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Disruptive and Conventional Technologies for the Support of Logistics Processes: A Literature Review

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Abstract. The supply chain has become a key element of increasing the productivity and competitiveness of companies. To achieve this, it is essential to implement a strategy based on the use of technologies, which depends on knowledge of the scope and impact of logistics technologies. Therefore, this article aims to identify the main technologies supporting logistics management and supply chain processes to establish their functionality, scope, and impacts. For this, conventional technologies and technologies framed by the concept of Industry 4.0 that allow the implementation of Logistics 4.0 in companies are analyzed. As a result of searching databases such as Scopus, Web of Science, and Science Direct, we provide an analysis of 18 technologies focusing on their definition, scope, and the logistics processes involved. This study concludes that technologies in logistics management allow for a reduction in total costs, improve collaboration with suppliers and customers, increase the visibility and traceability of products and information, and support decision-making for all agents in the supply chain, including the final consumer.

Keywords: Industry 4.0; Logistics 4.0; Logistics; Supply chain management; Technologies

1. Introduction

Logistics management plays a vital role in supply chains, as it is responsible for the efficient and effective flow of goods, services, information, and finances within and between organizations to satisfy an end consumer. To achieve this, logistics management must support its business processes with technologies that efficiently record, store, process, and deliver information related to procurement, warehousing, production management, service management, transportation, distribution, customer service, final products disposal, and other operations covered by logistics management (Winkelhaus and Grosse, 2019). In this way, supply chains add value by processing information and providing timely support forstrategic, tactical, and operational decision-making (Tang and Veelenturf, 2019);

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achieving sustainability (Thöni and Tjoa, 2017); and providing better customer service through the visibility and traceability of orders and requests pertaining to the company performing these logistics operations (Barreto et al., 2017).

Likewise, technologies support the real-time decisions of logistics processes by transforming the data collected in the supply chain into effective and efficient supply chain decisions (Villalobos et al., 2019), in turn providing the technological infrastructure required by Industry 4.0 to support complex virtual and physical systems (da Silva et al., 2019). Other benefits of technologies in the logistics supply chain include decision-making support; the facilitation of information exchange and real-time management for supply chain execution (Perego et al., 2011); the provision of accurate and sufficient information at the right time in the right format to the right person (Wijewickrama et al., 2021); an increase in cross channel visibility and incentives; the analysis of tradeoffs; and complexity optimization, among others (Gunasekaran et al., 2017).

The rapid development of technologies increases the number and scope of the tools applicable to several logistics processes, while rising internet penetration in society and organizations generates a pressure to implement technologies to support logistics processes (Gunasekaran et al., 2017). Similarly, the development of the Internet of Things (IoT) and the massive volume of data generated, received, and stored in organizations demand the implementation of technologies supported by techniques such as Big Data analytics, cloud services, and artificial intelligence, among others, to obtain added value in business processes through predictive, prescriptive, and descriptive approaches (Tang and Veelenturf, 2019). This situation has caused an increase in the number of information and communication technologies (ICTs) that can be implemented in logistics processes, which impedes decision-making about which technology is more convenient to implement in these processes.

Several reviews related to technologies and logistics can be found in the literature. Some of them are focused on specific topics such as freight transportation (Perego et al., 2011); the contribution of information technology (IT) to competitive advantage within logistics and supply chains (Gunasekaran et al., 2017); technology development to support the real-time decisions of fresh food logistics (Villalobos et al., 2019); the potential, influence, and status of research on blockchain technology in logistics and supply chain management (Gurtu and Johny, 2019; Wang et al., 2019; Musigmann et al., 2020; Paliwal et al., 2020); technology transfer in the supply chain oriented to Industry 4.0 (da Silva et al., 2019); the relationships between information and digital technologies of Industry 4.0 and lean supply chain management (Núñez-Merino et al., 2020); information sharing in reverse logistics supply chains (Wijewickrama et al., 2021); trends toward new technologies in logistics (Lagorio et al., 2020); and IT adoption and its role in supply chain management (Sorooshian and Teck, 2020).

However, there is no study analyzing the main technologies (both conventional technologies and technologies framed by the concept of Industry 4.0) supporting logistics management and supply chain processes, and establishing these technologies' functionality, impacts, and scope for logistics systems. Consequently, this article focuses on the following main research questions:

RQ1. What are the main technologies supporting logistics management and supply chain processes?

RQ2. What are the logistics systems addressed by the main technologies considered in the literature?

This article aims to perform a literature review to identify conventional technologies and technologies 4.0 for different logistics processes, and understand their scope, functionality, and application in logistics systems. The remainder of this paper is organized as follows. Section 2 presents the methods employed to conduct this study. Section 3 provides an overview of the main technologies for logistics management. Section 4 presents the logistics systems addressed by the main technologies. Conclusions are presented in Section 5.

2. Methods

In order to identify the main technologies utilized in logistics processes and systems, a search process was conducted in high-impact databases such as Scopus, Web of Science, and Science Direct using the search expression (logistics) AND (technolog* OR ICT) in the title, abstract, and keywords search fields. The search for documents for the literature review was based on the period between 2011 and 2020 and initially obtained 558 documents. Documents that did not address technologies for logistics or supply chain management as the priority topic were then excluded. Based on the refined set of documents (62), this study identified the main technologies adopted for supply chain logistics systems and provided the definition, scope, and impacts of these technologies, and the logistics processes covered by them. A wide range of technologies with different functionalities and specialties in logistics processes were identified, as was their technological advancement and innovation to provide successful solutions for improving efficiency and effectiveness in logistics management.

3. Main Technologies for Logistics Management

This section provides the definition, scope, and impact of the main ICTs used in logistics systems that allow for an improvement in logistics planning and the integration of different information systems, ensuring value generation in logistics processes through the manufacture of products and services. These findings show that conventional technologies are still prevalent in practice and have been widely implemented and standardized in diverse industrial sectors (Gunasekaran et al., 2017; Lagorio et al., 2020). These technologies include Collaborative Planning, Forecasting, and Replenishment (CPFR), Electronic Data Interchange (EDI), E-Procurement, Enterprise Resource Planning (ERP), Global Positioning Systems (GPS) and General Packet Radio Services (GPRS), Pick-to-Light and Pick-by-Voice, Radio Frequency Identification (RFID), Sales and Operations Planning (S&OP), Transport Management Systems (TMS), and Warehouse Management System (WMS). Similarly, disruptive technologies such as additive manufacturing, augmented reality, Big Data analytics, blockchain technology, cloud services, drones, IoT, and wearable technologies have begun to integrate high connectivity and mobile technology capabilities, forming the so-called Industry 4.0, which represents a new approach and research trend of technologies for logistics (da Silva et al., 2019; Lagorio et al., 2020; Núñez-Merino et al., 2020).

Regarding the trends in technologies for logistics and supply chains in Industry 4.0, this set of technologies opens the way to the concept of Logistics 4.0 or Intelligent Logistics, which aims to fulfill customers' needs using better communication to integrate the requirements of suppliers and customers in logistics activities (Tang and Veelenturf, 2019; Hasan et al., 2020). This situation creates challenges in developing and implementing internet-based platforms for inbound and outbound logistics, on which stakeholders can access updated information on logistics processes at any time (Chuang et al., 2017; Villalobos et al., 2019). Likewise, the technologies mentioned in this section serve as a reference to update logistics education courses, enhance teacher performance, show a balance between conventional and disruptive technologies, and demonstrate the relationship between them (Cano and Ayala, 2019; Simbolon et al., 2020).

3.1. *Additive Manufacturing/3D Printing*

This is a technology used to perform the union of materials layer by layer to manufacture a wide range of structures and objects with complex geometries from data from three-dimensional models. The process consists of printing successive layers of materials formed one on top of another (Pour et al., 2016). The scope and impact include mass customization, manufacturing decentralization, the reduction of product development time, greater integration of customers in value creation, and the reduction of inventories and transport costs through the sale of computer aided design models and products printed by customers at home (Durach et al., 2017).

3.2. *Augmented Reality*

This technology involves the combination of the digital and physical world in real time through cameras in wearable devices, computers, and smartphones, among others, that provide virtual images, graphics, and information (Stoltz et al., 2017). In warehouse management, its potential uses include operations of reception, storage, picking, and dispatching, and the support of assembly operations, staff training, and product inspection (Frigo et al., 2016). It helps to reduce errors and increases flexibility, reliability, work speed, adaptability, and safety at work (Stoltz et al., 2017).

3.3. *Big Data Analytics*

This is a technological tool that applies advanced statistics to any kind of stored electronic information to identify behavior patterns in the data, which allows for future behaviors to be predicted (Kache and Seuring, 2017). It involves Big Data and business analytics, so it handles a significant volume and variety of high-speed data that exceed the traditional capabilities of data management approaches. Big Data analytics studies skills, technologies, and practices to continuously evaluate organizational strategies and operations and provide a guide for business planning (Wang et al., 2016). Its uses range from strategic management for product development to customer service, relying on statistical and operations analysis, predictive modeling, forecasting, and optimization techniques (Wang et al., 2016). It increases the visibility and transparency of the supply chain and enhances the availability of information to improve the efficiency of operations and maintenance. Likewise, it promotes integration and collaboration (Kache and Seuring, 2017).

3.4. *Blockchain Technology*

Blockchain technology manages transactions and information and can be described as a distributed ledger or database that stores a history of assets and transactions between supply chain participants in real time. It develops a simultaneously recorded version of transactions (Musigmann et al., 2020) and helps avoid conflicts that occur when multiple modifications are made simultaneously from different computers (Gurtu and Johny, 2019). Blockchain technology is a part of an ecosystem of emerging technologies and can process and complete transactions in minutes using computer algorithms, with no need for third-party verification (Wang et al., 2019). Therefore, it eliminates the need for many manual processes, physical verification of documents, and intermediaries/brokers by protecting data integrity, allowing for the instant sharing of necessary information, and enabling programmable and automated control of processes (Gurtu and Johny, 2019). The role of blockchain in the supply chain is to act as an inter-organizational system that tracks products from raw materials to finished goods (Paliwal et al., 2020), manages smart contracts and supply chain finance, and provides increased visibility and traceability of a supply chain (Gurtu and Johny, 2019).

3.5. Cloud Services

Cloud services, and especially cloud centers, provide a computer model to access the internet at any time and in any place, using computer facilities, storage devices, and shared applications, according to the requests and the convenience of their use. This can be achieved through infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS) (Lin and Yang, 2018). Cloud services offer services such as the storage, retrieval, consultation, and secure protection of logistics information. Additionally, they offer intelligent processing and analysis of logistics information to support logistics operations; facilitate the exchange of logistics software for the planning, design, and simulation of operations; and allow the establishment of IoT platforms for quality tracking and traceability, container and product tracking, and general monitoring of hazardous cargoes, among others (Xu et al., 2012).

3.6. Collaborative Planning, Forecasting, and Replenishment

This is a tool representing the integration of a company's logistics systems with those of suppliers and customers through collaborative approaches (Panahifar et al., 2015). It is considered as the evolution of Vendor Managed Inventory and Efficient Consumer Response systems (Demiray et al., 2017). It coordinates various supply chain processes, including production and supply planning, demand forecasting, and inventory replenishment. CPFR improves inventory accuracy and responsiveness; reinforces relationships with partners; reduces cycle times and overall costs of the supply chain; increases revenues and profits; and reduces the whip effect, among others (Panahifar et al., 2015; Demiray et al., 2017).

3.7. Drones

Drones or unmanned aerial vehicles have the ability to travel without being linked to road infrastructure (Gonzalez-R et al., 2020), enabling retailers to offer unprecedented delivery speed and adaptable delivery lead times using dedicated aerial vehicles for individual orders (Perera et al., 2020). Factors such as the expanding online retail industry, the improved capability, reliability, and cost effectiveness of drones, and high competition among pick-up and delivery service providers will increase drone usage for delivery applications in the next few years (Karak and Abdelghany, 2019). The cooperative use of drones with another vehicle acting as a moving base is the most versatile solution, allowing the drones to operate over an enlarged action radius, at the cost of complicating the determination of landing locations (Gonzalez-R et al., 2020). Through decentralization, retailers can increase their high-speed and dedicated delivery capabilities to lower delivery times (Perera et al., 2020). Some of the technical challenges faced by drone delivery systems are related to the limited life of the electrical batteries powering each drone (Gonzalez-R et al., 2020) The most critical barriers to implementing drones in the logistics sector are technological advancements, government regulations, threats to privacy and security, public perceptions, and psychological and environmental issues (Raj and Sah, 2019; Sah et al., 2020).

3.8. Electronic Data Interchange

This represents the transfer of business data from the information system of a company to that of its supplier. It standardizes data structures used by different computer systems and languages to perform transactions with the minimum error, at the highest speed, and with the lowest cost, and does so transparently among the members of a supply chain (Rashid, 2013). With the support of GPS sensors, it facilitates knowledge of due dates and delivery times of products in advance, offering tolerable errors of estimation. It allows positive relationships to be built with partners for the adoption of technologies in logistics processes (Gunasekaran et al., 2017). It also facilitates the application of the Advanced Shipping Notice, which transmits detailed dispatch information to the customer in advance.

3.9. E-Procurement

This represents the integration and electronic application of each stage of the process of supplying goods and services in an organization, including operations such as orders, reception, post-purchase reviews, tenders, auctions, and negotiations (Toktaş-Palut et al., 2014). It presents five ramifications: e-ordering, e-sourcing, e-tendering, e-reverse auctioning, and e-informing (Tiwari et al., 2019). It allows for better management and control of suppliers, cost and total purchase time savings, power decentralization, and easy access to market data. It also improves decision-making, customer service levels, communication, and collaboration in the supply chain; simplifies and standardizes the purchase process; enhances compliance with regulations and laws; minimizes process errors; and reduces corruption among employees (Toktaş-Palut et al., 2014; Tiwari et al., 2019).

3.10. Enterprise Resource Planning

This information system links all functional areas and internal processes with external processes in a company, developing a close relationship between customers and suppliers. It allows for information sharing, improving the flow of information between supply chain partners (Ouali and Kocaoglu, 2016). Through modules, it allows access to and storage of data in real time within an organization, and also enables analysis and management functionalities (Özcan and Çimtay, 2016). It covers all resource planning for a company, including product design, information storage, material planning, capacity planning, communications systems, finance, human resources, and inventory management, among others (Ouali and Kocaoglu, 2016; Özcan and Çimtay, 2016).

3.11. Global Positioning Systems and General Packet Radio Services

GPS is a positioning technology that can work in any weather. It offers high precision and fast response to provide the location of a vehicle or load in the supply chain. GPRS is a communication technology based on GSM networks that offers advantages such as a higher speed of transmission and the switching of data packets (Sun, 2012). A combination of GPS and GPRS is usually applied to alarm systems and cargo vehicle position monitoring (Sun, 2012). In conjunction with technologies such as RFID, they allow the creation of intelligent and dynamic logistics systems for product collection and transportation, since RFID is used to record product information. These technologies are the main enablers of IoT (Thürer et al., 2016) and allow real-time tracking of the location of each transport unit (Naumova et al., 2020).

3.12. Pick-to-Light and Pick-by-Voice

Pick-to-Light is an order picking technology that supports picking operators (pickers) with light signals. Pick-by-Voice is a technology that uses audio and voice to control and guide the picking process (de Vries et al., 2015). These technological tools have wide implementation and worldwide acceptance because they facilitate the operation of picking operators, and increase the productivity and quality of order picking. They can be adapted to independent picking systems and different picking system zones (de Vries et al., 2015).

3.13. Radio Frequency Identification

RFID is responsible for transmitting information through radio waves, tags and readers so that the information collected is passed to the RFID middleware for processing and use in commercial applications (Lim et al., 2013). RFID helps to collect, manage, and analyze data within the production, warehousing, and transport processes of the supply chain. Additionally, it enables data management processes such as Big Data analytics through the collection of massive amounts of information from logistics operations (Zhong et al., 2015). RFID technologies improve the visibility and traceability of information in real time, identify the inventory level in different distribution areas of the supply chain, and track product movements (Lee et al., 2011). In addition, RFID converts production and logistics resources into intelligent objects capable of capturing information and interacting and reasoning to produce a ubiquitous environment (Zhong et al., 2015).

3.14. Sales and Operations Planning

This is a decision-making support tool that unifies different business plans into a set of integrated plans to balance supply and demand, and generate links between strategic plans and operational plans of each company and the whole supply chain (Pedroso et al., 2016). It provides the ability to strategically manage a business to achieve a continuous competitive advantage, integrating customer-focused marketing plans (Noroozi and Wikner, 2017). S&OP consolidates sales, marketing, product development, procurement, and finance plans in a unique set of organized tactics dispersed across a company's functional activities monthly or more frequently. This reduces the changes generated by the business environment, providing a more resilient supply chain (Pedroso et al., 2016).

3.15. Internet of Things

This technology connects ordinary objects and products to the internet, which allows them to transmit and receive data (Chuang et al., 2017). It is based on an infrastructure with self-configuration capabilities using standard and interoperable communication protocols where physical and virtual things have identities and physical attributes, and are integrated into an information network through intelligent interfaces. In logistics, IoT technologies connect different assets throughout the supply chain. The data generated from these connections enable real-time visibility of operations and generate new sources of value. IoT solutions for logistics integrate sensors with RFID and GPS to provide complete monitoring of products in real time, ensuring that they arrive in the condition required by the customer (Chuang et al., 2017).

3.16. Transport Management System

This is a system used by transport companies to assist in the planning, execution, monitoring, and control of tasks related to cargo consolidation, shipping, document management, delivery and collection of products, route planning, cargo audits, and order visibility, among others (Nunes et al., 2019). The TMS determines the service points, the routes for each vehicle, the total capacity of vehicles and drivers, the distances to travel, and the total delivery time (Nunes et al., 2019). It supports the negotiation and audit of freight, the choice of transport mode, multimodal transport, the estimation of the time and the sequence of stops, document preparation, and cargo consolidation planning, and minimizes economic and ecological costs (da Silva, 2018).

3.17. Warehouse Management System

This is a system that supports process planning, execution, and control in warehouses and distribution centers, including reception, slotting, storage, order picking, and dispatch processes (Correa et al., 2010). It can be integrated with cyber–physical systems to support cooperation between humans, intelligent machines, and robots based on the use of standard technologies such as RFID, wireless sensor and actuator networks, IoT, and cloud computing (Lee et al., 2018). The WMS facilitates the creation of information infrastructures that companies use in procurement, production, warehousing, and distribution activities (Baruffaldi et al., 2019). Commercial WMS includes a broad variety of solutions for operations planning and traceability in the warehouse, and to assign personnel and material handling equipment to various tasks (Correa et al., 2010).

3.18. Wearable Technologies

These encompass clothing and accessories that incorporate computers and advanced electronic technologies. Wearable technology devices refer to electronic technologies or computing devices designed to be comfortably used on the body (Büyüközkan et al., 2016). They establish a man–cyber–physical symbiosis to support dynamic, reliable, and real-time interaction between operators, machines, and production systems (Kong et al., 2018). These technologies enable real-world interaction with the virtual world (Stoltz et al., 2017) based on sensor gloves, RFID readers, smartwatches, glasses, rings, handles, headsets, belts, pens, and shoes, among others. These objects are characterized by being light and simple, and guarantee hands-free operation that does not interfere with the work of the operator (Kong et al., 2018).

4. Logistics Systems Addressed by the Main Technologies

ICT for logistics management can be applied to one or several logistics systems, with such systems understood as logistics planning, incoming logistics (procurement and purchasing), internal logistics (production and service management), warehouse logistics, outbound logistics (transportation and distribution), and reverse logistics (El Ouadaa et al., 2017; Gunasekaran et al., 2017; Lagorio et al., 2020). From Table 1, it can be inferred that in warehouse and distribution logistics systems the greatest number of technologies converge since these systems are responsible for processing a large number of transactions, orders, and deliveries within a company and supply chain.

Table 1 Technologies for logistics systems

Technology	Logistics Planning	Inbound Logistics	Internal Logistics	Warehouse Logistics	Outbound Logistics	Reverse Logistics
Additive Manufacturing	✓		✓			
Augmented Reality				✓		
Big Data Analytics	✓	✓	✓	✓	✓	✓
Blockchain Technology	✓	✓	✓	✓	✓	✓
Cloud Services	✓	✓	✓	✓	✓	✓
CPFR	✓	✓	✓	✓	✓	✓
Drones					✓	✓
EDI		✓	✓	✓	✓	
E-Procurement		✓				
ERP	✓	✓	✓	✓	✓	✓
GPS and GPRS					✓	✓
Pick-to-Light and Pick-by-Voice				✓		
RFID		✓	✓	✓	✓	✓
S&OP	✓					
IoT		✓	✓	✓	✓	
TMS					✓	✓
WMS				✓	✓	
Wearable Technologies				✓	✓	

Likewise, the scope of technologies in logistics is diverse, since some ICTs are applied to specific logistics systems (as in the case with additive manufacturing, augmented reality, drones, e-procurement, GPS and GPRS, pick-to-light and pick-by-voice, TMS, WMS, and wearable technologies), while others allow a transversal scope within and between the logistics operations of the supply chain. Consequently, technologies such as Big Data analytics, cloud services, CPFR, and ERP support both logistics planning processes and operational processes; automatic identification and information collection systems such as RFID are used in each logistics process to feed sensor networks and traceability systems offering visibility of the product flow throughout the supply chain; and IoT integrated with RFID and blockchain facilitates the generation and transmission of information to link all logistics activities and operations within and between companies to develop a close relationship between customers and suppliers, improving visibility to afford real-time product traceability, authenticity, and legitimacy (Kshetri, 2018; Wang et al., 2019).

Therefore, logistics technologies tend to increasingly connect supply chain processes to offer a rapid and assertive response to the requirements of customers and suppliers; provide visibility and information in real time; expedite decision-making; and create value among the stakeholders of the supply chain. Given this situation and the emergence of new ICTs for logistics management, some challenges in implementing these technologies must be faced. This process could be supported by several methods for the selection and validation of ICT (Cano et al., 2020). These challenges must respond to different aspects to generate competitiveness in modern logistics management and are related to the characteristics of the company and the importance of improving its operation; the type of supply chain (manufacturing or services); the goals and objectives of the company; the type of business; the nature of the market; and the technological competencies of the company (Cano and Baena, 2015a; Cano and Baena, 2015b; Cano and Baena, 2017).

5. Conclusions

Globalization, business competition, and the development of business technologies have induced industries to manufacture products at low cost, with better quality and availability for the market. This requires rapid technological adoption to make an important differentiation between productive organizations regarding logistics efficiency. This implies that companies must make significant investments in acquiring, updating, and maintaining technological infrastructure, considering the adoption of traditional technologies such as CPFR, EDI, E-Procurement, ERP, GPS and GPRS, Pick-to-Light and Pick-by-Voice, RFID, S&OP, TMS, and WMS with disruptive technologies of Logistics 4.0 including additive manufacturing, augmented reality, Big Data analytics, cloud services, wearable technology, and IoT. This situation generates challenges in complementing and updating technologies that have been appropriated in logistics processes to enable a transition toward Logistics 4.0 to increase efficiency and fulfil the requirements of customers and consumers. This approach allows logistics systems to respond quickly to costumers, increase the traceability and visibility of orders in real time, and facilitate collaborative decision-making with other agents in the supply chain.

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