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Embracing supply chain digitalization and unphysicalization to enhance supply chain performance: a conceptual framework

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Abstract

Purpose – The paper presents a research methodology that could be used to carry out a systematic literature review on the current state of the art of the technological development in the field of the digitalization and unphysicalization of supply chains (SCs). A three-dimensional conceptual framework focusing on the relationship between Digital Technologies (DTs), business processes and SC performance is presented. The study identifies the emerging practices and areas of SC management that could be positively affected by the implementation of DTs. With this in mind, the emerging practices have a high probability to be considered future best practices.

Design/methodology/approach – A systematic literature review was conducted on DTs in SC management. The methodology used aims to algorithmically and objectively standardize the information incorporated into thousands of scientific documents. Selected papers were analyzed to investigate the recent literature on SC digitalization and unphysicalization. A total of 87 DTs were selected to be analyzed and subsequently grouped into 11 macro-categories. 17 business processes linked to SC management are taken into account and 17 different impacts on SC management are presented. From a set of 1,585 papers, 5,060 emerging practices were collected and singularly summarized combining DT, business process and impact on SC performance.

Findings – A unique analytical perspective provided represents an important evolution when trying to organize the current literature on SC management. The widely used DTs in the practices and the most considered business processes and impacts are highlighted and described. The three-dimensional conceptual framework is graphically represented to allow for the emergence of the best combinations of DT, business

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process and impact on SC performance. These combinations suggest the most promising areas for the implementation of the emerging practices for SC digitalization and unphysicalization. Additional findings identify and define the most important contexts in which Big Data contributes to SC performance.

Originality/value – The research methodology used is offering progress through which to systemize the current practices as well as detect the potential of digitalization and unphysicalization under the three-dimensional conceptual framework. The paper provides a structured proposal for promising future research directions, assuming that the five research gaps as findings of this research could be the basis for prescriptions, as well as a future research agenda and theory development. Moreover, this research contributes to current managerial issues concerning SC management, referred to data and information management, efficiency and productivity of SC processes, market performance, SC relationship management and risk management in SC.

Keywords Supply chain management, Supply chain performance, Supply chain digitalization, Digital technologies, Unphysicalization, Artificial intelligence, Blockchain, Big data

Paper type Research paper

1. Introduction

Since the development of the Industry 4.0 paradigm, the issues of SC digitalization and unphysicalization have been widely investigated in literature (Nayal *et al.*, 2022; Rasool *et al.*, 2022; Wamba and Queiroz, 2022). The key elements of Industry 4.0 are interconnection, integration and relationship among firms (Toktaş-Palut, 2022; Tortorella *et al.*, 2022). Therefore, the Digital Technologies (DTs) linked to such a paradigm find the perfect context of application in supply chains (SCs), where various actors are engaged in cooperation, coordination and collaboration activities (Gebhardt *et al.*, 2021; Patrucco *et al.*, 2022). While digitalization is the switch from analogic to digital information, the term “unphysicalization” means the replacement and reduction of physical flows (Malhotra *et al.*, 2005). SC digitalization and unphysicalization lead to improving market performance, internal productivity and SC efficiency. Several studies have investigated the implementation of DTs in various business functions and processes as well as within many industries through the presentation of case studies and simulations (Clancy *et al.*, 2023; Huynh, 2022; Varriale *et al.*, 2021). Current literature on SC digitalization and unphysicalization consists of thousands of scientific articles, resulting in a fragmented and wide range of new business practices, solutions and applications, linked to numerous technologies, while also affecting various SC processes with different impacts (Hofmann *et al.*, 2019; Raji *et al.*, 2021). Embracing SC digitalization and unphysicalization is challenging and requires the implementation of pioneering DTs, whose benefits for SC are uncertain and not assured. Additionally, the world of DTs is dynamic, with the constant development of new high-paced DTs that are a consequence of technological progress (Park *et al.*, 2021; Varriale *et al.*, 2022). Supply chains can also leverage the emerging business models of the digital supply chain by transforming an organization into a digital supply chain (Alicke *et al.*, 2016). Therefore, it is complex to constantly monitor the technological evolution of Industry 4.0 technologies (Kapoor and Klueter, 2020). Some technologies will demonstrate their usefulness in the context of SC management, while others will fail or become obsolete. Promising technologies will support the implementation of emerging practices tested overtime in specific business contexts until a limited group demonstrates its stability in terms of SC performance enhancement. The results obtained from the lesson learned will constitute future best practices (Spieske and Birkel, 2021).

To date, there is no conceptual framework that explains the state of the art of the emerging practices for SC digitalization and unphysicalization. The main aim of this paper is to design a framework that, leveraging on years of scientific research carried out by scholars, provides a schema of new emerging practices using DTs that can potentially replace the current best practices for smart SC management. With the objective of detecting future best practices, there is a need to delineate the boundaries of application of each practice by defining (1) the SC process where it is possible to implement it, (2) the specific DTs used and (3) the expected impact on SC performance. In other terms, it is necessary to clarify how organizations can unphysicalize and digitalize their SCs.

By performing a systematic literature review (SLR) on SC digitalization and unphysicalization, information about these practices can be collected and classified using a taxonomy of labels linked to the SC process, SC performance and adopted DT. This will lead to the identification of the most recurring emerging practices that can be implemented within SCs to improve their performance. Since scientific research anticipates business developments (Cammarano *et al.*, 2022a; Martin, 2010), it suggests how the traditional SCs are going to evolve over the next years due to SC unphysicalization and digitalization. Through the research methodology strategy developed, a clear frame of the current literature on SC digitalization and unphysicalization highlights five research gaps that represents future developments on the topic.

A total of 87 technologies are taken into account. To simplify the discussion, they are grouped into the following 11 macro-categories: 3D printing, artificial intelligence, blockchain, computing, digital applications, geo-spatial tech, immersive environments, Internet of Things, open and crowd-based platforms, proximity tech and robotics. It is crucial to distinguish among DTs, since each one could be more or less suitable for a specific context of application within SC, that is depending on the specific business process and the purpose of the SC performance enhancement. This justifies the proposed multidimensional perspective, which is necessary so as to address the complexity of the issue of SC digitalization and unphysicalization. In addition, since Big Data (BD) are at the centre of the debate on SC digitalization, the eventual use within emerging practices will be also taken into account to find out the areas of useful implementation.

The paper is structured as follows. The first section describes the research strategy and design in using the literature review, the criteria for selecting the scientific papers and how emerging SC practices were identified. Then, a classification of the emerging practices detected from the literature review is presented in order to show how a standardized taxonomy was implemented to build the conceptual framework. Furthermore, the results from the analysis of the emerging SC practices are presented, also showing a schema that links the SC processes, DTs and expected impact on SC performance. The discussions section will comment on the value of such a framework, suggesting future research direction and linking the results of the analysis with practical challenges in SC management. Finally, some conclusions will close the work.

2. Research background

Theory on SC digitalization and unphysicalization can be grouped in two research streams, that is a theoretical/conceptual discussion versus a practical application. From the first perspective, a large group of scientific papers is focused on theoretical and conceptual research aimed at highlighting the role of digitalization within SCs. These papers suggest changes in the relationship among SC partners, as well as the need for an internal process reengineering, along with changes in the management and governance of each SC actor (Agnihotri *et al.*, 2022; Cammarano *et al.*, 2021; Yang and Lirn, 2017). Studies have focused on concepts such as smart SC, automation, integration and interconnection (Felstead, 2019; Szalavetz, 2019). A conclusion of the first stream is that “smart [and] connected products require a whole new supporting technology infrastructure” (Porter and Heppelmann, 2015, p. 994).

Regarding the second perspective, there are case studies and real-world applications focused on the implementation of specific technologies, such as artificial intelligence, drones, blockchain and cloud computing (Helo and Hao, 2021; Nascimento *et al.*, 2020).

From this field, the significant contribution of digitalization on the impact on either physical or information flows has been widely discussed (Loske and Klumpp, 2022; Yang *et al.*, 2021). New emerging business practices have been suggested, determining changes in business processes and traditional SC activities. Moreover, changes in data management, as a consequence of the availability of huge amounts of data collected and shared among SC partners, lead to greater support for decision making and operations management. This has been additionally stimulated by the expansion of Big Data and data analytics techniques within SCs (Handfield *et al.*, 2019; Xu *et al.*, 2021). According to Mital *et al.* (2018), the profitability of an enterprise depends on the performance of its SC that can also depend on the digitalization. Ardito *et al.* (2018) suggest that, "the research area related to supply chain management is the most interested in analyzing the implications of adopting Big Data analytics" (p. 2001).

In summary, both the theoretical and practical discussions on SC digitalization and unphysicalization have tried to highlight the advantages of innovating SCs by implementing DTs in SC processes. The adoption of DTs and the consequent role of digitalization and unphysicalization are seen as a possible solution to addressing traditional and new issues featuring SCs, such as:

(1) Need for new solutions to optimize information flows by relying on DTs, the related data and information management (Di Vaio and Varriale, 2020);

(2) Opportunities of enhancing efficiency and productivity of the SC processes by taking advantage of the opportunities coming from digitalization and unphysicalization (Loske and Klumpp, 2022);

(3) Value of the relationship with customers and the chance to carry out new ways to enter into contact with clients and manage relationships, with the aim of improving market performance and customer satisfaction (Das and Hassan, 2022);

(4) Changes in SC relationships management with the growing necessity for coordination, cooperation, alignment and integration among SC members aimed at reducing both the transaction costs as well as the time spent on the relationship (Nayal *et al.*, 2022);

(5) Managing risks linked to SCs, avoiding any interruption and disruptions caused by (i.e.) pandemics, cybersecurity issues, economic instability, wars and environmental disasters (Doetzer and Pflaum, 2021).

There is a lack of contributions in current literature that provide a comprehensive overview of the state of the art of multiple DTs and that propose multidimensional perspectives to address the aforementioned issues. It is also still fragmented into thousands of papers discussing case studies focused on one or relatively few DTs. Similarly, current literature reviews investigate a limited number of DTs without studying in detail the relationship among DTs, business processes and expected impact on performance (Büyüközkan and Göçer, 2018; Kamble *et al.*, 2018). Both the fragmentation of current literature and the complexity of the topic lead to difficulties in collecting information incorporated into thousands of contributions. Portraying the current state of the art of SC digitalization and unphysicalization by providing conceptual frameworks to implement DTs in SCs and identifying emerging practices that are the best candidates to become future best practices is a veritable challenge. The paper aims to fill this research gap by proposing a research methodology to algorithmically and objectively investigate literature as well as build a conceptual framework of three dimensions-DT, business process and impact-which is able to find patterns of possible DTs large scale implementation.

3. Research methodology

In this study a SLR was used, which is a method that guarantees reproducibility and summarizes the theoretical progress in which there is a large number of studies (Tranfield *et al.*, 2003). The SLR developed aims to understand which DTs impact on SC management and how. The methodology section is organized as follows: (1) research database and keywords, (2) criteria for identifying emerging practices and (3) the classification scheme used to analyze the data (Petersen *et al.*, 2015).

3.1 Definition of research database and keywords

The research was carried out exclusively in Scopus. A single database was used to improve the rigor, clarity and replicability (Cammarano *et al.*, 2022b; Paré *et al.*, 2015). The main reasons for using Scopus are twofold. Firstly, it is a large multidisciplinary database covering published articles, books, book chapters and proceedings in the humanities and science disciplines (Bramer *et al.*, 2016; Festa *et al.*, 2018). Secondly, it is possible to search by specific research areas. This aspect makes the study possible when considering that the SLR results highlight the fragmented and complex literature concerning DTs in supply chain management. The areas considered in this study are detected from the articles selected through the SLR and published in international journals within the subject area "business, management and accounting, economics, econometrics and finance" in Q1 and Q2 quartiles according to Scimago Journal Ranking and ISI Web of Science.

The 87 technologies identified for the analysis, the 11 macro-technologies in which they are categorized and the relative search keywords used in the search string in the title and keyword fields are reported in Table 1.

Regarding the proposed taxonomy, current literature lacks a general and acknowledged classification of DTs even if there are several articles. However, these classifications refer to specific industries and areas of applications as well as refer to one or relatively few macro-technologies (Cañas *et al.*, 2021; Ghobakhloo, 2020). Thus, the suggested taxonomy of DTs tries to summarize and merge available classifications with the categories of DTs emerging from the study of thousands of scientific articles carried out for this study. In Table 1 for each macro-technology, references to papers on SC management are reported to justify their relevance in the research field. For each technology, the query implemented on SCOPUS is the combination of the following elements: *[SUBJAREA] AND [PUBYEAR] AND [KEYWORDS]*. In particular, *[SUBJAREA]* refers to the query conditions to filter the results with the journal within the aforementioned subject areas, whereas *[PUBYEAR]* allows to consider only papers published from 2019 to 2022. As for *[KEYWORDS]*, only papers disclosing at least one keyword within either the title or keywords fields are selected. For example, the following query is used for blockchain:

[SUBJAREA] AND [PUBYEAR] AND (TITLE ("distributed ledger") OR KEY ("distributed ledger") OR TITLE ("blockchain") OR KEY ("blockchain") OR TITLE ("cryptocurrency") OR KEY ("cryptocurrency") OR TITLE ("smart contract") OR KEY ("smart contract") OR TITLE ("non-fungible token") OR KEY ("non-fungible token") OR TITLE ("NFT") OR KEY ("NFT"))

3.2 Criteria for identifying emerging practices

A content analysis was carried out by a group of management engineering experts involved in the study. The first step is to manually identify any emerging practices based on the use of DTs in the business world in each article. The term "emerging practice" indicates a new non-standard way of implementing a DT within a business process in order to achieve a specific positive impact on SC performance. Thus, emerging practices are investigated with this methodology, according to a multidimensional perspective and summarized as the

3D printing (3DP)	Binder jetting; bio-printing; direct energy deposition; fused filament fabrication; fused deposition modelling; laminated object manufacturing; polyjet; powder bed fusion; stereolithography	3D printing; 3D printer; additive manufacturing; rapid prototyping; rapid tooling; bio printing; direct energy deposition; direct metal laser sintering; fused filament fabrication; fused deposition modelling; polyjet; powder bed deposition; selective laser sintering; stereolithography; blinder jetting	(Attaran, 2020; Dong *et al.*, 2021; Zheng *et al.*, 2020)
Artificial Intelligence (AI)	Artificial neural network; Classification algorithm; Computer vision; Deep learning; Metaheuristic Algorithm; Natural language processing; Regression algorithm; Reinforcement Learning; Unsupervised learning	artificial intelligence; machine learning; metaheuristic; unsupervised learning; supervised learning; deep learning; computer vision; natural language processing; cognitive computing; artificial neural network; Reinforcement Learning; speech technology; speech synthesis; speech recognition; speech encoding; text-to-speech; speech-to-text; data analytics; data mining; data standardization; advanced analytics; predictive analytics; sentiment analysis; content analysis; text mining; user behavior analytics	(Dong *et al.*, 2021; Fatorachian and Kazemi, 2021; Riahi *et al.*, 2021)
Blockchain (BC)	Blockchain; Cryptocurrencies; NFT; Other distributed ledgers; Smart contracts	distributed ledger; blockchain; cryptocurrency; smart contract; non-fungible token; NFT	(Gurtu and Johny, 2019; Karakas *et al.*, 2021)
Computing (COM)	Cloud computing; Cloud storage; Cloudlet computing; Edge computing; Fog computing; Quantum computing	cloud computing; cloud storage; fog computing; edge computing; quantum computing; cloudlet computing	(Adamson *et al.*, 2017; Efthymiou and Ponis, 2021)
Digital Applications (DIGs)	API/webservices; Chatbot; Contact center automation; Digitization technologies; Mobile applications; Robotic process automation; Social media and network; Web applications and platform	digital platform; digital application; mobile application; social media; social network; web application; Application Programming Interface; web service; robotic process automation; software bots; digital signature; electronic signature; digital invoice; electronic invoice; digital contract; electronic contract; certified email; electronic storage; electronic document; digital document; electronic certificate; digital certificate; electronic archive; digital archive; dematerialization; dematerialized document; dematerialized archive; digitization; digital preservation	(Núñez-Merino *et al.*, 2020; Winkelhaus and Grosse, 2020)

(*continued*)

Table 1. List of macro-technologies, technologies and keywords

Geo-Spatial Tech (GEO)	Geographic information systems; Geo-spatial intelligence; Global navigation satellite system; Global positioning system; Remote sensing; Spatial analytics; Web mapping	Geo-spatial tech; Geo-spatial intelligence; geographic information systems; GIS; global navigation satellite system; GNSS; Web mapping; Remote sensing; global positioning system; GPS; Spatial modelling; Spatial analytics	(Oztemel and Gursev, 2020; Rejeb *et al.*, 2022)
Immersive Environments (IMMs)	Augmented reality; Digital Human; Digital twin; Gamification; Holograms; Metaverse; Mixed reality; Virtual reality	Augmented reality; digital twin; extended reality; gamification; mixed reality; virtual reality; metaverse; hologram; digital human	(Rejeb *et al.*, 2021a; da Silva *et al.*, 2019)
Internet Of Things (IOTs)	Internet of Things; 5G networks; Internet of Vehicles; LoRa; Mobile sensing; Smart sensors; Wearables; Wireless sensors	Internet of things; IoT; smart sensor; wearable sensor; 5G; wireless sensors; LoRa; mobile sensing; Internet of Vehicles	(Hofmann and Rüsch, 2017; Manavalan and Jayakrishna, 2019)
Open And Crowd-Based Platforms (OCPs)	Crowdfunding platform; Crowd shipping platform; Crowdsourcing platform; Open access; Open data; Open innovation platform; Open science; Open source	open science; open source; crowdsourcing; open data; crowd science; open access; crowd shipping; crowdfunding platform; open innovation platform	(Cricelli *et al.*, 2022; Messeni Petruzzelli *et al.*, 2019)
Proximity Tech (PRO)	Biometrics; Proximity sensors; Beacon; Bluetooth; Motion detectors; Near field communication; Qrcode/datamatrix; RFID	proximity tech; proximity sensor; beacon; RFID; Radio Frequency Identification; near field communication; NFC; QR code; datamatrix; bluetooth; motion detector; biometric; gaze tracking; facial recognition; eye tracking	(Ali and Phan, 2022; Musa and Dabo, 2016)
Robotics (ROB)	Autonomous mobile robot; AS/RS; Autonomous (driverless) vehicles; Cobot; Industrial robot; Service robot; Unmanned aerial vehicle; Unmanned ground vehicles; Unmanned underwater vehicles; Wearable robot	robotic; industrial robot; service robots; cobot; drone; autonomous vehicle; driverless vehicle; autonomous mobile robot; AMR; wearable robot; bionic robot; exoskeleton; AS/RS; social robot; robot-assisted gait training; robotics parcel lockers; Robot-assisted surgery; Unmanned ground vehicles; Unmanned underwater vehicles; Unmanned aerial vehicles	(Agnusdei *et al.*, 2022; da Silva *et al.*, 2019)

Table 1.

combination of the implemented DT, the business process using it and the expected impact on the performance (Figure 1).

The experts read scientific articles and intercepted those that clearly reported how DTs could be used in companies in order to promote emerging practices and gain a business advantage. The search on Scopus provided 78,108 studies covering a time horizon ranging from January 2019 to May 2022. From this articles list, a sample of 21,488 articles, equally distributed in various technologies, were searched. However, 1,131 documents were not downloadable. Therefore, 20,357 articles were analyzed. The articles suitable for the classification are those in which it is clear how the technologies impact on SCs and in what business process they have been used. For the purposes of this study, 1,585 suitable documents associated with SC management and DTs were selected. The selected articles contain all the information necessary to identify any emerging practices, that is which technologies are applied, in which business processes and with which impacts on market and organizational performance. Since the articles are useful for the analysis only it is possible to find out an emerging practice exhaustively described and well-connected with the business process and the expected impact on SC performance, a large number of the papers were excluded. Literature on SC management is featured by a significant range of studies that are not eligible for this research, such as (1) literature reviews, (2) conceptual papers that focus the analysis on the value of DTs, (3) documents that discuss technical issues, (4) articles that refer to the public sector, (5) articles describing emerging practices outside the field of SC management and (6) documents that do not formally clarify in which specific business process the emerging practice can be implemented, as well as not empirically demonstrating the positive impact on SC performance.

3.3 Classification scheme

The classification scheme for emerging practices is necessary to classify articles in a standardized way with specific labels as well as to ensure a rigorous classification of the research results. When emerging practices were detected in the article, they were classified with specific labels**:** the technology used, the business process and the relative impact achieved. Only emerging practices associated with specific business processes for SC management were considered, as shown in Table 2. The business processes taken into account concern all the activities that engage SC actors such as suppliers, distributors,

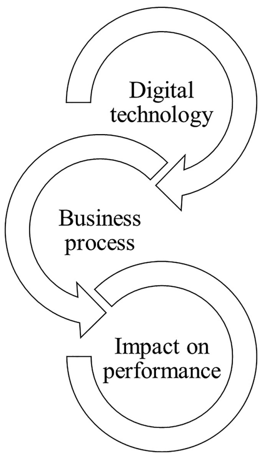

Figure 1. Conceptual schematization of an emerging practice

Business process	Description	Authors
Supplier evaluation and selection	Activities relating to sourcing, evaluation, qualification and supplier selection	(Rusch *et al.*, 2022; Zheng *et al.*, 2020)
Buyer–supplier relationships	Relationships management activities with buyers-suppliers. The processes of information sharing, cooperation and integration among the actors are included	(Attaran, 2020; Winkelhaus and Grosse, 2020)
Order management-purchasing	Activities that support the company for order management, including order generation, quotation, order receipt, quote acceptance, order processing, goods arrival and any reports of non-compliance products	(Qazi and Appolloni, 2022; Winkelhaus and Grosse, 2020)
Supplier payment	Activities that describe the payment process to the supplier	Attaran (2020)
Raw materials management	Inventory and warehouse management activities for raw materials or parts purchased from suppliers. In addition, activities such as physical handling of raw materials and goods purchased from suppliers are included	Brinch (2018)
Operations planning	Planning, scheduling, process and production programming activities	Hofmann and Rüsch (2017)
Operations control	Control and monitoring activities for evaluating performances such as times, processes, resources and movements	Zheng *et al.* (2020)
Inventory	Inventory management activities, stock monitoring of finished product aimed at maintaining the levels of stock	(Rusch *et al.*, 2022; Zhang *et al.*, 2021)
Warehouses	The activities considered in this business process are related to inbound and outbound handling processes, goods loading and unloading activities, shipping, packing and network monitoring of peripheral warehouses	(Ali and Phan, 2022; Barreto *et al.*, 2017)
Transportation	Activities involving the transport of goods managed in-house by the company. Primary transport activities are considered such as the movement of goods within the actors of a SC	(Agnusdei *et al.*, 2022; Barreto *et al.*, 2017)
3PL 4PL Couriers – Outsourcing	Relationships management activities with third- and fourth-party logistic providers such as couriers	Winkelhaus and Grosse (2020)
Distributors and wholesalers	Activities that include all material and information flows involving operators such as distributors and wholesalers	Rusch *et al.* (2022)
Delivery	Activities related to secondary transport performed in house by the company, that allows the product delivery to the final customer (retailer or end customer)	(Efthymiou and Ponis, 2021; Rusch *et al.*, 2022)
Sales and sales channels	Activities that refer to the sale of a product or service. This business process includes the management, monitoring and control of an existing sales channel or the creation of a new sales channel	(Rejeb *et al.*, 2021b)
Customer service	Activities with the customer before and during the product purchase or provision of service. This includes contacts with the customer to acquire product and service information and requests for their tracking status	Zheng *et al.* (2020)

Table 2.
List of business processes for SC management and their description

(*continued*)

Business process	Description	Authors
Post-sale service	Relationship activities with the customer after the sale of a good or the provision of a service. These activities include non-complaints products management, product status monitoring, information on product installation, assembly and maintenance notices	Attaran (2020)
Reverse logistics	Reverse logistics deals with the backward movement processes of goods, from the customer to an actor of the SC. The activities included are product return, recovery, disposal, reuse, repair and recycling	(Ni *et al.*, 2021; Winkelhaus and Grosse, 2020)

Table 2.

wholesalers, manufacturers, couriers, 3PLs and final customers. The classification takes into account the main areas of implementation of DTs reported in literature on SC management. References to prior literature were reported in Table 2.

In addition, this study aims to analyze the impacts that emerging practices, based on DTs, bring to SC management. In Table 3**,** the impacts have been divided according to whether they are market or organizational. The former refers to the impacts on external stakeholders, the latter to internal impacts. For each label, a definition of the impact nature is reported, as well as references to prior studies that have considered it important for SC management.

The manual classification of an emerging practice requires the attribution of three labels-technology, business process and impact-in order to standardize in which contexts it is used with which impacts. These labels, manually detected by the team of experts, are then used as categorical variables to present the research results. In this way, an emerging practice can be synthetized with a tuple *technology-process-impact*. Moreover, the emerging practices in which the use of BD was considered were signalled with a specific flag.

An example of the manual content analysis performed by the team of experts is provided in Figure 2. A practice implementing IoT to capture Big Data about suppliers and support their evaluation and selection has been detected from the work of Gottge *et al.*, 2020. The experts read the paper, captured an emerging practice and assigned labels to define the combination *technology-process-impact*. While the information about DT, business process and impact are mandatory, the flag *big data* is optional and depends on the presence of a formal reference to BD.

As previously reported, this study selected 1,585 suitable documents associated with SC management and DTs. Within these documents, one or more emerging practices have been found, that is one or more tuples *technology-process-impact* were recorded. Overall, the number of detected emerging practices, as well as tuples, is 5,060. In the next section, each tuple will be a statistical unit of analysis. It is necessary to highlight that in some cases the emerging practice has been associated with multiple DTs, different business processes and impacts. Therefore, to preserve the three-dimensional perspective, multiple tuples have been assigned to the same emerging practice to cover all the possible combinations *technology-process-impact*.

4. Results

4.1 Descriptive statistics

This section will provide descriptive statistics on each categorical variable under investigation. By counting the number of tuples, it is possible to give an overview of

Macro-impact	Impact	Description	Authors
Market	Attracting investors	Encourage investments to external stakeholders	Sodhi and Tang (2019)
	Brand reputation	Increase reputation and brand image	Lou *et al.* (2019)
	Competitive advantage	Increase the competitive advantage intended as market positioning related to competitors and increasing market shares	Kalaitzi *et al.* (2019)
	Customer satisfaction	Improve customer satisfaction in terms of product customization, customer experience and the level of service	Chavez *et al.* (2017)
	Government incentives	Encourage government incentives such as reducing taxes or receiving new subsidies	Ghazanfari *et al.* (2019)
	Product/service quality/ value/differentiation	Increase the value and quality of the product/service by ensuring the certification of the product origin or the differentiation with an innovative product	Vanteddu and Chinnam (2014)
	Revenues	Promote and support the increase in sales, sales channels and revenues	Bart *et al.* (2021)
Organizational	Costs reduction	Promote cost reduction by stock reduction or economies of scale	Rindfleisch (2020)
	Efficiency and productivity	Promote the increase of efficiency and productivity by reducing the breakdown of machines, increase the machines reliability and optimization of production	Chaudhuri *et al.* (2021)
	Employee engagement	Encourage employee involvement at work	Friedrich *et al.* (2020)
	Energy efficiency	Promote energy savings and ensure greater energy efficiency yields	Mulcahy *et al.* (2020)
	Flexibility	Increase the ability to meet demand through flexible production and design	Delic and Eyers (2020)
	Information management	Promote the products and processes traceability. Promote the monitoring and transparency of business activities	Tang and Veelenturf (2019)
	Innovation, knowledge and technology management	Promote progress for technological development and increase knowledge sharing and innovation among internal actors	Beltagui *et al.* (2020)
	Risk reduction	Promote the risk reduction at work, reduce fraudulent activities, manage privacy and security issues	Mol *et al.* (2020)
	SC relationships management	Encourage SC relationships and collaboration among external actors	Attaran (2020)
	Time reduction	Promote time reduction such as: time to market, design times and production times	Winkelhaus and Grosse (2020)

Table 3.
List of impacts and their description

which DTs, processes and impacts are the most investigated in literature. Table 4 illustrates the number of emerging practices classified for each technology. The most frequent practices related to SC management are associated with artificial intelligence, blockchain and the internet of Things with more than 500 practices. The number of emerging practices associated with immersive environments, open and crowd-based platforms and 3D printing is less than 300. The reason is that these DTs are less associated with the SC management. 3D printing is often associated with production activities, open and crowd-based platforms are linked to the concepts of innovation and crowd involvement and, finally, immersive

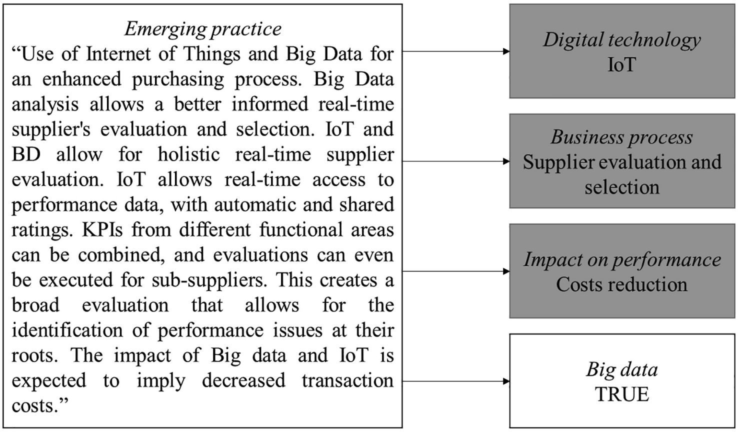

Figure 2.
Example of labelling of an emerging practice

Table 4.
Count of emerging practices associated to DTs

Digital technologies	# Emerging practices	# Emerging practices with BD	Frequency of BD
Artificial Intelligence	1,373	350	25%
Blockchain	598	71	12%
Internet of Things	563	180	32%
Digital Applications	468	107	23%
Proximity Tech	445	63	14%
Geo-Spatial Tech	424	73	17%
Robotics	392	8	2%
Computing	315	119	38%
Immersive Environments	248	21	8%
Open And Crowd-Based Platforms	207	14	7%
3D Printing	27	6	22%
Total	5,060	1,012	20%

environments are less consolidated technologies since they are highly innovative and disruptive. On the contrary, the literature on technologies based on traceability, authentication, certification and forecasting systems is rich of well-detailed examples, case studies and applications for SC management. The number of emerging practices that have combined the use of Big Data with other technologies is 1,012, about 20% of the total. Table 4 shows how the technologies closely connected with Big Data are those of data management such as artificial intelligence (25%), Internet of Things (32%) and computing (38%). Technologies such as robotics (2%), immersive environments (8%) and open and crowd-based platforms (7%) are less associated with the use of Big Data for SC management. For example, robotics is mainly related to material flows and less to information flows management.

Table 5 illustrates the distribution of emerging practices according to the business processes considered for SC management. Business processes such as operations control and operations planning cover more than 40% of the emerging practices. Both delivery and transportation play an important role in the distribution of emerging practices. This means that these technologies are often adopted in logistics. The technologies are less applied in

Table 5. Number of emerging practices by business process

Business process	#
Operations control	1,479
Operations planning	704
Transportation	401
Delivery	393
Customer service	357
Buyer–supplier relationships	296
Inventory	248
Warehouses	245
Sales and sales channels	183
Order management-purchasing	178
Supplier evaluation and selection	116
Reverse logistics	101
3PL 4PL Couriers-Outsourcing	99
Distributors and wholesalers	84
Raw materials management	77
Supplier payment	51
Post-sale service	48
Total	5,060

business processes such as 3PL 4PL Couriers-Outsourcing, distributors and wholesalers, raw materials management, supplier payment and post-sale service with less than 100 classified practices.

Tables 6 and 7 respectively show the emerging practices that have market and organizational impacts. On the one hand, the results show how often DTs are mainly used to

Table 6. Count of emerging practices by market impacts

Market impact	#
Customer satisfaction	435
Product/service quality/value/differentiate	374
Revenues	137
Competitive advantage	115
Brand reputation	52
Attracting investors	17
Government incentives	6
Total	1,136

Table 7. Count of emerging practices by organizational impacts

Organizational impact	#
Efficiency and productivity	883
Costs reduction	657
Information management	627
SC relationships management	561
Risk reduction	412
Time reduction	387
Energy efficiency	211
Flexibility	111
Innovation, knowledge and technology management	57
Employee engagement	18
Total	3,924

achieve better customer satisfaction and better product/service quality and differentiation. On the contrary, DTs are used less to improve brand reputation, attract investors and receive incentives from governments. It should be considered that the emerging practices that aim to achieve market impacts are about 22% of the sample.

On the other hand, the results illustrate how emerging practices can allow for the achievement of different organizational impacts. DTs aim to improve, automate, optimize and streamline SC management processes and operations. As a result, automation, optimization and efficiency allow to reduce managing operations costs. In this study, the technologies presented improve the data and information management processes among the participants of the SC. Nevertheless, impacts such as innovation, knowledge and technology management as well as employee engagement have been less considered in the literature considering the use of DTs.

4.2 DTs, business processes and impacts

This section reports the three-dimensional analysis of emerging practices considering the relationships among DTs, business processes and impacts. Figure 3 shows a framework in which the impacts appear on the rows and the business processes in the columns. The most frequent technologies in the sample are shown at the intersection between business processes and impacts. A filter was applied in which only the technologies that have a number of emerging practices greater than 10 for the specific business process and impact are present. To obtain further insights from this study, the market and organizational impacts have been separated and distinguished. For the purposes of this research, impacts such as attracting investors, competitive advantage, employee engagement and government incentives have been eliminated since for these impacts the emerging practices present are lower than 10. The emerging practices of the following business processes for SC management such as raw materials management, 3PL 4PL couriers – outsourcing, post-sales service and reverse logistics were not reported because the number is less than ten emerging practices analyzed. Finally, the grey boxes in Figure 3 show emerging practices in which Big Data is more frequently used in conjunction with the other technologies mentioned.

Starting from the supplier evaluation and selection, buyer–supplier relationships, order management-purchasing, supplier payment and inventory, warehouse, transportation, distributors and wholesaler, there is not a minimum number of ten emerging practices, based on DTs, useful that can achieve specific market impacts. On the contrary, DTs for these specific business processes are mainly used to achieve organizational impacts. In particular, blockchain technology can be used in various business processes such as *supplier evaluation and selection, buyer–supplier relationships, order management – purchasing* and *supplier payment* to improve SC relationships management. Blockchain technology enables various features such as security, authentication and certification of shared data. The actors belonging to the SC can trust and collaborate with the other participants in the network since trust is guaranteed by the security and decentralization technology features. Therefore, the technology supports specific business processes that engage the interaction among two or more members of the SC who could exchange crucial data or information. For the *supplier payment,* the use of cryptocurrencies can lead to facilitated financial exchanges for the cross-border shipments.

For business processes such as *buyer–supplier relationships* and *order management-purchasing*, blockchain technology is promising for costs reduction. Specifically, the use of smart contracts and the elimination of intermediaries allows for a time reduction for the order management activities and consequently in a resource costs reduction. Smart contracts, if properly implemented, could automate different order management activities between several players in the SC and reduce the activities cost. Furthermore, the absence of external

	Supplier evaluation and selection	Buyer-supplier relationships	Order management - purchasing	Supplier payment	Raw materials management	Operations planning	Operations control	Inventory
Brand reputation								
Customer satisfaction						AI	AI	
Product/service quality/value/differentiation						AI	AI; COM; DIG; GEO; IOT; PRO	
Revenues						AI		
Costs reduction		BC	BC			AI	AI; COM; GEO; IOT	AI
Efficiency & productivity						AI; COM; DIG; GEO; IMM; IOT	AI; BC; COM; DIG; GEO; IMM; IOT; OCP; PRO; ROB	AI
Energy efficiency						AI	AI; COM; IOT	
Flexibility								
Information management		BC				AI; GEO	AI; BC; COM; DIG; GEO; IOT; PRO	PRO
Innovation, knowledge and technology management							AI	
Risk reduction		BC				AI	AI; GEO; IOT; PRO	
Supply chain relationships management	BC	AI; BC; DIG; IOT; PRO	BC	BC			BC; IOT; PRO	AI; IOT
Time reduction						AI	AI; IOT; ROB	

Figure 3.
Analysis of DTs, business processes and impacts for SC management

	Warehouses	Transportation	3PL 4PL Couriers - Outsourcing	Distributors and wholesalers	Delivery	Sales and sales channels	Customer service	Post-sale service	Reverse logistics
Brand reputation							DIG		
Customer satisfaction					AI; ROB	AI; DIG	AI; DIG; IMM; PRO; ROB		
Product/service quality/value/differentiation									
Revenues							DIG		
Costs reduction	ROB	AI; GEO			AI; ROB				
Efficiency & productivity	ROB	AI			AI; ROB		DIG		
Energy efficiency					ROB				
Flexibility	ROB								
Information management		AI; BC; GEO							
Innovation, knowledge and technology management									
Risk reduction					ROB				
Supply chain relationships management		AI; IOT		BC					
Time reduction	ROB	AI			AI; ROB				

Figure 3

intermediaries could guarantee a further elimination of any additional expenses. The presence of huge transactions within the blockchain platform could promote the Big Data analysis and understand, for the *order management-purchasing* process, which suppliers are most promising and support a more detailed analysis for the raw materials procurement.

It is interesting to note that for the *buyer–supplier relationships* several technologies can be used to achieve better SC relationships management. In addition to the blockchain, other technologies such as artificial intelligence, digital applications, Internet of Things and proximity technologies have been considered associated with this impact. These technologies allow to collect data and information on SC relationships such as product orders and contacts with different players using Internet of Things, RFID, proximity sensors, record them on a shared platform (i.e. blockchain), carry out specific analysis for forecasting on data exchanges with the players in the SC using machine learning algorithms and, finally, communicating with the members of the SC through digital application (i.e. web application, social media and network, mobile application) in order to strengthen the relationships with certain actors. The widespread adoption of RFID technology provides supply chain managers "requires a higher level of automation of the decision-making processes" (Morenza-Cinos *et al.*, 2019, p. 1020). In this context, Big Data are often analyzed with advanced predictive techniques to make better and more accurate forecasts.

Regarding *inventory* management, the technologies mainly used in this business process aim to achieve specific organizational impacts such as: costs reduction, efficiency and productivity, information management and SC relationships management. Most of the emerging practices are based on the use of artificial intelligence. Regression and metaheuristic algorithms are often used to improve demand forecasting and better manage the amount of inventory quantities. The use of metaheuristic algorithms leads to an optimization of the stock level by reducing the cost of stock in the warehouse. These algorithms are often used in combination with Big Data to make advanced forecasts for inventory management. In addition to costs reduction, the use of algorithmic techniques allows to improve the efficiency and productivity of the inventory. Based on the data collected, artificial intelligence can modify orders, guarantee the delivery of the requested goods to warehouses on time. Proximity technologies such as RFID, Bluetooth, NFC, QR code and datamatrix support aligning the physical inventory with the virtual inventory by collecting information in real time. In this way, it is possible to make decisions in real time, avoiding errors from manual and repetitive practices. These technologies not only guarantee complete traceability and transparency of the items in stock but also facilitate the monitoring of available quantities. To achieve a better level of SC relationship management, both artificial intelligence and Internet of Things technologies are applied in the inventory. The Internet of Things ensures that raw materials, semi-finished and finished products are tracked within the internet. The use of machine learning techniques leads to managing the relationships among partners better as well as ensuring an optimal level of service based on the inventory stock.

Business processes such as operations planning and operations control consider different technologies that aim to achieve market impacts. Artificial intelligence allows to improve customer satisfaction, product/service quality/value/differentiation and increase revenues for *operations planning*. Specifically, regression, deep learning and artificial neural network algorithms make it possible to predict market demand by analyzing market data, planning production and distribution in an optimized way. For example, association rules algorithms could identify the most common combination of purchases by customers and detect product features that can attract the consumer tasting. The operations planning carried out with these algorithmic techniques ensures an increase in product turnover by reducing the unfilled order due to the absence of the product on the shelf. Artificial intelligence techniques are often used to achieve other organizational impacts within operations planning such as: costs reduction, efficiency and productivity, energy efficiency, information management, risk reduction and time reduction. These impacts are closely linked to each other. For example a correct and optimized activities planning with metaheuristic algorithms improves the efficiency and productivity of operations, saves time and resource costs and, finally, achieves energy gains. Algorithmic classification techniques often make it possible to classify issues and highlight opportunities for improvement in risk reduction by making the SC more resilient. Regarding the information management impact, artificial intelligence and geospatial technologies are also used for the operations planning. For example, GIS and web mapping allow for traceability, monitoring and control operations to collect information on sites in order to plan specific decisions. The larger the information volume, the more important it is to consider techniques to process Big Data. From the analysis of this amount of data, hidden information useful for the optimization of operations planning could often be intercepted. To achieve a greater efficiency and productivity for the operations planning, various technologies can be used such as computing, DTs, geospatial tech, immersive environments and Internet of Things. Geospatial technologies guarantee data collection through technologies such as GPS, GIS and GNSS. The Internet of Things makes it possible for items, equipment and products to be connected and available on the internet by facilitating operations planning activities. The use of cloud computing promotes the collection of a large amount of data for planning. The web or mobile applications allow to manage the activities planning in a simple and fast way. Finally, immersive environments tools such as digital twin and virtual reality assist to streamlining operations planning activities by simulating their behavior on a virtual space before implementing it in the real world. These analyses can be performed on Big Data which can be considered crucial for resolving issues on the operations planning of SC.

One of the business processes in which there **is** a considerable number of technologies that guarantee the achievement of different impacts is the *operations control*. Regarding the market impacts, to achieve a greater customer satisfaction, several emerging practices use natural language processing algorithms in combination with Big Data to monitor the level of customer satisfaction by analyzing the contents of online reviews. Moreover, to improve the product/service quality/value/differentiation different technologies could be adopted to achieve this impact. Technologies used for product tracking such as RFID, GPS, GIS, IoT and Bluetooth can improve the information exchange on the entire SC. The information is visible to all the players in the network and therefore the product could reach a higher market value. The unexpected increase of this information makes it necessary to use technologies such as cloud storage and cloud computing in order to store these data and analyze them with predictive analytics techniques based on BD. Technologies such as artificial intelligence, computing, geospatial technologies and Internet of Things aim to reduce operations control activities costs. The automation developing with these technologies aims to reduce the workload of human resources. Technologies such as cloud computing reduce the cost of IT hardware infrastructure. Artificial intelligence techniques allow for cost savings on the predictive control of machine downtime, while also ensuring a suitable level of inventory. According to Scuotto *et al.* (2017), the presence of human resources with ICT skills is relevant for the application of ICT to supply chain management. The technologies considered aim at efficiency and productivity for operations control activities. However, the sample under analysis does not consider 3D printing technology within this business process to achieve this specific impact. The main purpose of these technologies in operations control activities is that the processes are carried out correctly. Many of these technologies are used for monitoring such as mobile applications, open-source software, sensors, RFID, Internet of Things, GIS and cloud computing. Other technologies assist in monitoring and guaranteeing the achievement of efficiency and productivity such as through the use of autonomous mobile robots, cobots, drones, virtual and augmented reality. In SCs, it is increasingly important to monitor the aspects of energy efficiency with a sustainability perspective. The most used technologies are artificial intelligence, computing and the internet of Things. The scope of these technologies is to track energy consumption and verify at a later stage which processes, operations and activities produce greater energy inefficiency. Tracking and data management technologies are crucial for improving the information management for operations control activities. Big Data is increasingly used in these detailed analyses. For the control and monitoring activities, it is necessary to know in real time the products shipped, the stock in the warehouse in order to solve several issues. Technologies such as blockchain and computing can provide greater visibility and transparency on various activities as well as improve control and monitoring. The impact of innovation, knowledge and technology management for operations control activities is achieved through artificial intelligence which can identify solutions to hidden issues. In a supply chain, "the effective use of knowledge management technology is critical to effectively plan and predict future operations" (Desouza *et al.*, 2003, p. 130). To reduce risks, technologies such as artificial intelligence, geospatial technologies, Internet of Things and proximity technologies can trace different activities and avoid opportunistic behaviors by the actors in the SC network. Furthermore, machine learning algorithms applied to Big Data can improve the SC resilience by predicting potential effects produced by sudden catastrophic events such as the Covid-19 pandemic (Paul and Chowdhury, 2021). To monitor SC relationships, the technologies that can be used effectively are blockchain, Internet of Things and proximity technologies. These technologies can integrate and coordinate the actors in the SC and monitor the participants to have a correct behavior. Finally, artificial intelligence, Internet of Things and robotics technologies can reduce times. The use of robots reduces the time spent on checking and packing activities. In addition, the automation produced by the combined use of these technologies optimizes human resource times.

Robotics in *warehouses* improves various aspects such as cost reduction, efficiency and productivity, flexibility and time reduction. These impacts are correlated as cobots, drones and industrial robots reduce the time and human resources costs to carry out warehouse operations on material flows. Furthermore, greater efficiency and productivity are guaranteed, as the robots are programmable to carry out a significant number of warehouse activities without working breaks. These technologies guarantee greater flexibility in the warehouse operations management even in the presence of unexpected events. In this context, drones could help to improve the activities and operations related to the warehouse. These devices would not replace warehouse workers but would work with them to perform warehouse tasks more quickly and effectively.

Artificial intelligence techniques are often associated with achieving different impacts in *transportation*. Metaheuristic algorithms, deep learning and artificial neural networks can optimize the transport load and identify the most suitable routes in terms of cost and time reduction as well as efficiency and productivity. However, to achieve improvements in terms of information management and SC relationships management, other technologies are needed that allow for data collection and storage in a secure, shared and decentralized manner such as the internet of Things, geospatial technologies and blockchain. These technologies can monitor the shipments and products status in the trucks in real time. Thanks to artificial intelligence techniques, such as deep learning and artificial neural networks, it is possible to optimize transportation processes, prevent errors and detect potential issues and risk factors during the transportation. The use of machine learning techniques on Big Data allows for a better route planning.

Thanks to its intrinsic features of security, disintermediation, decentralization and encryption, blockchain technology allows for collaborative relationships of the actors such as *distributors and wholesalers*. The authentication and certification of transactions via blockchain allow to have trust in the technology, thus avoiding intermediaries.

Technologies such as artificial intelligence and robotics are widely used in *delivery* to achieve various impacts such as: customer satisfaction, cost reduction, efficiency and productivity, energy efficiency, risk reduction and time reduction. In particular, the use of unmanned vehicles can support the product shipment without the additional costs of human resources. Moreover, drones could be programmed with machine learning techniques to optimize routing and quickly reach their final destination. The use of Big Data is often needed to conduct and infer these predictions. These technologies can improve customer satisfaction in terms of perfect orders. The use of unmanned vehicles can allow for energy savings since they can avoid city traffic and reduce the number of risks related to accidents at work during the last mile delivery.

For *sales and sales channel* activities, artificial intelligence and digital applications are widely applied to improve customer satisfaction. New sales channels such as social media, mobile applications and web applications are essential in the e-commerce and m-commerce world. Managing data from these platforms allows to apply natural language processing techniques **to** online reviews as well as make improvements to the final product to achieve high customer satisfaction. These new sales channels have encouraged the growth of an omnichannel experience that allows the customer to buy products with a smartphone and to pick them **up** in a physical store.

Finally, digital applications are crucial in *customer service* activities to achieve better results in terms of brand reputation, customer satisfaction, revenues and efficiency and productivity. These technologies allow to get in touch with the customers and help them with the purchased products, increasing the brand reputation, customer satisfaction and revenues. The use of a mobile application support direct communication with the end customer, such as push notifications in the form of alerts or product recommendations based on each customer's search history. Augmented and virtual reality, metaverse, social robots and proximity technologies such as sensors on the shelves, can help the customer for the final product purchasing, better comprehension of their needs and ensure a suitable purchase. The metaverse fills the gap between e-commerce and physical commerce, transforming the user's shopping experience: from static product catalogues to real-time simulations of items such as clothing. As information on the web increases, it is increasingly necessary to manage **B**ig **D**ata in order to carry out an accurate analysis. Finally, chatbots and contact center automation can increase efficiency and productivity by reducing the workload performed by human beings.

5. Discussion

The purpose of this paper is twofold: first, to review and classify scientific publications dealing with SC digitalization and unphysicalization, aimed at suggesting the best solution to improve SC performance; second, to outline the directions for future research in the field. Some gaps and areas for further research activities have been identified. This review offers interesting insights to both academics and practitioners. On the academic side, it analyses and classifies relevant literature about practices adopting DTs and solutions based on DTs to improve SC performance, proposing directions for future research efforts. On the managerial side, it presents a holistic framework on three factors affecting the choice of implementation of DTs, suggesting viable innovative solutions that may be implemented to increase SC performance.

5.1 Scientific implications

The proposed research methodology systemizes the current practice as well as the potential of digitalization and unphysicalization according to a conceptual framework of three dimensions: technology, process and impact. The SLR aims to algorithmically and objectively investigate the recent literature on SC digitalization and unphysicalization, standardizing the information incorporated into thousands of scientific documents. The study can be seen as offering progress in terms of reviewing the main opportunities for SC management, while also identifying the main areas in which research on DTs is currently being caried out. While some SLRs already exist, the authors undertake a unique analytical perspective, resulting in an original set of variables for further investigation in the area. This study represents an important evolution in organizing the current literature on SC digitalization and unphysicalization into a framework in order to delineate the state of the art on SC digitalization and unphysicalization and suggests promising opportunities for future inquiry. The output is a database of emerging practices that can be implemented within specific SC processes, promising the enhancement of SC performance. The findings of this work help incorporate knowledge about SC digitalization and unphysicalization into a three-dimensional framework that can be easily used for defining strategies and organizing SC according to the expected impact on SC performance. A theoretical implication is related to the knowledge management referred to the DIKW model (data, information, knowledge and wisdom) and more in detail on how the knowledge emerged from these emerging practices can be collected (information), selected and analyzed (data) to obtain (through technologies such as artificial intelligence) knowledge and reach the wisdom. Another possible theoretical implication can be related to the strategic management or the influence of the knowledge/wisdom (obtained from the emerging practices) on the strategic decision-making process.

Since these emerging practices are based on the use of DTs, the database suggests how SC digitalization and unphysicalization could affect SC management and performance. By focusing on the most successful opportunities of the implementation of DTs and the most recurring practices reported by scholars, this research provides a conceptual framework for the implementation of DTs to support SC digitalization and unphysicalization, as synthesized in Figure 3. The research demonstrates that depending on both the business process and impact on performance only a few technologies result in a consolidated stage of implementation, revealing probable developments of the practice over the next years and allowing to affirm that they will probably support the development of future best practices in specific business processes.

Moreover, the methodology proposed for the SLR supports the classification of scientific papers and can be replicated to help academics to further understand the technologies, exploring the trends in SC digitalization and unphysicalization, while also identifying the areas where the technologies are most desirable and can be implemented.

5.2 Research gaps and future directions

Although the literature review revealed that many aspects have been investigated about DTs and the role of SC digitalization and unphysicalization, some elements should be further analyzed, in order to both provide academics with a comprehensive view about the theme and support practitioners in taking decisions in the field. In consideration of the information collected from current literature, it is possible to provide a structured proposal for promising future research direction based on the review findings and enriched by insights from the quantitative analysis of the emerging practices. According to the analysis and discussion, this paper has identified the following five research gaps, that could be the basis for prescriptions and a broad agenda to guide future research and theory development.

5.2.1 Multidimensional perspective. On the basis of the proposed methodology, there is a three-dimensional perspective for the investigation of SC digitalization and unphysicalization. Therefore, in addition to the specific DT, the variables SC process and SC performance have demonstrated their importance in defining patterns of evolution of emerging practices in SCs. Considering the investigated literature, many studies lack a systematic consideration of integrating digitalization and unphysicalization approaches into SC processes. Research often refers to a general implementation of DTs within SCs and business functions, without referring to any specific processes. As highlighted by the results, different processes within the same business functions could be differently beneficial to the adoption of DTs, as well as the DTs lack of a widespread use within all the processes managed by a business function. Similarly, much less research has paid attention to the characterization of the specific impact on the SC performance deriving from the implementation of DTs. The reference to a general positive advantage in implementing digitalization and unphysicalization within SC is more frequent in literature reviews, along with reporting limited details on the impact in terms of performance enhancement. From the results of the literature review, various categories of impact have been detected. Thus, the characterization of the specific expected impact is necessary to appropriately switch from theory to practice as well as to allow research to provide managers and practitioners with a representation of the possible future scenarios of the adoption of DTs.

As a consequence of the relevance of the variables business process and impact, this research suggests filling the gap by taking into account multidimensional perspectives in the evaluation of DTs and their implementation in SCs. Exploring the combinations of DT-business process-impact in future studies may contribute towards extending the theory of SC digitalization and unphysicalization. By contextualizing the adoption of DTs within specific business areas and clarifying the expected impact, scholars could better position their scientific contributions within a research field that is still fragmented, constantly evolving and characterized by a huge amount of articles. To do so, it could be useful for scholars to implement shared taxonomies for DTs, business processes and the type of expected impact. *For example*, from the analysis of literature, it emerges that the same technologies are sometimes classified in different categories, confirming the complexity of achieving a shared language among researchers.

5.2.2 Comprehensive view. Papers presenting a comprehensive view of all the innovative solutions, classifying them and analyzing the impact on SC performance seem to be missing. The majority of papers focuses on one or just a very limited number of emerging practices, typically considering one or relatively few digital technologies and a specific business process. Literature reviews or frameworks are also generally partial, since they miss some digital technologies or do not consider the different processes and the different impact that these solutions have on the SC.

Therefore, this paper represents a pioneering attempt to reorganize and classify literature on all DTs without focusing on specific business processes and impacts on performance. Scientific literature becomes the source for the development of a database of emerging practices using DTs in order to improve the performance of SCs and provide the state of the art of SC digitalization and unphysicalization, without focusing on only a few technologies. From the building of such a database, it is possible to provide a comprehensive view of all the DTs at the basis of the industry 4.0 paradigm. Only considering all the DTs, and making comparisons, it is possible to understand the current state of the art of SC digitalization and unphysicalization. Moreover, future developments could detect the pattern of evolution of each technology, by checking the diffusion and adoption within business processes and the growing consolidation of the expected impact, so that it is possible to intercept which DTs could be part of the future best practices.

5.2.3 Under-investigated combinations. From the analysis of the results, it emerges that some available solutions are still under-investigated and many combinations did not gain much academic attention. First, many combinations do not report any practice. This mainly depends on the limited implementation in specific business processes, such as post-sale services, supplier payment, raw materials management and relationship management with

3PL, 4PL, couriers, distributors and wholesalers. Similarly, considering the variable impact, research seems to be more interested in the organizational performance enhancement deriving from the implementation of SC digitalization and unphysicalization, while the advantages in terms of market performance seems to be less explored. The low interest could be linked to both the technological and technical problems to be faced in the implementation as well as on the difficulty in evaluating the impact on the customers in the short-term. However, research could explore the missing combinations in order to find new business practices that could use digital technologies to enhance SC performance. Moreover, new research opportunities and combinations could also derive from new technologies that will be proposed and can be added to this model.

Second, some combinations have been explored but in a rather limited number of applications, even if they could be interesting since they are promising in terms of the enhancement of SC performance and likely to be implemented. Literature could monitor these under-investigated combinations since it is probable that they could either remain confined to a limited number of applications or considerably grow and be the best candidates to become future best practices.

5.2.4 Lack of business process frameworks. The SLR carried out with this paper has highlighted the presence of specific combinations that could be the basis for the implementation of successful emerging practices within SCs. The most stable combinations are reported in Figure 3 and define a conceptual framework for the adoption of DTs to support SC digitalization and unphysicalization. The research suggests further investigation in order to formally propose best practices adopting those DTs, based on the idea that the proposed combinations are the most frequently reported in literature. Even though there are various solutions that have been discussed in many papers and seem to be more stable, to transform them into future best practices, there is the need for a systematic and standardized work to define the implementation mechanisms and strategies at the micro-level, building business process frameworks to support companies in their formal adoption. Business process frameworks are also necessary to highlight the transformation paths for organizations and SCs into a digitalization and unphysicalization paradigm.

5.2.5 Big data in SC management. In literature, there is a general tendency to associate the implementation of Big Data with positive impacts in SC management. However, from the analysis of the results, only about 20% of emerging practices use BD, with their frequent use within practices summarized with the three-dimensional framework being limited to specific combinations. Thus, this study reveals how BD are not always essential and that their use can be an advantage for SC only in specific contexts of application.

Moreover, the research bridges the conversation between BD and other digital technologies, according to the three-dimensional framework. The resulted themes and research opportunities will help to advance the understanding of how BD will reshape the future of SCs and processes adopting them. This study is unique in its discussion of how BD will reshape SC management, integrating the issue with a three-dimensional perspective, which has not been discussed to date. However, a lot of effort is needed to understand when and how BD are pivotal in the achievement of positive impacts in terms of business and SC performance.

5.3 Limits of the research

The limitations of the research regard the time-consuming activity of the manual content analysis of scientific papers and the subsequent process of classification of emerging practices performed by the experts. The information about emerging practices could be dispersed within the entire document, so that it is impossible to rely on automated systems to classify emerging practices. Furthermore, to classify emerging practices, an effort has to be made to convert the information into the proposed taxonomies. This limits the implementation of the methodology, which requires the analysis of a huge amount of documents to be able to obtain patterns and insights regarding the most promising areas of implementation of DTs. Additionally, gray literature was not considered, with several applications and case studies not having been considered. Similarly, many pioneering applications of DTs within SCs could have been implemented by companies but not reported by scientific literature.

Despite the aforementioned limitations, literature is widely recognized as the most reliable reference for forecasting the future development and implementation of cutting-edge technologies. Therefore, since literature anticipates business applications, the proposed conceptual framework could support both scientists and practitioners in exploring the usefulness of emerging practices in SCs.

5.4 Managerial implications

5.4.1 Contribution to practice. Regarding the practical implications, the conceptual framework provides insights to practitioners facing SC management issues, helping them benefit from the advantages deriving from digitalization and unphysicalization. The proposed framework links DTs with SC management, thus improving the common understanding among practitioners. It also reveals that specific technologies, implemented in specific processes, play a specific role in SC management, thus suggesting the definition of priorities and appropriate strategies of implementation, helping companies forecast the impact on performance. The proposed framework will be useful for managers and practitioners when identifying the most stable emerging practices and their contexts of application, in order to consider their implementation to face the new challenges in SC management. In summary, it emerges that the power of DTs is confirmed, but that emerging practices are more promising only in a limited range of SC areas and for specific purposes. Different levels of diffusion of digitalization and unphysicalization could be achieved depending on the specific SC process and the available DTs. Thus, managers and practitioners could rely on this framework to find the appropriate cutting-edge technology to implement within a specific SC process depending on the outcome that they wish to achieve. Similarly, the research highlights specific areas of usefulness of BD, to detect in which activities they could really make the difference.

In consideration of the current issues facing SC management, it is important to interpret the results from multiple perspectives and link the findings to the debate on SC digitalization and unphysicalization. In particular, the findings provide managers with a set of factors that are indispensable to solve the following SC management issues: (1) data and information management, (2) efficiency and productivity of the SC processes, (3) market performance, (4) SC relationships management and (5) risk management in SC.

5.4.2 Data and information management. Regarding the management of data, information and information flows, digitalization and digitization practices have already revolutionized SC management. The switch from analogic to digital information and the implementation of data acquisition, capture and transmission technologies have already widely enhanced SC performance. However, DTs could additionally contribute to further improvements of performance. The management of information flows between buyers and suppliers could benefit from the adoption of blockchain technology. Data collection could benefit from the use of proximity technologies and Internet of Things, specifically for the management of operations planning and inventory. Moreover, information management could benefit from the acquisition of geo-spatial data, with the most promising applications within operations planning, operations control and transportation activities. Furthermore, data storage through computing technologies could be particularly performing for operation control processes, also favored by the implementation of other DTs. The automation and the optimization of information flows is significantly affected by artificial intelligence, which is capable of elaborating huge amounts of data in order to support real-time decision making in transportation, planning and control activities. For the specific purpose of optimizing information flows management, BD are only crucial for operations planning and control. This means that the implementation of BD is not widely effective for all the processes, but suggested only for a few.

5.4.3 Efficiency and productivity of SC processes. Regarding the impact of SC digitalization and unphysicalization on the improvement of the efficiency and productivity of SC processes, upstream activities lack a specific technology that to date promises a robust benefit. On the contrary, downstream processes are assisted by DTs, particularly relying on artificial intelligence and robotics. Warehouse activities can be carried out automatically by industrial robots, with various technologies for warehouse management assisting humans to improve the quality of material handling. A general usefulness in terms of efficiency improvements of DTs in operations planning and control is demonstrated by a wide range of applications using almost all the categories of DTs. For these SC processes, this research has found the maximum range of heterogeneity of emerging practices, also in consideration of the usefulness of BD within these areas of application. Moreover, the combined use of BD and artificial intelligence could determine significant improvements in terms of the performance of transportation activities.

5.4.4 Market performance. The impact of SC digitalization and unphysicalization is predominantly investigated in terms of organizational performance, even though there is a direct relationship with market results. The activities where SC members directly enter into contact with the end customer can be beneficial to the implementation of specific DTs, but the opportunities are limited to a few categories. In general, artificial intelligence could optimize processes such as delivery, sales activities and customer service, with a direct impact in terms of customer satisfaction. Additionally, new delivery solutions employing robotics-such as drones – could improve customer satisfaction. A significant role is covered by digital applications that affect customer service activities by positively impacting on brand reputation, customer satisfaction and revenues growth. On the one hand, the use of web applications, apps and social media and networks allow firms to enter into contact with their customers, unphysicalizing many real-time customers support activities. On the other, robotic process automation, chatbots and contact center automation are powerful means to guarantee valuable customer service. Therefore, in the future SCs will dramatically rely on digital applications for the management of the relationships with end customers. Another interesting area of implementation is related to immersive environments. Since they create an additional space of contact with the SC, consumers will more and more require services provided through virtual reality, digital humans and metaverse. In summary, front-office activities could be radically converted into digital points of contact with customers. Artificial intelligence is fundamental to correctly manage operations planning and control with direct impacts on customer satisfaction, product quality/value/differentiation and revenues growth. However, other upstream and downstream SC processes not directly engaging the end customer are not likely to affect market performance. This can be considered a limitation of the implementation of DTs that leads to the consideration that SC digitalization and unphysicalization mainly affect internal SC organizational performance. Emerging practices are mainly focused on internal performance enhancement, suggesting that either future developments could switch to market performance objectives or DTs have a limited potential of dramatically changing the quality of the relationship with customers.

5.4.5 SC relationships management. Regarding the changes in the management of relationships among SC members, this research highlights how emerging practices will have an impact on various SC processes. SC digitalization is focused on upstream processes. At the basis of the evolution of the relationships with suppliers, there is the diffusion of blockchain technology. Both private and public blockchain solutions allow for the implementation of a series of opportunities, from the activation of smart contracts to automate processes to the exchanges of fungible and non-fungible assets as to other DTs, Internet of Things and proximity technologies, supporting buyer–supplier relationships, managing inventory alignment, controlling operations and transportation activities. Finally, artificial intelligence using BD has the power to improve the performance of the SC with a focus on buyer–supplier relationships, the sharing of inventory information and demand forecasting, along with transportation optimization.

5.4.6 Risk management in SCs. Another area of significant interest for the future of the SC is risk management. The issue will be more and more central due to the COVID-19 pandemic, cybersecurity issues, economic instability and causes of SC disruptions such as wars and environmental disasters. Regarding the upstream relationships, the blockchain is particularly effective in circumventing interruptions, since it guarantees transparency and traceability while also allowing for the real-time tracing of transactions. Regarding downstream activities, delivery technologies such as drones and unmanned aerial vehicles are able to make operations safer for humans, support contactless delivery, access areas in the case of humanitarian SCs. Furthermore, a range of technologies, often supported by BD, could reduce the risks in operations planning and control activities. In particular, artificial intelligence could elaborate information based on BD, data collected by the Internet of Things, proximity technologies and geo-spatial applications, by detecting or preventing SC risks.

6. Conclusions

This paper aimed to carry out a SLR on the current state of the art of SC digitalization and unphysicalization. The process was carried out by manually finding and interpreting 1,585 studies linked to DTs, detecting 5,060 emerging practices. These practices were classified by designing a three-dimensional conceptual framework that relates DTs, business processes and impacts on SC performance. From the classification, each practice was converted into a tuple of categorical variables that were analyzed further. The categorical variables are linked to an original taxonomy of labels proposed with this methodology. Thus, the research undertakes a unique analytical perspective to organize the current literature on SC digitalization and unphysicalization. It emerges that only a limited number of combinations is frequently found in literature, so that the related emerging practices are the best candidates to become future best practices. Therefore, this research highlights significant promising areas of implementation of DTs and suggests future directions for theoretical development, finding five research gaps. From the managerial perspective, the paper suggests to managers which emerging practices are the most suitable to implement within SCs in order to address current and future issues in SCs. The discussion section tried to summarize both the theoretical and practical contributions, also highlighting the limitations.

Future developments of this study could be aimed at evaluating the evolution over time of emerging practices based on DTs. In addition, other research databases outside the scientific literature could be integrated to further understand the potential of DTs in SC management also under the lens of risk management.

References

Adamson, G., Wang, L., Holm, M. and Moore, P. (2017), “Cloud manufacturing–a critical review of recent development and future trends”, *International Journal of Computer Integrated Manufacturing*, Vol. 30 Nos 4-5, pp. 347-380.

Agnihotri, R., Kalra, A., Chen, H. and Daugherty, P.J. (2022), "Utilizing social media in a supply chain B2B setting: a knowledge perspective", *Journal of Business Logistics*, Vol. 43 No. 2, pp. 189-208.

Agnusdei, G.P., Gnoni, M.G., Sgarbossa, F. and Govindann, K. (2022), "Challenges and perspectives of the Industry 4.0 technologies within the last-mile and first-mile reverse logistics: a systematic literature review", *Research in Transportation Business and Management*, Vol. 45, C, 100896, doi: 10.1016/j.rtbm.2022.100896.

Ali, I. and Phan, H.M. (2022), "Industry 4.0 technologies and sustainable warehousing: a systematic literature review and future research agenda", *International Journal of Logistics Management*, Vol. 33 No. 2, pp. 644-662.

Alicke, K., Rachor, J. and Seyfert, A. (2016), *Supply Chain 4.0–the Next-Generation Digital Supply Chain*, McKinsey & Company, available at: https://www.mckinsey.com/capabilities/operations/our-insights/supply-chain-40–the-next-generation-digital-supply-chain (accessed 10 March 2022).

Ardito, L., Scuotto, V., Del Giudice, M. and Petruzzelli, A.M. (2018), "A bibliometric analysis of research on Big Data analytics for business and management", *Management Decision*, Vol. 57 No. 8, pp. 1993-2009.

Attaran, M. (2020), "Digital technology enablers and their implications for supply chain management", *Supply Chain Forum*, Vol. 21 No. 3, pp. 158-172.

Barreto, L., Amaral, A. and Pereira, T. (2017), "Industry 4.0 implications in logistics: an overview", *Procedia Manufacturing*, Vol. 13, pp. 1245-1252.

Bart, N., Chernonog, T. and Avinadav, T. (2021), "Revenue-sharing contracts in supply chains: a comprehensive literature review", *International Journal of Production Research*, Vol. 59 No. 21, pp. 6633-6658.

Beltagui, A., Rosli, A. and Candi, M. (2020), "Exaptation in a digital innovation ecosystem: the disruptive impacts of 3D printing", *Research Policy*, Vol. 49, 1039833, pp. 1-16.

Bramer, W.M., Giustini, D. and Kramer, B.M.R. (2016), "Comparing the coverage, recall, and precision of searches for 120 systematic reviews in Embase, MEDLINE, and Google Scholar: a prospective study", *Systematic Reviews*, Vol. 5 No. 39, pp. 1-7.

Brinch, M. (2018), "Understanding the value of big data in supply chain management and its business processes: towards a conceptual framework", *International Journal of Operations and Production Management*, Vol. 38 No. 7, pp. 1589-1614.

Büyüközkan, G. and Göçer, F. (2018), "Digital Supply Chain: literature review and a proposed framework for future research", *Computers in Industry*, Vol. 97, pp. 157-177.

Cammarano, A., Varriale, V., Michelino, F. and Caputo, M. (2021), "A patent-based tool to support component suppliers assessment in the smartphone supply chain", *IEEE Transactions on Engineering Management*, pp. 1-18, doi: 10.1109/TEM.2021.3130656.

Cammarano, A., Michelino, F. and Caputo, M. (2022a), "Extracting firms' R&D processes from patent data to study inbound and coupled open innovation", *Creativity and Innovation Management*, Vol. 31 No. 2, pp. 322-339.

Cammarano, A., Perano, M., Michelino, F., Del Regno, C. and Caputo, M. (2022b), "SDG-oriented supply chains: business practices for procurement and distribution", *Sustainability*, Vol. 14 No. 3, p. 1325.

Cañas, H., Mula, J., Díaz-Madroñero, M. and Campuzano-Bolarín, F. (2021), "Implementing industry 4.0 principles", *Computers and Industrial Engineering*, Vol. 158, pp. 1-17.

Chaudhuri, A., Naseraldin, H., Søberg, P.V., Kroll, E. and Librus, M. (2021), "Should hospitals invest in customised on-demand 3D printing for surgeries?", *International Journal of Operations and Production Management*, Vol. 41 No. 1, pp. 55-62.

Chavez, R., Yu, W., Jacobs, M.A. and Feng, M. (2017), "Data-driven supply chains, manufacturing capability and customer satisfaction", *Production Planning and Control*, Vol. 28 Nos 11-12, pp. 906-918.

Clancy, R., O'Sullivan, D. and Bruton, K. (2023), "Data-driven quality improvement approach to reducing waste in manufacturing", *TQM Journal*, Vol. 35 No. 1, pp. 51-72, doi: 10.1108/TQM-02-2021-0061.

Cricelli, L., Grimaldi, M. and Vermicelli, S. (2022), "Crowdsourcing and open innovation: a systematic literature review, an integrated framework and a research agenda", *Review of Managerial Science*, Vol. 16, pp. 1269-1310.

da Silva, V.L., Kovaleski, J.L. and Pagani, R.N. (2019), "Technology transfer in the supply chain oriented to industry 4.0: a literature review", *Technology Analysis and Strategic Management*, Vol. 31 No. 5, pp. 546-562.

Das, S. and Hassan, H.M.K. (2022), "Impact of sustainable supply chain management and customer relationship management on organizational performance", *International Journal of Productivity and Performance Management*, Vol. 71 No. 6, pp. 2140-2160.

Delic, M. and Eyers, D.R. (2020), "The effect of additive manufacturing adoption on supply chain flexibility and performance: an empirical analysis from the automotive industry", *International Journal of Production Economics*, Vol. 228, pp. 1-15.

Desouza, K.C., Chattaraj, A. and Kraft, G. (2003), "Supply chain perspectives to knowledge management: research propositions", *Journal of Knowledge Management*, Vol. 7 No. 3, pp. 129-138.

Di Vaio, A. and Varriale, L. (2020), "Digitalization in the sea-land supply chain: experiences from Italy in rethinking the port operations within inter-organizational relationships", *Production Planning and Control*, Vol. 31 Nos 2-3, pp. 220-232.

Doetzer, M. and Pflaum, A. (2021), "The role of digitalized information sharing for flexibility capability utilization: lessons from Germany and Japan", *International Journal of Physical Distribution and Logistics Management*, Vol. 51 No. 2, pp. 181-203.

Dong, C., Akram, A., Andersson, D., Arnäs, P.O. and Stefansson, G. (2021), "The impact of emerging and disruptive technologies on freight transportation in the digital era: current state and future trends", *International Journal of Logistics Management*, Vol. 32 No. 2, pp. 386-412.

Efthymiou, O.K. and Ponis, S.T. (2021), "Industry 4.0 technologies and their impact in contemporary logistics: a systematic literature review", *Sustainability*, Vol. 13 No. 21, pp. 1-27.

Fatorachian, H. and Kazemi, H. (2021), "Impact of Industry 4.0 on supply chain performance", *Production Planning and Control*, Vol. 32 No. 1, pp. 63-81.

Felstead, M. (2019), "Cyber-physical production systems in industry 4.0: smart factory performance, innovation-driven manufacturing process innovation, and sustainable supply chain networks", *Economics, Management, and Financial Markets*, Vol. 14 No. 4, pp. 37-43.

Festa, G., Safraou, I., Cuomo, M.T. and Solima, L. (2018), "Big data for big pharma: harmonizing business process management to enhance ambidexterity", *Business Process Management Journal*, Vol. 24 No. 5, pp. 1110-1123.

Friedrich, J., Becker, M., Kramer, F., Wirth, M. and Schneider, M. (2020), "Incentive design and gamification for knowledge management", *Journal of Business Research*, Vol. 106, pp. 341-352.

Gebhardt, M., Kopyto, M., Birkel, H. and Hartmann, E. (2021), "Industry 4.0 technologies as enablers of collaboration in circular supply chains: a systematic literature review", *International Journal of Production Research*, Vol. 60 No. 23, pp. 6967-6995, doi: 10.1080/00207543.2021.1999521.

Ghazanfari, M., Mohammadi, H., Pishvaee, M.S. and Teimoury, E. (2019), "Fresh-product trade management under government-backed incentives: a case study of fresh flower market", *IEEE Transactions on Engineering Management*, Vol. 66 No. 4, pp. 774-787.

Ghobakhloo, M. (2020), "Determinants of information and digital technology implementation for smart manufacturing", *International Journal of Production Research*, Vol. 58, pp. 2384-2405.

Gottge, S., Menzel, T. and Forslund, H. (2020), "Industry 4.0 technologies in the purchasing process", *Industrial Management and Data Systems*, Vol. 120 No. 4, pp. 730-748.

Gurtu, A. and Johny, J. (2019), "Potential of blockchain technology in supply chain management: a literature review", *International Journal of Physical Distribution and Logistics Management*, Vol. 49 No. 9, pp. 881-900.

Handfield, R., Jeong, S. and Choi, T. (2019), "Emerging procurement technology: data analytics and cognitive analytics", *International Journal of Physical Distribution and Logistics Management*, Vol. 49 No. 10, pp. 972-1002.

Helo, P. and Hao, Y. (2021), "Artificial intelligence in operations management and supply chain management: an exploratory case study", *Production Planning and Control*, Vol. 33 No. 16, pp. 1573-1590, doi: 10.1080/09537287.2021.1882690.

Hofmann, E. and Rüsch, M. (2017), "Industry 4.0 and the current status as well as future prospects on logistics", *Computers in Industry*, Vol. 89, pp. 23-34.

Hofmann, E., Sternberg, H., Chen, H., Pflaum, A. and Prockl, G. (2019), "Supply chain management and Industry 4.0: conducting research in the digital age", *International Journal of Physical Distribution and Logistics Management*, Vol. 49 No. 10, pp. 945-955.

Huynh, P.H. (2022), "'Enabling circular business models in the fashion industry: the role of digital innovation'", *International Journal of Productivity and Performance Management*, Vol. 71 No. 3, pp. 870-895.

Kalaitzi, D., Matopoulos, A., Bourlakis, M. and Tate, W. (2019), "Supply chains under resource pressure: strategies for improving resource efficiency and competitive advantage", *International Journal of Operations and Production Management*, Vol. 39 No. 12, pp. 1323-1354.

Kamble, S.S., Gunasekaran, A. and Gawankar, S.A. (2018), "Sustainable Industry 4.0 framework: a systematic literature review identifying the current trends and future perspectives", *Process Safety and Environmental Protection*, Vol. 117, pp. 408-425.

Kapoor, R. and Klueter, T. (2020), "Progress and setbacks: the two faces of technology emergence", *Research Policy*, Vol. 49 No. 1, 103874.

Karakas, S., Acar, A.Z. and Kucukaltan, B. (2021), "Blockchain adoption in logistics and supply chain: a literature review and research agenda", *International Journal of Production Research*, pp. 1-24, doi: 10.1080/00207543.2021.2012613.

Loske, D. and Klumpp, M. (2022), "Verifying the effects of digitalisation in retail logistics: an efficiency-centred approach", *International Journal of Logistics Research and Applications*, Vol. 25 No. 2, pp. 203-227.

Lou, Y., He, Z., Li, Y. and He, S. (2019), "Should short warranty always be interpreted as low quality: the effect of brand advantages on warranty's signalization", *International Journal of Production Research*, Vol. 57 No. 14, pp. 4468-4479.

Malhotra, A., Gosain, S. and El Sawy, O.A. (2005), "Absorptive capacity configurations in supply chains: gearing for partner-enabled market knowledge creation", *MIS Quarterly: Management Information Systems*, Vol. 29 No. 1, pp. 145-187.

Manavalan, E. and Jayakrishna, K. (2019), "A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements", *Computers and Industrial Engineering*, Vol. 127, pp. 925-953.

Martin, B.R. (2010), "The origins of the concept of 'foresight' in science and technology: an insider's perspective", *Technological Forecasting and Social Change*, Vol. 77 No. 9, pp. 1438-1447.

Messeni Petruzzelli, A., Natalicchio, A., Panniello, U. and Roma, P. (2019), "Understanding the crowdfunding phenomenon and its implications for sustainability", *Technological Forecasting and Social Change*, Vol. 141, pp. 138-148.

Mital, M., Del Giudice, M. and Papa, A. (2018), "Comparing supply chain risks for multiple product categories with cognitive mapping and Analytic Hierarchy Process", *Technological Forecasting and Social Change*, Vol. 131, pp. 159-170.

Mol, J.M., van der Heijden, E.C.M. and Potters, J.J.M. (2020), "(Not) alone in the world: cheating in the presence of a virtual observer", *Experimental Economics*, Vol. 23, pp. 961-978.

Morenza-Cinos, M., Casamayor-Pujol, V. and Pous, R. (2019), "Stock visibility for retail using an RFID robot", *International Journal of Physical Distribution and Logistics Management*, Vol. 49 No. 10, pp. 1020-1042.

Mulcahy, R., Russell-Bennett, R. and Iacobucci, D. (2020), "Designing gamified apps for sustainable consumption: a field study", *Journal of Business Research*, Vol. 106, pp. 377-387.

Musa, A. and Dabo, A.A.A. (2016), "A review of RFID in supply chain management: 2000-2015", *Global Journal of Flexible Systems Management*, Vol. 17, pp. 189-228.

Nascimento, A., Tavares, E., Alves, G., Sousa, E. and Nogueira, B. (2020), "Performability evaluation of transport modes for cloud-based inbound logistics: a study based on coffee industry", *International Journal of Manufacturing Technology and Management*, Vol. 34 No. 2, pp. 126-147.

Nayal, K., Kumar, S., Raut, R.D., Queiroz, M.M., Priyadarshinee, P. and Narkhede, B.E. (2022), "Supply chain firm performance in circular economy and digital era to achieve sustainable development goals", *Business Strategy and the Environment*, Vol. 31 No. 3, pp. 1058-1073.

Ni, Z., Chan, H.K. and Tan, Z. (2021), "Systematic literature review of reverse logistics for e-waste: overview, analysis, and future research agenda", *International Journal of Logistics Research and Applications*, pp. 1-29, doi: 10.1080/13675567.2021.1993159.

Núñez-Merino, M., Maqueira-Marín, J.M., Moyano-Fuentes, J. and Martínez-Jurado, P.J. (2020), "Information and digital technologies of Industry 4.0 and Lean supply chain management: a systematic literature review", *International Journal of Production Research*, Vol. 56 No. 16, pp. 5034-5061.

Oztemel, E. and Gursev, S. (2020), "Literature review of Industry 4.0 and related technologies", *Journal of Intelligent Manufacturing*, Vol. 31, pp. 127-182.

Paré, G., Trudel, M.C., Jaana, M. and Kitsiou, S. (2015), "Synthesizing information systems knowledge: a typology of literature reviews", *Information and Management*, Vol. 52, pp. 189-199.

Park, I., Yoon, B., Kim, S. and Seol, H. (2021), "Technological opportunities discovery for safety through topic modeling and opinion mining in the fourth industrial revolution: the case of artificial intelligence", *IEEE Transactions on Engineering Management*, Vol. 68 No. 5, pp. 1504-1519.

Patrucco, A., Moretto, A., Trabucchi, D. and Golini, R. (2022), "How do industry 4.0 technologies boost collaborations in buyer-supplier relationships?", *Research Technology Management*, Vol. 65 No. 1, pp. 48-58.

Paul, S.K. and Chowdhury, P. (2021), "A production recovery plan in manufacturing supply chains for a high-demand item during COVID-19", *International Journal of Physical Distribution and Logistics Management*, Vol. 51 No. 2, pp. 104-125.

Petersen, K., Vakkalanka, S. and Kuzniarz, L. (2015), "Guidelines for conducting systematic mapping studies in software engineering: an update", *Information and Software Technology*, Vol. 64, pp. 1-18.

Porter, M.E. and Heppelmann, J.E. (2015), "How smart, connected products are transforming companies", *Harvard Business Review*, Vol. 93 No. 10, pp. 96-114.

Qazi, A.A. and Appolloni, A. (2022), "A systematic review on barriers and enablers toward circular procurement management", *Sustainable Production and Consumption*, Vol. 33, pp. 343-359.

Raji, I.O., Shevtshenko, E., Rossi, T. and Strozzi, F. (2021), "Industry 4.0 technologies as enablers of lean and agile supply chain strategies: an exploratory investigation", *International Journal of Logistics Management*, Vol. 32 No. 4, pp. 1150-1189.

Rejeb, A., Keogh, J.G., Leong, G.K. and Treiblmaier, H. (2021a), "Potentials and challenges of augmented reality smart glasses in logistics and supply chain management: a systematic literature review", *International Journal of Production Research*, Vol. 59 No. 12, pp. 3747-3776.

Rejeb, A., Keogh, J.G., Wamba, S.F. and Treiblmaier, H. (2021b), "The potentials of augmented reality in supply chain management: a state-of-the-art review", *Management Review Quarterly*, Vol. 71, pp. 819-856.

Rasool, F., Greco, M. and Grimaldi, M. (2022), "Digital supply chain performance metrics: a literature review", *Measuring Business Excellence*, Vol. 26 No. 1, pp. 23-38.

Rejeb, A., Rejeb, K., Abdollahi, A., Zailani, S., Iranmanesh, M. and Ghobakhloo, M. (2022), "Digitalization in food supply chains: a bibliometric review and key-route main path analysis", *Sustainability*, Vol. 14 No. 1, pp. 1-29.

Riahi, Y., Saikouk, T., Gunasekaran, A. and Badraoui, I. (2021), "Artificial intelligence applications in supply chain: a descriptive bibliometric analysis and future research directions", *Expert Systems with Applications*, Vol. 173, pp. 1-19.

Rindfleisch, A. (2020), "The second digital revolution", *Marketing Letters*, Vol. 31, pp. 13-17.

Rusch, M., Schöggl, J.-P. and Baumgartner, R.J. (2022), "Application of digital technologies for sustainable product management in a circular economy: a review", *Business Strategy and the Environment*, John Wiley & Sons, Ltd, Vol. n/aNo. n/a, available at: https://doi.org/10.1002/bse.3099

Scuotto, V., Caputo, F., Villasalero, M. and Del Giudice, M. (2017), "A multiple buyer–supplier relationship in the context of SMEs' digital supply chain management*", *Production Planning and Control*, Vol. 28 No. 16, pp. 1378-1388.

Sodhi, M.M.S. and Tang, C.S. (2019), "Research opportunities in supply chain transparency", *Production and Operations Management*, Vol. 28 No. 12, pp. 2946-2959.

Spieske, A. and Birkel, H. (2021), "Improving supply chain resilience through industry 4.0: a systematic literature review under the impressions of the COVID-19 pandemic", *Computers and Industrial Engineering*, Vol. 158, 104752.

Szalavetz, A. (2019), "Digitalisation, automation and upgrading in global value chains - factory economy actors versus lead companies", *Post-communist Economies*, Vol. 31 No. 5, pp. 646-670.

Tang, C.S. and Veelenturf, L.P. (2019), "The strategic role of logistics in the industry 4.0 era", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 129, pp. 1-11.

Toktaş-Palut, P. (2022), "Analyzing the effects of Industry 4.0 technologies and coordination on the sustainability of supply chains", *Sustainable Production and Consumption*, Vol. 30, pp. 341-358.

Tortorella, G., Fogliatto, F.S., Gao, S. and Chan, T.K. (2022), "Contributions of Industry 4.0 to supply chain resilience", *International Journal of Logistics Management*, Vol. 33 No. 2, pp. 547-566.

Tranfield, D., Denyer, D. and Smart, P. (2003), "Towards a methodology for developing evidence-informed management knowledge by means of systematic review", *British Journal of Management*, Vol. 14 No. 3, pp. 207-222.

Vanteddu, G. and Chinnam, R.B. (2014), "Supply chain focus dependent sensitivity of the point of product differentiation", *International Journal of Production Research*, Vol. 52 No. 17, pp. 4984-5001.

Varriale, V., Cammarano, A., Michelino, F. and Caputo, M. (2021), "The role of supplier innovation performance and strategies on the smartphone supply market", *European Management Journal*, Vol. 40 No. 4, pp. 490-502, doi: 10.1016/j.emj.2021.09.010.

Varriale, V., Cammarano, A., Michelino, F. and Caputo, M. (2022), "OEM vs module supplier knowledge in the smartphone industry: the impact on the market satisfaction", *Journal of Knowledge Management*, Vol. 26 No. 11, pp. 166-187.

Wamba, S.F. and Queiroz, M.M. (2022), "Industry 4.0 and the supply chain digitalisation: a blockchain diffusion perspective", *Production Planning and Control*, Vol. 33 Nos 2-3, pp. 193-210.

Winkelhaus, S. and Grosse, E.H. (2020), "Logistics 4.0: a systematic review towards a new logistics system", *International Journal of Production Research*, Vol. 58 No. 1, pp. 18-43.

Xu, J., Pero, M.E.P., Cicculo, F. and Sianesi, A. (2021), "On relating big data analytics to supply chain planning: towards a research agenda", *International Journal of Physical Distribution and Logistics Management*, Vol. 51 No. 6, pp. 656-682.

Yang, C.S. and Lirn, T.C. (2017), "Revisiting the resource-based view on logistics performance in the shipping industry", *International Journal of Physical Distribution and Logistics Management*, Vol. 47 No. 9, pp. 884-905.

Yang, J., Ma, X., Crespo, R.G. and Martínez, O.S. (2021), "Blockchain for supply chain performance and logistics management", *Applied Stochastic Models in Business and Industry*, Vol. 73 No. 3, pp. 429-441.

Zhang, S., Huang, K. and Yuan, Y. (2021), "Spare parts inventory management: a literature review", *Sustainability*, Vol. 13 No. 5, pp. 1-23.

Zheng, T., Ardolino, M., Bacchetti, A. and Perona, M. (2020), "The applications of Industry 4.0 technologies in manufacturing context: a systematic literature review", *International Journal of Production Research*, Vol. 59 No. 6, pp. 1922-1954.

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