International Journal of Production Economics 220 (2020) 107439

Contents lists available at ScienceDirect

International Journal of Production Economics

journal homepage: www.elsevier.com/locate/ijpe

Supply chain digitisation trends: An integration of knowledge management

Dara G. Schniederjans[a], Carla Curado[b], Mehrnaz Khalajhedayati[a,*]

[a] University of Rhode Island, USA
[b] ISEG – Technical University of Lisbon, USA

ARTICLE INFO

Keywords:
Digitisation
Knowledge management
Forecasting
Supply chain

ABSTRACT

The rapid digitisation of industry, or industry 4.0, is trending in supply chain management. While the amount of data made available through digitisation has enabled supply chain benefits, there still exist challenges regarding the rapid digitisation of the field. Therein lies opportunities for scholars to leverage the growing amount of data through knowledge management to cultivate valuable information for organisations. The purpose of this paper is to understand future inquiries for scholars to broaden their perspectives and leveraging knowledge management to enhance the supply chain digitisation research paradigm. This is done through both a large-scale literature review as well as a textual analysis and forecasting on industry- and field-applications, technologies and topics in digitisation. Utilizing textual data as well as google trends data from 2010 to 2018, comparisons are conducted on two measurements (prevalence and growth) to determine significant differences between the scholarly publications and practitioner (news and video) media to compare scholarly vs. practitioner activity in the aforementioned areas of supply chain digitisation. Applying the field of knowledge management to supply chain management through a knowledge management theoretical framework, this paper provides future research inquiries pertaining to how scholars can utilize the largely ignored areas of supply chain digitisation as well as the growing areas to explain how the human dimension of supply chain management can be further explored for the purposes of optimizing supply chain digital performance.

1. Introduction

The rapid digitisation of industry, or Industry 4.0, is trending in supply chain management. The opportunities surrounding digitisation have made it possible for supply chains to access, store and process a large amount of data both from within a firm and externally. For example, manufacturing firms are now able to obtain individualized customer data to personalize the sales process, product design and service. One application of this is through smart devices which record and share data in order to identify opportunities using learning algorithms (Feng and Shanthikumar, 2018). Digitisation also allows for demand information to be shared directly to actuators in manufacturing plants, leading to shorter changeover time and enhanced service level. The amount of data stored and disseminated has also enhanced both predictive accuracy and facilitation of prescriptive solutions. Specifically, forecasting applications of big data have recently proliferated in such areas as entertainment (Goel et al., 2010); auto parts (Choi and Varian, 2012), hotels (Yang et al., 2014) and the retail industry (Cui et al., 2017). Retail stores can now collect data from their consumers including an entire purchase history, where they can be subsequently identified through membership information or payment methods allowing the company to understand and analyze the characteristics of the shopper and predict consumer behavior (Guha and Kumar, 2018). In addition to demand planning, digitisation has also had a profound impact on the manufacturing environment with sensors, processors and actuators collecting real time data about machines, enabling not only communication between machines but also sharing the data throughout the supply chain network to keep downstream and upstream supply chain partners informed of various processes.

While the amount of data made available throughout digitisation has enabled these benefits, there are a myriad of challenges that are currently unaddressed in scholarly literature. This is made evident in both news and media where there is a lack of knowledge surrounding how to implement and utilize the proliferation of data for the strategic vision of the supply chain network. For example, the adequate assessment and detection of biases, noise and abnormality in data as well as the information sharing across the boundaries of legally independent organisations is needed to enhance the sharing of competencies and the exploitation of opportunities not only between large entities in the supply chain but also the small and medium enterprises who have limited resources and capabilities (Feng and Shanthikumar, 2018). Another facet understudied in scholarly literature is trust in knowledge

* Corresponding author. College of Business, Supply Chain Management, University of Rhode Island, 7 Lippitt road, Ballentine Hall, Office 216, USA.
E-mail addresses: schniederjans@uri.edu (D.G. Schniederjans), ccurado@iseg.ulisboa.pt (C. Curado), mkhalajhedayati@uri.edu (M. Khalajhedayati).

https://doi.org/10.1016/j.ijpe.2019.07.012
Received 2 November 2018; Received in revised form 14 June 2019; Accepted 13 July 2019
Available online 16 July 2019
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sharing which is vital especially considering the increased need to store proprietary data in a globally connected digitized environment. As an example, equipment suppliers are often reluctant to share machine status which ultimately impacts both productivity and quality. Finally, when it comes to coordination, the ultimate goal of balancing and consolidating limited resources across different organisations requires the optimization of resource allocation as well as human resource capability investments in knowledge sharing distributed networks (Feng and Shanthikumar, 2018).

Digitisation has caused both excitement and fear speculating both the possibilities to supply chain management as well as inevitable threats including the loss of jobs in the field. Articles like Lyall et al. (2018) foretell the “death of supply chain”, explaining that leading companies are utilizing robotics and artificial intelligence to automate labor-intensive tasks and processes in purchasing, invoicing, accounts payable and customer service. Further sensor data has rendered machine use and maintenance to an automatic state. Blockchains are beginning to reduce third party involvement. Robots are utilized to automate production. Lastly, drones and autonomous vehicles are beginning to approach implementation, soon to automate transportation. Lyall et al. (2018) concludes that it is these developments in digitisation that will allow a single organisation to manage the supply chain remotely while reducing safety concerns and the need for workers in remote locations. Yet despite this concern, organisations still face the challenges of extracting knowledge from data as well as implementing these technologies within a small portion of the supply chain, much less, end-to-end.

However, individuals are still needed to optimize the use of these technologies for supply chain network performance. Knowledge management, which involves the process of creating, sharing, using and managing knowledge and information in an organisation, is needed to facilitate the process of converting these vast amounts of data to knowledge. Although facets of digitisation including machine learning seek to automate “learning” in organisations, the proliferation of these technologies are not yet viable in strategic thinking for supply chain management. Yet, with all the data made available, understanding how to extract, share and use knowledge is becoming more fundamental. Thus, this paper seeks to address the following research questions: what industry- and field-applications, technologies and topics in supply chain digitisation are prevalent and growing among scholars and practitioners? And further are there differences between the prevalence and growth between scholars and practitioners? Finally, if there are differences, from a knowledge management perspective, how can supply chain scholars apply knowledge management to specific industry- and field-applications, technologies and topics to benefit not only scholarly research but practitioner insight?

To address these questions, this study utilizes a large-scale literature review as well as a textual analysis and forecasting (on scholarly publications and news/video media data) referencing the industry- and field-applications, technologies and topics in digitisation. Utilizing textual data as well as google trends data from 2010 to 2018, comparisons are conducted on two measurements (prevalence and growth) to determine significant differences between the scholarly publications and practitioner (news and video) media to compare scholarly vs. practitioner activity in the aforementioned areas of supply chain digitisation. Applying the field of knowledge management to supply chain management through a knowledge management theoretical framework, this paper provides future research inquiries pertaining to how scholars can utilize the largely ignored areas of supply chain digitisation as well as the growing areas to explain how the human dimension of supply chain management can be further explored for the purposes of optimizing supply chain digital performance.

The paper is organized as follows: first, an overview of knowledge management and its relation to supply chain digitisation is presented. Following this, the paper presents the methodology including the collection and interpretation of textual data from both scholars and practitioners as well as the statistical analyses conducted to assess the differences in frequencies. Additionally, a variant of the Croston method of forecasting (Linear Exponential smoothing) is utilized to forecast both scholarly publications as well as practitioner media to determine growth in specific industry- and field-applications, technologies and topics. A research model is then presented which indicates the two dimensions of frequency and growth on industry- and field-applications as well as technologies and topics from both a scholar and practitioner standpoint. Similarities between these two dimensions are then applied to the field of knowledge management to gather scholarly insights and future research directions to utilize knowledge management for enhancing the benefits of digitisation for supply chain management.

2. Literature review

Knowledge management (KM) bridges information demand and supply on behalf of learning processes and, consequently, organisational performance improvement (Curado and Bontis, 2011). Knowledge assumes tacit and explicit forms (Polanyi, 1962). Tacit knowledge is deeply rooted in action, commitment, and involvement and, thus, it is hard to formalize and communicate. Explicit knowledge is codified and transmittable in formal, systematic language and thus it is captured in libraries, archives, and databases (Nonaka, 1994). There is a permanent interaction between tacit and explicit knowledge that moves across individuals, groups, organisations, and back to individuals again (Nonaka and Toyama, 2003). The theory of knowledge creation (Nonaka, 1994) proposes that knowledge is created over an endless cycle and, thus, increases organisational knowledge via: a) socialization, b) externalization, c) combination and d) internalization. Socialization demands face-to-face communications among organisation members to exchange tacit knowledge. Externalization requires individuals to transform tacit into explicit knowledge thereby allowing it to be captured by others in the organisation. Combination consists of transforming explicit knowledge into more complex forms, and internalization converts explicit knowledge back into tacit form allowing individuals to include it into their personal routines (Curado and Bontis, 2011). Given such a theory, we must acknowledge that a major step in the knowledge creation process is based upon human interaction, challenging the technology basis of supply chain digitisation.

According to the (March 1991) model, knowledge management relies on the tension between the processes of exploration and exploitation. Exploration consists of the development of new organisational routines and solutions. Whereas exploitation consists of leveraging current routines to refine solutions and pre-existing knowledge. Both knowledge management strategies should be applied for sustainable competitive advantage. The correct balance is hard to achieve since organisations learn from experience how to divide resources between exploration (efficacy driven) and exploitation (efficiency driven) (Curado and Bontis, 2011). In order to use the exploration strategy (creating innovations) digitisation supports high-qualified employees; whereas when opting for applying an exploitation strategy (improving routines) digitisation replaces low-qualified employees (Wilkesmann and Wilkesmann, 2018). According to Cepeda Carrión et al. (2004) acquiring, managing and transferring knowledge involves technology, processes and people. These are considered the three pillars of knowledge management. They are involved in knowledge management processes and they serve both exploration and/or exploitation.

Alavi and Leidner (2001) framework of knowledge management processes encompasses; a) knowledge creation, b) knowledge storage/retrieval, c) knowledge transfer, and d) knowledge application, to create value from the knowledge assets the firm possesses. Knowledge management involves not only technical capabilities of managers and workers, but also social networks to design, modify and execute work flows thus enabling the free circulation of knowledge in internal processes as well as to reach search engines to capture and apply external knowledge (Rojas et al., 2017). The use of digitisation technologies assists routines that support knowledge management practices within industrial applications (Wilkesmann and Wilkesmann, 2018), thus, literature often relates knowledge management and Digitisation (Cárdenas et al., 2018; Ilvonen et al., 2018; Shamim et al., 2017; Wilkesmann and Wilkesmann, 2018). According to Schneider Electric (2017) there are six main managerial challenges of digitisation: (1) strategy and analysis, (2) planning and implementation, (3) cooperation and networks, (4) business models, (5) human resources and (6) change and leadership. To overcome these challenges firms must use a combination of the three pillars of knowledge management: technology, processes and people.

In general, knowledge management relates to supply chain management by providing the tools necessary to manage large amounts of data generated by supply chain operators and their customers (Carlos et al., 2013; Dost et al., 2016; Olson, 2018; Pérez-Salazar et al., 2017; Schoenherr et al., 2014). Supply chain management demands managers to understand, monitor and control operations in the entire supply chain, from sourcing, logistics, production and retail delivery to customers (Olson, 2018). All these tasks involve managing knowledge not only from the technology side through information systems (Gunasekaran and Ngai, 2007) but also the quality of knowledge provided in the supply chain through data management and analytics (Olson, 2018), regarding either tacit or explicit knowledge (Schoenherr et al., 2014). As a result, knowledge management contributes to supply chain performance (Dost et al., 2016; Schoenherr et al., 2014) since the domains of knowledge management in supply chain management are both intra- and inter-organisational (Carlos et al., 2013) allowing firms to respond to internal and external stakeholder needs. While the role of knowledge management in supply chain management is established in current literature, the role of knowledge management as it relates to digitisation has yet to be fully explored provided the recency of digital technology in both areas of study. A general understanding is needed on the digitisation eco-system.

Fig. 1, adapted from (Stroup, 2017) provides a general overview of the defining characteristics of digitisation as well as the interdisciplinary nature of digitisation. While the figure is not all encompassing of the various technologies that exist, it provides a basic overview of the eco-system of digitisation and how it works toward not only the proliferation of big data applications but also internal and external stakeholder value. The technologies are separated into common fields based on the review of literature conducted, however, many of these technologies can be applied in different contexts and other fields.

Digitisation commonly referred to as internet of things (IOT) is

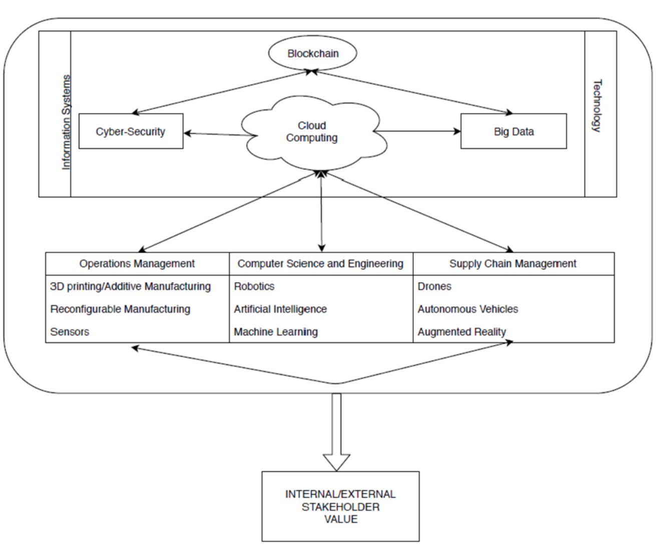

Fig. 1. Digital technologies.

defined as, "intelligent production incorporated with the internet of things, cloud technology and big data. With the ability to collect, share and use information to make better decisions and be more productive through decentralizing technology processes" (Stroup, 2017). What distinguishes the new era of digitisation is the trend toward the decentralization of information sharing and automation. For example, traditionally, actuators in manufacturing facilities would be connected through a super computer which would directly send data to stations independently. In the new digitisation environment, these actuators can communicate directly with one another, bypassing the super computer through sensor capabilities. Additionally data through sensors can be collected and shared throughout the supply chain network via information technologies and systems such as cloud computing (Stroup, 2017). This trend toward not only the rapid and real time sharing of information but also of automation has given rise to various other technologies that can be controlled with minimal to no human intervention. However, as seen through the definitions of these technologies, while these technologies provide opportunities for data flow and information processing, the dissemination of knowledge is still a much-needed consideration among scholars.

On the information systems side are the technologies that consist of: cloud computing and blockchain. Cloud computing is a massively scalable computing paradigm that offers software, infrastructure and platforms as a service, providing real time data sharing capability throughout the supply chain (Cao et al., 2017). Whereas blockchain technology refers to incorruptible digital ledgers of transactions that are programmed to record value of any type of transaction, allowing for a secure and transparent form of sharing transactional data (Tapscott and Tapscott, 2016; Underwood, 2016).

Other technologies have been developed not only for the aggregation and dissemination of large amounts of data but also to aid in transportation/warehouse/and distribution management. Drones are aerial vehicles that require no human pilot on board (Floreano and Wood, 2015). Various applications exist in supply chain including transportation of last-mile delivery as well as replacement for conveyor systems in the warehouse. For individual drivers, autonomous vehicles are any type of vehicle capable of utilizing sensors to detect environmental changes rendering the capability of navigation without human input (Gehrig and Stein, 1998). Companies like Uber have already initiated the utilization of self-driving trucks to haul freight in Arizona. While the current undertakings are a lower level of automation, Uber has invested in implementation plans for higher level autonomous vehicles (Bhuiyan, 2017).

From the warehouse management side, augmented reality (AR) is an interactive digital experience of a real-world environment where objects are augmented by computer generated perceptual data which may include visual, auditory, haptic, somatosensory and olfactory perceptions (Schuettel, 2017). Wearable devices are particularly becoming more prevalent in warehouse management, where pickers now utilize glasses which instruct where to pick, how much to pick and will record this information.

Sensors that detect physical phenomenon (i.e. pressure, force, acceleration, temperature, etc.) can convert data into an output typically in the form of an electronic signal. Sensors are not only used in a manufacturing environment, but now some freight contain sensors that detects miles, miles per gallon, fuel, location, speed, etc. The digitisation of industry requires machines that are self-aware learning and maintained. Where technologies actively suggest task arrangements and adjust operational parameters to maximize quality (Feng and Shanthikumar, 2018). The design of robotics is progressively improving through developments like artificial intelligence. For example, the external communication between human beings averages approximately 10 bits per second, whereas robots can communicate at rates over one gigabyte per second. Facets like machine learning and artificial intelligence are enhancing the uses of robotics. Machine learning is a subset of artificial intelligence where computers are given the ability to progressively improve their performance on a task with data but without the need for explicit programming (Michalski et al., 1984). Finally from the production side are technologies like 3D printing and reconfigurable manufacturing have the potential to greatly reduce lead time and transportation costs throughout the supply chain (Schniederjans, 2017). 3D Printing is the process in which material is joined and solidified through computer aided design to create a three-dimensional object. In addition reconfigurable manufacturing systems are designed to accommodate rapid changes in structure (inclusive of hardware and software components) in order to adjust to production capacity and functionality which is capable of being altered by market or an intrinsic system change (Koren et al., 1999).

All these technologies serve as a catalyst for greater dissemination of information and big data analytics which have been applied to a variety of supply chain problems in network design, risk management, inventory management and retail. In general, the eco-system of digitisation has adjusted from being regarded as a connected network between things to an extended connection between things, items and all stakeholders contributing to the evolution of the business eco-system through big data applications and greater amounts of information (Rong et al., 2015). The enhanced connectivity and automation provided by digitisation continues to proliferate new supply chain applications and innovative practices for companies. However, the challenges persist without human intervention to adequately extract knowledge from this connectivity. The importance of knowledge management in the new era of digitisation is further solidified by studies like (Xue, 2014) who found that when an IT department is allocated with more decision rights and has more business knowledge, then knowledge creation capability drives the firm toward more strategic risk which in turn results in operational and strategic benefits to the firm. While previous research has been conducted on business applications in a variety of industries (Atzori et al., 2010; Karakostas, 1962; Paschou et al., 2013; Turcu and Turcu, 2013) as well as security and privacy (Kothmayr et al., 2013; Roman et al., 2013), digitisation literature is currently in its infancy, with scholarly and practitioner interest but minimal insights into avenues to assess the importance of industry- and field-applications as well as technologies and topics from both a scholar and practitioner standpoint. Further, as knowledge management is likely to enhance the benefits to a supply chain, applying knowledge management to the specific industry- and field-applications as well as technologies and topics will be necessary to ensure optimization of supply chain digitisation.

3. Methodology

The research questions in this study seeks to assess first: what industry- and field-applications, technologies and topics in supply chain digitisation are prevalent and growing among scholars and practitioners? And further are there differences between the prevalence and growth between scholars and practitioners? Finally, if there are differences, from a knowledge management perspective, how can supply chain scholars apply knowledge management to specific industry- and field-applications, technologies and topics to benefit not only scholarly research but practitioner insight? Thus, the most appropriate method to use was content analysis of both scholarly publications and practitioner news/video media. Content analysis is a research method that utilizes a set of procedures in order to make valid inferences from textual (and/or visual and auditory) data (Weber, 1990). Used as a means of describing trends in communication content and comparing media or levels of communication (Weber, 1990), content analysis was the most appropriate methodology for the research questions developed.

3.1. Data acquisition

3.1.1. Scholarly textual data

To address the first research question, a variant of the systematic literature review proposed by Durach et al. (2015) was conducted on scholarly publications as well as practitioner media. The units of analyses (scholarly publications in supply chain digitisation and practitioner media in supply chain digitisation) required several sets of media platform searches. A scholarly literature review search was performed through ABI/INFORM Complete (ProQuest) and Academic Search Complete (EBSCOhost) databases. A search string[1] was initially developed by a co-author whose areas of expertise are in technology and supply chain management. Later, two reference librarians helped to refine the search string based on domain knowledge in the databases as well as the topic. Further inclusion/exclusion criteria included: peer reviewed articles in supply chain digitisation, (2) removal of predatory journals as indicated on 2018 Beall's List of predatory journals and publishers and (3) Removal of articles not written in the English language. Further revisions to the search string were necessary to ensure a focus on supply chain digitisation. Both reference librarians suggested including a title search specifying supply chain keywords, as well as an abstract and subject search on digitisation. This was the higher-level exclusion criteria which significantly decreased the number of referenced articles but ensured any article whose focus was not on supply chain digitisation was removed from further consideration. Articles were accessed from a period of January 2010–June 2018. Some of the journals included: *Decision* Support *Systems, Supply Chain Management: An International Journal, Management Science, Operations Research, International Journal of Physical Distribution and Logistics Management, International Journal of Management and Information Systems,* etc. A total of 52 academic articles on supply chain digitisation were utilized as a basis for examining scholarly activity in supply chain digitisation.

3.1.2. Practitioner magazine textual data

Practitioner Magazines were utilized to gather textual data representative of the practitioner standpoint on supply chain digitisation. Practitioner magazines including: *Supply Chain Quarterly, Supply Chain Management Review, DC Velocity, Inbound Logistics, Logistics Management, Supply Chain Dive, Modern Materials Handing, TechCrunch, CIO Magazine, InfoSecurity Group Magazine, Wired, Fast Company,* and *ComputerWorld* were accessed to obtain an interdisciplinary perspective of supply chain digitisation (i.e. computer science and information technology personnel insights can provide a more broad understanding of how supply chain digitisation fits into the larger inter-organisational network digitized eco-system).

To ensure the focus on supply chain digitisation similar exclusion/inclusion criteria to the scholarly textual data was also utilized. This criterion included: (1) title on supply chain; topic/focus on digitisation (2) company/practitioner focus (i.e. interviews with supply chain digitisation implementations, specific company representatives, or talks about a company implementing, using or considering supply chain digitisation). (3) removal of any advertisements (4) removal of new company announcements (5) removal of text not related to digitisation (i.e. with large interviews with one question pertaining to supply chain digitisation, only the textual data related to that question was kept).

This data was initially collected through a web scraper. This included accessing the practitioner magazine websites and running the web scraper code to collect data including: “title”, “date”, “author”,

[1] “supply chains” OR “supply chain” OR “supply chain management” OR “suppliers” OR “supply network” OR “logistical network” OR “demand chain” OR “supply management” OR “reverse logistics” AND “Fourth industrial revolution” OR “smart factory” OR “Connected Enterprise” OR “Industrie 4.0″ OR “Industry 4.0″ OR “smart industry” OR “smart manufacturing” OR “Industrial internet” OR “re-industrialization” OR “Digitisation” OR “Digital” OR “Digitisation” OR “Internet of things” OR “IoT” OR “location detection technologies” OR “location detection technology” OR “Advanced human-machine interfaces” OR “fraud detection” OR “3D print” OR “additive manufacturing” OR “smart sensors” OR “big data” OR “augmented reality” OR “cloud computing".

"affiliation", "main text", and "abstract text". Coding was altered based on the layout type of each publication. A total of 353 practitioner magazine articles on supply chain digitisation were utilized as a basis for examining practitioner activity in supply chain digitisation.

3.1.3. Video textual data

Along with structured data (i.e. scholarly and practitioner magazine articles), unstructured data (via video) was also utilized. It is suggested up to 80% of the world's data are unstructured (Tachizawa et al., 2015), which are currently underutilized in current research. Video data provides supplementary practitioner insight not only from different representatives within one company but also different thoughts (maybe from a lower level employee) on supply chain digitisation.

Video data was collected through YouTube and Google Video with a revised search string but with the same search criteria (i.e. title on supply chain; topic focus: digitisation). In addition, our research questions focus on practitioner perspective required us to refine the video inclusion/exclusion criteria to include (1) company/practitioner focus (i.e. interviews with supply chain digitisation implementations, specific company representatives, or talks about a company implementing, using or considering supply chain digitisation): (2) removal of any advertisements (3) removal musical only videos with just pictorial data (i.e. no textual data) (3) videos without English subtitles.

Video data was collected by two graduate assistants and a co-author. Facets including: "title", "date", "author", "affiliation", "text" and "summary" data when available were retrieved through YouTube and Google Video. Textual data was collected by a main interface and closed captioning, when available. Textual data was reviewed and subsequently adjusted by the co-author to ensure accuracy.

Data acquisition and subsequent cleansing of data occurred over a seven-month period between January 2018–July 2018. Data was collected and cleansed by one professor and two graduate student assistants whose expertise lies in social media and supply chain management. Table 1 presents the textual sources and inclusion/exclusion criteria. A total of 74 videos on supply chain digitisation were utilized as a basis for examining a supplementary viewpoint of practitioner activity in supply chain digitisation.

3.2. Coding of data

Researchers coded the textual data in two stages (1) coding of the scholarly data and (2) coding of the news/video data. For each stage: independent coders tagged each document on (1) industry- and field-applications, (2) technologies and (3) topics in supply chain digitisation. Coded classifications were first conducted through term frequencies (i.e. "autonomous vehicles or self-driving cars" mentioned 49 times in article 1). Only frequencies above three mentions were utilized to tag articles. These tags were then validated by reading through each document. Any deletions (i.e. social responsibility was mentioned twice but not related to supply chain digitisation) were recorded and then checked for interrater agreement afterwards. Initial industry- and field-applications, technologies and topics were informed by a 20%/80% randomized split in (1) scholarly data and (2) practitioner data. That is initial topics were developed through a thorough analysis of the 20% and then subsequent industry- and field-applications as well as technologies and topics were added when the remaining 80% did not fit into one category. Since the research question requires a comparison between the scholarly and practitioner data, the process only coded industry- and field-applications, technologies and topics that both sets of data have in common. For example, some practitioner media focused on journalism applications while the scholarly data did not, thus this was not utilized for further comparison. Table 2A (Available in Appendix A) provides the final list of 1) industry- and field-applications, (2) technologies and (3) topics in supply chain digitisation as well as sample articles for each.

Table 2
Growth rate comparison of technologies in different data sets.

Technology	Practitioner publication growth rate	Google trends growth rate
IOT	410.85	158.73
Big Data	149.74	347.34
Augmented reality	111.20	245.20
Artificial intelligence	33.00	12.17
Blockchain	60.48	39.20

4. Analyses

To address the first research question of "what industry- and field-applications, technologies and topics in supply chain digitisation are prevalent and growing among scholar and practitioners, this study presents data on the prevalence of (1) industry- and field-applications, (2) technologies and (3) topics in supply chain digitisation as well as how this has evolved over time in both scholarly publications and news/video media. To address the differences between the prevalence between scholars and practitioners a Mann Whitney U test is performed iteratively to determine significant differences. The similarities and the differences are accounted for in a model depicting "high vs. low" prevalence in both scholarly and practitioner publications. Following this and utilizing a variant of the Croston method of forecasting linear exponential smoothing is applied to each set of data to determine growth and decay in each (1) industry- and field-applications, (2) technologies and (3) topics among both the scholarly publications and practitioner media. This is then compared to account for differences in growth/

Table 1
Practitioner and scholarly publications sources, exclusion criteria and frequencies.

Type	Sources	Exclusion Criteria	Frequencies
Practitioner publications (Video)	YouTube; Google Video	Advertisements, Non-English (without English subtitles), No subtitles	Initial: 11,200 Company use and focus on digitisation: 360 Date Range: 340 Repeats on similar platforms: 120 English or Subtitles: 74
Practitioner Publication (News)	Practitioner Magazines	Advertisements, New Company Announcements, Interviews	Initial: 143,222 Company use and focus on digitisation: 10,347 (title summary search) Date Range: 538 Repeats on similar platforms, advertisements, new company announcements, interviews: 353
Scholarly Publications	ABI/INFORM Complete (ProQuest) and Academic Search Complete (EBSCOhost) databases	Peer Reviewed Scholarly Publications; Beall's list; English	Initial: 3,800 Peer Scholarly Publications: 1,546; Beall's List and English: 1080 Title and subject/abstract classifications and date range: 52

decay. These analyses will then finish addressing the first two research questions. Finally, after comparing both prevalence and growth a final model will be applied to knowledge management to help scholarly insight into developing research questions to help addressing growing but also limited research areas for supply chain digitisation.

4.1. Prevalence-scholarly publications

4.1.1. Industry- and field-applications

The prevalence of scholarly publications from 2010 to 2018 indicates a proliferation of studies in industries including: healthcare, aerospace, finance and humanitarian relief. Both food supply chain (including agriculture) (10.20%), healthcare (8.16%) appeared to have higher frequencies than any other industry which did not surpass 2.04% of scholarly publications. These industries became particularly prevalent in 2017. Areas of interest in supply chain digitisation included logistics/transportation (16.33%), manufacturing (12.24%), procurement (6.12%), information systems and information technology (IS/IT) (6.12%) and distribution (4.08%) were particularly prevalent. Areas including procurement and IS/IT became more prevalent in 2013 and continued into 2018. This was followed shortly by logistics/transportation which became more prevalent in 2014 as did distribution. Manufacturing also became more prevalent in 2013 but diminished in 2017.

4.1.2. Technologies

From 2010 to 2018, the most prevalent technology discussed was cloud computing (22.45%), which was particularly prevalent in 2011–2013. Many studies also focused on internet of things (IOT) (38.78%) e-commerce (4.08%) or big data (16.33%) in general with minimal focus on a technology or facet. This was common throughout 2011–2017. Other common technologies referenced were 3D printing (6.12%), Sensors (4.08%) and radio frequency identification coupled with big-data (2.04%). E-commerce was more prevalent in 2010 but has since made a resurgence. 3D-printing became more prevalent in 2016. Minimal research was found on other technologies or facets of technologies including: blockchain, artificial intelligence, drones, autonomous vehicles, augmented reality, or robotics.

4.1.3. Topics

Most scholarly publications included in this study reference potential benefits of utilizing the technology including economic, environmental and social benefits for various stakeholders (38.78%) which grew particularly in 2015–2018. This is followed by scholarly publication referencing social implications of utilizing such technology (i.e. worker safety, impacts on jobs, customer wellbeing, etc.) which became particularly prevalent in the latter part of 2011, decreased and then came back in 2015. Following this is inter-organisational collaboration/integration (18.37%), global and environmental impacts (both at 14.29%), digitisation problems/challenges (12.24%), and economic implications (both at 4.08%). Other topics including company applications and mergers and acquisitions did not reach beyond 2.04%.

4.2. Prevalence- practitioner (news/video) publications

4.2.1. Industry- and field-applications

Similar to scholarly publications, the prevalence of practitioner publications from 2010 to 2018 indicates food supply chain (including agriculture) as the top industry (4.02%) which rapidly grew in 2014 and maintained in 2016 and 2017 and healthcare at 2.36%. Other common industries included: textiles and courier (both at 1.89%), electrical manufacturing (1.65%), finance and humanitarian (both at 1.18%). Other industries did not surpass 0.24%. Areas of interest in supply chain digitisation included: logistics/transportation (25.77%), manufacturing (8.27%), IS/IT (10.87%), strategy (6.62%), customer relationship management (6.15%) and distribution and retail (both at 3.07%). Other areas of interest did not exceed 2.13%. Practitioner publications in IS/IT lead the frequencies in 2010 and resurged in 2015–2016. During that time warehouse and procurement became more popular in 2014.

4.2.2. Technologies

Dissimilar from scholarly publications, facets of technologies including big data represented the most prevalent technology topic in news/video literature (11.58%) which had an initial emergence in 2011 and increased to a large extent in 2015. Further, the majority of news/video tended to focus on IOT rather than specific technologies (51.77%). Following big data, was blockchain (8.98%) and closely following was cloud computing (7.80%). E-commerce also was commonly discussed at 5.20% as was augmented reality (4.96%), artificial intelligence (4.49%), and sensors (4.02%). At the lower end was 3D printers (3.78%), autonomous vehicles and mobile applications (both at 3.55%), and robotics (3.07%). RFID and drones did not exceed more than 1.18%. Most technologies had a larger emergence in 2015, except for mobile applications which remained steady from 2010 to 2018.

4.2.3. Topics

Similar to the scholarly publications, most practitioner publications included in this study reference potential benefits of utilizing the technology (30.02%) which grew particularly in early 2014. Unlike the scholarly publications, Economic implications followed shortly thereafter (23.17%). This was then followed by social implications (19.86%), global implications and collaboration/integration (both at 15.37%), company applications and future oriented discussions (both at 13.00%). Challenges and environmental implications did not exceed 8.27%. Benefits and future oriented discussion were especially prevalent in the early years (i.e. 2011–2012) whereas other topics appeared to increase in the early half of 2015.

4.3. Frequency analysis and model

Frequencies of each industry and field application, technologies and topic were tabulated for both scholarly publications and news/video publications. Since our study also addressed growth, summed frequencies and percentages of those frequencies are utilized to rank and conduct and iterative Mann-Whitney U test to determine significant differences. This is done iteratively where we first determine similar rankings between scholarly and news/video media (i.e. Food supply chain both received the highest ranking of 1 for both scholarly and news/video media), if the null hypothesis cannot be rejected (at a critical value of U as defined by the smallest of the U1 or U2 (at $\alpha = 0.05$), where

$$U1 = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1 \tag{1}$$

$$U2 = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2 \tag{2}$$

Where $U = \textit{the lowest value of } U1 \textit{ or } U2$, n_1 is the number of each industry and field application or technologies or topics in scholarly publications and n_2 is the number of each industry and field application, or technologies, or topics in news/video publications, R_1 represents the sum of ranks in the scholarly publications, and R_2 represents the sum of ranks in the news/video publications. We utilize those industry- and field-applications, technologies and topics and classify them into four categorizations in the research model presented in Fig. 2, where (high, high) refers to (scholarly publications ranked high/practitioner publications ranked high) and (low, low) refers to (scholarly publications ranked low/practitioner publications ranked low). The significant differences are then utilized to determine (high, low) vs. (low, high) categorizations where (high low) refers to (scholarly publications ranked high/practitioner publications ranked low) and (low, high) refers to

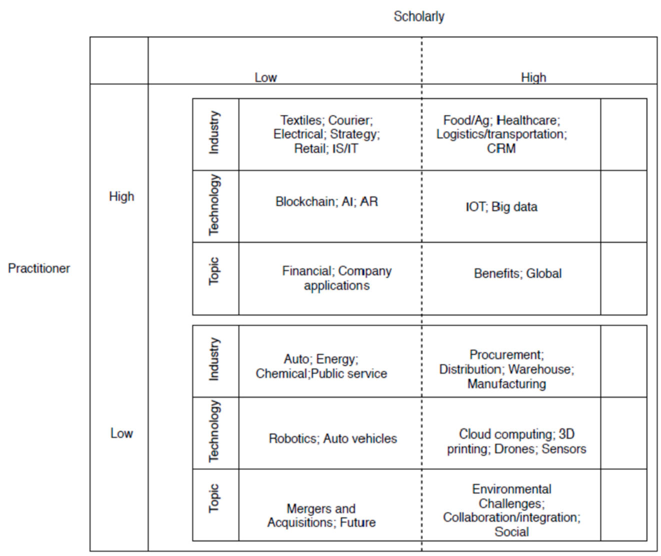

Fig. 2. Prevalence of industry- and field-applications, topics and technologies.

(scholarly publications ranked low/practitioner publications ranked high). This was done for each industry and field application, technologies and topic categorization. At the two sided-level of significance ($\alpha = 0.05$), for the industry- and field-applications a critical value of $U \leq 75$ was obtained for n1 and n2 = 16. For the technologies a critical value of $U \leq 13$ was obtained for n1 and n2 = 8. For the topics, a critical value of $U \leq 5$ was obtained for n1 and n2 = 6.

4.4. Growth-forecasting analysis

To adequately compare scholarly publications (which typically get published either annually, bi-annually, or quarterly), dates of publication were collected and then condensed to reflect bi-annual frequencies. Following this, a variant of the Croston method of forecasting which accurately accounts for intermittency and obsolescence in data was used to forecast growth into six period progressions. This variant, referred to as the linear exponential smoothing (LES) method (Prestwich et al., 2014), is similar to hyperbolic exponential smoothing (HES) but uses a different forecasting function to control the rate of the decay of the data by adjusting β. Specifically, LES applies single exponential smoothing (SES) to generate smoothed estimates of $\hat{\gamma}_t$ by using the formula,

$$\hat{\gamma}_t = \alpha\gamma_t + (1-\alpha)\hat{\gamma}_{t-1} \tag{3}$$

where $\alpha \in (0,1)$ is a smoothing parameter and observed values are indicated by γ_t. The forecast f_t for LES utilizes the following formula,

$$f_t = \begin{cases} \frac{\hat{\gamma}_t}{\hat{\tau}_t}, & if \;\; \gamma_t > 0 \\ \left(\frac{\hat{\gamma}_t}{\hat{\tau}_t}\right)\left(1 - \frac{\beta\tau_t}{2\hat{\tau}_t}\right)^+, & if \;\; \gamma_t = 0 \end{cases} \tag{4}$$

where x^+ demotes max $(0, x)$. During obsolescence forecasts will decay to zero controlled by β. When zero is reaches, this remains until further nonzero periods occur.

LES was utilized after conducting a review of the data which contained intermittent periods as well as some obsolescence. Provided the findings of Prestwich et al. (2014) who compare LES with two other Croston variants designed to adjust for obsolescence and intermittent data (i.e. Teunter, Syntetos and Babai (TSB) method and HES) and suggests it to be the best variant for handling obsolescence.

After forecasting the data into six periods, the growth is determined through the formula,

$$Growth\;\; Rate = \frac{f_{t+6} - \gamma_t}{\gamma_t} x\; 100 \tag{5}$$

Where f_{t+6} is the final (six period) forecasted value from the last observed value γ_t from the first half of 2018. Growth rates for each industry and field application, technologies and topic were tabulated for both scholarly publications and practitioner media. These were then grouped according to four categorizations with NGD referring to "no growth, decline", (growth, growth), (growth, NGD), (NGD, growth), and (NGD, NGD). The categorization of (growth, growth) indicates growth in both scholarly and practitioner publications. The categorization of (growth, NGD) indicates growth in scholarly publication and no growth or decline in practitioner publications. The categorization of (NGD, growth) indicates no growth or decline in scholarly publications and growth in practitioner publications. Finally, the categorization of (NGD, NGD) indicates no growth or decline in both scholarly and practitioner publications.

4.5. Growth scholarly publications

4.5.1. Industry- and field-applications

Growth in scholarly publications was particularly prevalent in scholarly healthcare publications (78.17%) followed by food supply chains (12.91%). Areas covered included logistics/transportation (50%), IS/IT, manufacturing, procurement and distribution (all growing at an average rate of 25%), aeronautical increased by only 6.46%. Decreasing industry scholarly research included courier, electrical manufacturing, textiles, energy, equipment automobile and chemical engineering and manufacturing (100%), humanitarian (32.39%), and public service (3.68%). Fields including strategy, CRM, retail and warehouse management showed no growth.

4.5.2. Technologies

From 2010 to 2018, IoT is forecasted to increase 164.66%. With specific areas including big data (20.9%) and cloud computing (64.44%) to increase. Technologies like augmented reality, block chain, autonomous vehicles, robotics, artificial intelligence and drones have yet to emerge and thus project forward. Additionally, e-commerce, mobile applications, and 3D printing were projected to decrease over time.

4.5.3. Topics

All supply chain digitisation topics were projected to increase at a steady rate 25% this included: benefits, global issues, future transformation, company applications, challenges, economic impacts, as well as social and environmental implications. The only topic that was set to gradually increase by 6.58% was collaboration and mergers and acquisitions.

4.6. Growth news/video practitioner publications

4.6.1. Industry- and field-applications

Similar to scholarly publications, food/agriculture (60.22%) and healthcare (13.56%) were both set to increase. However, growth was also indicated for public service (42.49%) followed by finance (13.56%), courier (8.56%), electrical manufacturing (6.42%) and by a slight amount humanitarian relief (0.05%). Unlike scholarly data, an industry that was projected to decline included aeronautical engineering (−21.82%). However, industries including chemical manufacturing (36.58%) automobile manufacturing (−27.40%), energy (−22.62%), equipment manufacturing (−22.61%) were all forecasted to decrease. All areas were set to increase to differing degrees. The largest area was logistics/transportation at 92.1% increased followed by IS/IT (39.95%), strategy (38.13%), CRM (34.42%), retail (27.14%), manufacturing, procurement, distribution (all at 25%) and warehouse management at 13.32%.

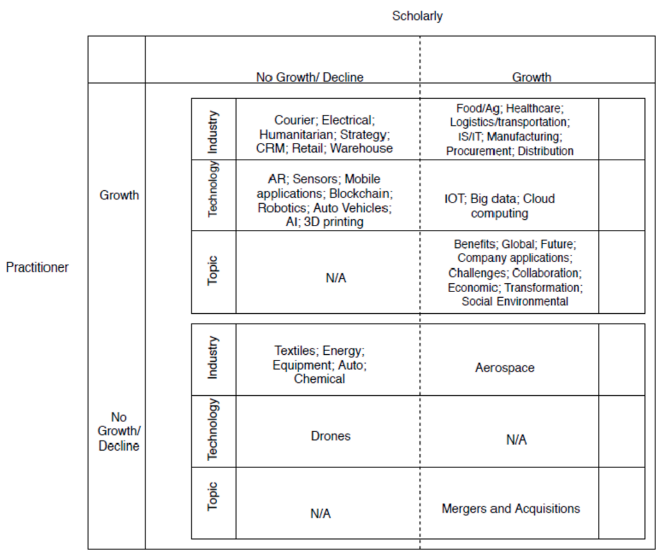

Fig. 3. Growth of industry- and field-applications, topics and technologies.

4.6.2. Technologies

From 2010 to 2018, practitioner publications dealing with IoT (410.85%), big data (149.74%) and cloud computing (91.72%) were all projected to increase to a large extent. Also similar to scholarly data drones (−12.09%) were projected to decrease. Unlike scholarly data, technologies including augmented reality (111.20%) was set to increase by a substantial amount. Followed by sensors (72.13%), mobile applications (66.68%), blockchain (60.48%), robotics (48.57%), autonomous vehicles (45.94%), E-commerce (41.44%), artificial intelligence (33%), ad 3D printing (27.95%) were projected to grow.

4.6.3. Topics

The topics of supply chain digitisation in practitioner publications followed a similar trajectory as scholarly publications. Except for collaboration/integration and mergers and acquisitions (0%), all topics were expected to grow to varying degrees. Benefits surpassed all topics with 125.67% growth. Followed by global implications (57.03%), company applications (54.88%), challenges (53.60%), social implications (41.77%), economic implications (39.35%) and environmental implications (30.7%). Fig. 3 depicts the delineated categories and the industries/fields, technologies and topics within these categorizations.

4.7. Comparison of prevalence and growth

Fig. 4, presents the consolidated models of Figs. 2 and 3. Specifically, Fig. 4 identifies the similarities between growth and prevalence among industry, technology and topic. It identifies which topics, technologies and industries are growing and prevalent from a practitioner and scholarly perspective. However, it goes a step further by also identifying what industries, technologies and topics are growing and prevalent among practitioners but not growing and prevalent among scholars for the purpose of identifying what is currently weak in the scholarly arena. Therefore, this figure addresses the final research question of this paper, from a knowledge management perspective, how can supply chain scholars apply knowledge management to specific industry- and field-applications, technologies and topics to benefit not only scholarly research but practitioner insight.

A sensitivity analysis was performed on the technologies presented in Fig. 4 to determine the efficacy of growth in each technology. This was done utilizing a google trends search, where the technology keyword was utilized and searched on google trends from January 2010–June 2018. Search data was then downloaded, where we combined the monthly data to bi-annual and utilized the Holt's technique to project six periods into the future. The Holt's method was utilized based on the differences in the data. Growth rates were then computed and compared. Although the growth rates varied (i.e. due to a combination of scholarly and practitioner interest), similar growth rates were found between the practitioner-oriented data in prevalence and growth. Table 2 presents these statistics.

5. Results

In a context of technological evolution that supports digitisation of industry, the traditional Knowledge Pyramid (Ackoff, 1989) suffered an enlargement to incorporate the origin of the building blocks for data, subsequent information and later knowledge, resulting in organisational actionable intelligence (Jennex, 2017). The available sensors allow us to collect and analyze internal and external realities and generate data, therefore the roots of data are digitalized. Considering such context, we apply the knowledge management approach by Alavi and Leidner (2001) to supply chain digitisation and propose an integrative approach to enhance the benefits of digitisation for supply chain management. Although the specific issues of industries are not accounted for generalization's sake, we offer an integrative model in Fig. 5 to highlight the supply chain digital optimization contribution to organisational digital performance and benefits through the use of knowledge management.

Considering the proposed integrated approach and the reported

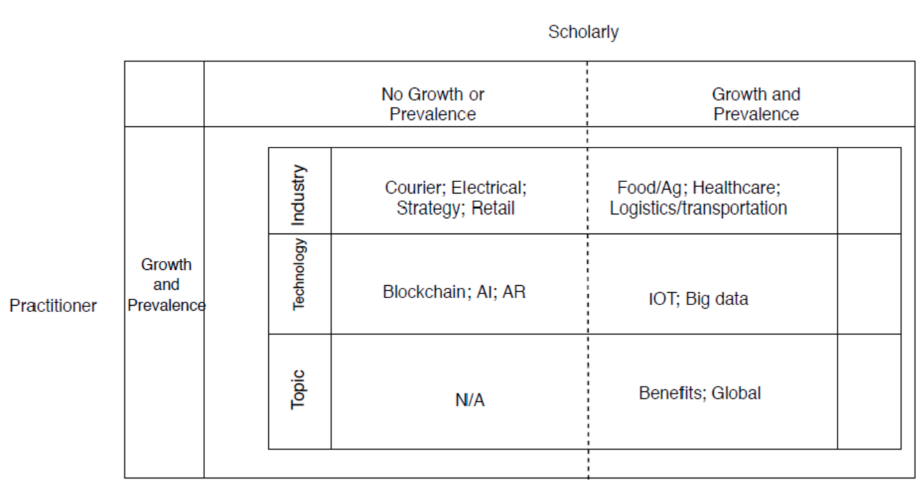

Fig. 4. Industry and field application, topics and technologies for scholarly attention.

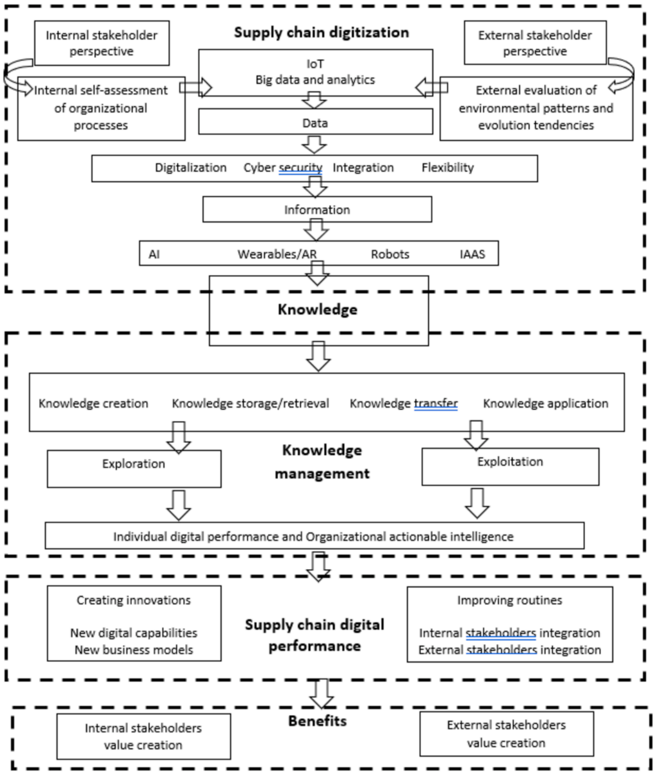

Fig. 5. Proposed integrated approach for supply chain digitisation and knowledge management (Adopted from (Cárdenas et al., 2018; Wilkesmann and Wilkesmann, 2018)).

industry applications, technologies and topics for practitioner and scholarly attention, we suggest insights and questions for future research to apply knowledge management in support the supply chain digitisation.

The research questions in Table 4 are based on the framework presented in Table 3 which is combined with the findings presented in Fig. 4. Provided concerns about substantial job losses and the related decline of supply chain management as a field (Lyall et al., 2018), the research questions presented in Table 4 detail the application of knowledge management for the purpose of enhancing supply chain digital performance. Specifically, these questions can be utilized to further support socialization and human level engagement through knowledge management for the purpose of enhancing supply chain digital performance (Corso et al., 2010).

We summarize our proposed questions from three perspectives: industry, technology, and management. From an industry perspective, research in knowledge management and industry digitisation is typically studied in health industries (Barata et al., 2018) particularly addressing tacit and explicit knowledge challenges (Al-Karaghouli et al., 2013). However, this research is analyzed at the technology- and process-level rather than the individual-level (Lombardi et al., 2015). As a result, we specify research questions that focus on the human requirements and consequences of knowledge management use in supply chain digitisation as they relate to health industries. Even in non-intensive knowledge management industries (i.e. food industries), we see evidence of digitisation having a potential to support socialization and engagement for the purposes of sharing tacit knowledge (Curado and Bontis, 2011; Corso et al., 2010). Thus, one of our questions calls for research assessing the use of digital technologies in improving supply chain network performance in the food/agricultural industries.

From a technology perspective, we focus our questions on how technology might be able to address large-scale problems and facilitate supply chain performance through knowledge management capability. Specifically, IoT in literature has been associated with helping to solve issues in information asymmetry (i.e., differing information processing capabilities between suppliers and buyers) as well as complexity in information (i.e., where suppliers do not understand how to manage information in order to engage in customization) (Ng et al., 2015). Thus, some of our proposed questions focus on the implications of IoT in increasing/decreasing knowledge among personnel. Another example is in blockchain implications towards cyber security. Future research might even reference the theory knowledge creation proposing how blockchain moves the knowledge from socialization to externalization to combination and then to internalization (Nonaka, 1994). Referencing knowledge management theory, questions pertaining to the role of blockchain in cybersecurity and how knowledge management can facilitate this process is likely to foster greater insight for the technology itself.

Regarding managerial issues, according to industry experts and academics (Schneider, 2018) combining practical and scholarly importance of challenges of Digitisation should result in high impact research further exploring: a) creating conditions for acceptance for change; b) building digital capabilities; c) developing new business models, and d) providing implications for future business models as they relate to knowledge management. These topics reflect the need of several combinations of the three pillars of knowledge management: technology, processes and people. Hence, research on knowledge management should provide a lens for designing and implementing the requested solutions. Supply chain knowledge management capability (knowledge acquisition, conversion, application and protection within the supply chain) contributes to knowledge in the supply chain (both tacit and explicit) and enhances the supply chain performance. Future research in knowledge management as it relates to supply chain digitisation helps to foster a greater understanding of the human role in supply chain digitisation.

6. Discussion and conclusion

In this study, content analysis was carried out to collect and interpret textual data from scholars and practitioners to validate the iteration of different applications of industry and field, technologies and topics. Statistical analyses were performed to determine significant differences between the frequencies and growth of supply chain digitisation industry/field applications, technologies and topics in scholarly and practitioner-oriented literature. Finally, a comparison was made to consider the differences in prevalence as well as growth/decay to derive future research inquiries that relate to the utilization of knowledge management in supply chain digitisation.

Table 3
Alavi and Leidner (2001) Basic concepts.

	Knowledge Perspective	Role of Digitisation
1	Knowledge vis-à-vis data and information (personalized information)	Help the user assimilate information
2	State-of-mind (knowing/understanding)	Provide access to sources of knowledge
3	Object (object to be stored/manipulated)	Gathering, storing, and transferring knowledge
4	Process (applying expertise)	Provide Link among sources of knowledge (depth/breadth)
5	Access to Information (condition of access to information)	Provide effective search and retrieval for locating relevant information
6	Capability (potential to influence action)	Enhance intellectual capital by supporting development of org. competencies

Table 4
Research questions.

Alavi and Leidner knowledge perspective (2001)	Suggested research inquiries
1	1. In what ways does IOT improve and/or worsen transparency within a supply chain network as it relates to data/information/knowledge exchange? 2. To what degree does the application of IOT/Blockchain/big data increase or decrease the transfer of knowledge within healthcare supply chains? And does this impact supply chain performance?
2	1. How does blockchain affect security and safety of patient medical records? And how might knowledge management and supply chain personnel protect patient rights? 2. What are the downsides of IOT use in electrical manufacturing? And how might human tacit knowledge help to decrease these issues?
3	1. How can supply chain management professionals leverage the innovative use of knowledge management applications supported by digital technologies (including but not limited to augmented reality) to attract and retain logistics/transportation talent? 2. Does big data through IOT impact knowledge creation in retail healthcare for the purpose of increasing return on investment?
4	1. How can knowledge management affect integration among supply chain internal and external stakeholders to optimize value creation and mitigate problems associated with blockchain implementation? 2. As retailers look to combine their online presence with physical stores, how can knowledge management foster the initial collection and dissemination of data into knowledge for customer and supplier value creation?
5	1. How can artificial intelligence/augmented reality help to accelerate and/or simplify digital supply chain integration in logistics/transportation? 2. How can knowledge management contribute to the maturity of the demand-driven value network through both intra- and inter-organisational domain of knowledge management allowing firms to respond to internal and external stakeholders' needs? And how might personnel knowledge foster this relationship?
6	1. How can knowledge management be integrated with supply chain processes (including but not limited to customer/supplier relationship management, demand management, order fulfillment, product development and returns management) to optimize the use of technologies involving artificial intelligence/augmented reality to improve supply chain network performance in the food/agricultural industry? 2. How can logistics/transportation evoke an intrapreneurial spirit among employees and foster an ability to keep pace with the technological and business changes brought about through supply chain digitisation? 3. How can knowledge management be applied by leadership to support the convergence of the digital and physical supply chains and foster internal and external stakeholder value creation in supply chain networks?

To address the first question (i.e. what industry- and field-applications, technologies and topics in supply chain digitisation are prevalent and growing among scholars and practitioners), we looked at prevalence as well as growth. To do this, a variant of the Croston method of forecasting was utilized for intermittency and obsolescence in data to forecast growth (Prestwich et al., 2014). This method was applied after conducting a review of the data which included intermittent periods and some obsolescence as well. Our analyses show that healthcare and food supply chain (including agriculture) are the most prevalent industries and logistics/transportation and CRM are the most prevalent topics considered in both scholarly and practitioner' publications. Additionally, the most prevalent technologies include IoT and big data. In terms of growth, our analyses show growth in such industries and field applications as: food/agriculture, healthcare, logistics and transportation, IS/IT, manufacturing, procurement, and distribution. Technologies including IoT, big data and cloud computing continue to see growth in the coming years. Additionally, areas of growth are expected in such topics as benefits derived from the technologies, global issues, future, applications, challenges, collaborative and economic implications as well as social and environmental issues involved in a shift toward supply chain digitisation.

In addressing the second question, (i.e. are there differences between the prevalence and growth between scholars and practitioners?), our analyses see distinct differences in the prevalence and growth in industry, technologies and topics among the practitioner and scholarly communities. Specifically, block chain, artificial intelligence and augmented reality tended towards high levels of prevalence among practitioners and low levels among scholars. This was also true in growth. Additionally, while practitioners are expected to continue to apply these technologies to such industries as courier, electrical, strategy and retail, the scholarly community does not appear to show much potential for growth in these industries.

To address the third research question (i.e. how can supply chain scholars apply knowledge management to specific industry- and field-applications, technologies and topics in order to benefit not only scholarly research but practitioner insight?), the two models presented in Figs. 2 and 3 were then compared and combined to obtain a conception of industries, technologies and topics that were both growing and prevalent among scholars as well as those areas that have shown growth and prevalence among practitioners but not scholars. In this sense, a framework was offered to develop research questions that can be used to reflect how supply chain management and knowledge can combine to create a new paradigm reflecting the benefits of digitisation while mitigating the social concerns often plaguing supply chain digitisation (i.e. potential loss of jobs). While this framework provides fundamental insights on future areas of inquiry, we are not suggesting that research should ignore the industries, technologies and topics in the (not prevalent/no growth/decline) categorization. For example, there is much insight to be made on drones as well as the applications in the automotive industry, textile industry etc. This study simply implores researchers to assess certain areas that have yet to be fully explored as the next decade will likely see tremendous advancements in our understanding of how knowledge management and digitisation influences supply chain digital performance.

Acknowledgement

The authors gratefully acknowledge financial support from FCT-Fundação para a Ciência e Tecnologia (Portugal), national funding through research grant UID/SOC/04521/2019.

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