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Impact, benefits and challenges of IoT for logistics and supply chain management

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Abstract

Smooth flow, integrity, and traceability of the processes in supply chain (SC) and logistics management is vital for Supply Chain Management (SCM). Companies are looking for and utilizing new technological applications for end-to-end management of the entire set of SC processes and assets to ensure on-line and real-time monitoring across processes and partners. Therefore, this article comprehensively addresses the role and impact of the Internet of Things (IoT) on SCM via a comprehensive literature review. The applications of the IoT term in the SC are examined in detail, and its benefits and challenges are discussed from SCM perspective. The findings reveal the dramatic impact that IoT has on SC processes as one of the most essential technologies of the twenty-first century.

1. Introduction

Due to the emergence of global markets, a sharp competition environment has been created. Since businesses are not self-sufficient, global, and competitive environment steers the workflow through the SC (Abdel-Basset, Manogaran, and Mohamed, 2018). SC function in a dynamic and turbulent environment and are exposed to a variety of risks at every level (Ben-Daya, Hassini, and Bahroun, 2019). Thus, SC processes should be planned, executed, and controlled in seamless coordination and integration. Delivering the right product to the right consumer in the appropriate volume, at the right location, and at the right time is what SCM entails (Wu et al., 2016) under complex and dynamic environments, with customer demands changing rapidly, rapid changes occurring in technology and new products being introduced to the market at significant speeds.

In this context, providers of logistics that can transport products by air, land, sea, and rail form wide and complex networks, and it is vitally important to reach information quickly in order to make the right decision across wide logistics network. (Lacey et al., 2015). The fact that the process gets stucked at one point will affect the entire value creation chain and competitiveness. Therefore, material flows and logistics processes both within the enterprise and across partners are to be optimally managed (Gunasekaran and Ngai, 2004; Erkan,2014). This can be achieved by making the SC smart.

Smart SC can be defined as a modern, networked system that extends from standalone, regional, and sole proprietorship applications to the broad and systematic application of SC (Abdel-Basset et al., 2018). In this

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context, information technology (IT) assumes a vital role in the supply chain's effective management (Ross, 2002). IT has the power to improve SC performance by integrating various processes and partners both internally and outside, as well as through increasing communication, data and information collecting and transfer (Williamson, Harrison and Jordan, 2004Consequently, one of the most important and new developments in information technology is the IoT.

Kevin Ashton invented the term "Internet of Things" in 1999 (Keary, 2016) to describe a "network of physical things embedded with sensors, software, and other technologies that can connect and exchange data with other devices and systems over the Internet". These devices include everything from standard household goods to complex industrial machines (Boyes et al., 2018). Within IoT context, SC visibility can be characterized as a group of physical items digitally connected for sensing, tracking, and interaction among information exchange (Da Xu, He and Li, 2014). This facilitates the planning, control, coordination, and traceability of SC processes across partners, with the integration of many technologies such as radio frequency identification (RFID), sensors, quick response (QR) codes, cloud, robotics, 3D printers and various ERP/SRM (enterprise resource planning/ supplier relationship management) and customer relationship management (CRM) solutions allowing for analysis and decision support.

With this understanding, this article focuses on impact, benefits, and challenges of IoT from logistics and SCM perspective.

The following is the section structure for the rest of the article: Section 2 describes the research methodology. Section 3 examines the impact and benefits of IoT from a logistics and SC perspective. Section 4 introduces main IoT applications. Section 5 includes main challenges of the IoT. Section 6 reviews the future of the IoT in the SC. Section 7 includes the discussion. Section 8 provides conclusion and further research suggestions.

2. Methodology

The focus of this article is to provide a systematic review on the impact of IoT technology on SC and logistics management. Hence, the systematic literature survey conducted in this study attempts to answer the following research questions: a) What are the impacts and benefits of IoT from logistics and SC perspective? b) What are the main IoT applications used in logistics and SC domain? c) What are the challenges of utilizing IoT technology in managing the SC processes? d) How are the IoT applications in logistics and SC expected to happen in the future?

The systematically reviews and analyzes the literature from academic articles, conference proceedings, book chapters and company reports, seeking to provide a complete and reliable overview (Abdel-Basset et al., 2018). Thus, criterion for obtaining and including the journal papers and conference papers in the review is that they have a strong affinity with the IoT, logistics and SC processes.

In this context, the reference list includes resources addressing the following dependencies among these concepts, and revealing the nature of IoT-SC coupling:

- The relationship of the SC with the IoT
- Benefits of IoT on SC processes
- Holistic challenges of IoT in this area
- IoT applications in SC and logistics management
- The impact of future IoT applications on the SC

The articles used in this study are searched from ScienceDirect, IEEE Xplore and Google Scholar using the following search terms:

- "IoT impact on SC and logistics management"
- "IoT"
- "IoT in the SC"
- "IoT applications in SC and logistics'', and
- "IoT in the future"

The article collection and analysis process took place between March and December 2021. The following table offers the distribution of resources with respect to type:

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Table 1. Distribution of resources with respect to type

Articles	72
Book chapters	4
Conference papers	20
Web links	17
Thesis	1
White paper	1
Report	2
Total	117

3. IoT impact and benefits from logistics and SC perspective

There are various discussions in the literature about the role of IoT in the SC. According to Morgan, the IoT is a technological concept connecting various devices with the ability to use software and automated processes for smart practices, turning the web on and off (Morgan, 2014). This means that integration of abundance of devices and objects within IoT and SC context opens unprecedented businesses opportunities (Abdel-Basset et al., 2020). The literature review by Ben-Daya, Hassini, and Bahroun (2019) shows that IoT in the context of SCM is conceptualized only with minimal experimental or exploratory studies.

The concept of IoT can be considered into three basic parts: internet-oriented (middleware), object-oriented (devices, sensors) and semantically oriented (information) (Atzori, Iera, and Morabito, 2010). IoT has grown in popularity since the introduction of wireless technology (Anirudh, Pandey, Sodhi, and Bagga, 2017), and IoT and associated technologies are strongly linked with the service-oriented architecture SOA (Yuqiang, Jianlan, and Xuanzi, 2010).

It is generally supported in literature that adopting IoT solutions can provide more transparency in business processes and greater visibility in information and material flows (Ahmed et al., 2021,; Haddud et al., 2017; Lacey et al., 2015). In this way, various studies, both in the services and industrial industries, support the theoretical benefits by highlighting better accuracy, real-time information availability, and more effective operational operations performed along the forward and backward flow of physical products. (Haddud et al., 2017). IoT is also supported to increase the worker safety. Thanks to IoT sensor-based applications, employees are informed of accidents and find solutions as quickly as possible. In addition, wearable devices that can monitor human health and environmental conditions also become part of today's logistic systems (Haghi, Thurow, and Stoll, 2017).

The IoT impact and benefits from the logistics and SC perspective are expounded in detail in the Table 2 below.

Table 2. IoT impact and benefits

Fields	Impact & Benefits	Related Supporting Technologies	Source
Transportation and Logistics	Transportation visibility between across partners the whole chain. (full logistics traceability)	RFID, sensor-based technology, near field communication (NFC).	Ellis, Santagate, and Morris, 2015; Govinda and Saravanaguru, 2016; Al-Dweik et al., 2017
	Ability to monitor the vehicle's location and condition, tracking package conditions.	Smart vehicle monitoring system (SVMS), telematics sensors, multi-sensor tags, 4G, GSM/GPRS module.	Macaulay, Buckalew, and Chung, 2015; Mallidi and Vineela, 2018; Wang et al., 2016; Manoj Kumar and Dash, 2017.
	Reduced RFID scanning and recording times by more than 300 percent.	RFID tags, sensors, smartphones.	Tadejko, 2015; Yan et al., 2014.

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	Quality assurance, real-time responsiveness, and cost optimization.	RFID, time-temperature integrators (TTIs), wireless sensors, smart packaging.	Giannakourou and Taoukis, 2003; Shih and Wang , 2016; Bogataj, Bogataj, and Hudoklin , 2017.
	Fleet management and route optimization by reducing the transportation distances and fuel consumption.	Vehicle tracking systems, GPS (Global Positioning System), RFID, mobile scanners, GIS (Geographical Information Systems), CTF (Control Total Fleet).	Manoj Kumar and Dash, 2017; Tadejko, 2015; Vivaldini, Pires, and Souza, 2012; Almomani et al., 2011.
	End-to-end SC risk management.	Sensor networks, cloud centralized database.	Macaulay, Buckalew and Chung, 2015; Tsang et al., 2018.
	Keeping track of temperature in food, beverage, flower, and pharmaceutical industries throughout the entire logistics cycle.	TTIs, temperature data loggers, RFID.	Popa, et al., 2019; Mijanur Rahman et al., 2018; Hasanat et al.
Warehousing	More than 1000% savings in transaction times via high speed, technology-oriented applications.	QR-code scanner, RFID tags, wireless connection, mobile and desktop application, temperature sensors, cloud service.	Mostafa, Hamdy, and Alawady, 2019; Macaulay, Buckalew, and Chung, 2015; Wu et al., 2020.
	Collaborative warehousing	Smart things, multi-agent systems, RFID.	Reaidy, Gunasekaran, and Spalanzani, 2015; Mostafa, Hamdy, and Alawady, 2019.
	Prevention of possible accidents by determining risks in advance.	Sensor node, RFID tag, RFID reader, automated guided vehicle (AGV).	Dutt, 2019; Trab, et al., 2018.
	Monitoring inventory data, equipment, and vehicles with digital voice.	Mobile devices, RFID tagged, voice picking systems.	Tadejko, 2015; Wong, 2016.
	More efficient transfer and loading processes of the packaged products.	Autonomous systems, RFID, cloud computing, artificial intelligence (AI).	Mostafa, Hamdy, and Alawady, 2019; Song et al., 2020.
Inventory Management	Reducing inventory levels throughout the SC.	QR Code, RFID.	Jayaram, 2017; Haddud et al., 2017.
	Better inventory management, control, and real time visibility	RFID, blockchain, cloud, wireless connectivity, big data.	Dasaklis and Casino , 2019; Jayaram, 2017; Fernández-Caramés et al., 2019.
	Enabling VMI through real time visibility	Smart things, cloud, big data.	Jayaram, 2017; Fernández-Caramés et al., 2019.

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Production	Enabling visibility and transparency of different production stages and workflows based on real-time shop-floor information.	RFID readers, sensors, cyber-physical systems, cloud.	Zhong, Xu and Wang, 2017; Ahmed et al., 2021; Tu, Lim and Yang, 2018.
Maintenance	Allowing continuous monitoring of equipment, remote monitoring, machine condition monitoring and anomaly detection in real time for predictive failure analysis.	Sensors, cloud-based, big data.	Rio and Banker, 2014; Tedeschi et al., 2016.
	Enabling improved equipment uptime and accurate failure prediction for predictive maintenance.	Big data, monitoring chips, sensors, machine learning algorithms.	Song et al., 2020; Grizhnevich, 2018; Lee, Lee and Kim, 2019.
Purchasing/ procurement	Enabling real time and fast feedback in purchasing.	Industry 4.0, business intelligence (BI).	Gottge, Menzel, and Forslund, 2020; Osmonbekov and Johnston, 2018.
	Improving purchasing performance, developing an effective energy consumption system, and diversifying resource allocation.	Industry 4.0, BI.	Gottge, Menzel, and Forslund, 2020; Zhou et al., 2019.
SRM	Real-time data exchange and visibility with the suppliers. Suppliers can choose which monitoring services can access their equipment and ensure that they are working on their own system. SRs become more attentive to client expectations as a result of the real-time data offered by IoT.	Cloud server, sensors, RFID, big data.	Chen, et al., 2018; Lee, 2019.
Distribution Channels	Providing an ideal platform for decentralized administration of warehouses in distribution areas.	Big data, cloud computing, active distribution network (ADN).	Li, Shahidehpour, and Liu, 2018; Reaidy, Gunasekaran, and Spalanzani, 2015.
	Providing intelligent management in the SC process by integrating technical equipment such as intelligent distribution centers, intelligent transportation, automatic separation equipment and information processing systems.	Distributed energy resources (DERs), near-field communications, wireless sensor networks, RFID, big data.	Li, Shahidehpour, and Liu , 2018; Want, 2006; Tsang, et al., 2018.

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	Providing a higher level of security, efficiency, and convenience for distribution channels in SC processes.	Active distribution network (ADN), DERs, near-field communications, wireless sensor networks, RFID, cloud services.	Li, Shahidehpour, and Liu, 2018; Want, 2006; Liu, Zhang, and Wang, 2018.
After-sales service	Maximizing profit while providing efficient control of information flow in the after-sales process.	RFID, fog Computing, cloud.	Hu, et al., 2018; Curtin, Kauffman, and Riggins, 2007.
	Supporting business goals, system architecture design and evaluation.	RFID, thing-to-cloud communication (TCC), wireless sensor networks (WSN).	Hu, et al., 2018; Curtin, Kauffman, and Riggins, 2007.
	Ensuring customer loyalty and profitability by making decisions based on real-time data.	WSN, big data.	Yerpude and Singhal , 2017; Hu, et al., 2018; Nedelcu, 2013.
CRM	Ability to create meaningful reports by using huge amounts of IoT data, such as consumer information and contextual inputs and historical corporate data.	Big data, sensors, cloud-based software.	Rizvi , 2017; Yerpude and Singhal, 2017.
	Enabling improved reports for customer behavior, place and demands by using real-time data from the IoT.	Big data, sensors, cloud-based software.	Rizvi, 2017; Yerpude & Singhal, 2017.

The above table shows that IoT provides benefits to enterprises by affecting the operations of almost every transportation, logistics and SC-related processes (Grawe, 2009). It became evident that, core material management related processes, as well as supplier-centric and customer centric processes. Factors such as inventory accuracy, real-time information, increased efficiency, and productivity, and reduced human intervention are very effective in many different processes in logistics and SC operations (Vass, Shee, and Miah, 2020). Undoubtedly, these concepts are critical for SC operations consisting of consecutive and interconnected links. Hence, it is evident that almost all of the SC processes are affected by the IoT.

4. Main IoT application areas

Companies use many technologies within the context of IoT connectivity in every part of their chain. IoT applications cover many issues such as synchronous shipment tracking, route optimization, warehouse capacity optimization, predictive asset maintenance, and many more (Tadejko, 2015). Within IoT philosophy, companies can achieve unprecedented levels of visibility in almost every aspect of their applications, thanks to connected devices, embedded sensors, and analytical technologies (Koomey, Matthews, and Williams, 2013). With real-time visibility, logistics providers can engage in more informed decision-making processes, and they can interact with customers better. Hence, a variety of IoT applications are witnessed in areas such as the pharmaceutical SC (Datta, 2016; Siddiqui et al., 2021), retail industry (Shin and Eksioglu, 2015), construction industry (Woodhead, Stephenson, and Morrey, 2018) and petrochemical industry (Li, 2016). In the following subsections, IoT applications used in logistics and SC processes are discussed under three most widely used areas of practice: a) transportation and fleet management, b) warehouse management, and c) equipment and employee monitoring.

4.1 Transportation and fleet management

Transportation and fleet management have multiple critical applications for both inbound and outbound material flow. Vehicles are among the most critical assets requiring higher efficiency for transportation and fleet management, and directly affect the inbound and outbound performance of the SC. Hence, on-line and in real time

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vehicle visibility, as well as vehicle-infrastructure integration, have been vital applications for the use of sensor-based data (Macaulay, Buckalew, and Chung , 2015). While fleet vehicles are the power behind mobility in commercial and public areas, fleet managers have an important role in organization and supervision in terms of performance, maintenance, and monitoring purposes. IoT makes a great contribution to fleet management with its ability to connect vehicles and retrieve various data on vehicle performance, route, passengers, and cargo (Alrifaie et al., 2018).

Seoul City Transportation Information Center (TOPIS) and smart port initiatives at Hamburg are two remarkable examples on the IoT in logistics, according to the report prepared in cooperation with DHL and Cisco (Macaulay, Buckalew, and Chung, 2015). Seoul City Transport Information Center (TOPIS) was created in 2004, which evolved from the bus management system. This transport information center is in charge of collecting and maintaining information for all modes of public transportation in order to provide efficient public transportation services. TOPIS uses road sensors, GPS devices, loop detectors, video, and citizen reports to collect data from streets, buses, taxis, and residents. In this way, passengers can access bus arrival times 7/24, allowing them to choose their route and which buses to take. This system has increased public transportation efficiency and improved flow while also increasing customer satisfaction (Paterlini et al., 2015). Fleet management is also very important in ports as well as bus management systems. In this context, fleet management initiatives are carried out in Hamburg, Europe's second busiest port. With the developed smart port initiative, efficiency was increased, and the port was prepared for additional development. The initiative's overarching purpose is to keep the Hamburg Port Authority's IT infrastructure up to date, modernize it, and improve it in order to promote efficient operations and economic development. The Hamburg Port Authority provides parking and traffic information to drivers by installing more than 300 road sensors to monitor port traffic and bridge wear. Furthermore, sensors provide a solution integrating road traffic data into waterways to help manage potential disruptions (Macaulay, Buckalew, and Chung, 2015).

In the similar direction, Microsoft argues that Azure IoT, which uses its developed services such as Azure IoT Edge, Azure IoT Hub, Azure Machine Learning and Azure Map, will make a great contribution to fleet operations. IoT enables management, analysis and predictive maintenance of daily operations using real-time appliance and location information provided with Azure Map. Fleet managers can monitor dozens of vehicles located in different parts of Europe to see if there is a problem in the fleet with warnings. In addition, the fleet manager can learn information such as the route of the vehicle, the name of the driver, the departure and arrival point, the first projected arrival time, the delayed arrival time, and the sort of load the route is designed for. In this way, it can see the problem in any mishap and intervene in the process (Sergi et al., 2021).

4.2 Warehouse management

Warehouses are always critical in the flow of goods in the SC. Today's logistics providers strive to provide their customers with quick, cost-effective, and flexible warehousing operations, which is a source of competitive advantage. Since a multitude of different kinds and forms of goods need to be received, processed, and delivered quickly, appropriate technologies must be used. Thus, warehouses are one of the most critical areas to launch IoT applications and take advantage of technology's opportunities (Macaulay, Buckalew, and Chung, 2015).

Businesses can give a digital voice to their physical assets via IoT-enabled tools designed to monitor inventory data, equipment, and vehicles in warehouse management (Tadejko, 2015). Unique identification of the data source gives the system the power to interact at the sensor level and further create its own interaction history. Currently, sensors have undergone significant improvements to enable business logic to be configured and executed in the same way (Sundmaeker et al., 2010). Therefore, sensor technology is the one which stands out among many technologies with their real-time data capture capability, enabling real-time data collecting from sensors with unique identifiers to detect the point of the data source (Yerpude and Singhal, 2017). There is an interaction between the sensors placed in appropriate places in the warehouse and the digital identifiers that form the basis and reveal inventory movement tracking. Within the IoT context, RFID has also a vital place along with sensors in warehouse management. Owing to smart racks and RFID tags that can track parts, IoT can generate real-time data consumed by various applications and analytical business models (Sundmaeker et al., 2010). In addition, the use of low-cost, small identification appliances such as RFID in warehouses and the adoption of tagging at the pallet or product level supports IoT-driven smart inventory management (Macaulay, Buckalew, and Chung, 2015).

IoT-enabled warehouses have a wide range of effects on SC operational efficiency. It is a great advantage that product location and packaging integrity can be followed, and equipment malfunctions can be detected and signaled early. In this context, Oracle, which provides services in the field of business analysis and software, demonstrates the benefits of IoT application in warehouses such as supply transparency, predictive maintenance,

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and real-time product tracking (Ray, 2016) In addition to this, applications of smart glasses, and autonomous mobile robots (AMR) significantly affect warehouse automation, efficiency, and accuracy (Dutt, 2019). Smart glasses allow warehouse directors to see visual depictions of order picking instructions and product location information. This brings improved collection accuracy and performance. Autonomous mobile robots, on the other hand, can operate on their own and use sensors and cameras to navigate. Autonomous robots include an integrated browser where they validate the selected item, reducing the workload of warehouse workers (Murauer, 2019; Rauschnabel, Brem, and Ro, 2015).

Keeping thousands of items that can help you stay connected is possible, thanks to the availability of wireless networks and compact computer chips. This is highly important for global companies such as Amazon, DHL, and Alibaba to take their inventory management to the next level. Therefore, these global companies use IoT technology. For example, Amazon, an important global technology organization focusing on e-commerce, cloud computing, and artificial intelligence, employs a warehouse where robots function with store managers and simple jobs like barcode scanning and package delivery are delegated to IoT devices. In this way, warehouse managers can easily track inventory and increase their productivity, making SC processes smoother and more efficient (Dutt, 2019).

4.3 Equipment and employee monitoring

Another main class of IoT applications in logistics is equipment and employee monitoring, which has great benefits such as real time monitoring and increased safety and security (Macaulay, Buckalew, and Chung, 2015). Ben-Daya, Hassini and Bahroun (2019) argue that tracking can detect product losses, correct quantities can be guaranteed, and monitoring product status will ensure the right quality. Real time equipment monitoring allows for continuous machine condition monitoring and anomaly detection for predictive failure analysis (Rio and Banker, 2014; Tedeschi et al., 2016; Lee, Lee and Kim, 2019.) Zhang and Sun (2013) highlight that real-time data monitoring and optimization will have benefits such as reducing waste of production resources, reducing logistics costs, and increasing risk and transportation efficient. In this way, it will be easier to respond to unforeseen events, act at the right time and provide the necessary visibility that ensures the optimization of the entire process.

The predictive software used by Union Pacific, the largest railway in the United States, to reduce train crashes can be given as a specific example. Union Pacific argues that with this software program, it can predict the probability of derailments to occur days in advance, and thus, millions of dollars of damage can be prevented by increasing security (Murphy, 2012). This software enables the analysis of data from acoustic and visual sensors located under each of the wagons (Hickins, 2012). Similarly, possible threats of irregularities in the bearings or tracks being detected can be notified to train operators within five minutes (Macaulay, Buckalew, and Chung, 2015).

IoT devices also allow their managers to monitor personnel's physical safety using wearable devices and vital sensors. For instance, managers will be able to protect employees from exposure to toxic substances or to easily evaluate the performance of the employee and follow their break times (Awolusi et al., 2019). As a result of the cooperation of companies, new applications are created, contributing greatly to supply and logistics processes. Narrowband Internet of Things (NB-IoT) application by DHL SC and Huawei Technologies can be given as an example with successful outcomes. DHL and Huawei have integrated NB-IoT chipsets into their systems, allowing for a simple and cost-effective deployment that utilizes popular cellular telecommunications bands. In addition, these chipsets include vehicle detectors that do not necessitate infrastructure expenditure. Thanks to this, net dock availability can be automatically collected in real time at each terminal, giving dispatchers and drivers visibility. When a truck arrives, the driver can use an application on his phone to check in and receive a queue number as well as an expected wait time, and dock availability with real-time status updates are automatically obtained. Furthermore, incoming trucks can be prioritized based on the demands of the production site, and shipments can be unloaded at the most appropriate pier. This reduces waiting time for drivers in half, when materials arrive on schedule and resources are maximized effectively, considerably minimizing the chance of production delays (DHL, 2017).

5. Main challenges of the IoT

Although there is a great interest in technologies like IoT, big data, 3D printing in the SC, integrating built-in systems and operations with advanced technologies while planning SC pose challenges to managers (Haddud et al., 2017)

According to Tadejko, these challenges range from contextual applications to techniques and security and privacy issues in a context, where everything is interconnected, and contact information and data related to the local environment are sent to a distributed cloud computing system (Tadejko, 2015). Undoubtedly, putting technology

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into application requires handling managerial, organizational, and technological aspects simultaneously, and this involves business process reengineering, project management skills and handling organizational change. here may be a lack of skills and expertise and adopting a new technology and integrating it with other technologies can be difficult for employees. This hinders and significantly delays the implementation and adoption of IoT (Balestrini et al., 2015). Therefore, it is vital to manage all kinds of technological problems that may occur withing a managerial and organizational perspective.

Within this context, main technology-related challenges are detailed in Table 3 under three main categories of privacy and security, scalability, and technological compatibility.

Table 3 IoT challenge areas from technical perspective

Challenges	Description	Source
Privacy and Security	Difficulties of authentication, authorization, privacy, system access to applications, network, and data. Significant obstacles in terms of determining who has access to what and with what credentials.	Alaba, 2017; Tadejko, 2015; Tawalbeh et al., 2020; Sandeep, Kumar, and Kumar, 2020.
	Device and network security risks and vulnerabilities. IoT devices and platforms should be protected from both information and physical breaches, which necessitates the use of security technology.	Haddud et al., 2017, Tawalbeh et al., 2020; Alaba et al., 2017; Radovan and Golub, 2017.
	Many IoT devices have limited storage space, memory, and processing capacity. Security approaches that rely heavily on encryption may not be suitable for these restricted devices.	Gerber and Kansal, 2020; Wang et al., 2019.
	Long-lived device management is extremely difficult, especially if a security flaw is discovered that cannot be fixed within that IoT endpoint.	Tawalbeh et al., 2020; Alaba et al., 2017.
Scalability	As the IoT system connects devices and provides multiple applications over the internet, it can pose design and growth challenges in order to meet scalability and flexibility in response to changing environments and people's needs.	Gupta, Christie, and Manjula , 2017; Bao, Chen, and Guo, 2013; Ravulakollu et al., 2018.
	Failure to determine criteria such as the working conditions of the device, how it will be served, what operational needs and costs it will require may affect scalability operational costs.	Oueslati, 2020; Tran et al., 2020; Gupta, Christie, and Manjula, 2017.
	Ensuring integration with the existing systems, including legacy systems.	Clement, McKee, and Xu, 2017; Banafa, 2017; Chopra, 2020.

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Technology compatibility	When connecting devices, extra hardware and software may be required.	Tadejko, 2015; Farahani, Meier, and Wilke, 2017.
	Integration of smart 'network enabled' objects under severe energy and environmental constraints.	Banafa, 2017; Koley and Ghosal, 2015; Tadejko, 2015.
	Availability of personnel with the necessary technological competence and expertise.	Balestrini et al., 2015; Taivalsaari and Mikkonen, 2018.

These challenges must be overcome when using IoT in the SC to ensure that the process runs smoothly. In this context, for the security problem, one of the most common difficulties, SAP author Velzen suggests 5 solutions; a) Manage the risks that may be encountered in security applications correctly. b) limit device-to-device communication, c) retain control over the IoT infrastructure, d) use encryption from end-to-end, and e) leverage existing expertise (Velzen, 2017). In addition, in the article published by IBM, authorizing and authenticating devices, managing device updates, determining strategies to detect security vulnerabilities in advance are also highlighted to be essential to cope with the challenges (Gerber and Kansal, 2020).

6. The future of the IoT in the SC

The concept of IoT has evolved greatly in time (SAP, 2017), and when the term IoT was first introduced, few could grasp and imagine how wireless connectivity of devices would shape business and human life. In the previous sections, it was explained how it integrates data and information regarding the on-line and real-time management of all SC processes, including design, procurement, production, and delivery of innovative products. In the future, the increased assimilation of the technology based on automation will enable an entirely new era in the smart systems evolution (Majeed and Rupasinghe, 2017; Shah, 2020).

The conclusion from SAP's research into what the future SC should look like is that customers must create durable, robust, flexible, and sustainable SC. For this, 4 items are suggested to be done (Hero, 2021):

- Being more agile to detect, anticipate and respond to disruptions.
- Increasing productivity with the digitalization of industrial companies (Industry 4.0).
- Improving connectivity with business partners to enable next-level collaboration.
- Conducting sustainable business practices.

In this context, IoT sensors are a critical component of Industry 4.0, which is still the most recent trend toward digitization in manufacturing and logistics (Matthews, 2020). They provide visibility, speed, responsiveness, real time tracking and cooperation in SC processes. In their future factory concept within IoT, Majeed and Rupasinghe (2017) argue that future factories will involve complicated processes, process networks, machines, sensors, robotics, and devices, and that this system will necessitate new operational principles for a better human-machine connection. In this approach, in the future success and competitive advantage will be determined by rapid, smart, and self-adapting production processes.

In addition, it is mentioned that applications like smart transportation system, clever city design, intelligent monitoring and smart security will be realized through IoT (Khan et al., 2012). It is argued that with the smartness of the entire system, it will provide benefits such as discovering emergency routes, safer human and asset tracking, mobile emergency command and timing tracking, and tracking vehicle rules violations. These smart systems brought by IoT will enable easier tracking of SC processes, communication between units in the chain and continuing more smoothly.

Consequently, there is wide consensus that future of SC will be shaped around the ideas of IoT and smartness.

7. Discussion

Previous sections highlighted that while it is very important that SC processes run smoothly, it involves challenges. IoT provides unparalleled visibility into all components and processes of the SC with early warnings of internal and external circumstances that require improvement (Ben-Daya et al., 2019).

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The first contribution of this research is to establish the link between the SC and IoT. In line with the inferences, it has been seen that the IoT has drastically altered warehouse and inventory management by closely integrating transportation, distribution, and CRM systems (Yang, Yang, and Plotnick, 2013; Banker, 2014; Parry et al., 2016; Aryal et al., 2018). The second contribution of the research is that many companies in the logistics and SC can apply technologies based on IoT-related data in every part of the chain. As exemplified in the IoT applications section in SC processes, IoT can be applied in many areas such as route optimization, real-time cargo tracking, storage capacity optimization, predictive asset maintenance. These applications demonstrate the benefits of adopting and integrating IoT technologies in SCM. IoT enables the interconnection of logistics processes by allowing sensors, connectivity, and human processes to interact, enhancing SC performance dynamics in terms of cost, quality, delivery, and flexibility (Vass, Shee, and Miah, 2021). Literature strongly supports that the sectors in which IoT is used are numerous, and the benefits obtained are quite significant (Ben-Daya et al., 2019; Macaulay, Buckalew, and Chung, 2015).

In addition to these benefits, it cannot be denied that some difficulties and challenges are encountered, one of the most critical ones being the security (Tellis, 2006). In section 5, challenges were grouped under 3 main headings, namely privacy and security, scalability, technology level and compatibility. Difficulties under these 3 main headings have been discussed, touching upon the uncertainty of technologies, security of data, easy adaptation, scaling operational costs in the literature review of many researchers (Banafa, 2017; Gerber and Kansal, 2020; Gupta, Christie, and Manjula, 2017; Alaba, 2017). These difficulties must be overcome in order for the process to continue smoothly (Haddud et al., 2017). Otherwise, it jeopardizes the entire idea of the linked, traceable process (Tadejko, 2015). In addition, considering the potential risks before adopting and implementing IoT helps preparing for the problems that may be encountered for the management of SC process (Haddud et al., 2017). It is obvious that if these challenges are overcome and companies are prepared for the challenges in advance, the impact of IoT in the SC and logistics will increase exponentially. This is supported by forward-looking research, such as smart factories (Majeed and Rupasinghe, 2017), smart cities (Khan et al., 2012), and smart SC processes (Hero, 2021).

8. Conclusion and further research suggestions

This paper which has focused on the effects of IoT in logistics and SCM areas revealed that IoT has emerged one of the most significant technologies of the 21st century in recent years (SAP, 2017). The primary goal of this research was to investigate the IoT concept in SC processes and applications, with its benefits, challenges, and predictions for the future. IoT was examined within the scope of SCM, and various applications in managing the SC processes and the values provided for these processes of the chain are explained with examples. These applications demonstrate the benefits of adopting and integrating IoT technologies in SCM. Evidently, IoT seems to affect the sustainability (economic, environmental, and social) of companies (Vass, Shee, and Mia, 2021; Formaneck, 2019). Challenges related with the implementation and suggestions to overcome were also mentioned.

Findings reveal that assimilation and application of IoT will gradually increase into the future. It is emphasized that IoT, which is predicted to make the concept of smartness become widespread in SC processes, is transforming the level of visibility and traceability of the entire chain by providing online, real-time monitoring of the processes.

The authors are of the opinion that in future research, merger of current set of technologies including big data, RFID, sensors, cloud, blockchain within the IoT concept will continue to deserve attention in the field of logistics and SCM. Assimilation is not complete, and it is obvious that the use of IoT in logistics and SCM applications will continue to be a promising research area.

Contribution of researchers

Authors have equal contribution in all the sections.

Conflicts of interest

The authors declared that there is no conflict of interest.

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