A Systematic Literature Review on Innovative Technologies Adopted in Logistics Management

A Systematic Literature Review of Innovative Technologies Adopted in Logistics Management

Alexandra Lagorio, Giovanni Zenezini, Giulio Mangano & Roberto Pinto

Abstract: Many innovative technologies have been successfully adopted in logistics and supply chain management processes to increase efficiency, reduce costs or enhance communication. In recent years, considerable attention from both practitioners and academics has been focused on evaluating the impacts of innovative technologies adoption. However, the current body of literature on technology adoption, implementation and evaluation in logistics is quite fragmented; thus, an updated and structured overview of the scientific literature in this field might be useful. To this end, this work presents a systematic literature review (SLR) that aims to increase the understanding of the trend toward new technologies in logistics and identify the main research trends and gaps. The principal research trends that emerged from the SLR involve the technologies, their evolution over time and their relationships with the research methodologies. The main literature gaps concern integration and communication, technology-adoption processes and differences between inbound and outbound logistics.

Keywords: innovative technologies; logistics management; systematic literature review; supply chain; industry 4.0

1 Introduction

Logistics managers are increasingly being called upon to increase efficiency in business environments, within which customers' needs have been changing rapidly in recent years, pushing companies to implement the operational flexibility required to manage demand volatility, product variety and products' short life cycles and to shrink delivery times effectively (Soni and Kodali, 2010). In this respect, the adoption of increasingly advanced technologies can help logistics managers go beyond logistics operations' complexity. For example, information-based technologies and new application opportunities are positively related to the supply chain (SC) and logistics flexibility (Shang and Marlow, 2005).

Many technologies have been developed and implemented in the "logistical transformation" that is taking place to align logistical processes with the requirements of the new production context underpinning the Industry 4.0 paradigm. Today, the terms *Smart Logistics* and *Logistics 4.0* are used to describe the application of Industry 4.0 technologies in the logistics domain. Specifically, Logistics 4.0 refers to a "*logistics system that enables individual customer requirements to be met sustainably without increasing costs and supporting industrial development in an environmentally friendly way* *thanks to digital technologies*" (Winkelhaus and Grosse, 2019). The technologies applied in the supply chain (SC) and logistics can be defined as "*tools and technologies that can be implemented for integrated management of the supply chain within and beyond organizational boundaries*" (Liu et al., 2016). As technology supports physical processes, information exchange and decision-making systems (Cooper et al., 1997), changes and improvements affect several functional areas of industrial logistics – from warehouse management to transportation and resource planning.

Logistics and supply chain management (SCM) have always been at the forefront of industrial innovation. Logistics and SCM fields were the first in which many technologies have been introduced (such as the first experiments with self-driven vehicles in warehouses) (Lu et al., 2017). Some of these technologies have reached a significant maturity level and are now adopted widely, such as radio-frequency identification (RFID) (Hassan et al., 2015). However, some recent technologies are becoming fundamental, and their application is gradually spreading in the field of logistics, such as blockchains (Gunasekaran et al., 2019) and drones (Shukla and Tiwari, 2017). Different studies are underway in both academic and industrial research to define these technologies and their possible uses in logistics; however, logistics managers and companies should be aware of all the possible impacts of technologies to exploit their benefits more effectively.

1.1 Research background

According to Giunipero et al. (2008), only 5% of papers in SCM literature focus primarily on information technology. Not surprisingly, even though technological innovation is always on researchers' agendas, an analysis of extant literature found few structured literature reviews that deal with technological issues applied to the domain of logistics and SCM. For example, Blankley (2008) examined the financial impacts of technology in SCs, identifying first-order operational impacts, such as inventory reduction, that lead to second-order impacts in terms of sales growth and reduced costs of goods sold. The author also notes that technology improves knowledge-intensive tasks that require a high level of communication and coordination within and between organisations. Similarly, Skipper et al. (2008) investigated technology-enabled coordination and communication strategies in supply networks. Technologies herein represent the communication level required among organisations in supply networks. Mediating technologies cover one-to-one interactions that connect people using common resources in standardised ways. Long-linked technologies, or one-to-many technologies, are involved in a sequential series of activities in which one phase's output serves as inputs for subsequent phases. Electronic data interchange (EDI) and RFID are examples of such technologies because they follow the standard workflow and provide data to multiple participants in an SC. Intensive, or many-to-many, technologies help change a specific business object (e.g. products, raw materials) and are utilised and modified by multiple participants in the network. Enterprise resource planning (ERP) is a good example of intensive technologies because it provides integrated, updated views of business processes using common databases accessed by different functional areas within an organisation. Forman and Lippert (2005) examined the antecedents of technology internalisation in SCs and noted some factors that positively correlate with logistics firms' technology adoption, such as complexity, relative competitive advantage within an industry, perceived usefulness and benefits, support from top management and personnel training. However, they also stress that new processes ensuing from the use of technologies might prevent these technologies from being internalised. Moreover, they acknowledge that a wide variety of theories is required to encompass the diversity of issues linked to technology adoption.

In more recent scientific literature concerning innovation in logistics and the SC domain, only a few sub-topics emerged, such as sustainability, third-party logistics (TPL or 3PL) and urban logistics, with only marginal attention paid to technology. One important theme present in the scientific literature involving technologies in logistics and SC analysis is sustainability. Björklund and Forslund (2018) analysed technological logistics innovation in the sustainability field, structuring their literature review around three dimensions: softness, the extent of change and scope. In this context, the relationship between information and communication technology (ICT) and the implementation of sustainable initiatives is crucial (Centobelli et al., 2017). Chen et al. (2017) highlight the boost that technological innovation gives to collaboration in the SC and how communication improvements among actors can enable good sustainable practices. Jafari (2015) analysed the different definitions of *flexibility* for logistics practitioners. Selviaridis and Spring (2007) analysed 3PL literature in terms of the research purpose and nature, the method employed, the theoretical approach and the analytical level. The authors found that most research in this field is survey-based and that a key success factor for logistics alliances is 3PLs' ability to remain up-to-date on new technologies. Marasco (2008) identified a similar positive relationship between partnering with a 3PL and technology uptake. However, the author argued that ICT developments in 3PLs could take multiple paths that deserve further examination. Logistics technology comprises one of the most important selection criteria underlying logistics outsourcing decisions (Alkhatib, Darlington and Nguyen, 2015). In particular, within an information system that facilitates communication and the execution of logistics customers' logistics operations using attributes such as EDI, tracking/tracing, information accessibility, the informatisation level, materials handling equipment and information security, it is paramount that 3PLs offer customers a competitive service (Aguezzoul, 2014).

With the rise of e-commerce, 3PLs are increasing their urban operations. Urban logistics is a growing sub-topic in logistics and SCM, with peculiar characteristics that differentiate it slightly from the mainstream domain. For instance, scholars have traditionally focused on optimisation methods rather than surveys due to the necessity of reducing negative externalities from urban logistics operations, as Dolati Neghabadi, Samuel and Espinouse (2018) discovered. The same authors found that technological developments in urban logistics still need more investigation and analysis. Lagorio, Pinto and Golini (2016) analysed 104 papers on the sub-topic of urban logistics and found that only 12% focused on the implementation of ICT, mostly through quantitative modelling rather than a survey, corresponding with findings from Dolati Neghabadi, Samuel and Espinouse (2018). Mokaddem and Javab’s (2019) review included 56 papers published from 2010 to 2018, with an emphasis on information transportation systems as a lever to enhance city logistics (CL) processes. Karakikes et al. (2018) also studied this topic through their corpus of 82 papers, aiming to evaluate the impact of CL solutions, such as electric vehicles, bicycles and parcel lockers. Finally, in CL contexts, electric vehicles have been studied as an alternative to traditional ones in a systematic literature review (SLR) by de Oliveira et al. (2017). Moreover, many scientific papers published before 2010 did not delve deeply into any specific technology and instead assessed the likely impact of information-based technologies (e.g. EDI) on some aspects of logistics and SCM, such as coordination mechanisms or financial outcomes. Scholars have acknowledged that SCM and logistics are dynamic domains from which new topics arise and that methodological approaches and theories are needed to continuously tackle their inherent complexities (Giunipero et al., 2008; Nilsson and Gammelgaard, 2012). Consequently, the SLR presented in the present paper aims to better understand the state of the art in scientific literature concerning technologies’ role in the logistics field by identifying the main research trends and gaps.

1.2 The paper’s contribution

The overview of the current literature presented in the previous section on technology adoption in logistics and SCs appears to be quite fragmented, with technologies often not being the main focus in the studies. Only a few papers in the logistics context are related directly to examining the adoption of technologies, their characteristics and the advantages and disadvantages that can result from their application. Thus, the main goal of the present research is to understand technologies’ role in the logistics arena more effectively by identifying the main research trends and gaps through an SLR. To this end, an extensive analysis is conducted and explained in this paper, which is structured as follows. Section 2 describes the methodological steps completed to build the SLR. Section 3 describes the corpus. Section 4 deeply examines leading research trends, highlighting the most cited technologies, their evolution over time and their relation to the primarily used methodologies. Section 5 discusses the main research gaps identified during the SLR. Finally, Section 7 concludes the paper.

2 Research Methodology

A systematic literature review (SLR) is viewed as an optimal research method for this work because of the nature of its goal, which is to understand the role of 4.0 technologies and evaluate the main research trends and unresolved issues. A literature review can be viewed as "systematic" if it is "*based on clearly formulated questions, identif(ies) relevant studies, appraises their quality, and summarizes the evidence by use of the explicit methodology*" (Tranfield et al., 2003). Moreover, an SLR provides a replicable research protocol with a detailed description of the performed steps within the SLR, which enables an in-depth evaluation of the conducted study. This study follows the guidelines provided in the most prominent contributions (Touboulic and Walker, 2015) to devise a robust and replicable study. In particular, a three-step protocol has been developed to identify the correct procedure for performing automated research so that other researchers can replicate the SLR (Lagorio et al., 2016). This section thoroughly defines the inclusion/exclusion criteria (Section 2.1), paper-selection criteria based on titles and abstracts (2.2) and the final selections based on reading the full texts and the snowballing approach (2.3).

2.1 Inclusion/exclusion criteria

First, a preliminary list of keywords and inclusion criteria was created, with the concept of new technologies in logistics management defined through its various possible synonyms in the keywords to make the research as comprehensive as possible. The research focused on papers published in refereed journals in the fields of logistics, operations, management and economics during the 2010-2018 period. The first year includes studies published at the same time as the first definition of the Industry 4.0 concept provided during the International Hannover Fair in 2011 (Mariani and Borghi, 2019). Conference proceedings and grey literature, i.e. technical reports and works in progress, were excluded from the corpus of collected papers. Therefore, the review was limited to peer-reviewed publications to maintain homogeneity among the papers in the corpus (Tranfield et al., 2003), gain consistency across themes and sources (Touboulic and Walker, 2015) and ensure the selected papers' quality (Burgess et al., 2006). The search was conducted based on the aforementioned list of keywords and inclusion criteria. The SCOPUS database was used in the analysis because most academics recognise it as one of the most complete bibliometric databases of scientific and technical peer-reviewed literature (Araùjo Vila et al., 2020). A double-blind control test was then performed on the papers to verify and refine the selection criteria (Tranfield et al., 2003). More specifically, each author carried out a manual selection of articles to check their consistency with the inclusion and exclusion criteria and with the primary goal of the research. Every paper that elicited disagreement among the authors regarding inclusion/exclusion criteria was read and discussed until a consensus was reached among them. These discussions led to the definition of the final selection criteria reported in Table 1. The query was then relaunched, resulting in the extraction of an initial corpus of 341 papers.

Table 1. Systematic literature review inclusion criteria

Inclusion Criteria	Description
Keywords	Logistic* AND Technology* AND Innovation*
Language	English
Document types	Articles
Source types	Peer-Reviewed Journals
Subject areas	Business, Management, Accounting; Engineering; Computer Science; Decision Sciences
Time interval	Jan. 2010-Dec. 2018

2.2 Paper selection based on titles and abstracts

Each of the four researchers involved in this study reviewed the title and abstract of each paper in the selection. Following discussions, the authors removed papers from the corpus that lay outside the research scope. In particular, the authors excluded 146 papers that did not focus strictly on technologies in logistics. The full list of papers included in the study is available from the authors upon request via email.

2.3 Paper selection based on reading full texts and the snowballing approach

The final step of the protocol entailed refining the list of selected papers. The authors read the full versions of the candidate papers and then excluded 58 that lay outside the scope of the research. At this point, a corpus of 137 papers had been analysed. After that, a forward and backward snowballing process was conducted, yielding a final corpus of 152 papers. Backward snowballing exploits the reference list to identify potential new papers to be included. The authors read titles, abstracts and full papers if necessary and then decided whether to include them in the final corpus. Forward snowballing identifies new papers starting from the analysis of papers that cited the ones contained in the first list of 137 papers. The approach to going through the papers is similar to in the backward method (Wohlin and Claes, 2014). The two procedures were iterated until no new papers were found. The preliminary list of 137 papers was divided into 4 parts. Each author then applied both backward and forward snowballing techniques to his/her portion of the papers. The four final lists of papers obtained from the snowballing – one from each author – were very similar. Thus, it can be stated that good convergence in terms of the final list of papers was reached, leading to a final corpus of 152 papers (Figure 1).

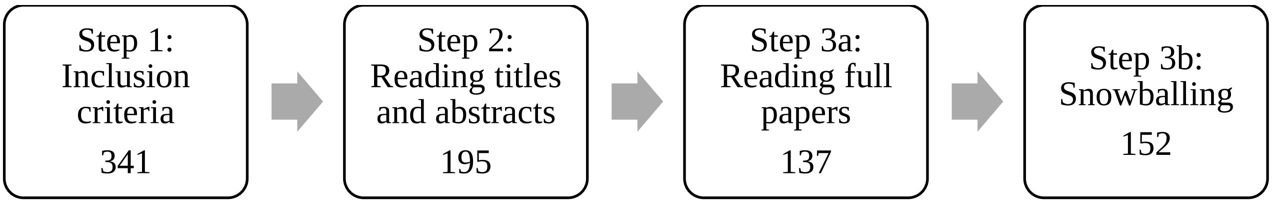

Figure 1. SLR results according to the selection protocol that the authors performed

3 Corpus Description

This section presents the first results from the systematic literature review (SLR). In particular, the number of publications by year and journal is traced; then, the areas of application and research methodologies are examined deeply. Due to space constraints, the complete list of papers contained in the corpus is available upon request from the authors via email.

3.1 Paper distribution by year, journal and country

Figure 2 presents the number of papers in the corpus published by year. It can be noted that the number of papers focusing on technologies in logistics is quite constant during the different examined periods. Also notable is the accelerating increase in the number of contributions analysing technologies in logistics in the final years: By dividing the corpus into (almost) equal shares, in 2018 alone, a higher number of contributions was published than in the two previous years (about 26% of the corpus in 2018, compared with 22% in the 2016-2017 biennium), and about the same number as in 2010-2012 and 2013-2015 (Figure 2).

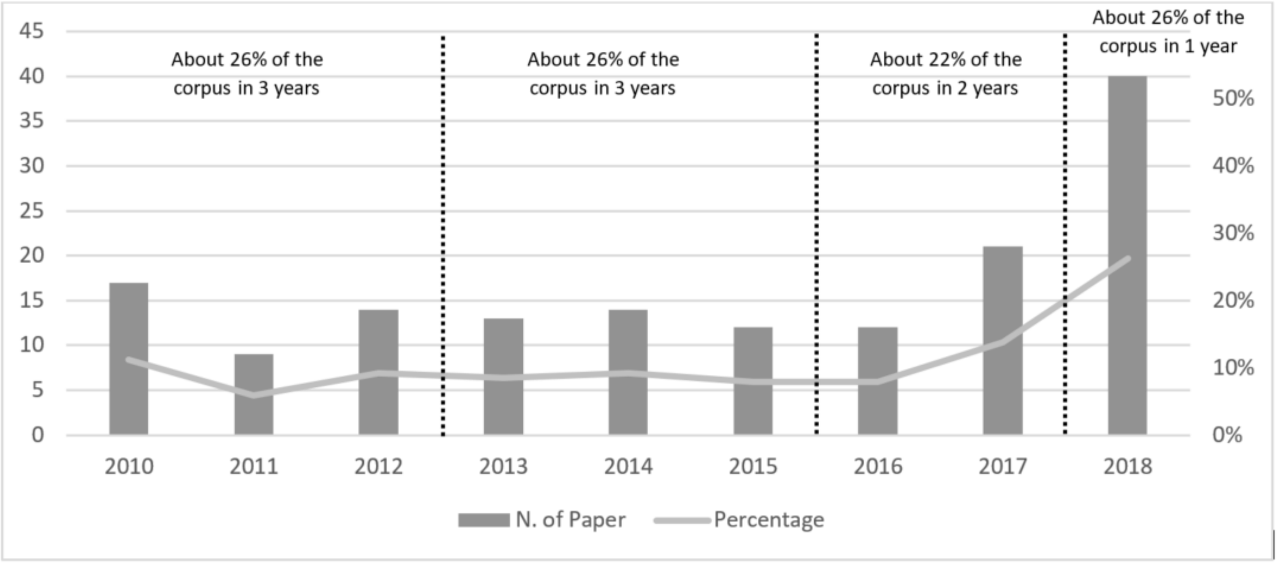

Figure 2. Percentage of papers in the corpus for intervals of different years

In considering the academic journals that have published at least five papers that fall within the inclusion criteria, it is possible to observe that they belong to different sectors. The list includes journals that deal with more economic-managerial topics (e.g. *International Journal of Production Economics*, *Business Process Management Journal*), technical and operational aspects (e.g. *Expert Systems With Applications*, *European Journal of Operational Research*, *International Journal of Logistics Research and Application*) and production (e.g. *International Journal of Production Research*, *Production Planning and Control*), as well as SC and logistics management (e.g. *International Journal of Physical Distribution and Logistics Management*, *Supply Chain Management*) and transport (e.g. *Transportation Research Part E)* (Figure 3). This result confirms both the broad diffusion of the subject under analysis and its fragmentation.

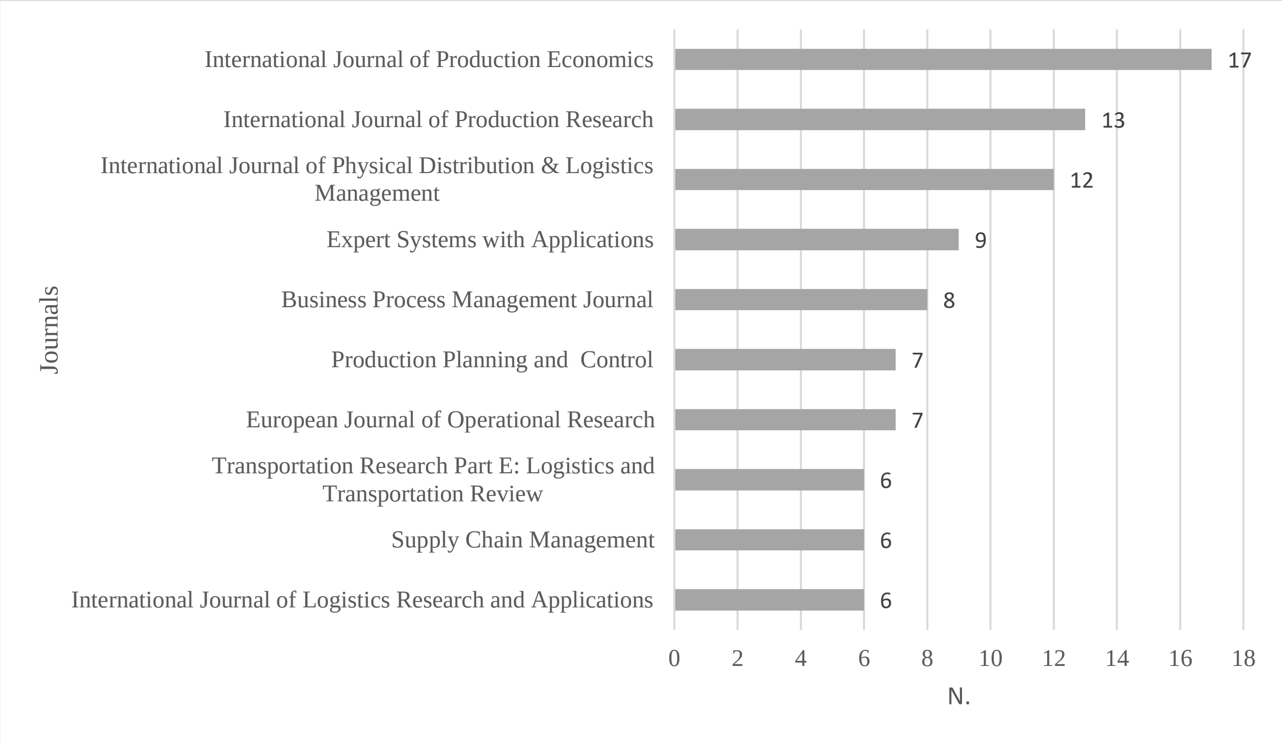

Figure 3. Papers' distribution by most frequent journals

3.2 Areas of application

The main application area is in SCM, which involves the design, planning, execution and monitoring of logistics processes (LeMay et al., 2017). Innovative technologies can support this broad range of activities significantly. About one-third of the papers focus on the SCM issue and the enhancements brought about by new technologies. Likewise, other studies focus on SC operations in terms of carrying out activity flows from the supplier to the customer (Huan et al., 2004). Inventory management activities – which are related to the processes of ordering, storing and using a company's inventory (Wallin et al., 2006) – are another deep investigative area of application. Also, the theme of the exploitation of innovative technologies in the logistics service provider (LSP) arena is present, with a particular emphasis on LSP operations processes. Another promising field of application is reverse logistics, wherein "*products are returned after their use and then brought to disassembly centers for conversion into new finished goods or raw materials*" (Prajapati et al., 2019).

Some themes that often gain media attention are not represented with the expected frequency within the corpus. For example, transportation comprises only five papers. Also, healthcare logistics comprises only five papers, which mainly refer to material flows in health services (Pohjosenperä et al., 2019). Also, only three works address the small and medium enterprise (SME) arena. In the identified sample, only two contributions are associated with smart city issues. Finally, only two studies describe the contribution of the supplier selection process and SC risk management.

4 Main Research Trends

This section describes the main research trends that emerged from the performed SLR. In particular, the most cited technologies, their evolution over time and their relation with the primarily adopted methodologies are investigated.

4.1 Technologies

The authors classified the papers in the corpus based on the leading technologies that they addressed. The technologies were not included among the keywords of the papers in the selection criteria to allow them to emerge from the corpus inductively. The classification followed a two-stage approach. First, each author independently analysed the same subset of 50 random papers and inductively defined his/her list of technologies. After a review of the lists and a discussion among the authors, the final technology list was defined and applied to the remaining 102 papers. This second stage highlighted the classification's substantial stability, as there were only a few disagreements, which the authors settled on a case-by-case basis. The results from the identification of technologies are reported in Figure 4. It should be noted that each paper resulted in one or more technologies being addressed, with a maximum of three technologies per paper. The authors decided to adopt the categories "IT" and "IoT" for all papers regarding these technologies from a more general perspective (e.g. benefits, technology adoption). The authors opted for this choice because not all the papers that related to a single specific technology could be included in a broader category. Conversely, not all the papers that approached technology from a broader perspective cited single specific technologies.

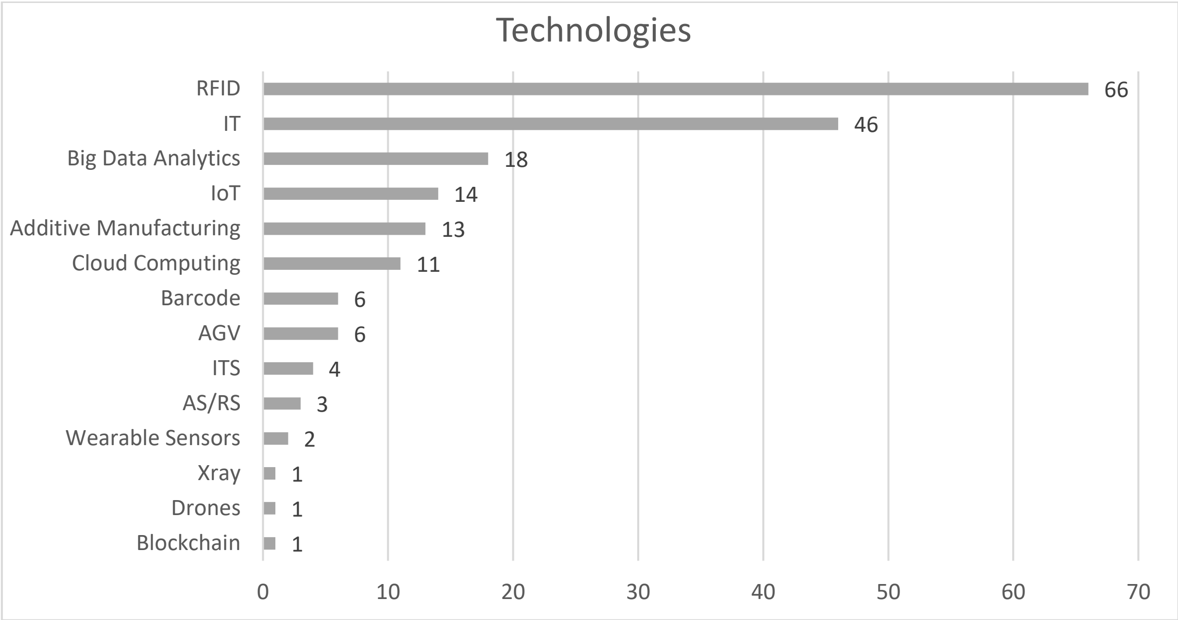

Figure 4. Technologies that emerged from the corpus of analysed papers

The technologies that emerged from the analysis can be included in the technological innovations that are commonly indicated in the scientific literature (Kagermann et al., 2013; Lu et al., 2017), such as technologies that are transforming industrial production and that are part of the Industry 4.0 paradigm. In particular, in the corpus, great relevance is given to information technology (IT). IT, or information and communications technology (ICT), in logistics is identified as all applications used to plan, implement and control procedures to transport and store goods and services from origin to destination (Hazen and Byrd, 2012). In the industrial context, logistics IT comprises technologies that have seen more widespread adoption. This increasing diffusion is due to the increasing need to exchange information throughout the SC between manufacturers, suppliers, service providers and – with the spread of e-commerce – customers. An example of these technologies is integrated management software (enterprise resource planning [ERP]), which comprises information systems designed to automate the flow of materials, information and financial resources within the company or between different partner companies within the same SC. IT has revolutionised traditional logistics and SCs, providing benefits such as increasing efficiency and responsiveness (Gunasekaran et al., 2017) and supporting SC integration and collaboration (Neubert, Dominguez and Ageron, 2011). Investments in IT/ICT positively impact a company's performance in terms of quality, visibility in the SC and production and data analysis (Brinch et al., 2018). Consequently, the benefits are linked mainly to the company's competitiveness, image and added value. A survey that Belvedere and Grando (2017) conducted shows that this effect is particularly strong in the current digital transformation revolution because ICT provides accessible information throughout the SC, accelerating all logistics activities, including order exchange or inventory management. Another survey by Evangelista et al. (2012)

shows that a positive correlation exists between the financial performance of IT and SCs at both the strategic and operational levels. The recent spread of online commerce has led to companies paying increasing attention to the critical relationship between their ICT systems and those of their suppliers, customers and partners, along with the SC, to achieve better integration, competitiveness and added value. The introduction of innovative IT has also been hampered by the availability of the widely applied, established and relatively low-cost technology known as electronic data interchange (EDI). EDI technology is used to exchange information within the organisation, involving the direct routing of information without human interference and according to predefined formats and rules. In recent years, cloud computing (CC) has also begun to proliferate and has proven to be vital in the logistics sector. CC figuratively refers to a bundle of virtualised and distributed resources shaped in a diffuse, all-pervasive way, similar to a cloud. This type of technology allows access to software applications and data storage, without a significant investment in infrastructure but with investment in software functionality and services. Furthermore, CC is increasingly viewed as a viable way to gain the capacity to meet growing demand for high-quality, cost-effective services. In particular, LSPs may be able to improve their services and achieve better planning and more reliable day-to-day operations with less investment in infrastructure (Subramanian, Abdulrahman and Zhou, 2015). Thus, CC has reshaped both intra-organisational and inter-organisational IT by changing how business is conducted (Maqueira et al., 2018). Big data analytics (BDA) is also part of the IT field and usually refers to massive data sets that go beyond typical database software tools' ability to capture, store, manage and analyse data based on their nature. BDA generally comprises three dimensions: "volume", "velocity" and "variety" (Manyika et al., 2011). Even if the use of BDA in the SC and logistics is promising, there is still no defined research field of application (Arunachalam, Kumar and Kawalek, 2018). Finally, the successful adoption of this IT must be based on the standardisation of technologies that both public authorities and industry can promote. In particular, public operators can make a precise standard mandatory by defining specific rules. Instead, private companies can ask other operators along the SC to adopt a specific standard to avoid the problem of non-communication between different operators' systems. In addition to a large amount of generated data, the interconnectivity between the different companies that comprise the SC, as well as the connections between SCs and the external environment, can substantially support customers, public authorities and transport companies in achieving mutual growth. For example, by integrating ICTs and sensor systems into physical objects, smart cities can collect and manage big data to support global improvement initiatives. For example, real-time traffic information can provide short-term forecasts on traffic flow rates, congestion on city streets and speeds to improve vehicle routing and planning for both public and private transportation (Meyer et al., 2014). Many papers in the corpus are also related to the internet of things (IoT), a term that Massachusetts Institute of Technology (MIT) first coined in the late 1990s to refer to a "*devices or sensors connected world where objects are connected, monitored, and optimized through either wired, wireless, or hybrid system*s." The IoT, which applies traditional management logics used for information flows to physical flows of goods, is gaining momentum. The IoT aims to facilitate interactions between people, data and goods to be transported, optimising not only the exchange of information but also the physical flow of goods. The aim is to make network connections more relevant, useful and economically advantageous, taking full advantage of collaborations in the logistics chain. Thus, to create this interconnection among the digital and physical worlds, sensors or automatic identification and data capture (AIDC) technologies, such as barcodes or RFID (Romero and Lefebvre, 2015), are necessary. The RFID sensor is a widely used key technology that is viewed as a prerequisite or essential element in the IoT. RFID is based on unique tags that are read by electromagnetic devices; then, the data are passed to a radio transmitter, and a carrier radio frequency transmits them to a remote receiver capable of recording and managing the information. Its main aspects are the absence of lines of sight, the simultaneous high-speed reading of multiple tags and the identification of entire storage units. The feasibility in terms of its ease of use has influenced the adoption of RFID among companies, making it one of the most adopted (and studied) technologies ever. Many innovative projects have been carried out involving the research and development departments of the world's leading companies (such as Amazon and Volvo). Thanks to its unique tracking capabilities, RFID can improve efficiency and responsiveness in both the short and long terms. Recent applications have demonstrated its feasibility in humanitarian aid SCs, in which, after a disaster, a rapid response to victims' needs is the main concern (as was the case, for example, when identifying survivors during Hurricane Katrina in the U.S.). Another RFID application is its integration with demand planning to facilitate the adjustment of lot size to the actual demand that the RFID system monitors. In particular, RFID can be applied effectively in the food industry to manage the problem of inventory quality and improve the timing of required actions and, in turn, the level of customer satisfaction. Also, in the healthcare sector, RFID technology is used to track and trace medical supplies, high-value products, furniture, patients and hospital staff. In particular, real-time visibility allows for improving the delivery of health services (such as the delivery of reports). Also, in the RFID jewellery sector, in addition to the positive influence on logistics activities, marketing innovation opportunities are linked to new services that can be added for customers (e.g. real-time tracking, exact delivery times for personalised goods). Finally, the use of RFID also represents a value-added functionality for wholesale distributors, a quality that could motivate suppliers to upgrade their systems, such as through ERP and warehouse management systems (WMSs), to support RFID data systems. However, several problems remain that hinder the proliferation of RFID in some industrial application fields, e.g. lower-than-expected reader and tag performance, a lack of cost distribution over the entire distribution chain, the physical limits of real systems (low operating distances, failure to read, incomplete applicability to all goods, low-speed read-write) and a lack of flexibility. Despite this, RFID helps implement service innovation and can be viewed as a catalyst for faster process improvement. In this context, the importance of BDA in the modelling and analysing of transport systems (urban and rural), as well as in distribution through large data sets generated by different information sources – such as GPS, mobile phones and transactional data in business operations – becomes crucial. More recently, the IoT is demonstrating its ability to improve the operational efficiency of processes within logistics chains. For example, IoT technologies are becoming the standard in seaports, e.g. the Port of Hamburg. In the port transport area of interest, another effective technology is the X-ray scanner used on containers and swap bodies, which has many benefits, including increased security, labour efficiency, theft reduction, fast handling and cost savings from inspecting goods (Min et al., 2016). By integrating this technology with the management software and IT described in the previous section, it is possible to guarantee complete and more precise product traceability. In particular, it is possible to make the IT flow and the actual flow of goods increasingly integrated and synchronised. Other papers examined additive manufacturing (AM) – i.e. 3D printing, rapid manufacturing or direct digital manufacturing – a revolutionary digital technology that utilises an abstract digital design file that can be transformed into physical objects by using a 3D printer (Chan et al., 2018). This technology should impact logistics SCs' structures (e.g. the location of a production plant) and logistics (e.g. transport and storage). With the proliferation of this type of technology and the decrease in costs related to its implementation, most researchers and operators in the sector imagine two types of future scenarios: the return of "factories" in urban centres (giving rise to a kind of new digital craft shop) and a reduction in product transport volume, with low profit margins of which transport costs account for a high percentage (construction material). However, autonomous vehicle warehouses are not cited in the papers that comprise our review's corpus. The main components of an autonomous warehouse are autonomous vehicles (AGVs), lifts and a system of rails in the rack area called an automated storage/retrieval system (AS/RS). Among the latest technological trends, those related to the management of warehouses, fleets, control platforms and equipment handling within the SC and vehicle optimisation technologies are viewed as crucial in logistics systems. In the field of storage systems, automated vehicle storage and retrieval systems (AVS/RSs) are used to achieve greater operational efficiency and competitive advantage, especially in operating environments with a high density of small and medium components or raw materials. With an emphasis on storage processes, more importance is attached to the use of AVS/RSs, which comprise vehicles, lifts and guidance systems within the storage and production area. Autonomous vehicles provide horizontal movement (x-axis and y-axis) within a tier using rails, while lifts provide vertical movement (z-axis) between tiers (Roy et al., 2017). The operational processes involved in the storage and handling of goods within the company can also be made more efficient through innovations in the packaging sector. For example, reducing packaging weight elicits a direct positive effect on transport costs. Also, adequate transport packaging can reduce, or even eliminate, waste at the end customer's premises, minimise risks to the environment and reduce storage costs. Finally, other technologies are mentioned in the corpus of papers, namely three that should be included in the aforementioned categories based on the context in which they are applied: wearable sensors, blockchain and drones. In three papers included in the corpus, wearable sensors and other such devices help operators take on physical jobs that would otherwise be too difficult (Baghdadi et al., 2018; Cole et al., 2018; Maman et al., 2017). Gunasekaran et al. (2017) cited blockchain as an emerging technology that could increase agility in the SC. Shukla and Tiwari (2017) explain how drones could be used to collect data in the agriculture sector, e.g. for monitoring crop fields.

Another analysis was performed on the leading technologies of the corpus and their corresponding years of publication. Table 3 summarises the results from the aforementioned analysis. RFID is a consolidated technology in the logistics sector because it is present in all the years covered by the literature analysis. During the final years, a decrease occurs in the number of related papers. Conversely, BDA, the IoT and AM are more recent topics that have raised great interest, particularly in 2018. An increase was also seen in the number of papers relating to IT in 2018, but in contrast to the three aforementioned technologies, this is a topic that has been studied since the beginning of the considered time interval. Finally, barcodes and AGVs are not widely studied technologies, probably because they are more operative and practice-oriented, and they suffer from a lack of scientific studies, even though their applications are more widespread and frequent.

Table 3. Analysis of the number of papers for each technology and year

Technology	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
RFID	11	9	11	8	7	8	3	4	5	66
IT	6	3	5	4	3	2	5	7	11	46
Big Data Analytics						3	1	2	12	18
IoT			1	2		1	2	1	7	14
Additive Manufacturing					2		2	2	7	13
Cloud Computing					1	3	2	1	4	11
AGV						1		3	2	6
Barcode	1		2		1	1			1	6

4.2 Approaches for studying technology in logistics

Technology adoption in a specific application field can be analysed through different methodological perspectives. In some papers, the scientific literature is used to build theoretical models on the impacts of the development of technology on operational and managerial processes. For example, Tsai and Tang (2012) assumed from the scientific literature that the adoption level of RFID technology positively influences operational performance and then tested this hypothesis through a large-scale survey. Therefore, this type of methodology is referred to as *ex-post*. On the other hand, technologies can be investigated through a modelling framework and single or multiple case studies regarding the technologies' implementation steps, barriers and advantages in terms of future technological developments. These can be referred to as *ex-ante* methodologies.

Extant literature focuses more heavily on *ex-post* methods, which appear in 98 papers in the corpus, compared with *ex-ante* methods, which are proposed in 65 papers. The sum of the methodologies is higher than the overall number of papers in the corpus (152) due to the presence of multi-methodology papers. As mentioned above, *ex-post* studies rely heavily on large-scale *ex-post* surveys, which comprise 37% of *ex-post* methodologies (i.e. 36 papers out of 98). A case study methodology is proposed in 27 papers, and another significant share of papers investigates technology uptake through systematic or narrative literature reviews. The remaining 18 papers use various methods, such as quantitative case studies, content analysis or interviews and other qualitative methodologies (Figure 5).

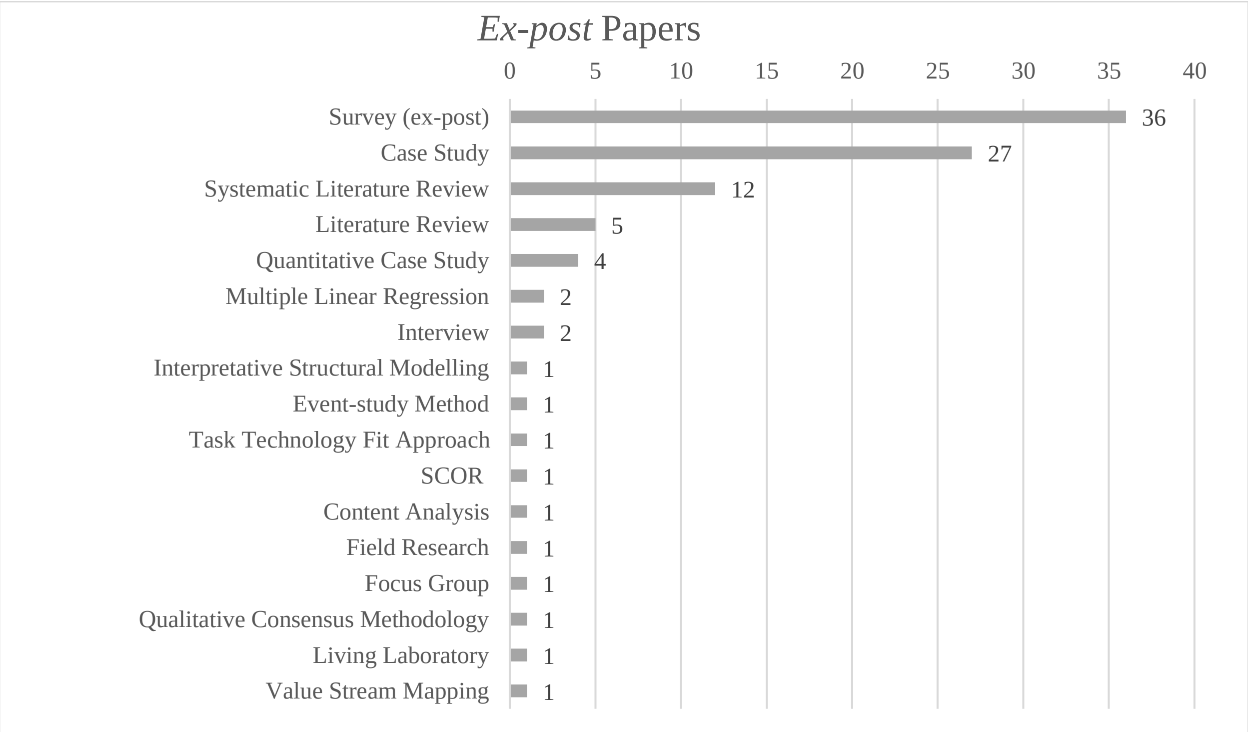

Figure 5. Methodologies used in ex-post papers

However, *ex-ante* papers are more divided across several research methodologies. In this regard, scholars can study technology adoption via the use of analytical formulation and optimisation algorithms, or through simulation models, which both use traditional approaches, such as discrete-event or system dynamics or the fine-tuning of the simulation to the case at issue. The most exploited methodologies in *ex-ante* papers are modelling the system architecture (17 papers), analytical models (10 papers), simulation models (7 papers), *ex-ante* surveys (7 papers) and queuing models (5 papers) (Figure 6).

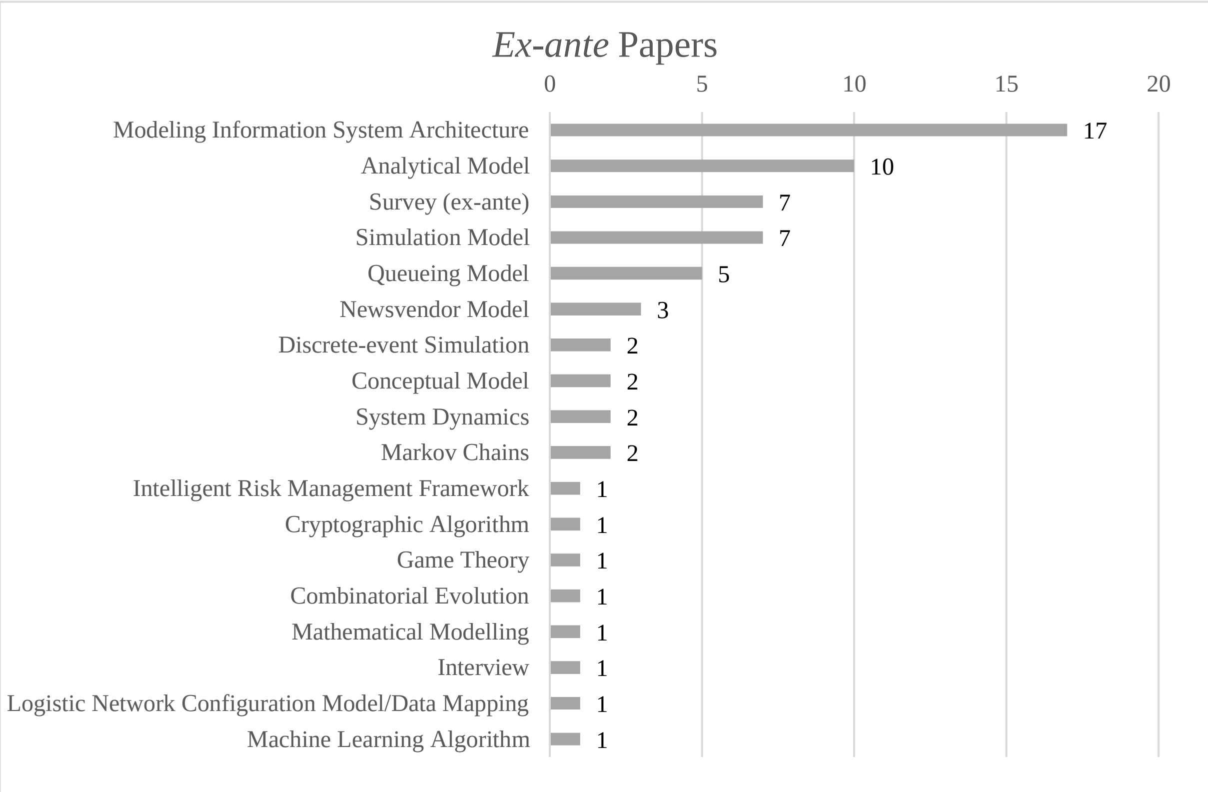

Figure 6. Methodologies used in ex-ante papers

Very few papers proposed an *ex-post* validation of an *ex-ante* methodology. Among them, Paltricccia and Tiacci (2016) proposed an analytical model to calculate total management costs of materials in a collaborative supply network, validate the model through a simulation study and apply the methodology to a real case study on the introduction of RFID. Lao et al. (2012) also derived the validation of their *ex-ante* system architecture model of RFID introduction for food safety control activities from a real case study application. Table 2 shows the trends in the methodologies that the *corpus* papers adopted during the period examined.

Table 2. *Ex-Post* and *Ex-Ante* methodologies per year

Ex-Post Methodologies	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
Ex-Post Survey	6	2	4	2	5	2	2	3	10	36
Case Study	3	4	4	3	3		4	3	3	27
Systematic Literature Review	1		1	1			1	2	6	12
Quantitative Case Study	2			1	1					4
Literature Review						2	1		2	5
Interview					1				1	2
Multiple Linear Regression		1						1		2
SCOR		1								1
Field Research						1				1
Event-Study Method									1	1
Content Analysis									1	1
Focus Group									1	1
Interpretative Structural Modelling									1	1
Task Technology Fit Approach				1						1
Value Stream Mapping				1						1
Qualitative Consensus Methodology									1	1
Living Laboratory			1							1
Total *Ex-Post* Methodologies	12	8	10	9	10	5	8	9	27	98

Ex-Ante Methodologies	2010	2011	2012	2013	2014	2015	2016	2017	2018	Tot
Modelling Information System Architecture	2		3	2	1	3	1	1	4	17
Analytical Model			2	2	1	1	1	3		10
Simulation Model	2		1	1					3	7
Ex-Ante Survey	1			1				3	2	7
Queuing Model						1		4		5
Newsvendor Model					1	1			1	3
Conceptual Model				1			1			2
Discrete-Event Simulation		1					1			2
System Dynamics									2	2
Markov Chains								2		2
Game Theory									1	1
Combinatorial Evolution					1					1
Cryptographic Algorithm			1							1
Mathematical Modelling		1								1

Intelligent Risk Management Framework							1			1
Ex-Ante Interview									1	1
Logistic Network Configuration Model			1							1
Machine Learning Algorithm									1	1
Total *Ex-Ante* Methodologies	5	2	8	7	4	6	5	13	15	65

Methodologies are classified as *ex-ante* or *ex-post*. For each one, methodologies are listed according to the decreasing order of total occurrences in the corpus. First, it can be observed that the use of surveys is proposed annually, with 10 published contributions in 2018. This methodology is suitable for evaluating perceptions (Nouri and Kyj, 2008) of new technology both at the beginning of its lifecycle and when a certain maturity level has been reached. Also, case study papers have been viewed as a suitable way to describe the innovation in technology, as demonstrated by the number of papers published from 2010 to 2018. Also, the process of modelling information system architecture has always attracted researchers' attention. In eight out of the nine years examined, at least one paper proposed this methodology.

SLRs acquired significant relevance in the final year of the analysis, and 6 out of the 11 papers identified were published in 2018. This result might be attributable to an increasing interest in the topic among academicians and the existing need to track trends and patterns in the logistics research context. Particularly in this field, several works focus on the impact of big data on SC capabilities, especially in terms of demand forecasting, human resources management and communications. It should be noted that five of the *ex-post* methodologies that were adopted in only one paper (event-study method, content analysis, focus group, interpretative structural model and qualitative consensus) were used in 2018, i.e. there might be a need for new methods to evaluate innovative technologies. However, when considering *ex-ante* methodologies, combinatorial evolution, cryptographic algorithm, mathematical modelling and logistics network configuration models were used in only one paper during the first part of the period of the study considered.

Previous analyses have shown that technology adoption is more likely to be studied through a survey of practical or theoretical implementations if the research objective is to study technology adoption after implementation (i.e. an *ex-post* study). Conversely, analytical formulation or simulation modelling best serves an *ex-ante* study perspective. A more detailed analysis is provided below to examine whether the methodological approaches outlined so far have been applied more frequently to specific technologies, i.e. scholars might have drifted toward a subset of the existing methodologies to study a specific technology. However, some methodologies may be relatively spread out across more technologies.

To elaborate on these research questions, the methodologies used with each technology are examined. In Table 4, the percentages of papers that use a specific methodology for analysing the essential technologies presented in the corpus are listed, namely RFID, big data analytics (BDA), ICT, additive manufacturing (AM), the IoT, cloud computing (CC) and AS/RSs and AGVs. Methodologies present in less than four papers are not included in the analysis. Also, it is possible that one paper discusses more than one technology, such as Gunasekaran et al. (2018), who refer to BDA, the IoT and blockchain.

Table 4. Share of methodologies used for each technology

	Technology							
Methods	Corpus	RFID	ICT	BDA	IoT	AM	CC	AS/RS, AGV
Survey (*ex-post*)	22%	13%	39%	21%	7%	8%	27%	-
Case Study	17%	26%	24%	16%	13%	-	9%	-
Modelling Information System Architecture	10%	14%	8%	11%	20%	-	27%	30%
Systematic Literature Review	7%	5%	6%	21%	7%	8%	-	-
Analytical Model	6%	11%	2%	5%	7%	-	-	-
Survey (*ex-ante*)	4%	1%	-	5%	13%	15%	9%	-
Simulation Model	4%	4%	6%	5%	7%	-	9%	10%
Literature Review	3%	1%	2%	5%	7%	8%	9%	-
Queuing Model	3%	-	-	-	-	-	-	50%
Quantitative Case Study	2%	4%	-	-	-	8%	-	-
Sum of Other Methods	20%	20%	12%	11%	20%	54%	9%	10%

The data show that ICT has a larger share of *ex-post* surveys and case studies than the corpus average, probably owing to a consolidated field with a large number of existing implementations. Case studies are also used often in RFID papers, probably because this is a technology that requires organisational changes and entails several aspects of the business. However, RFID is also studied through *ex-ante* formulations, i.e. the effects of RFID implementation are not yet as clear as they seem.

However, none of these methodologies is used to study AS/RSs and AGVs, given the innovative nature of such technologies, which have not yet seen large-scale implementation. Automated warehouses and guided vehicles are studied through *ex-ante* methodologies, such as queuing models and modelling information system architecture. Besides automated warehouses, modelling the system architecture is also used extensively for CC implementations. It can be argued that automated warehouses and CC are architectural, rather than stand-alone, innovations, requiring middleware platforms to connect various system components.

Furthermore, analytical and architectural formulations or simulation models are not present in AM literature, which instead comprises more *ex-post* methodologies. However, it should be noted that 54% of AM papers use methodologies that are not shared by other technologies and, thus, are not included in the analysis.

Literature reviews are used more often in BDA papers compared with the corpus average because this field is more theoretical than the others present in this study. As mentioned above, AM appears to be the most comprehensive technology across the various methodologies, but other technologies are investigated through a small subset of methodologies. To provide a mathematical formulation for this issue, we adopted the Herfindahl-Hirschman index (HHI), which was initially developed to assess market competitiveness and has been used in various research fields beyond economics (Depken, 1999; Wang et al., 2009; Gaultois et al., 2013). It has been used here to measure how open a technology is to different methodologies by measuring the concentration of methodologies used for that technology.

The HHI_j is calculated for each technology and the whole corpus as follows:

$$HHI_j = \sum_{i=1}^{n} (S_{ij})^2 \qquad \forall j \in J \tag{1}$$

in which S_{ij} is the share of $i \in I$ methodologies for $j \in J$ technologies.

Figure 7 confirms that papers focusing on automated warehousing and automated vehicles, as well as on ICT, are concentrated heavily within a few methodologies. Concerning AS/RS and AGV papers, these findings stem from the novelty of these innovative technologies, which still require strong mathematical foundations before being implemented on a large scale. CC represents the third most concentrated technology, owing to 6 methods out of 11 that are perfectly split between an *ex-ante* (i.e. modelling the system architecture) and an *ex-post* (i.e. *ex-post* surveys) methodology. Therefore, CC currently appears to be positioned halfway between being innovative and being established. Finally, Figure 7 shows that the IoT is the second most widespread technology.

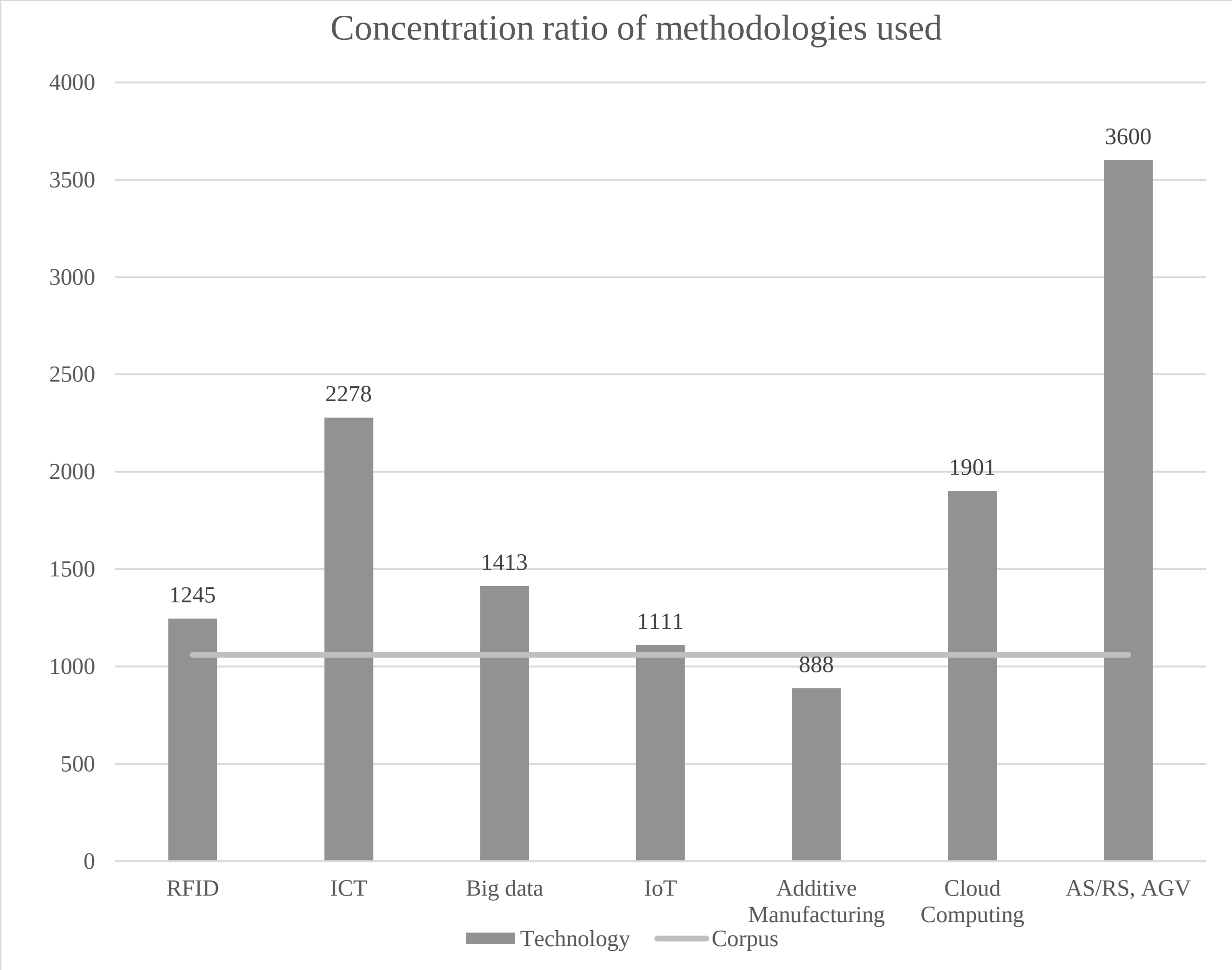

Figure 7. Concentration ratio of methodologies for the most studied technologies. The horizontal line represents the average concentration ratio for the whole corpus

5 Main Research Gaps

A gap analysis was carried out and classified inductively in a similar way to the main research trends. In particular, the classification of the gaps followed a two-stage approach (Lagorio et al., 2016). First, each author independently analysed the same subset of papers and inductively defined his/her list of gaps. After a review of these lists and a discussion among the authors, the final gap list was defined and applied to the remaining papers in the corpus. This second stage highlighted the substantial stability of the classification, as there were few disagreements, which the authors resolved on a case-by-case basis. The authors themselves highlighted the gaps in the articles, while, at other times, gaps emerged from limitation sections included in papers. Moreover, in some cases, gaps were found in the motivations that led the authors to make a specific choice regarding the research direction. Finally, certain gaps have been identified in topics that are not often investigated in the paper corpus (Anand et al., 2012).

The gaps have been classified according to the following factors: communications and integration, technology adoption processes, differences among inbound and outbound logistics and practitioners and academic insights.

5.1 Communications and integration

RFID appears to be the technology adopted most often, with 66 applications of this technology in the corpus. Thus, it is possible to assume that RFID makes the greatest impact.

Nevertheless, the adoption of RFID in SCs has changed during the past few years. In particular, in the first part of the period examined, RFID was studied as a stand-alone technology. It can be coherently noted that most of the papers published before 2014 were based on *ex-post* methodologies, such as surveys, case studies or systematic literature reviews. These contributions focused mostly on impacts, determinants and benefits arising from the adoption of RFID technology (Sarac et al., 2010; Smart et al., 2010; Osyk et al., 2012). More recently, a shift can be observed in terms of approaching the assessment of RFID, which has been studied in the context of other technologies and new fields of application. As a matter of fact, in the past few years, RFID has been applied in healthcare logistics, humanitarian logistics and cold logistics, revealing a broader spectrum in its fields of application. In the beginning, this technology was mainly exploited in more consolidated contexts, such as warehousing, inventory management and SCM.

More specifically, the IoT and BDA have demonstrably taken more advantage of this technology through opportunities in the data collection process offered by RFID (Shukla and Tiwari, 2017; Nguyen et al., 2018; Raman et al., 2018). Thus, RFID can be viewed as a crucial lever in the digital transformation of SCs in the sense that it enhances SC transparency and traceability (Haddud et al., 2017).

This demonstrates an increasing interest in academia in terms of the most innovative technological trends (such as the Industry 4.0 paradigm) and related applications in logistics contexts. Thus, scholars might help support claims that such technology provides efficiency, reduces operation costs and improves delivery times. Finally, to obtain more lasting success in future SC digital transformations, it is crucial that more *ex-ante* studies be conducted, e.g. concerning analytical frameworks. Despite a large number of papers related to RFID and the IoT in general, few papers have examined these technologies' benefits with regard to improving communications. However, before any investment can be made in the development of an ICT system aimed at improving communication and collaboration with other actors in the SC, a company should research the technological and information standards that partners use. Choosing a system that cannot "talk" with partners' systems can compromise the positive effects of the investment. Few extant studies have examined the benefits of IT system integration through the SC and how this technology can positively impact relationships with customers and suppliers. The complete exchange of information in real time is at the heart of the introduction of 4.0 technologies in logistics, allowing the continuous tracking of goods' positions and statuses. This upgrade in freight traceability could significantly improve communication between various SC levels, opening up new possibilities for collaboration between actors and the optimisation of order and shipment processes.

5.2 Technology adoption process

Although the importance of research into and the development of 4.0 technologies related to logistics are becoming increasingly clear, some technologies remain poorly applied. The low number of applications is due to high technology implementation costs and the little flexibility they offer concerning the effort required, which is defined not only in economic terms but also in terms of the resources to be employed, the skills, the necessary changes at the organisational level and the process management required for their implementation. This result demonstrates that, especially in some environments, such as city logistics (CL) and the digital supply chain (DSC), technological patterns remain in their infancy. For instance, the technologies adopted in CL are not yet well established, with innovations related mainly to regulation schemes implemented by public authorities and to projects aimed at facilitating stakeholders' coordination (Lan et al., 2020). A similar conclusion can be drawn regarding the DSC. A comprehensive, well-established and commonly adopted definition of the DSC has yet to be established, and most applications are based on the introduction of isolated digital capabilities in consolidated SC processes (Korpela et al., 2017). However, not only radical changes but also the incremental implementation of some of these technologies can lead to significant advantages, especially from the exchange of information within the SC.

Given these premises and the costs associated with the modernisation of machines and processes, these expectations are typical *ex-ante* research. Instead, by observing the methodologies adopted in the papers of the corpus, it is essential to note that there are fewer *ex-ante* papers than *ex-post* papers. This aspect was consistent during the entire period examined as the use of *ex-ante* approaches typically entails a lack of information (Striebing et al., 2019). *Ex-ante* methodologies, in this context, are used mostly for technologies that require a significant initial investment or that need to be integrated with an existing business or IT practices. This is the case with automated warehouses aided by AGVs. Logistics firms need to reorganise their warehouses for automated vehicles, and this could change the way companies organise their logistics tasks (e.g. picking and packaging). CC and IoT implementations also require the full coverage of logistics objects to enable effective communications between these objects and online applications; thus, they are often modelled and implemented around the reuse of existing software (Verdouw et al., 2018).

However, *ex-post* evaluations systematically and objectively analyse and assess a specific element's purpose, execution process, benefit, effect and influence (Liu et al., 2019). This means that in the field under study, it is more common to evaluate an actual set of information related to specific technology to assess the main success factors and criticalities.

Stemming from the previous discussions, it might be argued that more *ex-post* validations of an *ex-ante* methodology are needed, as very few papers propose such frameworks. This aspect calls for research that focuses on the evaluation of technologies through *ex-ante* methodologies via *ex-post* approaches after their actual implementation. This gap is particularly significant with regard to automated warehouses, which are already one of the largest logistics markets in the world. Moreover, new trade-offs should be examined through the evaluation of such technology, especially the automation of e-fulfilment centres, which increase efficiency levels but require flexible operations due to the increasing frequency and variety of goods handled in e-commerce contexts.

BDA implementations have so far been examined under two main perspectives, namely the theoretical lens of literature reviews and empirical research on survey-based studies. Therefore, this represents a research gap in terms of *ex-ante* methodologies for BDA applications, which researchers in this field could be motivated to fill.

However, unlike consolidated technologies, such as RFID and ICT, AM scholars have adopted a forward-looking perspective on how to understand the benefits and barriers associated with AM in SC and logistics contexts. AM scholars have examined issues in future application scenarios regarding AM in SCM contexts, rather than investigating the impact of consolidated industry practices. In this context, multiple barriers remain open for discussion, including intellectual property protection (Chan et al., 2018), employee training, regulations and customer awareness (Durach, Kurpjuweit and Wagner, 2017). Thus, further work on case studies is urgently needed to develop insights into how to reduce AM barriers and achieve large-scale mass production. Moreover, more quantitative *ex-ante* methodologies are needed to evaluate AM's overall impact on the level of inventories across the SC. Furthermore, there is no mention of the spread of either fabrication laboratories (i.e. FabLabs, which are small workshops that offer personalised digital manufacturing services) in more advanced cities or 3D printers in less-advanced countries (e.g. for the construction of medical prostheses or bricks).

5.3 Inbound and outbound logistics

The success of the application of IT differs between inbound and outbound logistics in the sense that the objectives that guide their adoption are different. Even if inbound and outbound logistics have the maximisation of productivity in common, thereby reducing time and costs and recognising the need to be better integrated, they concern different processes. This distinction gives rise to differences in the implementation and efficacy of IT solutions that are adopted. Although the selection criteria refer generically to logistics, most of the applications described in the analysed papers refer to internal logistics. For this reason, we found few references to the fields of transportation, smart cities and urban logistics, probably because outbound logistics are more complex, involving a greater number of stakeholders, both in the private sector (e.g. suppliers, carriers, customers) and in the public sector (e.g. local administrators and decision-makers). However, it is because of the severity of these criticalities that improvements in communications and real-time data accessibility are more desirable in outbound logistics than in other sectors. In particular, in light of the growing importance of sustainable last-mile processes, it would be interesting to assess the impact of logistics services providers' uses of technologies in urban environments.

5.4 Practitioners and academic insights

In the current 4.0 era, logistics processes aim to create transparent systems within which everyone can share and access information. In this way, logistics will not be a lever merely for enhancing the company's competitive advantage, but will play a supporting role in top management decisions by providing advanced insights and precious predictions. The primary Industry 4.0 technologies applied in the logistics field have been discussed thoroughly in this study. Among them, the IoT and big data have become crucial. Pallets and containers equipped with sensors will be able to transmit relevant shipment data, making it possible to deal with events such as delays and disruptions.

Similarly, big data will facilitate the understanding of different SCs' future scenarios. Through their large selection of data sources (from vehicle diagnostics to driving patterns and location information), big data are likely to lead to significant optimisation at different levels of logistics, warehousing and last-mile delivery processes. Also, these technologies are likely to disrupt the current processes of many modes of transport and logistics companies (Kunz et al., 2019).

Considering that the analysis of the scientific literature about technologies is also a way to test technologies' maturity (Lezama-Nicolás et al., 2018), what emerges from this research study is that many of the technologies frequently discussed among consultancies and practitioners (such as drones and blockchain) have still not reached their maturity. These potential future applications might lead to assumptions that we could be in a sort of hype phase, wherein technology's actual utility has not been demonstrated formally and broadly (Walker, 2017). This results in a so-called expectations race (Hoppmann et al., 2020) in which companies operate with ever-higher expectations to gather resources from many different stakeholders (Ruef and Markard, 2010). The articles that have analysed the state of the art in technological implementation in companies show that most of the companies, especially the smaller ones, remain in the middle of the transition process to 4.0 technologies and are focusing on understanding the requirements to make the best investments in terms of the competencies they need to acquire (Cimini et al., 2020). The most recent technologies' real potential remains fairly unknown, as they often are in the *trigger phase*, in which the spectrum of potential applications has not yet been explored fully, and the following phase, related to the trough of disillusionment, has yet to be reached (O'Leary, 2008). Consequently, investments will only continue if the surviving vendors can improve their products and services with regard to providing a higher level of customer satisfaction and meeting market requirements.

From an academic research perspective, several aspects are worth considering. More than 10 years ago, Giunipero et al. (2008) discussed some historical shortcomings of SCM literature. Analysing the SLR results laid out in this paper, the authors have found that most of the issues that Giunipero et al. (2008) proposed have been settled. For instance, survey papers in the corpus have consistently provided a thorough description of their sample strategies and response rates, including the collection of larger sample sizes that cover up to 625 respondent firms (Tan et al., 2010). Furthermore, results from survey papers have benefited from the use of more sophisticated statistical analyses, such as structural equation modelling (SEM) (Hafeez et al., 2010; Su and Yang, 2010; Ahmad and Mehmood, 2016; Jeble et al., 2018).

It can be argued that to achieve more significant sample sizes and better response rates, it is necessary for scholars to stimulate interest in logistics firms, thereby gaining valuable insights from improved relationships. A further indication of logistics scholars' enhanced ability to interact with firms is the vast amount of case studies present in the corpus. A case study methodology is particularly suitable when a complex phenomenon has either not been examined or has remained underexamined in the past (Acharya et al., 2018), enabling researchers to observe underlying human behaviours that unfold as a response to innovation-driven changes within complex organisations characterised by long-standing structures, working procedures to follow and stated or unstated incentives to reach (Feibert and Jacobsen, 2019). Thus, case studies can help grasp the complexity of technological innovation, which ultimately entails interactions with people. Therefore, scholars should expand their methodological toolkit by including longitudinal case studies and focus groups to unlock the full potential of firms' observations. However, logistics scholars, so far, have proposed conducting very few longitudinal case studies and focus groups (Teo et al., 2011; Wamba, 2012; Maqueira, Moyano-Fuentes and Bruque, 2019). Quantitative methods should also acknowledge behavioural aspects' effects on technological contexts and include them in mathematical formulations. Efforts in this direction are being made insofar as the application of methodological approaches, such as system dynamics (Ghadge et al., 2018; Kochan et al., 2018) and game theory (Gong, Kung and Zeng, 2018), have been tenuously gaining traction in recent years. In particular, more structured methodologies have recently arisen, such as content analysis, focus groups, system dynamics and game theory, even if they are not replacing more well-established ones. More traditional approaches, such as surveys and case studies, always capture the academic community's attention. Therefore, two main results can be highlighted. First, new technological solutions require innovative methodological approaches to accomplish more consolidated ones for a deeper understanding, e.g. content analysis, which is typically adopted in social sciences. Similarly, system dynamics is a simulation approach broadly adopted to describe complex systems' behaviours. It is broadly adopted in epidemiology to capture the diffusion of infections (Sterman, 2000) and has been proven to be effective in logistics that deal with higher complexity levels (Mangano et al., 2019; Cagliano et al., 2017).

Second, during more recent periods, aspects related to human behaviour and interactions have also been considered in the logistics context. For instance, game theory, adopted as an efficient method for investigating cooperation (Abapaur et al., 2020), can be used to increase the understating of companies' behaviours in logistics.

6 Conclusions

This research presents a systematic literature review of recent scientific works concerning the adoption of technologies in the logistics field. A corpus of 152 journal papers was analysed to highlight the main research trends and gaps that might drive future research on this topic.

In terms of the methodology used, more papers examined technology adoption from an *ex-post* perspective, particularly via surveys, case studies and literature reviews. On the other hand, *ex-ante* papers rely on analytical frameworks, optimisation algorithms or simulation models to estimate the impact of technology adoption. Moreover, by analysing the methodology used, it appears that the bulk of the literature is mostly explorative-oriented, with only a few studies reporting real performances after new technology is implemented.

Regarding implemented technologies, the most cited are RFID and IT. RFID is a consolidated technology that is viewed as one of the central elements in IoT system implementation, as well as as an enabler, rather than a stand-alone technology. BDA implementation can also benefit from opportunities in the data collection process from using RFID, showing promising results for its adoption in logistics management. However, more *ex-ante* methodologies are needed to help logistics managers understand the impact of using such technology. In the IT arena, CC is a suitable tool for efficiency in communication, but requires a reshaping of both intra-organisational and inter-organisational IT. Finally, AM has been attracting more interest in recent years, and consequently, scholars have started to examine the barriers and potential benefits associated with this technology.

This work provides some theoretical and practical implications. From a theoretical perspective, it integrates the literature in the logistics and supply chain management fields by identifying and classifying the main research streams related to the adoption and implementation processes regarding innovative technologies. Thus, this paper offers a current picture of the relationships between technologies and logistics management. From a practical perspective, this work might help logistics companies identify the technologies that are most likely to enhance their processes and select the best methodological tools for analysing the potential impact and implementation processes to be undertaken. This study might also help developers of technologies identify promising areas in businesses.

However, this research also has limitations. In particular, the research is limited to peer-reviewed journals, so conference papers were not considered. Future research might analyse technologies' role in logistics by using more innovative and complex methodologies to take human behaviours and interactions with technologies into consideration and to avoid the risk of not considering companies' needs in their digitisation processes. In particular, it is necessary to better understand how different technologies can be combined and integrated to take advantage of digital supply chains in order to create a systemic, integrated and collaborative environment.

References

Abapour, S., Nazari-Heris, M., Mohammadi-Ivatloo, B., & Hagh, M. T. (2020). Game theory approaches for the solution of power system problems: a comprehensive review. Archives of Computational Methods in Engineering, 27(1), 81-103.

Aguezzoul, A. (2014). Third-party logistics selection problem: A literature review on criteria and methods. Omega (United Kingdom), 49, 69–78. doi: 10.1016/j.omega.2014.05.009.

Ahmad, N. and Mehmood, R. (2016). Enterprise systems and performance of future city logistics. Production Planning & Control, 27(6), 500–513.

Alkhatib, S. F., Darlington, R. and Nguyen, T. T. (2015). Logistics service providers (LSPs) evaluation and selection literature review and framework development. Strategic Outsourcing, 8(1), 102–134. doi: 10.1108/SO-12-2014-0028.

Anand, N., Quak, H., van Duin, R., & Tavasszy, L. (2012). City logistics modeling efforts: Trends and gaps-A review. Procedia-Social and Behavioral Sciences, 39, 101-115.

Arunachalam, D., Kumar, N., & Kawalek, J. P. (2018). Understanding big data analytics capabilities in supply chain management: Unravelling the issues, challenges and implications for practice. Transportation Research Part E: Logistics and Transportation Review, 114, 416-436.

Baghdadi, A., Megahed, F. M., Esfahani, E. T., & Cavuoto, L. A. (2018). A machine learning approach to detect changes in gait parameters following a fatiguing occupational task. Ergonomics, 61(8), 1116-1129.

Belvedere, V. and Grando, A. (2017). ICT-enabled time performance: an investigation of value creation mechanisms. Production Planning and Control, 28(1), 75–88.

Björklund, M., & Forslund, H. (2018). A framework for classifying sustainable logistics innovations. Logistics Research, 11(1), 1-12.

Blankley, A. (2008). A conceptual model for evaluating the financial impact of supply chain management technology investments, The International Journal of Logistics Management, 19(2), 155–182. doi: 10.1108/09574090810895942.

Brinch, M., Stentoft, J., Jensen, J. K., & Rajkumar, C. (2018). Practitioners understanding of big data and its applications in supply chain management. The International Journal of Logistics Management, 29(2), 555-574.

Burgess, K., Singh, P. J., & Koroglu, R. (2006). Supply chain management: a structured literature review and implications for future research. International Journal of Operations & Production Management, 26(7), 703–729. DOI:10.1108/01443570610672202

Cachon, G. P. and Fisher, M. (2000). Supply Chain Inventory Management and the Value of Shared Information. Management Science, 46(8), 1032–1048.

Cagliano, A. C., Carlin, A., Mangano, G., & Rafele, C. (2017). Analyzing the diffusion of eco-friendly vans for urban freight distribution. *The International Journal of Logistics Management*. 28(4), 1218-1242

Centobelli, P., Cerchione, R., & Esposito, E. (2017). Environmental sustainability in the service industry of transportation and logistics service providers: Systematic literature review and research directions. Transportation Research Part D: Transport and Environment, 53, 454-470.

Chan, H. K., Griffin, J., Lim, J. J., Zeng, F., & Chiu, A. S. (2018). The impact of 3D Printing Technology on the supply chain: Manufacturing and legal perspectives. International Journal of Production Economics, 205, 156-162.

Chen, L., Zhao, X., Tang, O., Price, L., Zhang, S., & Zhu, W. (2017). Supply chain collaboration for sustainability: A literature review and future research agenda. International Journal of Production Economics, 194, 73-87.

Cimini, C., Boffelli, A., Lagorio, A., Kalchschmidt, M., & Pinto, R. (2019). How do Industry 4.0 technologies influence organisational change? An empirical analysis on Italian SMEs. Journal of Manufacturing Technology Management. https://doi.org/10.1108/JMTM-04-2019-0135

Cole, R., Lindsay, C. F., & Barker, F. (2018). Reverse exchange of healthcare devices: the case of hearing aid equipment in the UK. Production Planning & Control, 29(13), 1045-1057.

Cooper, M. C., Lambert, D. M. & Pagh, J. D. (1997). Supply Chain Management: More Than a New Name for Logistics. The International Journal of Logistics Management, 8(1), 1–14.

Depken, Craig A. (1999). Free-Agency and the Competitiveness of Major League Baseball. Review of Industrial Organization, 14(3), 205–17.

Dolati Neghabadi, P., Evrard Samuel, K., & Espinouse, M. L. (2019). Systematic literature review on city logistics: overview, classification and analysis. International Journal of Production Research, 57(3), 865-887.

Durach, C. F., Kurpjuweit, S. & Wagner, S. M. (2017). The impact of additive manufacturing on supply chains. International Journal of Physical Distribution & Logistics Management, 47(10), 954–971.

Evangelista, P., Mogre, R., Perego, A., Raspagliesi, A. & Sweeney, E. (2012). A survey based analysis of IT adoption and 3PLs' performance. Supply Chain Management: An International Journal, 17(2), 172–186.

Forman, H. and Lippert, S. K. (2005). Toward the development of an integrated model of technology internalization within the supply chain context. The International Journal of Logistics Management, 16(1), 4–27. doi: 10.1108/09574090510617330.

Gaultois, M. W., Sparks, T.D., Borg, C. K. H., Seshadri, R., Bonificio, W. D. & Clarke D. L. (2013). Data-Driven Review of Thermoelectric Materials: Performance and Resource Considerations. Chemistry of Materials, 25(15), 2911–20.

Ghadge, A., Karantoni, G., Chaudhuri, A., & Srinivasan, A. (2018). Impact of additive manufacturing on aircraft supply chain performance. Journal of Manufacturing Technology Management, 29(5), 846–865.

Giunipero, L. C., Hooker, R. E., Joseph-Matthews, S. A. C. H. A., Yoon, T. E., & Brudvig, S. (2008). A decade of SCM literature: past, present and future implications. Journal of supply chain management. Wiley Online Library, 44(4), 66–86.

Gong, F., Kung, D. S. and Zeng, T. (2018). The impact of different contract structures on IT investment in logistics outsourcing. International Journal of Production Economics, 195, 158–167.

Gunasekaran, A., Yusuf, Y. Y., Adeleye, E. O., Papadopoulos, T., Kovvuri, D., & Geyi, D. A. G. (2019). Agile manufacturing: an evolutionary review of practices. International Journal of Production Research, 57(15-16), 5154-5174.

Gunasekaran, A., Subramanian, N., & Papadopoulos, T. (2017). Information technology for competitive advantage within logistics and supply chains: A review. Transportation Research Part E: Logistics and Transportation Review, 99, 14-33.

Haddud, A., DeSouza, A., Khare, A. & Lee, H. (2017). Examining potential benefits and challenges associated with the Internet of Things integration in supply chains, Journal of Manufacturing Technology Management, 28(8), 1055-1085.

Hafeez, K., Keoy, K. H. A., Zairi, M., Hanneman, R., & Koh, S. L. (2010). E-supply chain operational and behavioural perspectives: an empirical study of Malaysian SMEs. International Journal of Production Research, 48(2), 525–546. doi: 10.1080/00207540903175079.

Hassan, M., Ali, M., Aktas, E., & Alkayid, K. (2015). Factors affecting selection decision of auto-identification technology in warehouse management: an international Delphi study. Production Planning & Control, 26(12), 1025-1049.

Hazen, B. T. and Byrd, T. A. (2012). Toward creating competitive advantage with logistics information technology. International Journal of Physical Distribution & Logistics Management, 42(1), 8–35.

Hoppmann, J., Anadon, L. D., & Narayanamurti, V. (2020). Why matter matters: How technology characteristics shape the strategic framing of technologies. Research Policy, 49(1), 103882.

Huan, S. H., Sheoran, S. K., & Wang, G. (2004). A review and analysis of supply chain operations reference (SCOR) model. Supply Chain Management: An International Journal, 9(1), 23-29.

Jafari, H. (2015). Logistics flexibility: a systematic review. International Journal of Productivity and Performance Management.

Jeble, S., Dubey, R., Childe, S. J., Papadopoulos, T., Roubaud, D., & Prakash, A. (2018). Impact of big data and predictive analytics capability on supply chain sustainability. The International Journal of Logistics Management, 29(2), 513–538.

Kagermann, H., National, Wahlster, W. & Helbig, J. (2013). Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0 —— Final Report of the Industrie 4.0 Working Group, Acatech, available at:https://doi.org/10.13140/RG.2.2.14480.20485.

Karakikes, I., Nathanail, E., & Savrasovs, M. (2018). Techniques for Smart Urban Logistics Solutions' Simulation: A Systematic Review. In International Conference on Reliability and Statistics in Transportation and Communication (pp. 551-561). Springer, Cham.

Kochan, C. G., Nowicki, D. R., Sauser, B., & Randall, W. S. (2018). Impact of cloud-based information sharing on hospital supply chain performance: A system dynamics framework. International Journal of Production Economics, 195, 168–185.

Korpela, K., Hallikas, J., & Dahlberg, T. (2017). Digital supply chain transformation toward blockchain integration. In *Proceedings of the 50th Hawaii international conference on system sciences*

Kunz, W. H., Heinonen, K., & Lemmink, J. G. (2019). Future service technologies: is service research on track with business reality?. Journal of Services Marketing.

Lagorio, A., Pinto, R. and Golini, R. (2016). Research in urban logistics: a systematic literature review', International Journal of Physical Distribution & Logistics Management, 46(10), 908–931. doi: 10.1108/IJPDLM-01-2016-0008.

Lan, S., Tseng, M. L., Yang, C., & Huisingh, D. (2020). Trends in sustainable logistics in major cities in China. Science of The Total Environment, 136381.

Lao, S. I., Choy, K. L., Ho, G. T. S., Tsim, Y. C., Poon, T. C. & Cheng, C. K. (2012). A real-time food safety management system for receiving operations in distribution centers', Expert Systems with Applications, 39(3), 2532–2548.

Leitão, P., Colombo, A. W. & Karnouskos, S. (2016). Industrial automation based on cyber-physical systems technologies: Prototype implementations and challenges. Computers in Industry, 81, 11–25.

LeMay, S., Helms, M. M., Kimball, B., & McMahon, D. (2017). Supply chain management: the elusive concept and definition. The International Journal of Logistics Management, 28(4), 1425-1453.

Lezama-Nicolás, R., Rodríguez-Salvador, M., Río-Belver, R., & Bildosola, I. (2018). A bibliometric method for assessing technological maturity: the case of additive manufacturing. Scientometrics, 117(3), 1425-1452.

Liu, Z., Prajogo, D. and Oke, A. (2016). Supply Chain Technologies: Linking Adoption, Utilization, and Performance. Journal of Supply Chain Management, 52(4), 22–41.

Liu, Y., Liu, T., Wang, B., & Xu, M. (2019). Developing a methodology for the ex-post assessment of Building Energy Efficiency Special Planning in Beijing during the 12th Five-Year Plan" period. Journal of cleaner production, 216, 552-569.

Lu, S., Xu, C., Zhong, R. Y., & Wang, L. (2017). A RFID-enabled positioning system in automated guided vehicle for smart factories. Journal of Manufacturing Systems, 44, 179-190.

Maman, Z. S., Yazdi, M. A. A., Cavuoto, L. A., & Megahed, F. M. (2017). A data-driven approach to modeling physical fatigue in the workplace using wearable sensors. Applied ergonomics, 65, 515-529.

Mangano, G., Zenezini, G., Cagliano, A. C., & De Marco, A. (2019). The dynamics of diffusion of an electronic platform supporting City Logistics services. *Operations Management Research*, *12*(3-4), 182-198.

Manyika, J., Chui, M., Brown, B., Bughin, J., Dobbs, R., Roxburgh, C., Hung, & A., Byers. (2011). Big Data: The Next Frontier for Innovation, Competition, and Productivity. McKinsey Global Institute.

Maqueira, M. J., Moyano-Fuentes, J., & Bruque, S. (2019). Drivers and consequences of an innovative technology assimilation in the supply chain: cloud computing and supply chain integration. International Journal of Production Research, 57(7), 2083-2103.

Marasco, A. (2008) Third-party logistics: A literature review. International Journal of Production Economics, 113(1), 127–147. doi: 10.1016/j.ijpe.2007.05.017.

Mariani, M. and Borghi, M. (2019). Industry 4.0: A bibliometric review of its managerial intellectual structure and potential evolution in the service industries. Technological Forecasting and Social Change, 149, ISSN119752.

Meyer, G., Buijs, P., B. Szirbik, N., & Wortmann, J. C. (2014). Intelligent products for enhancing the utilization of tracking technology in transportation. International Journal of Operations & Production Management, 34(4), 422-446.

Min, H., Park, J. W., Lim, Y. K., So, A., & Cho, Y. K. (2016). Challenges and opportunities for implementing X-ray scanning technology at the Korean hub ports. International Journal of Logistics Systems and Management, 25(4), 513-531.

Mokaddem, Y. E., & Jawab, F. (2019). Researches and applications of intelligent transportation systems in urban area: systematic literature review. ARPN J. Eng. Appl. Sci, 14(3), 639-652.

Neubert, G., Dominguez, C. & Ageron, B. (2011). Inter-organisational alignment to enhance information technology (IT) driven services innovation in a supply chain: the case of radio frequency identification (RFID). International Journal of Computer Integrated Manufacturing, 24(11), 1058–1073.

Nguyen, T., Li, Z. H. O. U., Spiegler, V., Ieromonachou, P., & Lin, Y. (2018). Big data analytics in supply chain management: A state-of-the-art literature review. Computers & Operations Research, 98, 254-264.

Nilsson, F. and Gammelgaard, B. (2012). Moving beyond the systems approach in SCM and logistics research. International Journal of Physical Distribution and Logistics Management, 42(8/9), 764–783. doi: 10.1108/09600031211269749.

Nouri, H., & Kyj, L. (2008). The effect of performance feedback on prior budgetary participative research using survey methodology: An empirical study. Critical Perspectives on Accounting, 19(8), 1431-1453.

O'Leary, D. E. (2008). Gartner's hype cycle and information system research issues. International Journal of Accounting Information Systems, 9(4), 240-252.

Oliveira, C. M. D., Albergaria De Mello Bandeira, R., Vasconcelos Goes, G., Schmitz Gonçalves, D. N., & D'Agosto, M. D. A. (2017). Sustainable vehicles-based alternatives in last mile distribution of urban freight transport: A systematic literature review. Sustainability, 9(8), 1324.

Osyk, B. A., Vijayaraman, B.S., Srinivasan, M. & Dey, A. (2012). RFID adoption and implementation in warehousing. Management Research Review, 35(10), 904-926

Paltriccia, C. and Tiacci, L. (2016). Supplying Networks in the Healthcare Sector: A New Outsourcing Model for Materials Management. Industrial Management & Data Systems, 116 (8), 1493–1519.

Pohjosenperä, T., Kekkonen, P., Pekkarinen, S., & Juga, J. (2019). Service modularity in managing healthcare logistics. The International Journal of Logistics Management, 30(1), 174-194.

Prajapati, H., Kant, R., & Shankar, R. (2018). Bequeath life to death: State-of-art review on reverse logistics. Journal of Cleaner Production, 211, 503-520.

Raman, S., Patwa, N., Niranjan, I., Ranjan, U., Moorthy, K., & Mehta, A. (2018). Impact of big data on supply chain management. International Journal of Logistics Research and Applications, 21(6), 579-596.

Romero, A. and Lefebvre, E. (2015). Combining barcodes and RFID in a hybrid solution to improve hospital pharmacy logistics processes. International Journal of Information Technology and Management, 14(2-3), 97-123.

Roy, D., Krishnamurthy, A., Heragu, S. S., & Malmborg, C. (2017). A multi-tier linking approach to analyze performance of autonomous vehicle-based storage and retrieval systems. Computers & Operations Research, 83, 173-188.

Ruef, A., & Markard, J. (2010). What happens after a hype? How changing expectations affected innovation activities in the case of stationary fuel cells. *Technology Analysis & Strategic Management*, *22*(3), 317-338.

Sarac, A., Absi, N., & Dauzere-Peres, S. (2015). Impacts of RFID technologies on supply chains: a simulation study of a three-level supply chain subject to shrinkage and delivery errors. European Journal of Industrial Engineering, 9(1), 27-52.

Selviaridis, K. and Spring, M. (2007). Third party logistics: A literature review and research agenda', The International Journal of Logistics Management, 18(1), 125–150. doi: 10.1108/09574090710748207.

Shang, K. C. and Marlow, P. B. (2005). Logistics capability and performance in Taiwan's major manufacturing firms. Transportation Research Part E: Logistics and Transportation Review, 41(3), 217–234.

Shukla, M., and Tiwari, M. K. (2017). Big-data analytics framework for incorporating smallholders in sustainable palm oil production. Production Planning & Control, 28(16), 1365-1377.

Skipper, J. B. et al. (2008). Towards a theoretical foundation of supply network interdependence and technology-enabled coordination strategies. International Journal of Physical Distribution and Logistics Management, 38(1), 39–56. doi: 10.1108/09600030810857201.

Smart, A. U., Bunduchi, R., & Gerst, M. (2010). The costs of adoption of RFID technologies in supply networks. International Journal of Operations & Production Management, 30(4), 423-447.

Soni, G. and Kodali, R. (2010). Internal benchmarking for assessment of supply chain performance. Benchmarking: An International Journal, 17(1), 44–76.

Sterman, J.D. (2000), Business Dynamics: Systems Thinking and Modeling for a Complex World,

McGraw-Hill, New York, NY.

Striebing, C., Schmidt, E. K., & Palmén, R. (2019). Pragmatic ex-ante evaluation using an innovative conceptual framework: The case of a high-tech entrepreneurship program for women. Evaluation and program planning, 77, ISSN 101714.

Su, Y. and Yang, C. (2010). A structural equation model for analyzing the impact of ERP on SCM. Expert Systems with Applications, 37(1), 456–469. doi: 10.1016/j.eswa.2009.05.061.

Subramanian, N., Abdulrahman, M. D. and Zhou, X. (2015). Integration of logistics and cloud computing service providers: Cost and green benefits in the Chinese context. Transportation Research Part E: Logistics and Transportation Review, 74, 81–93.

Tan, K. C. et al. (2010). Supply chain information and relational alignments: mediators of EDI on firm performance, International Journal of Physical Distribution & Logistics Management, 40(5), pp. 377–394.

Teo, T. S. H. et al. (2011). A framework for stakeholder oriented mindfulness: Case of RFID implementation at YCH Group, Singapore. European Journal of Information Systems, 20(2), 201–220. doi: 10.1057/ejis.2010.58.

Touboulic, A. and Walker, H. (2015). Theories in sustainable supply chain management: a structured literature review. International Journal of Physical Distribution & Logistics Management, 45(1/2), 16–42.

Tranfield, D., Denyer, D. & Smart, P. (2003). Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. British Journal of Management, 14(3), pp. 207–222.

Tsai, W.-C. and Tang, L.-L. (2012). A model of the adoption of radio frequency identification technology: The case of logistics service firms. Journal of Engineering and Technology Management, 29(1), pp. 131–151.

Verdouw, C.N., Robbemond, R.M, Verwaart, T., Wolfert, J. & Beulens, A. J. M. (2018). A reference architecture for IoT-based logistic information systems in agri-food supply chains. Enterprise Information Systems, 12(7), 755-779. DOI: 10.1080/17517575.2015.1072643

Wallin, C., Johnny Rungtusanatham, M., & Rabinovich, E. (2006). What is the "right" inventory management approach for a purchased item? International Journal of Operations & Production Management, 26(1), 50-68.

Walker, Mike. 2017. Hype Cycle for Emerging Technologies, 2017. Stamford: Gartner

Wamba, S. F. (2012). Achieving supply chain integration using RFID technology, Business Process Management Journal, 18(1), pp. 58–81.

Wang, J., Shahidehpour, M., Li, Z. & Botterud, A. (2009). Strategic Generation Capacity Expansion Planning with Incomplete Information. IEEE Transactions on Power Systems, 24(2), 1002–1010.

Winkelhaus, S., and Grosse, E. H. (2019). Logistics 4.0: a systematic review towards a new logistics system. International Journal of Production Research, 1-26.

Wohlin, C. (2014). Guidelines for snowballing in systematic literature studies and a replication in software engineering. In Proceedings of the 18th international conference on evaluation and assessment in software engineering, ACM, May 2014.

Yang, T., Fu, C., Liu, X., Pei, J., Liu, L. & Pardalos, P. M. (2018). Closed-loop supply chain inventory management with recovery information of reusable containers, Journal of Combinatorial Optimization, 35(1), 266–292.