoption of some technologies.

Social barriers:

There are two main social barriers in the adoption of Logistics 4.0: job losses and the little qualified logistics personnel. Although Logistics 4.0 can put many mechanized jobs at risk, it offers the possibility to place the workforce in a position that requires greater cognitive skills and involves tasks that cannot be performed by machines. It is estimated that the implementation of Logistics 4.0 will expand the duties of logistics operators, with the inclusion of new multifunctional and more cognitive tasks for which people must possess analytical, entrepreneurial, and managerial skills (67), as well as assertive communication, knowledge of the use of information technologies and automation, and team management, among others (1). On the other hand, the implementation of the Industry 4.0 could help operators to execute their activities, reducing their workload, simplifying cognitive activities, and increasing the knowledge of systems (126).

In the implementation of digitalization and RPA in logistics, some companies have overestimated the gains of the technologies and did not invest in the necessary organization and human skills development (125). Nevertheless, there are three vectors of development in Logistics 4.0 which require human work: innovation, Information and Communication Technologies (ICTs), and the knowledge paradigm (32). In the innovation axis, human resources and organizational culture stand out as the drivers of logistics value creation in companies (43), as well as of the knowledge represented by employees that are highly trained and educated in the new 4.0 technologies (12). Nevertheless, there is a skills gap between young and older workers, which can only be reduced through continuous training and coaching. Therefore, the implementation of Logistics 4.0 requires the existence of educational processes in line with the new needs (12). These educational programs must ensure that humans can be creative decision-makers who can interact and collaborate continuously with cyber-physical systems in decision support (5,14). There must be a focus on the core competencies of employees in Logistics 4.0: ICT knowledge, critical and innovative thinking, and self-learning (6).

Moreover, the slow adoption of new automation systems, the low level of SC technification (33,123), the existence of legal gaps, the lack of congruence between development plans, insecurity problems, and the low percentage of technological innovation (41) may represent barriers to the implementation of Logistics 4.0 in many countries (127). Given the above, it is important to highlight that a fragmented implementation of the principles of Logistics 4.0 will not allow industries to create competitive advantages, but rather to increase the technical gaps in their sectors (128).

8. Challenges of Logistics 4.0

Logistics 4.0 promises to drive the creation of competitive advantages in global markets in the following years. This will eventually require the integrated collaboration between academia, governments, and companies. On one side, in the academic field, there is a huge gap in the research of Logistics 4.0 between developed and developing countries. Therefore, it is necessary to expand research towards the potential of Logistics 4.0 technologies in developing countries, as well as towards the barriers present in each context. To this effect, it is essential to apply maturity models in Logistics 4.0, thus allowing researchers to know the degree of the application of these types of technologies and their principles in the productive sectors of their countries.

Developing countries have greater barriers in the adoption of Logistics 4.0 due to the low technification of their SCs. For example, in the Colombian case, it was found that 69,3 % of the companies in the country know at least one technological tool related to logistics, but 64,4 % of the companies do not use any (129). For that reason, it is a priority to provide help and advice to small and medium-sized companies that often have difficulties in adopting new technologies and adjusting their processes (61). These programs should be promoted from public institutions.

On the other hand, Logistics 4.0 has been mainly implemented in the manufacturing sector, but it could be implemented in agro-industrial activities, providing great benefits to food supply chains (FSCs). With the implementation of technologies such as blockchain and smart sensors, it is possible to enhance traceability systems that allow for the tracking and control of food (20,130–132).

9. Conclusions

Logistics 4.0 is a field of research that arouses growing interest due to its implications at the economic and social levels. Mainly in its role as a consolidator of flexible, sustainable, and collaborative supply chains that improve response times, coverage, and the level of service of logistics systems. However, there is still no common framework to serve as a guide for its characterization and study, and some researchers and companies confuse its implementation with the use of digital technologies, leaving aside its other attributes.

Additionally, although it is evident that the implementation of 4.0 technologies in logistics systems can generate great benefits in the performance of supply chains, only some companies around the world have adopted these technologies in their operations. This could be due to the lack of common research frameworks in the field of Logistics 4.0, as well as to the lack of state proposals aimed at its use. This situation is even worse in developing countries, where companies face great barriers to access to technology and education, which affects the creation of competitive advantages for industries, supply chains, and countries. Therefore, the contribution of governments, academia, and industries becomes necessary in the implementation and adoption of Logistics 4.0.

10. Author contributions

All authors contributed equally to the research.

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