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Digitally-enabled sustainable supply chains in the 21st century: A review and a research agenda

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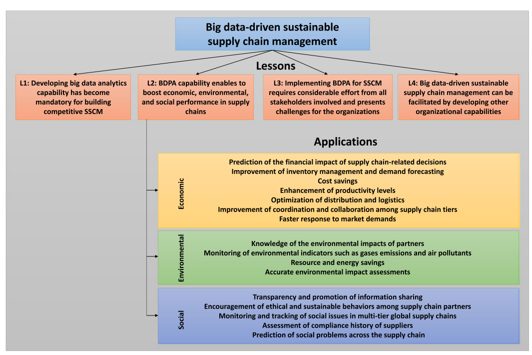
HIGHLIGHTS

- Digitally-enabled sustainable supply chains provide both challenges and opportunities.
- The state-of-the-art regarding digitally-enabled sustainable supply chains is still to be presented.
- A systematisation of the knowledge in this field is presented with a focus on big data.
- A research agenda containing pressing research gaps is presented.

GRAPHICAL ABSTRACT



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ABSTRACT

While the potential benefits of integrating digital technologies and supply chain management have been widely reported, less is known concerning the current state-of-the-art literature on big data-driven sustainable supply chains. Therefore, this study aims to systematise published studies which address the implications of big data for sustainable supply chain management. Through a systematic literature review, this work makes three significant contributions: (a) it provides an overview of extant literature on this topic in recent years; (b) it proposes seven gaps in the literature in order to foster future investigations on big data-driven sustainable supply chains; (c) it offers four lessons for business practitioners aiming to use big data for sustainable supply chain practices. These lessons suggest that: developing big data analytics capability has to become a business priority in order to effectively build competitive sustainable supply chains; big data has benefits for each of the dimensions of the triple-bottom-line in supply chains; the implementation of big data for sustainability in supply chains presents some challenges for firms; the development of complementary organizational capabilities is needed to overcome challenges and facilitate the benefits of big data technology for sustainable supply chain management.

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1. Introduction

It is generally accepted that emerging digital technologies can enhance firms' performance (Dubey et al., 2019; Fosso-Wamba et al., 2015) as well as the performance of supply chains around the globe (Rai et al., 2006; Govindan et al., 2018). While the potential benefits of integrating digital technologies and supply chain management have been widely reported by both academics and practitioners (Wang et al., 2016; Kamble et al., 2020), less is known regarding the current state-of-the-art literature on digitally-enabled sustainable supply chains, and in particular regarding big data analytics. Understanding the current status of knowledge concerning digitally enabled sustainable supply chains with a focus on big data analytics is a relevant priority for a number of reasons:

- First, the technologies of the fourth industrial revolution, also known as 'industry 4.0', have the potential to re-shape operations and supply chain management (Govindan et al., 2018). New information technologies (IT), such as advancements related to big data (BD), have the potential to create more successful supply chains (Rai et al., 2006) and firms (Dubey et al., 2019).
- Sustainability in supply chains is considered a key component of contemporary and socially responsible supply chains. Any discussion of supply chain management which does not consider the sustainability component would be incomplete.

In this work, the use of big data analysis in digitally-enabled sustainable supply chains is defined as the application of a wide range of emerging industry 4.0 technologies to unleash the full potential of supply chains (SC), which, through the use of large amounts of data in decision-making processes, thus transform themselves into supply chains which are technologically advanced, socially responsible, environmentally-friendly (Song et al., 2017a, 2017b), and economically successful. This definition is inspired by a blending of the following classic concepts:

- Digitally-enabled supply chain management: IT-powered supply chain management operating through new digital platforms and technologies (Rai et al., 2006).
- Sustainable supply chain management (SSCM): according to the classic work of Seuring and Müller, (2008, p.1700), 'sustainable supply chain management as the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements'.
- Digitally-enabled industry 4.0: also known as the fourth industrial revolution, this phenomenon is related to the latest transformations in manufacturing due to the emergence of digitalization and extensive connectivity between cyber-physical systems.
- Big-data predictive analytics (BDPA): 'the ability to access, analyse and manage vast volumes of data with the support of robust information architecture' (Dubey et al., 2019, p.341). Big data has unique characteristics such as the four V's: volume, variety, velocity, and veracity (Jabbour et al., 2019).

In this context, the innovations and emerging technologies of industry 4.0, such as big data, offer great opportunities to promote sustainable practices in supply chains (Govindan et al., 2018; Moeuf et al., 2018). Corbett (2018) adds that big data creates revolutionary new possibilities for the sustainable management of supply chains' impacts. However, Kamble et al. (2020) highlight that there is a need to better understand how sustainable performance in SC can be achieved in a data-driven environment. Thus, the question which motivates this article is: what do we know about the use of big data in digitally-enabled sustainable supply chains? Thereby, this paper aims to extend the understanding of digitally-enabled sustainable supply chains by systematising published studies addressing the implications of big data.

2. Research methodology

2.1. Identification and selection of publications

The research methodology adopted in this study is a systematic literature review, with our chosen approach following the procedures of other recent works (Jabbour et al., 2019; Gaur and Kumar, 2018; Lu et al., 2018). This approach combines an overview of the relevant literature by means of bibliometric research (Fahimnia et al., 2015) and content analysis to propose relevant lessons and future research directions (Bhimani et al., 2019; Gaur and Kumar, 2018).

The articles included in this study were identified through searches performed in the Scopus database. The Scopus database is among the most widely used and recognised academic databases in the world (Harzing and Alakangas, 2016), indexing around 70% more sources than the Web of Science (Brzezinski, 2015). These searches were conducted using the title, abstract and keyword options by applying the following query and Boolean operators:

- TITLE-ABS-KEY ("big data") AND TITLE-ABS-KEY ("sustainab*") OR TITLE-ABS-KEY ("green") AND TITLE-ABS-KEY ("supply chain").

To provide robustness in our approach, we adopted a review protocol as suggested by Lu et al. (2018). Fig. 1 summarises the criteria and selection protocol. The initial search returned 113 documents, including journal articles, book chapters, conference papers, editorials, short surveys and review articles. The year of publication was not specified in the search. In order to refine the initial sample, we selected only journal articles and reviews, and specified papers written in English. After this step, 64 papers remained. Next, each of these papers was read in-depth and only those identified as being relevant in responding to the defined research question were selected. Ultimately, 33 publications remained in the sample. The time span covered by these articles runs from 2015 until December 2019.

2.2. Data extraction from publications

After defining the final sample, a coding scheme was adopted to extract and systematise the relevant information from the publications through content analysis. This classification scheme was based on previous reviews (Gaur and Kumar, 2018; Jabbour, 2013) and comprised the following categories:

- Context analysed in the study: this concerns the country analysed in the article, classified either as a developing or developed economy;
- Main purpose of the research: this relates to the main research objective of the analysed article;
- Method: this refers to the methodological approach used in the paper;
- TBL elements involved: the triple-bottom-line refers to the simultaneous consideration of economic, social, and environmental benefits (Elkington, 1994);
- Supply chain economic sector: this regards to the specific economic sector analysed in the study;
- Integration with other Industry 4.0 technologies: this concerns the involvement of other industry 4.0-related technologies, such as internet of things, blockchain, cloud computing, among others, in conjunction with big data for SSCM;
- Underpinning theory: this relates to the use of specific organizational

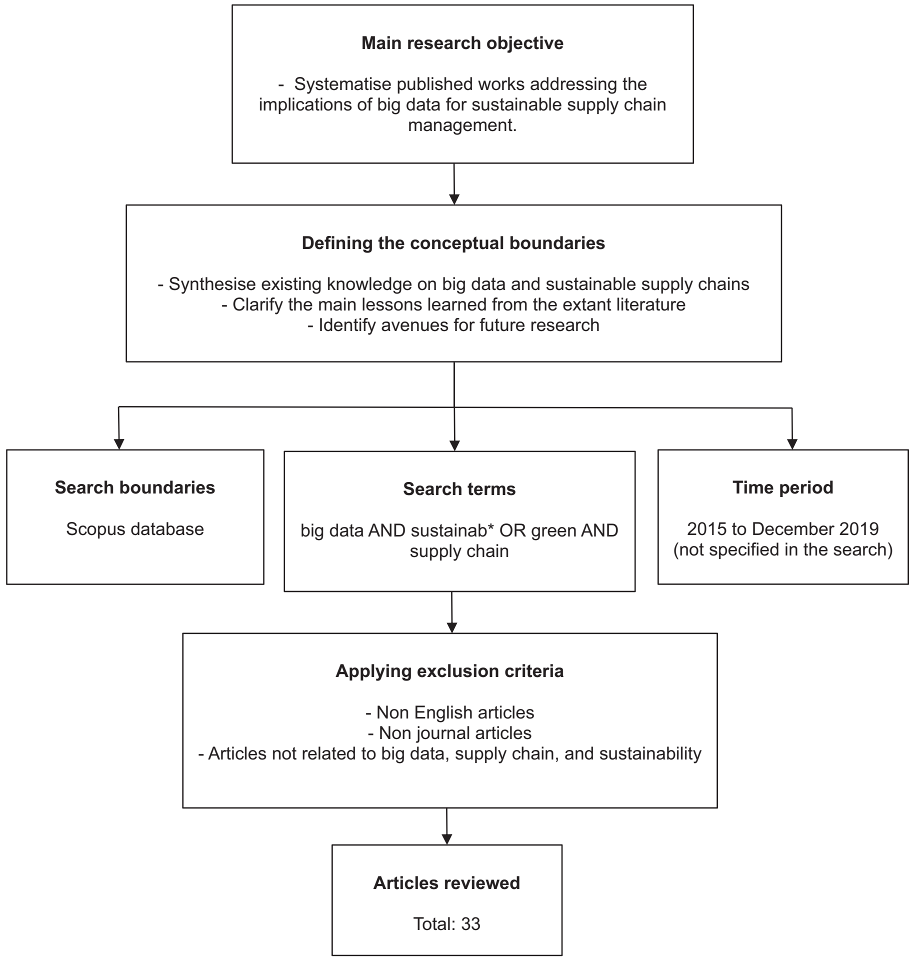

Fig. 1. Literature review protocol and criteria.

theories to support the study's findings;

- Potential implications for big data-driven sustainable supply chain: each selected paper provides a potential lesson regarding the use of big data analytics in managing sustainable supply chains.

Therefore, this step of the systematic review was used to deepen understanding on the relationship between big data analytics and SSCM, to systematise and assess the main categories discussed, and to identify avenues for future research.

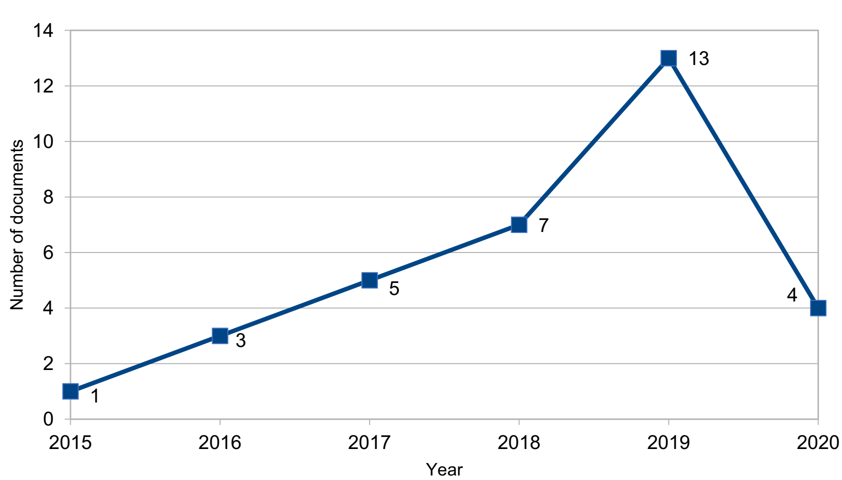

Fig. 2. Evolution of publications relating to big data and sustainable supply chain management.

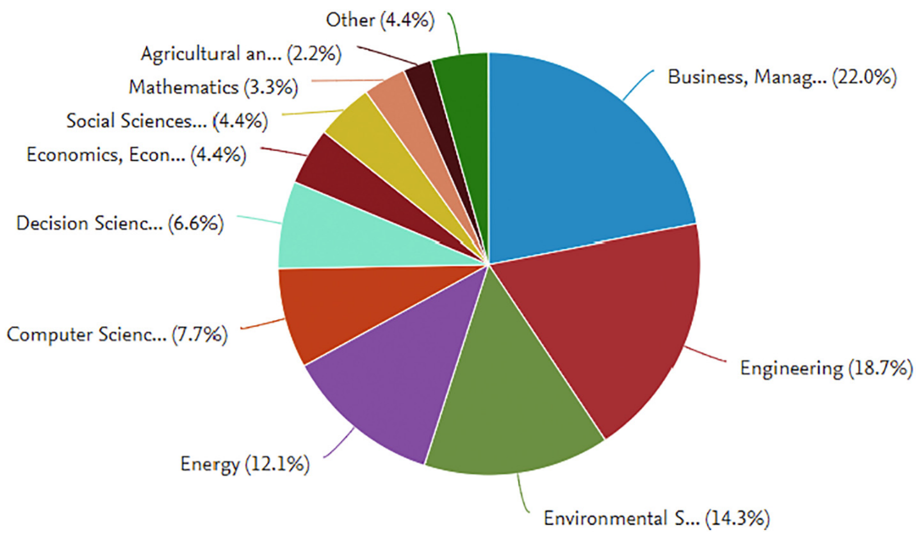

Fig. 3. Publication distribution according to journals' subject area (Note: one journal can be categorised into more than one area).

3. Results and discussion: current lessons and future research avenues for big data-driven SSCM

In this section, our analyses of the results and relevant discussions will be presented. Appendix A provides a detailed summary of the articles reviewed. First, we present the results of the bibliometric analysis to provide a panoramic perspective on the topic. Next, the content analysis findings are displayed, diving into discussions of the literature and presenting gaps and lessons.

Fig. 2 presents the chronological distribution of the publications analysed. This shows a growing trend in papers addressing big data and sustainable supply chains. The peak was reached in 2019, with 13 articles, while the first paper dates from 2015. This is aligned with Zhao et al. (2017), who argue that there is a long way to go concerning the integration of big data science and sustainable supply chain management. In addition, although this search was conducted in 2019, there are already 4 publications dated 2020. Therefore, big data analytics and sustainable supply chain are increasingly prevalent concepts in the literature, which reveals growing interest in the topic.

The principal publishing location of the articles analysed is *Journal of Cleaner Production* (8 publications), followed by *Sustainability* (3), *Computers and Operations Research* (2), *International Journal of Production Economics* (2), *Resources Conservation and Recycling* (2) and *Technological Forecasting and Social Change* (2). Fig. 3 presents the distribution of the relevant journals according to subject area. Journals in the fields of business, management and accounting are the most common (22%), followed by engineering journals (18.7%), environmental science (14.3%) and energy (12.1%). Despite the fact that the majority of the studies appeared in journals related to business, management and engineering, Fig. 3 shows that there are many different fields contributing to developing the literature on the application of big data analytics for SSCM.

According to Fig. 4, the most commonly used methodological approach in the analysed articles is the quantitative approach, followed by qualitative and conceptual papers. Notably, only 17.6% of the sample adopted a modelling approach. Specifically, few of these studies applied big data to model sustainable supply chains. This is aligned with Kaur and Singh (2018), who assert that despite the huge potential of using big data for optimization and modelling,

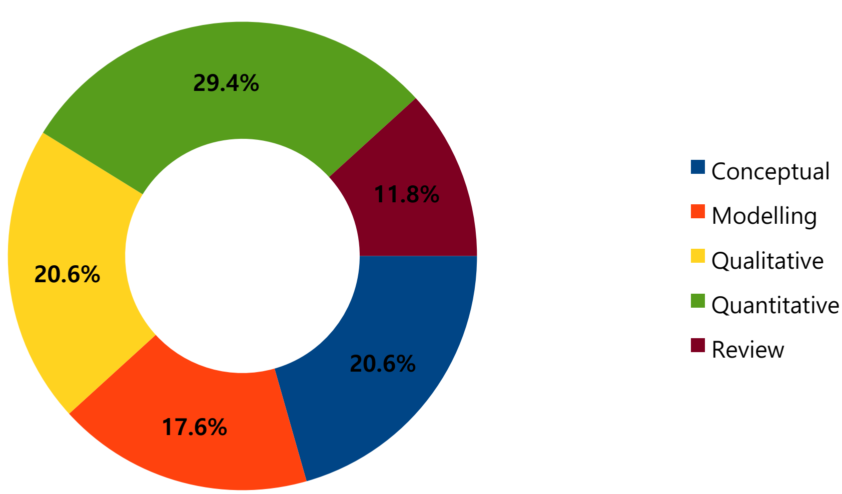

Fig. 4. Main methodological approaches of the relevant publications.

very few attempts have been made so far to develop supply chain models for sustainability using big data (Kaur and Singh, 2018; Xu et al., 2019; Jiao et al., 2018; Zhao et al., 2017). This finding led to our first recommendation:

Gap 1. : To push forward efforts in using big data to model sustainable supply chains.

Fig. 5 presents the number of publications that address BDPA for SSCM, integrating other industry 4.0 technologies. Although there are several emerging digital technologies from industry 4.0, which are frequently combined to create a digitally-enabled supply chain, 23 out of the 33 papers analysed only address the application of big data, without considering different technologies. The Internet of Things (IoT) was integrated with big data analytics in 9 articles, with blockchain appearing in 5 publications. According to Zhang et al. (2020), blockchain technology can serve as a bridge to connect IoT technologies with big data analytics in order to ensure the sharing of truthful data with supply chain members. Furthermore, the implementation of IoT and the use of big data analytics allow for monitoring and preventive maintenance of machines and robots, as well as ongoing communication throughout the supply chain (Roy and Roy, 2019). Although there are plenty of avenues available for exploring the integration of big data with other digital technologies for SSCM, only a few studies have so far tried to do so. Therefore, the second gap is:

Gap 2. : To explore the interfaces of big data with other emerging industry 4.0-related technologies for promoting sustainable supply chain management.

From our in-depth analysis of the studies, a number of lessons and other avenues for future research emerged. The first lesson is that developing big data analytics capability has become mandatory for building competitive sustainable supply chains (Mani et al., 2017; Tseng et al., 2019). Indeed, this is the suggested pathway for firms seeking to achieve sustainable supply chain outcomes (Bag et al., 2020). BDPA can be used to discover SSCM-related insights through higher quality and completion of data (Belaud et al., 2019), which contribute to better voluminous data in an effective and refined manner, which supports sustainable outcomes across the supply chain (Bag et al., 2020).

In order to foster successful big data initiatives among supply chain partners and achieve sustainable outcomes, there is a need to build a truly data-driven culture and to invest in relationship management capability (Dubey et al., 2018). However, how best to build such a data-driven culture – not only within firms, but also among SC members – remains unclear. Thus, the third avenue for future research is:

Gap 3. : To examine how to build a data-driven culture in order to foster successful big data collaborative initiatives among sustainable supply chain partners.

The second lesson relates to the benefits that big data analytics can offer for implementing sustainable practices in the supply chain. BDPA capability enables the promotion of economic, environmental and social performance in supply chains (Dubey et al., 2019; Jeble et al., 2018; Tseng et al., 2019). In this sense, managers, who face a constant trade-off between the triple-bottom-line factors should acknowledge that big data can provide significant benefits in all three dimensions (Dubey et al., 2019). In addition, it offers numerous operational advantages for firms (Tseng et al., 2019).

Concerning the economic dimension, the potential benefits of using big data in analysing operations management and supply chain activities include a 15–20% increase in Return on Investment (ROI) and productivity, reduction of costs, and creation of new competitive advantages and strategies for growing revenue (Ahmed et al., 2018; Roy and Roy, 2019; Visconti and Morea, 2019). Ahmed et al. (2018) explain that big data can predict the financial impact of supply chain-related decisions before they are implemented, hence avoiding losses. In addition, big data can assist in maintaining optimal inventory levels and mitigate the bullwhip effect, both of which are crucial for the company's financial success (Samir et al., 2019). Finally, Tseng et al. (2019) suggest that a data-driven sustainable supply chain may deliver economic benefits such as cost saving, enhanced coordination and collaboration among supply chain tiers, and faster response to market demands.

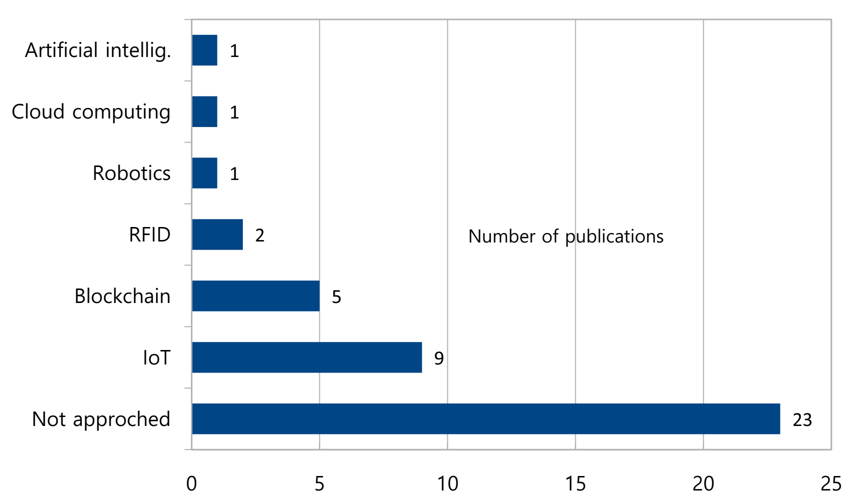

Fig. 5. Integration with other industry 4.0 technologies (Note: one paper can have addressed more than one technology).

and faster decision-making (Zhang et al., 2020). Astill et al. (2019) state that BDPA adds value for SSCM by highlighting inferences from the data that humans may fail to note. Currently, many companies collect massive amounts of data across different business processes, but struggle to analyse this volume of data and find its true value (Singh and El-Kassar, 2019). The use of BDPA has enabled organizations to manage

In terms of environmental impacts, big data can support preliminary decision-making on resource utilization, processes and technologies, upstream and downstream chains (Belaud et al., 2019). It can be used to monitor environmental indicators such as CO2 emissions and air pollutants, helping promote better understanding of environmental

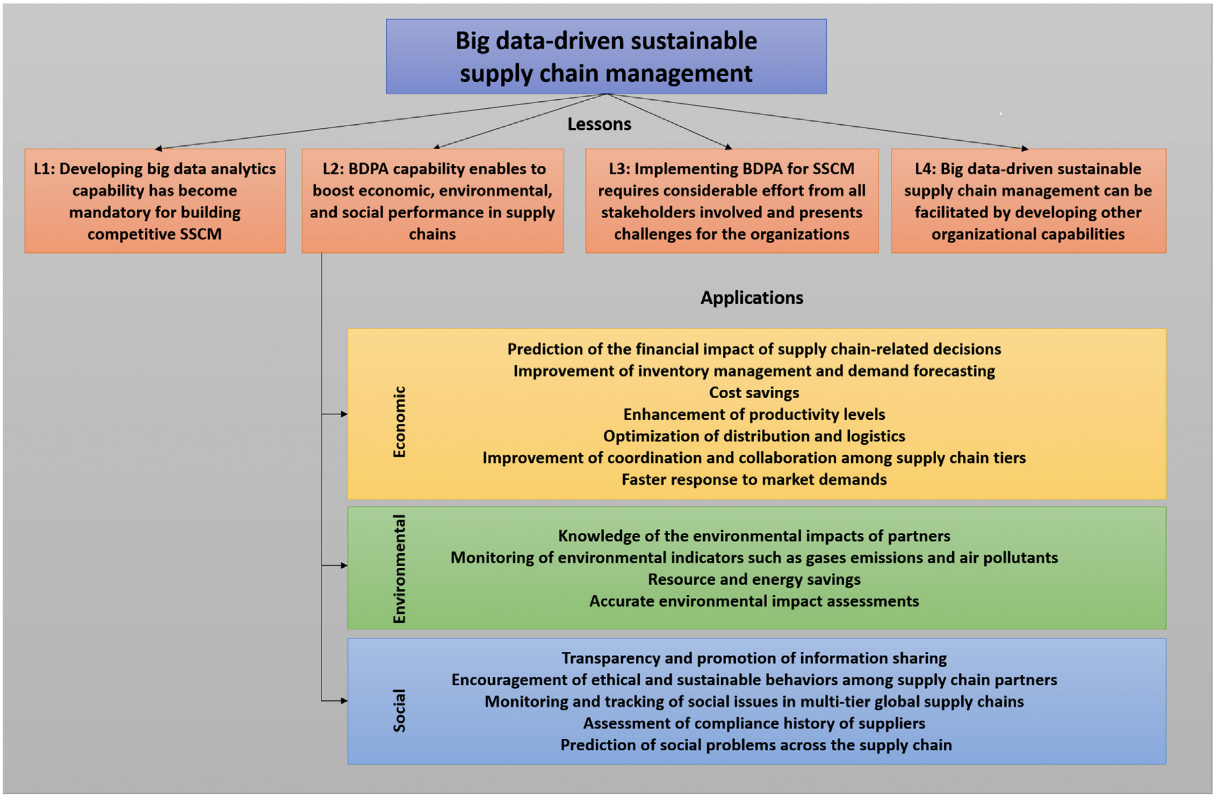

Fig. 6. Systematisation of managerial contributions of the study.

impacts on SSCM and providing more accurate environmental impact assessments (Badiezadeh et al., 2018; Jiao et al., 2018). In this sense, BDPA offers informed decision making regarding various environmental sustainability issues in the supply chain, and it can help to mitigate uncertainty and greenhouse gas emissions burdens (Jiao et al., 2018). Such decision-making support is particularly important when trying to maximise resource utilization (Gupta et al., 2019). In addition, Mani et al. (2017) mention that BDPA's environmental benefits for supply chains can arise together with economic gains, presenting a win-win situation, such in the case of big data helping with timely sales forecasts, which decrease stock and waste, and at the same time, save energy and resources. The relationship between BDPA and environmental concerns can be particularly relevant to emerging markets such as Brazil, India, China, Russia, and South Africa (BRICS) (Song et al., 2020; Song et al., 2019a; Song and Wang, 2019). In this context, big data is also capable of offering insightful information for promoting emerging business concepts, such as the circular economy (Gupta et al., 2019) and closed-loop supply chain (Jiao et al., 2018), which leads to the fourth gap:

Gap 4. : To understand how big data analytics can drive closed-loop actions in sustainable supply chains.

within supply chain organizations (Astill et al., 2019). Moreover, firms can analyse customer preferences and buying behaviour to negotiate with suppliers (Ahmed et al., 2018). Overall, BDPA acts as a facilitator in resolving the operational complexities of SSCM (Jeble et al., 2018; Gupta et al., 2019).

In this context, big data is claimed to be essential for decision making in highly volatile and competitive markets (Kaur and Singh, 2018) since it improves supply chain planning and demand forecasting (Wang et al., 2016), identifies consumption patterns and supply chain bottlenecks (Samir et al., 2019), as well as reducing risks and uncertainties (Wu et al., 2017). Therefore, big data offers an opportunity to make sustainable supply chains more resilient to external shocks (Kaur and Singh,

Big data has a significant potential application for social sustainability in supply chains (Badiezadeh et al., 2018). It encourages ethical behaviours among supply chain tiers by allowing higher traceability and transparency, which may increase commitment to sustainable practices and also the reputation of industries (Kamble et al., 2020; Roy and Roy, 2019; Shukla and Tiwari, 2017). In the same vein, Raut et al. (2019) argue that BDA promotes information sharing with suppliers and ensures their involvement in implementing sustainable practices. Additionally, Venkatesh et al. (2020) show that BD assists in monitoring and tracking social sustainability in multi-tier globally sourced supply chains; for instance, in assessing the compliance history of suppliers. Considering that social concerns in managing supply chains include child labour, unethical behaviour, equality and discrimination, forced labour and slavery, among other issues, it is significant that companies can predict various such social problems through the information management practices facilitated by big data analytics (Mani et al., 2017). Specifically, for agri-food supply chains, big data and industry 4.0-related technologies are capable of shortening the SC, offering social benefits to deprived communities (Kamble et al., 2020).

Finally, regarding operational gains, BDPA offers numerous opportunities. First, it allows information sharing and efficient decision-making among supply chain members (Dubey et al., 2019; Kamble et al., 2020; Raut et al., 2019). Consequently, BPA can help to ensure suppliers' cooperation in implementing sustainable practices (Raut et al., 2019) while, at the same time, being used to effectively predict and mitigate supply chain risks and uncertainties (Mani et al., 2017; Wu et al., 2017). In addition, BDPA has a role in supply chains' strategic and operational planning phases (Wang et al., 2016). In terms of strategic planning, big data technology can assist in decisions regarding sourcing, supply chain network design, product design and development (Wang et al., 2016). In operational planning, it can be applied to enhance demand forecasting, procurement, production, inventory and logistics (Visconti and Morea, 2019; Wang et al., 2016), increasing the optimization of procedures

2018; Papadopoulos et al., 2017; Visconti and Morea, 2019). Yet, empirical studies which effectively address big data support to make supply chains resilient and sustainable are lacking (Fosso-Wamba et al., 2015; Visconti and Morea, 2019). Thus, the fifth recommendation is:

Gap 5. : To conduct more empirical research to explore BDPA's support in promoting resilience in sustainable supply chains.

The third lesson comprises the challenges on big data-driven SSCM. Managers and practitioners need to acknowledge that despite the benefits of BDPA for the sustainability of supply chains, its implementation also presents challenges for the organizations. Adopting BDPA in supply chains requires considerable effort from all stakeholders involved and presents barriers ranging from technical issues, such as Internet connection and storage requirements, to those concerning device security, privacy and confidentiality of sensitive business data, as well as government requirements and regulations and consumer acceptance (Astill et al., 2019; Jagtap and Duong, 2019). Nonetheless, few studies have addressed the drawbacks and barriers of using BDPA to assist in sustainable supply chains; we therefore suggest:

Gap 6. : To explore the challenges and barriers faced by companies implementing big data analytics to improve sustainable supply chain management.

In this same vein, our fourth and last lesson regards the complementary capabilities needed to overcome barriers and to fully reap the benefits of BDPA for SSCM. It is necessary to be aware that big data-driven sustainable supply chain management can be facilitated by developing other organizational capabilities. For example, Singh and El-Kassar (2019) suggest that while technological challenges in assimilating big data become greater when firms decide to embrace internal and external sustainable practices in supply chains, such challenges could be handled by developing corporate commitment and green human resource management (Green HRM) capability. Similarly, Mandal (2018) indicates that managers need to concentrate on effective planning and propose appropriate training for employees and partners in order to leverage big data analytics to support strategic and operational supply chain activities. In addition, investing in a skilled workforce and promoting knowledge sharing capabilities are both important for big data implementation (Dubey et al., 2019). Therefore, we propose:

Gap 7. : To investigate the role of different organizational capabilities such as Green HRM in handling challenges and promoting big data technology for sustainable practices in supply chains.

Considering the current calls for research on sustainability, environmental management and big data technology (Song et al., 2019b), we believe this work provides useful guidance for practitioners and academics by presenting implications and lessons to leverage digitally-enabled sustainable supply chains as well as gaps for future research. Fig. 6 summarises the managerial contributions.

4. Final remarks

The purpose of this study was to extend the understanding of digitally-enabled sustainable supply chains by systematising published studies addressing the implications of big data. Through a systematic review of selected articles, this work makes three significant contributions. First, it provides an overview of the extant literature on this topic in recent years. The second contribution is the proposition of seven literature gaps to foster future investigations on big data-driven sustainable supply chains. Third, this study offers four lessons for firms' managers aiming to use big data for sustainable practices in supply chains. Accordingly, the findings of this study have implications for scholars and practitioners.

For academics, this work proposes seven recommendations for future investigations throughout the results and discussion section. These research gaps represent opportunities for scholars to advance the body of knowledge on big data applications for SSCM. In particular, new studies based on big data, which use modelling methods aimed at the optimization of sustainable supply chains, constitute an important contribution to this field.

This research gap (Gap 1) has the greatest potential to generate results directly related to managerial implications for supply chain management. With the integration of new digital technologies from industry 4.0 to BDPA (Gap 2), the predictive capacity of the modelling method is increased. Studies generated on this basis may result in a set of management practices that guarantee:

- Sharing of accurate data between supply chain members, assisting decision-making (Zhang et al., 2020);
- Monitoring of operational processes throughout the chain (Roy and Roy, 2019; Tseng et al., 2019), generating benefits directly related to productivity, resource optimization and ROI;
- Significant improvement in the management of relationships between members (Dubey et al., 2018), including the development of a culture of data integration and sharing;
- Better management of sustainable practices in the supply chain, monitoring environmental (understanding and dynamics of the impacts generated) and social (appropriate, ethical and transparent attitudes of members, as well as impacts on the community) indicators, reducing risks in both dimensions.

In addition, for business managers, we have provided four general managerial implications: developing big data analytics capability has to become a business priority in order to effectively build competitive sustainable supply chains; big data has benefits for each of the triple-bottom-line dimensions in the supply chain; the implementation of BDPA for the sustainability of supply chains presents significant challenges for firms; and the development of other organizational capabilities is needed to overcome challenges and deploy the benefits of big data technology for SSCM.

Regarding methodological limitations, it should be noted that this study selected only articles containing specific keywords in the title, abstract and keyword fields. Thus, there may exist publications addressing the research topic which were left out of our sample. It is also limited to analysing the content of publications found in the Scopus database. Although Scopus is a highly recognised academic database, it may not gather every relevant document on the subject. Another limitation is related to the scope of the research, which deals directly with big data implications for sustainable supply chain management. Although other industry 4.0 integration technologies have been mentioned in BD studies, our analysis does not directly relate to the impact or challenges of any of these technologies on the development of sustainable supply chains. This postpones the discussion of other industry 4.0 technologies' role in the development of BDPA in SSCM, which may be addressed in future research.

In terms of recommendations for future research, it is suggested that the seven research gaps highlighted in this study are addressed in specific studies in order to deepen the perspective on the dimensions of each gap. Future studies using the modelling method stand out as a promising avenue, as this method can present better practical contributions for business managers interested in sustainable supply chain development. In addition, empirical studies associated with the efforts of management to use BDPA in global supply chains is recommended, as the need for resilience is an important requirement for sustainable performance. Conversely, it is also suggested that specific studies investigate disadvantages and barriers (external, integration and intra-organizational) to BDPA adoption in the development of sustainable supply chains. There are ample opportunities for future research on this topic, as different technological approaches and economic, social and environmental management can be related to SSCM.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Summary of the analysed studies

Author (s)/year of publication	Context	Main purpose of the research	Method	TBL elements involved	Supply chain sector	Integration with other Industry 4.0 tech	Underpinning theory	Potential implications for big data-driven sustainable supply chains
Ahmed et al. (2018)	NA	To analyse the usage of big data to enhance environmental impact and green supply chain management.	Conceptual	Environmental	NA	NA	NA	Big data applied to operations and SC helps to reduce costs and increasingly creates new competitive advantages and strategies for growing retailers' revenue. It also assists in identifying SC bottlenecks and analysing customer preferences and buying behaviour to inform negotiations with suppliers.
Astill et al. (2019)	NA	To describe enabling technologies that have the potential to increase food production transparency.	Review	Economic, environmental, and social	NA	Blockchain and IoT	NA	Enabling transparency in food supply chains via implementation of big data, IoT, and blockchain will require considerable effort from all stakeholders involved, resulting in many new challenges related to technical issues, government requirements and regulations, and consumer acceptance.
Badiezadeh et al. (2018)	Developing economy: Iran	To assess performance of sustainable supply chain management in the presence of big data.	Quantitative Data envelopment analysis	Economic, environmental, and social	Food supply chain	NA	NA	Big data can be used to address environmental crises such as CO2 emissions and air pollutants. It helps to achieve a better understanding of environmental impacts on SSCM as big data can be used to evaluate social crises.
Bag et al. (2020)	Developing economy: South Africa	To explore how big data analytics (BDPA) supports sustainable supply chain outcomes.	Quantitative Survey Partial Least Squares Structural Equation Modelling (PLS-SEM)	Economic	Mining	NA	Dynamic capability	Developing BDPA management capability helps firms to develop sustainable supply chain outcomes, and it is particularly strong when there are high organizational levels of supply chain innovativeness.
Belaud et al. (2019)	NA	To develop an approach that integrates big data to improve sustainability management in supply chain design, aiming to valorise agricultural waste.	Qualitative Case study	Economic, environmental, and social	Agri-food	NA	NA	Enhancement of sustainability assessment thanks to big data architecture, resulting in higher quality and completion of data, and supporting preliminary decision-making on biomass, processes and technologies, upstream and downstream chains.
Dubey et al. (2019)	Developing economy: India	To investigate the effects of big data analytics on social and environmental performance in supply chains.	Quantitative Survey PLS-SEM	Environmental and social	Manufacturing	NA	Dynamic capability	BDPA is an important organizational capability to improve social and environmental performance in SC. The firms which invest in appropriate talent and build knowledge sharing culture are more successful in building BDPA capability, which may help eliminate resultant complexities in SCs due to information

(*continued*)

Author (s)/year of publication	Context	Main purpose of the research	Method	TBL elements involved	Supply chain sector	Integration with other Industry 4.0 tech	Underpinning theory	Potential implications for big data-driven sustainable supply chains
								asymmetry. Furthermore, decision-making supported by big data helps to improve coordination among supply chain partners, which plays an important role in achieving sustainability in supply chains.
Dubey et al. (2018)	Developing economy: India	To examine the role of big data in collaborative performance among supply chain partners engaged in a sustainable development programme.	Quantitative Survey PLS-SEM	Economic, environmental, and social	Auto-component	NA	Dynamic capability	The study indicates that sharing strategic resources and building a data-driven culture help in successful alliance formation and collaborative initiatives via big data in the supply chain for sustainable programmes.
Edgeman and Wu (2016)	NA	To explore the contributions of supply chain proficiency in relation to sustainable enterprise excellence, resilience and robustness.	Conceptual	Economic, environmental, and social	NA	NA	NA	Data analytics and intelligence are enablers of supply chain proficiency.
Gupta et al. (2019)	Developing economy: India	To identify the various ways in which big data analytics can be utilised to facilitate the adoption of the circular economy (CE) paradigm.	Qualitative Interviews	Economic, environmental, and social	NA	NA	Stakeholders theory	BDPA offers crucial support to extract meaningful patterns out of the data concerning various closed-loop supply chain members, deriving insightful information. This information can then become a basis for informed decision-making regarding various production and consumption issues at all levels.
Hazen et al. (2016)	NA	To examine the relationships between big data, predictive analytics and sustainable supply chain management through the lens of several organizational theories.	Review	Economic, environmental, and social	NA	NA	Social capital theory, institutional theory, resource dependence theory, transaction cost economics, agency theory, resource-based view, and ecological modernisation	Big data has a substantial impact upon sustainable supply chain management as it becomes less of an innovation and more of a staple of the modern supply chain.
Jagtap and Duong (2019)	Developed economy: UK	To understand the use of big data in new food product development.	Qualitative Case study	Economic and environmental	Beverage	NA	NA	Big data can accelerate the new product development process (NPD) and the launch of the product. It also supports stakeholders to identify any shortcomings of food products and address them earlier, leading to massive savings in the costs involved in launching new products.
Jeble et al. (2018)	Developing economy: India	To develop a theoretical model to explain the impact of big data and predictive analytics on the sustainable business development goals of the organization.	Quantitative Survey PLS-SEM	Economic, environmental, and social	Automobile	NA	Resource-based view and contingency theory	Big data analytics as an organizational capability may help organizations' initiative to improve the environmental, social and economic performance of the supply chain.
Jiao et al. (2018)	NA	To propose data-driven approaches to generating robust sustainable closed-loop supply chain designs	Modelling	Environmental	NA	NA	NA	A data-driven framework promotes environmental benefits and facilitates GHG management to some degree in sustainable closed-loop supply chains.

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Author (s)/year of publication	Context	Main purpose of the research	Method	TBL elements involved	Supply chain sector	Integration with other Industry 4.0 tech	Underpinning theory	Potential implications for big data-driven sustainable supply chains
		by using big data that mitigate uncertainty and greenhouse gas emissions burdens.						
Kamble et al. (2020)	NA	To propose an application framework for the agri-food supply chain to develop data analytics capability and achieve sustainable performance.	Review	Economic, environmental, and social	Agriculture	Blockchain and IoT	NA	The blockchain, internet of things and big data technologies will shorten agricultural supply chains, offering social benefits to deprived communities. In addition, it will provide visibility, traceability of food products, transparency, authenticity, and quality of agro-products.
Kaur (2019)	Developing economy: India	To model a sustainable food security system using various internet of things driven technologies.	Modelling	Economic, environmental, and social	Food supply chain	IoT, blockchain, robotics, cloud computing, RFID, and artificial intelligence	NA	Big data can help in effective planning of food procurement processes, and it can allocate resources to regions accordingly. In addition, BD can assist in the prediction of crop yield before the harvest actually happens.
Kaur and Singh (2018)	NA	To propose a model for sustainable procurement and logistics in a supply chain using big data.	Modelling	Environmental	NA	NA	NA	Using big data in supply chain modelling provides a competitive edge to an organization and makes the supply chain resilient and sustainable since it assists in effective and efficient decision-making.
Mandal (2018)	Developing economy: India	To explore the influence of BDPA management capabilities on sustainable tourism supply chain performance.	Quantitative Survey PLS-SEM	Economic, environmental, and social	Tourism supply chain	NA	Dynamic capability	The study suggests that tourism managers concentrate on effective planning for the deployment of a BDPA infrastructure. Additionally, managers should focus on offering appropriate training to their key tourism SC partners for leveraging analytics capabilities to support routine and strategic activities.
Mani et al. (2017)	Developing economy: India	To explore the application of big data analytics in mitigating supply chain social risk and to demonstrate how such mitigation can help in achieving environmental, economic, and social sustainability.	Qualitative Case study	Economic, environmental, and social	Manufacturing	IoT	Knowledge-based view	Companies can predict various social problems including workforce safety, fuel consumption monitoring, workforce health, security, physical condition of vehicles, unethical behaviour, theft, speeding and traffic violations through big data analytics, thereby demonstrating how information management actions can mitigate social risks.
Papadopoulos et al. (2017)	Developing economy: Nepal	To propose and test a theoretical framework to explain resilience in supply chain networks for sustainability using unstructured big data.	Qualitative and Quantitative Content analysis Survey Confirmatory factor analysis	Economic and social	Manufacturing and Services	NA	NA	The study suggests the use of big data analysis to propose a particular framework in the context of resilient supply chains that enable sustainability.
Raut et al. (2019)	Developing economy: India	To analyse the predictors of sustainable business	Quantitative Survey	Economic, environmental, and social	Manufacturing	NA	NA	BDPA capabilities provide a useful framework for information sharing with

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		performance through big data analytics in the context of developing countries.	Structural Equation Modelling - Artificial Neural Network (SEM-ANN)					the supplier. It ensures cooperation and involvement of the supplier in the implementation of sustainable practices.
Roy and Roy (2019)	NA	To show how industries can use smart management systems (SMgS) to be competitive.	Conceptual	Economic and social	NA	IoT	NA	BDPA and IoT have proven to provide a competitive advantage for several industry leaders, since they increase the profitability of companies due to decrease in human labour, continuous, automated/semi-automated operation, monitoring preventive maintenance of machines and robots, and ongoing communication throughout the supply chain.
Samir et al. (2019)	NA	To provide an overview of the analysis of big data from the internet of things in new logistics processes.	Conceptual	Environmental	NA	IoT	NA	Big data and IoT can improve the level of service, monitor transport and storage, manage all the complexity of strategic data, maintain correct inventory levels, mitigate the bullwhip effect, guarantee surveillance of all the movements associated with delivery and manage information regarding logistics operation.
Shukla and Tiwari (2017)	Developing economy: Malaysia	To propose a big data analytics framework enabled by cutting-edge technologies to incorporate smallholders in the sustainable palm oil certification process.	Qualitative Case study	Economic, environmental, and social	Palm oil producer	RFID	NA	Using the BD framework in the palm oil supply chain, managers can work closely with suppliers and have higher control and visibility of the entire process. This will provide higher transparency and traceability to consumers, thus increasing their willingness and commitment towards sustainable palm oil.
Singh and El-Kassar (2019)	Developing and developed economies: Kingdom of Saudi Arabia, the United Arab Emirates, Egypt, and Lebanon	To examine the extent of sustainable capabilities driven by corporate commitment resulting from the integration of big data technologies, green supply chain management, and green human resource management practices.	Quantitative Survey PLS-SEM	Economic and environmental	Manufacturing	NA	Dynamic capability	Firms should integrate big data technologies into their strategic and operational architectures for attaining sustainable performance. Big data offers huge opportunities which are pertinent to businesses, especially those operating in different fields and industrial sectors, and that in turn increases firms' productivity and both their environmental and financial performance.
Tachizawa et al. (2015)	NA	To analyse the impact of smart city initiatives and big data on supply chain management.	Conceptual	Economic, environmental, and social	NA	NA	Network theory, complexity theory, adaptive structuration theory, and transaction cost	Big data and smart cities alone have limited capacity to improve SSCM processes. However, if they are combined, they can support improvement initiatives.
Tseng et al. (2019)	Developing economy: Taiwan	To assess data-driven sustainable supply chain management (SSCM).	Quantitative Exploratory factor analysis	Economic, environmental, and social	Textile	NA	NA	Big data was found to possess great potential for promoting SSCM performance in terms of impact, economic benefits,

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Author (s)/year of publication	Context	Main purpose of the research	Method	TBL elements involved	Supply chain sector	Integration with other Industry 4.0 tech	Underpinning theory	Potential implications for big data-driven sustainable supply chains
								operational risk and social development. In a highly competitive environment, efforts to achieve and promote efficiency and effectiveness of big data are critical for firms to retain their competitive advantages.
Venkatesh et al. (2020)	NA	To develop a system architecture that integrates the use of blockchain, internet-of-things and big data analytics to allow sellers to monitor their supply chain social sustainability.	Conceptual	Social	NA	Blockchain and IoT	NA	Big data analytics can be used for social sustainability traceability in supply chains and monitor sustainability compliance efficiently and effectively.
Visconti and Morea (2019)	NA	To detect whether and how big data can improve the quality and timeliness of information in infrastructural healthcare investments, making them more sustainable.	Qualitative Scenario planning	Economic	NA	IoT	NA	Adoption of big data standards is reported to improve the healthcare supply chain. Potential benefits of using big data in analysing operations management and supply chain activities are an increase in return on investment, productivity, and competitiveness.
Wang et al. (2016)	NA	To review and classify the literature on the application of big data to logistics and supply chain management.	Review	Economic, environmental, and social	NA	NA	NA	It was found that in the strategic phase of SC planning, big data plays a vital role to help companies make strategic decisions on sourcing, SC network design, as well as on product design and development. In the operational planning phase, big data has been used to assist management in making SC operation decisions, which often include demand planning, procurement, production, inventory, and logistics.
Wu et al. (2017)	Developed economy: Taiwan	To explore the decisive attributes of supply chain risks and uncertainties using big data.	Modelling FDEMATEL Interpretive Structural Modelling (ISM)	Economic, environmental, and social	LED lamp industry	NA	Collaboration theory	Firms are capable of developing capabilities by using big data to enhance their accuracy in the decision-making process to mitigate supply chain risks and uncertainties.
Xu et al. (2019)	NA	To assess investment in big data business and its sustainable effects on supply chain coordination.	Modelling	Economic	NA	NA	NA	It was found that when the big data cost met a certain threshold, the profit of the supply chain and its members would increase whether supply chain members choose to invest in big data individually or jointly.
Zhang et al. (2020)	NA	To propose a system architecture for life cycle assessment (LCA) that integrates the use of blockchain, IoT, and big data analytics and visualization.	Conceptual	Environmental	NA	Blockchain and IoT	NA	Integrating big data analytics and visualization can substantially enhance the effectiveness of LCA by increasing the capabilities in data analysis and interpretation.
Zhao et al. (2017)	Developing economy: China	To present an optimization model using BDA for a green	Modelling	Economic and environmental	Manufacturing	NA	NA	The big data approach has been applied to data acquisition and data quality

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		SCM scheme that minimises the inherent risk incurred by hazardous materials, associated carbon emissions, and economic cost.						control.

Note: NA – Not Applicable.

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