

Innovation in the supply chain and big data: a critical review of the literature

Innovation in
the supply
chain and big
data

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Abstract

Purpose – This paper aims to propose a framework investigating the diffusion and adoption process of big data (BD) in the supply chain (SC) as a tool to manage process innovation at technological, operational and strategical levels.

Design/methodology/approach – A comprehensive systematic literature methodology is used to develop the theoretical conceptual framework, which comprehensively describes and captures the innovative stages of BD technology adoption process in SC with a multilevel perspective.

Findings – Results show that BD has modified the supply network concept, starting from the dyadic relationships, triads up to the creation of a streamlined and integrated network. These changes are reflected in a novel integrated vision including both benefits and barriers.

Research limitations/implications – The proposed framework supports companies in redesigning the processes affected by the adoption of BD, helping them in identifying the critical elements, barriers, benefits and expected performance. One limitation is the focus of the study on the analysis of the processes of adoption of BD technology in the SC considering a particular structure of SC characterized by only two levels of supply and by a reduced number of members.

Originality/value – Although the role of BD in supply chain operations management (SCOM) is well acknowledged in the literature, its adoption and diffusion process from an interorganizational perspective is still missing. Specifically, the adoption stages of BD in SC have been defined at a strategic level, and successively the SC operations and technological perspective have been integrated to depict the operationalization of BD implementation and diffusion.

Keywords Big data, Supply chain, Operation management, Innovation, Enabling technologies

Paper type Literature review

1. Introduction

Managing customer and supplier value is the most relevant objective of supply chain operations management (SCOM) (Lam *et al.*, 2004; Ancarani, 2009; Miocevic, 2011). To achieve this goal, SCOM must integrate robust multi-market models with demand data (Lin and Ng, 2011; Ng *et al.*, 2012) and supply-focused processes (Bustinza *et al.*, 2013). Organizations within a supply chain (SC) are asked to provide customers with the desired products at the

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right time, which requires flexible manufacturing and customization, high service levels to manage facility location problems, the reduction of forecasting errors, lower procurement costs and quicker interactions throughout the SC (Raguseo, 2018; Koch and Blind, 2021). Until recent years, this operational efficiency was highly difficult to achieve. Yet, nowadays, this issue might be lessened, thanks to the availability of multiple knowledge sources and the possibility to manage in real time (Chen *et al.*, 2015) an enormous and diversified amount of data about products' life cycles, inbound/outbound logistics, product-customer interactions and market needs (Ardito *et al.*, 2019; Bag *et al.*, 2021). As a result, SCOM members may build an industrial digital ecosystem that allows them to gather and rely on data favouring the integration of demand- and supply-focused processes (Schrauf and Berttram, 2016; Fakhar Manesh *et al.*, 2021). In this context, big data (BD) is part of an emerging competitive area that will transform how SCs are managed and designed (Karadayi-Usta, 2020). This pivotal role of BD is further corroborated by some recent literature reviews in the field of supply chain management (SCM) (Fosso Wamba *et al.*, 2015), also placing particular attention to the context of operations management (Nguyen *et al.*, 2018). The crucial consideration is ensuring that the data are used in a way that is meaningful and adds value in addressing real problems and issues through network representation learning and neural network approaches (Yang *et al.*, 2017).

Nevertheless, a topic that is still on the minds of many SCOM academics and practitioners is how to cope with the large capital and time to invest in building BD platforms (Bhatia and Kumar, 2020). Indeed, it is difficult to screen and select the most effective available technologies (e.g. RFID, NFC, sensors, tags) and information systems to design effective BD platforms for given products, sectors and SCOM activities. Furthermore, these efforts should be coordinated among all the SCOM members, hence leading to managerial and organizational complexities (Schoenherr and Speier-Pero, 2015; Wang *et al.*, 2016). These issues are further exacerbated by the uncertain long-term benefits that BD may provide to achieve a sustainable competitive advantage (Chen *et al.*, 2012), especially considering that such benefits may not be equally shared among SCOM members. Besides, the implementation of BD platforms still forces SCOM to deal with the effective use of BD. Indeed, due to the unprecedented volume, variety and velocity of data that can be acquired and elaborated, SCOM managers are more and more concerned about poor data quality (Mancilla and Sepúlveda, 2017). Accordingly, quality issues are increasing, and data quality is increasingly difficult to evaluate. Thereby, several data pre-processing techniques, including data cleaning, data integration and data reduction, are required to remove noise and correct for inconsistencies (Schoenherr and Speier-Pero, 2015). These techniques are required for allowing companies to achieve better financial performance by leveraging the available amount of data (Raguseo and Vitari, 2018). Furthermore, data requirements may change due to different needs, problems and future opportunities; thus, not all data are useful – some data might be unfocused and, hence, ineffective. Thereby, it is also essential to elaborate data to produce valuable knowledge that lets SCOM members create and deliver customer value for current and future needs. To this aim, it is necessary to adopt BD analytics (e.g. data mining, case-based reasoning, exploratory data analysis, business intelligence and machine learning), which “is the practice of using data to generate useful insights that can help firms make better fact-based decisions with the ultimate aim of driving strategy and improving performance” (Tan *et al.*, 2015).

Considering the above discussion, it is clear how previous literature has investigated the pivotal role of BD in SCOM and the benefits achieved by companies in adopting this technology. Previous studies also focus on the process of BD implementation in organizations (Hazen *et al.*, 2012; Hossain *et al.*, 2016; Gunasekaran *et al.*, 2017). Although the role of BD in SCOM is well acknowledged, the adoption process of such technology in the SC from an interorganizational perspective is still missing. Given these premises, we identify three research questions that will be addressed:

RQ1. How does the BD adoption process develop along with the SC?

RQ2. What is the impact of BD on the supply network at the strategic, technological and operational levels?

RQ3. How do SC actors interact following the introduction of BD?

The purpose of this article is to call attention to the research needs for examination of the BD adoption process with a multilevel perspective and suggest important areas in need of timely research. This paper aims to serve as a resource to inform researchers about the approaches that can be used to explain how the process of adoption of BD can impact the supply network. In the next sections of this article, we review several well-established innovation adoption processes in other contexts that we believe to be most useful for examining this problem space and analyse the extant literature on the role of BD in the SCOM context. We then design and discuss an integrative framework and a summary of the benefits and barriers of the different adoption stages of the BD in the SC at a strategic, operational and technological level. Finally, we close with the identification of a detailed research agenda, limitations and implications.

2. Theoretical background

2.1 Organizational innovation adoption process

The process of adoption and diffusion of innovation in organizations has been of great interest to researchers for more than a decade (Baig *et al.*, 2019; Gunasekaran *et al.*, 2017; Hazen *et al.*, 2017). This process is based on several stages. Preliminarily, there is a decision to make full use of an innovation as the best course of action available. This phase refers to the extent to which the full potential of the innovation is explored and embedded with the operational or managerial operations (Hossain *et al.*, 2016). This is followed by the acceptance of the technology into the organization that concerns how well an organization's stakeholders perceive the technology (Gunasekaran *et al.*, 2017; Upadhyay and Kumar, 2020). When the organization reaches such a level of awareness and an organizational and technical infrastructure exists to support the use of technology, it starts the internalization of the acquired capabilities within the business and governance processes. At this stage, the use of the purchased technology becomes part of the standard organizational practice (Gunasekaran *et al.*, 2017; Hazen *et al.*, 2012; Upadhyay and Kumar, 2020). The literature also defines the concept of diffusion of technology that has been integrated or spread across the firm's organizational processes so that expected goals and benefits are attained (Gunasekaran *et al.*, 2017; Liang *et al.*, 2007). According to Hazen *et al.* (2012), the mere adoption of innovation does not necessarily imply that innovation is being used or adding value to the firm. This may be because it is not always clear how firms can leverage innovations to enable such capabilities to improve overall performance. Given this background, researchers proposed numerous models that analyse the process of introducing innovation from an organizational perspective. Several recent studies propose a three-stage model of technological adoption adapted from the model proposed by Hazen *et al.* (2012) (i.e. acceptance – routinization – assimilation). However, the topic dates back to the past century, and several models have been proposed since then. One of the most known models was proposed by Zmud and Apple (1992) in which they analyse the nature of effective technological incorporation processes and propose a method to measure the level of technological innovation introduction. Rogers (2003) proposes a six-phase innovation-development process (i.e. identification of needs/problems, innovation research, innovation development, innovation commercialization, innovation diffusion and adoption, consequences of the innovation diffusion). Scozzi *et al.* (2005) design three phases of

innovation development planning based on planning, learning and development. [Liang et al. \(2007\)](#) develop and test a theoretical model to evaluate the assimilation of enterprise systems within organizations. [Hossain et al. \(2016\)](#) study the assimilation process of the adoption of radio frequency identification technology. [Pae \(2017\)](#) provides an integrative framework that examines the factors affecting the routinization level of business technologies and the consequent mutual benefits in the buyer-supplier organization context. [Gunasekaran et al. \(2017\)](#) study the impact of the assimilation process of BD on the organization. [Vagnani et al. \(2019\)](#) introduce a conceptual framework in which the attributes of innovation–adoption decisions in organizations are mediated by both the behavioural preferences of managers and organizations’ resources and moderated by the innovation life cycle. All the studies mentioned focus on the process of adopting innovations from an organizational point of view. From these premises, it emerges that several models have been proposed investigating how the technologies can be implemented in organizations, including BD. However, a novel perspective considering as a unit of analysis the SC and not organization is still missing.

2.2 The role of big data in operations management

The introduction of BD in operations supports top management to handle different uncertainties and risks. According to the Gartner’s glossary, BDs are characterized by “5V” that include volume, variety, velocity, value and veracity. As a result, “volume” alludes to the enormous amount of data that may be gathered in the many areas of the SC. The term “velocity” describes how quickly digital processes can expand the size of BD because data are continuously generated by social interaction, monitoring devices, and several areas of the SC. “Variety” refers to the various sorts of data currently available, which come from several disparate sectors of the SC, both structured and unstructured data, not only from within the SC but also from outside sources ([Xu and Duan, 2019](#)). In data analysis research, the term “veracity” is used to refer to topics ranging from data quality and accuracy to correctness and truthfulness ([Saha and Srivastava, 2014](#)). The data must be accurate and reliable. The term “value” refers to the discovery of useful information that may subsequently be converted and extracted for study ([Makris et al., 2019](#); [Xu and Duan, 2019](#)). Simply collecting data and utilizing the greatest technology available on the market does not indicate that you will have information or, more importantly, that you will be able to extract insight.

BD allows companies to identify deviations between planned and real processes. Among the topic areas in the field of operations management (OM) supported by BD, strategic sourcing is one of the most common. Strategic sourcing is one of the company’s long-term strategic problems that focuses on managing collaboration and relationships with suppliers ([Nasiri et al., 2020](#)). The role of BD is twofold: to examine existing suppliers and to identify the best ones in terms of efficiency, costs and ability to adapt to future challenges that may arise day by day ([Tiwari et al., 2018](#)). A substantial cost factor in modern SC is caused by inefficient order management caused by suppliers unsuitable to meet business needs. This, however, also happens because there is a lack of knowledge of customer behaviour and the behaviour of decision-makers who place orders. This lack of knowledge has a significant negative impact on business costs. However, BD technology allows companies to capture and analyse data from both suppliers and customers ([Frank et al., 2019](#); [Bock and Isik, 2015](#)). [Merlino and Sproge \(2017\)](#) advise companies to take advantage of BD not only to improve their companies’ relationship with customers but also to better understand their suppliers and improve their replenishment strategy by optimizing inventory management. When a company engages with a new supplier, every single supplier information is important. Not only from financial statements or other public data but also unstructured data, including new programs, documents, social media posts, and information on the Internet are valuable sources that should be examined. BD allows not only a “hard analysis” of the operational and financial performance of suppliers but also the evaluation of “soft” characteristics, such as reputation

(Moretto *et al.*, 2017). SC network design is another operation supported by BD that determines SC's physical configuration. The goal of the SC network design is to create a network as efficiently as possible, which allows companies to satisfy customer demand and guarantee the lowest possible cost to manage the network. BD permits companies to achieve these goals more efficiently and quickly. This process includes different variables, many of which are related to the position, such as the distribution centers, the network of shops and the routes to supply those shops. BD, therefore, allows to both acquire data from different sources and integrate data for strategic decisions. Another fundamental strategic choice involves the operation of product design and development. The widespread of data available on the web, such as consumer reviews and blogs, has led to the development of many techniques to obtain useful information from these data sources to understand the trend of consumer preferences, which they can use to guide companies in product design and production processes. Such data, with the right analysis methods, can provide accurate predictions of customers' preferences and help companies to improve product design and development (Feng and Shanthikumar, 2018). Besides, the impact of BD with regards to improving innovation and product design capabilities along the SC marks a key opportunity for creating a competitive advantage (Sestino *et al.*, 2020). Accurate forecasting and demand planning are the basis for efficient SCM and execution (Hoffmann, 2016; See-To and Ngai, 2018). For this reason, the impact of BD flows on demand forecasting is studied, which provides a possible channel for extracting relevant knowledge on the structure of customer demand. Predicting the demand to be satisfied for a certain product is fundamental in both production and distribution processes. Demand forecasting, with the help of BD, is used to plan production and distribution planning and, therefore, improve SCM. Popular techniques used to analyse BD applied in SCOM include network analysis, regression models, natural language processing, stochastic incorporation, supervised learning algorithms and system modelling. Also, BD can integrate sales data, competition data and market trends to forecast demand. Another critical topic in SCOM is inventory. In this field, BD improves material-management systems to control the ordering and distribution of products throughout a company's extended SC. In the area of service, BD revolutionizes and transforms marketing science studies. BD helps managers in planning and directing customer service teams to meet the needs of customers. Customer service and customer relationship management systems benefit enormously from BD. The data serve to offer a better and customized service to customers. At the same time, they allow companies to anticipate consumer needs or repeat accidents in the past. The analysis of BD also influences the optimization of the service in the management of after-sales operations (Addo-Tenkorang and Helo, 2016; Choi *et al.*, 2018). The after-sales service is an integral part of the commercial process. Sometimes, it can be considered only as a problem by both customers, who fear the worst when it is the first time that they must deal with the assistance of a new company, and sellers, concentrated only in the sale and delivery of the good. After-sales can instead be an important lever in bringing significant results if managed appropriately. Logistics and transportation are two areas of the OM in which BD has obtained remarkable results. Thanks to this technology, a streamlining of material flows and an improvement in end-to-end visibility are obtained. BD has the potential to reduce traffic congestion, which is a major concern in cities around the world and an obstacle to economic growth. The reduction of congestion has benefits for society and positively affects the quality of life. As positioning technologies become increasingly widespread in all road vehicles, the interactions between vehicles and other vehicles, and between vehicles and the environment, will become increasingly sophisticated. This complex level of real-time communication between the vehicle and the surrounding environment will allow for an increase in speed on motorways, which could lead to shorter travel times and less road congestion. From a transport operations perspective, information

3. Methodology

The theoretical basis of this study that led to the definition of the conceptual structure discussed in the next sections was based on a deductive approach grounded on a large amount of scientific literature and secondary data analysis (Shepherd and Sutcliffe, 2011). A comprehensive systematic literature methodology is used to develop the theoretical conceptual framework, which comprehensively describes and captures the critical stages of BD technology adoption process in SC with a particular focus on technological, operational and strategical levels. This approach is particularly useful when the research aims to provide a broad perspective on a given topic from a theoretical and contextual point of view. Systematic reviews are useful in reporting in detail materials and methods used to conduct the search, ensuring a rigorous appraisal of validity, the objective or quantitative summary, transparency, rigour and the evidence-based inferences (Cook et al., 1997). The systematic review methodology has been conducted based on a previous contribution by Seuring and Gold (2012). Summarizing these previous contributions, the review protocol adopted is based on the following steps:

- (1) *Material collection*: identification of the keywords and related search strings, selection of the databases;
- (2) *Material selection*: definition of inclusion/exclusion criteria and identification of the final sample;
- (3) *Material analysis*: the content of the selected material was analysed in detail for the definition of the conceptual framework.

3.1 Material collection

Material collection represents the first step when adopting a systematic approach. This phase involves the search and selection of an expert panel, database, keywords and finally of a search string. The expert panel for conducting this search consists of a full professor with more than 30 years of experience in the technology adoption processes, two associate professors with specialization in the theme of adoption SCM and finally a senior PhD candidate specializing in Industry 4.0 with a specific focus on BD.

The choice of the database to be used for the development of this paper fell on Scopus. This is because it comprehensively covers the peer-reviewed academic literature, indexing the contents of 24,600 active titles and 5,000 publishers and hosting material from journals, books and conferences. The expert panel chose the string considering words related both to the adoption process and to BD. These keywords were structured in a search string with the use of Boolean operators to increase the number of papers to be captured by the initial search. Table 1 presents the results of the initial scoping. Specifically, the search was conducted considering abstract, title and keywords of the extant literature, while any filters were adopted in the time range and source.

Table 1.
Initial scoping

Search string	Papers
TITLE-ABS-KEY (("big data" OR "big data analytics" OR "BD" OR "BDA") AND (adoption OR acquisition) AND (process OR supply AND chain))	199

3.2 Material selection

This phase aims at the selection of the sample of articles related to the topic under investigation. Therefore, two different exclusion criteria have been identified. The first is based on reading the title and abstract of the articles in order to carry out a first screening and exclude the articles not focused on the BD adoption process but related to more generic issues. The second criterion is based instead on reading the full text of the articles in order to exclude all the sheets dealing with issues outside the analysis domain. Table 2 presents in detail the criteria adopted and the final number of papers obtained.

4. Material analysis

The objective of this phase is linking together the 61 studies collected with different but complementary perspectives for the integration and comprehensive presentation of theoretical background. Specifically, we aim to combine knowledge from various perspectives; as a result, we obtained a narrative synthesis that allows these authors to tell a story based on accounts of previous literature.

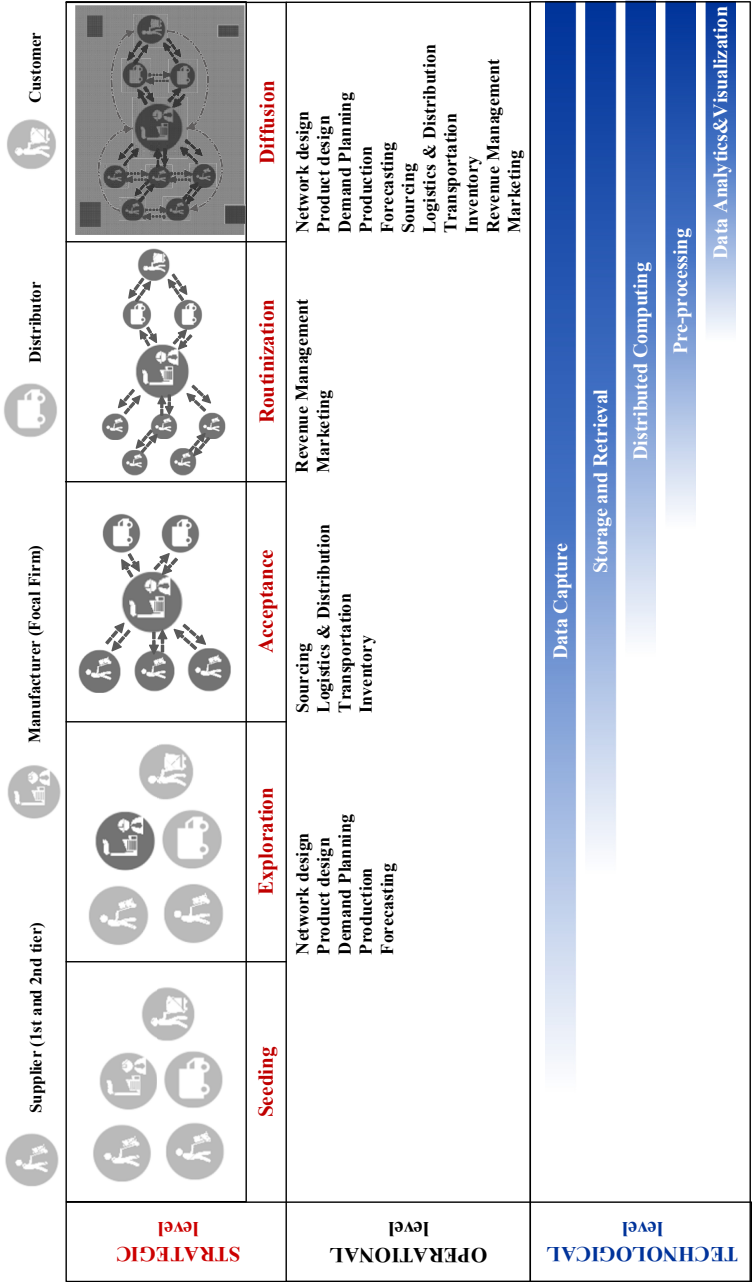
The introduction of the new Industry 4.0 (I4.0) technologies, and in particular of BD, has shown positive effects on the effectiveness and efficiency of companies' operations (Schoenherr and Speier-Peró, 2015). Technological advancements and innovation impact whole SCs, which become increasingly connected as supply networks in contrast to the traditional linear configuration. Thus, Industry 4.0 represents a new industrial paradigm able to transform the current ways of value creation, since it involves changes in technical and product developments (Saggi and Jain, 2018). Indeed, the introduction of digital technologies has brought extensive organizational consequences and opportunities. Consequently, new and adapted organizational models are needed. However, as discussed above, this paper focuses on the SCM context. Starting and adapting previous contributions, we built an integrated framework (Figure 1). The framework depicts the adoption process of BD in SCM considering three levels of analysis: strategic, technological and operational.

At the beginning of the adoption of the new technology, in the seeding phase, the SC actors approach the technology independently. In the framework, the different actors are represented by blurred icons to highlight the evanescence of the idea of acquiring the BD technology that homogeneously pervades the environment. After the first phase of seeding in the SC, the focal firm (*FF*), which in our paper is represented by the manufacturer, shows the willingness to adopt BD driven by the climate of interest that arose in the previous phase of seeding. The *FF*, in this case, is no longer blurred but is represented in a defined way as the fulcrum of the network that is being created. Starting from this condition, the first vertical relationships due to the adoption of the BD will begin. From the operational level, this stage includes the daily operation of a facility such as a network design, product design, demand planning, production and forecasting that involve internal SC actors (Dubey *et al.*, 2019; Hoffmann, 2016; Moretto *et al.*, 2017). When technology is in the early stages of diffusion (i.e. in the acceptance phase), the SC downstream and upstream relationships between *FF*, customer and first-tier suppliers are established. In particular, if we consider a traditional SC with only two levels of supply; in the early stages, the relationships arise between manufacturer and first-tier suppliers and manufacturer and distributors. We are still in an

Criteria of exclusion/inclusion	Article removed (–)
<i>Initial sample</i>	199
1. Title and abstract reading	–101
2. Full-text reading	–37
<i>Final sample</i>	61

Table 2.
Exclusion criteria

Figure 1.
Big data technology
adoption in the supply
chain: a novel
framework integrating
strategic, operational
and technological
levels



initial state where relations are only vertical. This kind of integration allows data to flow easily and transparently from top to bottom and vice versa. These types of relationships are of the “buyer-supplier” type, and, unlike horizontal relationships, they can be assimilated to partnerships between the actors at different levels of the SC (Christopher and Gattorna, 2005). The SC integration is fundamental: manufacturers must not only focus on their organizations, but also be involved in the management of the network of upstream and downstream firms to gain a competitive advantage (Narasimhan and Carter, 1998). In this phase, the actors involved are characterized by full and not fuzzy colour, and the vertical relationships between the *FF* and the adjacent actors are represented by the arrows that connect the icons in both directions.

The operations involved are not only internal, but some involve the supply and distribution areas such as sourcing, logistics and distribution, transportation and inventory. Once the acceptance phase has passed, the routinization phase begins. This phase coincides with the provision of a solid infrastructure for the full exploitation of the BD. The supply network becomes more complex with the addition of two tiers: upstream second-level suppliers and downstream customers, respectively. The vertical relationships between the different levels around the *FF* intensify and the data flows become increasingly transversal. A high level of vertical integration assumes great strategic importance also for practitioners, as the strategic importance of integration is similarly reflected in the SC Council’s popular SCOR (supply-chain operations reference) model which assumes that all firms include the procurement, implementation and delivery of processes that connect strategically suppliers and customers to manufacturers (see www.supply-chain.org). In Figure 1, all the actors involved are represented by full-colour icons, and the interchange relationships in the different levels are represented by arrows. The operational level is characterized by the addition of an additional component of the network, that is, the customer, and therefore the operations of revenue management and marketing are added. In the final phase of diffusion, technology has now run in, and the infrastructure is running at full speed. The supply network is flat and characterized by vertical relationships between the different levels and horizontal within the individual levels. The data flow circulates homogeneously inside and begins to radiate outwards. In this terminal stage, horizontal relations of the “supplier-supplier” type are also established which, according to Christopher and Gattorna (2005), can be called alliances. Horizontal connections contribute indirectly to strengthen the business relationship through augmenting the impact of vertical connections (Hadjikhani and Thilenius, 2005). Figure 1 depicts the different types of connections both vertical and horizontal with dark grey arrows and the relationships between the *FF* and the upstream and downstream actors with light grey arrows. Besides, the diffusion phase is represented as a unique and integrated entity enclosed within an oval that branches out to external partners. In the framework, there is also a further technological level that must be integrated with the previous ones. In particular, the five phases from data acquisition to data analysis and visualization begin in conjunction with the five different phases of adoption of the technology. The data collection step takes place already from the initial steps and involves the actors from the beginning interested in technology up to involving the internal network. The phases of data storage and retrieval and distributed computing instead require the presence of adequate infrastructure, for which they start only in a subsequent step of adopting the technology and involve particularly the *FF* and the actors connected to it. The last two phases of pre-processing and data analysis and visualization, on the other hand, require the active intervention of the managers of the different areas who have greater sensitivity in the analysis of data from their businesses. In conclusion, the introduction of the BD gives rise to a triple strategic, operational and technological processes. This technology modifies the shape of the SC, making it flat and integrated, and conveys the flows to and from the *FF* up to the portrayals

towards the outside. From an almost operational and technological point of view, it remains to understand the benefits and barriers that SC actors will face in the different phases, which will be discussed in detail in the following section.

5. Discussion

The main aim of this paper is to highlight how BD technology can be adopted within SC from a strategic, operational and technological point of view. BD is part of a set of I4.0 technologies that aim to optimize decision-making (DM) processes for industrial applications. In answering the question RQ1 formulated in the introduction section, we found that BD has modified the supply network concept starting from the dyadic relationships, triads up to the creation of a streamlined and integrated network. These changes are reflected in an integrated vision including both benefits and barriers. From this perspective, it is fundamental to have a deep knowledge of how BD influence SCOM both positively and negatively to identify research questions still open. As for questions RQ2 and RQ3, we have noted that starting from the exploration phase, internal operations are positively affected by the adoption of BD. In strategic planning, BD plays a vital role. It has been shown that BD helps companies make better decisions regarding network design, product design, forecasting, production and demand planning (Wang *et al.*, 2016). Through the BDA, companies can identify the bottlenecks of production processes, understand the causes of problems and find solutions, to make production more efficient, lean and competitive. The product design phase instead benefits BD through data analysis. The use of BD to analyse user behaviours and market trends allows companies to precisely quantify customer requests and translate consumer needs into product characteristics and quality requirements. The control and improvement of product quality are integrated into every step from raw material to the finished product (Tao and Qi, 2019). Besides, the analysis of the BD allows companies to detect trends in demand and determine optimal prices. Raman *et al.* (2018) argue that forecasting is positively moderated by the impact of the BD, thus ensuring effective management of the SC. Going beyond the perspective of internal processes, in the acceptance phase in which the dyadic relationships are established between *FF*, *customer* and *first-tier suppliers*, the external operations of sourcing, logistics and distribution, transportation and inventory begin to experience the benefit of BD analysis. In sourcing operations, the BD improves communication in the triads between the *FF* and suppliers and the *FF* and distributor, on the one hand reducing response times, and on the other speeding up deliveries. Moreover, improved transparency and flexibility will lead to a reduction in inventory levels and lead times (Makris *et al.*, 2019). The analysis of BD in logistics and transport activities leads to a more precise estimate of the relative accident risk factors, which helps to implement proactive measures to avoid accidents (Choi *et al.*, 2018). It makes the transport system more efficient, bringing positive consequences in terms of sustainability by reducing emissions into the atmosphere. In the routinization phase, the benefits also involve the customer, and consequently the revenue management and marketing operations. The benefits in this case intensify the interaction with customers who can guide production and therefore lead to a general increase in customer satisfaction, product customization and loyalty. In the diffusion phase, the technology is significantly extended beyond the manufacturer's boundaries and characterized by horizontal and vertical information flows, and the transversal benefits of BD involve all SC actors. There is an improvement in corporate strategies as defined based on direct data, improvement of relations with both internal and external stakeholders, thanks to a streamlining of relationships that become horizontal, reduction of the communication gap between demand management and SCM and effective communication between man, equipment and products. Table 3 summarizes the main findings discussed above related to the benefits of BD diffusion and adoption in SC operations management. However, despite the

Strategic level	Adoption phases	Seeding	Exploration	Acceptance	Routinization	Diffusion
Operational level	Operations		<i>Network design; product design; demand planning; production; forecasting</i>	<i>Sourcing; logistic and distribution; transportation; inventory</i>	<i>Revenue management; marketing</i>	<i>Network design; product design; demand planning; production; forecasting; sourcing; logistic and distribution; transportation; inventory revenue management marketing</i>
Benefits	DM optimization					x
	Reduction of down time		x			x
	Competitive advantage					x
	Customer satisfaction				x	
	Transparency		x			x
	Flexibility			x		x
	Correctness of data					x
	Easy access to new markets					x
	Real-time data/Decisions		x			
	Identification of competitors' opportunities and threats					x
	Timely responses to changes					x
	Effective communication between employee's equipment and products					x
	Improvement of business strategies					
Barriers	Reduction of communication gap between demand management and SCM					x
	Improvement of relations with stakeholders					x
	Sustainability				x	
	Reduction of inventory level				x	
	Production systems with unique requirements		x			x
	Privacy laws; data protection				x	
	Demanding knowledge extraction					x
	Cost increase					x
	Complexity in data elaboration					x
	High investment costs					
	Difficulty in detecting data relations			x		x

Table 3. BD benefits and barriers

astonishing number of benefits, it is not possible to leave behind the barriers that companies face when adopting BD technology. We found that, from the internal operations perspective, the major barriers are found mainly in the exploration and acceptance phases of technology when building the internal infrastructure. The BD definition requires the use of high volume, high speed and high variety data. Given these characteristics, it requires new technologies to capture, store and analyse them since, with current instruments, BD is difficult to be stored, processed and analysed (Jeble *et al.*, 2018; Valdez *et al.*, 2019). Zhao *et al.* (2017) showed that very few studies existed on the integration of BD science and SCM. To date, indeed, only a small percentage of the BD is used in the DM process of the SC. This happens even though the production systems have become intelligent and the huge amount of data coming from the different phases of the SC are available. The diffusion in the use of sensors, intelligent devices and social collaborations, the data – also coming from a high variety of heterogeneous sources – are available not only in a structured form but also in a semi-structured and unstructured form: this makes difficult the integration and even the identification of useful and useless data. Database and data warehouse technologies are becoming inadequate to manage the amount of data the world is generating. Despite the exponential growth in the volume and speed with which data are generated in production environments (e.g. integrated sensors), most of them remain unused (Peres *et al.*, 2018). Considering the acceptance phase, which also involves external operations, the barriers we find are mainly linked to the process of integrating data from different sources. The routinization phase involves both downstream and upstream collaborations, and this may increase costs for fulfilment of customized orders and investments in equipment for the analysis of preference data. Another aspect to be considered is regarding the processing of sensitive consumer data. Privacy and information security have now a pivotal role; huge amounts of tangible and intangible data are generated every day, from which companies can gain significant economic benefit. The exploitation of such personal information is subject to a few constraints and frequently with almost no supervision. Being aware of this situation, the European Union has responded quickly to the growing threat of the misuse of data by issuing the General Data Protection Regulation. Companies that neglect to consider and implement privacy and data protection requirements will be subject to control actions. Cyber risk is one of the well-known shortcomings of the new SC 4.0 system. It is necessary to intensify the attention in this sector and carefully monitor the information that is shared. Lastly, the diffusion phase is the one that catalyses all operations and internal, external vertical and horizontal relations and is therefore characterized by global barriers. These barriers are humans, linked to the modification of the organizational mentality for the adoption of a new technology that leads to sharing sensitive information causing conflicts between the members of the organization and, on the other hand, economics linked to huge costs investment in training and equipment. For companies, it is necessary to keep under control all the costs that are generated along with the SC. Consequently, the ability of the SCM to provide high-performance services at the lowest possible costs is one of the key aspects of competitive advantage. We must not forget that the competitive advantage is given not only by the costs but also by the production and delivery times to the final consumer. On the other hand, recently government and consumers have started to worry more about the environmental effect caused by SC and production processes (Gružauskas *et al.*, 2018). Current SCM practices require the choice between economic performance and minimization of negative environmental effects. As a result, Table 3 summarizes the barriers discussed above from a strategic and operational perspective. As for the technological level, benefits and barriers can be summarized. As benefits, we highlight the formation of a solid infrastructure that leads to the streamlining of all phases, from data capture to data analysis and visualization, the creation of faster, more intelligent and streamlined processes and the generation of new information coming from data analytics phase. However, the barriers are often linked to the characteristics of the data

and therefore to their volume which creates difficulties in the data capture, storage and retrieval phases, and to the high complexity which generates difficulties in the final processing phase (physical infrastructure). Other barriers relate to the unavailability of not updated data, the quality of retrieved data and the missing skills to manage them.

6. Conclusions

In this study, we conceptualized a framework that explains how BD technology can be integrated within the SC, according to a strategic, operational and technological perspective. In the first instance, we conducted a systematic review of the literature and analysed the content of 61 articles, analysing the process of adopting technology by outlining the key phases of the adoption process from a strategic perspective. Then, we detailed these phases with particular emphasis on the SC operations focusing on the operational level of BD implementation. Finally, the framework integrates the technological-level perspective related to the adoption of BD technology. This in-depth analysis has allowed us to outline a detailed framework that shows how relationships between SC actors change because of the implementation of BD technology. Starting from this framework, a taxonomy of benefits and barriers classified according to the strategic and operational levels has been proposed. The framework and the taxonomy allowed us to respond to the research questions provided in the introduction. Considering question [RQ1](#), the phases in which the process of introducing the BD into the SC is divided have been identified: seeding, exploration, acceptance, routinization and diffusion. In the first phase, the latent interest in the new technology begins to spread. Such technology begins to become increasingly popular among different businesses. Some companies start to show interest and decide to test and invest in the technology with the aim to explore potential benefits for their business. In the second step, one or more companies begin to use the new technology or rely on external consultants to start testing the benefits promised and achieved by other companies for their own business.

After the exploration phase, when some experimental results of testing experiences revealed the benefits of the technology, companies started thinking about the internalization of technology management activities. In the routinization phase, the focal firm has an internal structure to make the best usage of the technology, which is now integrated into most of the company's operations (e.g. purchasing, production planning and control, warehousing, logistics, inventory management, distribution, delivery, vendor management).

Finally, in the diffusion phase, the technology is significantly extended beyond the manufacturer's boundaries. The other SC actors are also organized in such a way as to collect production, purchase, customer, maintenance and customer support data in order to process them. The manufacturer can integrate all data for more accurate predictive analytics. The relationships along the SC are now consolidated and even extend towards external partners and other SCs. Regarding [RQ2](#) and [RQ3](#), we have noted that the introduction of BD in the SC has radically changed its traditional nature. From the seeding to the diffusion phase, the SC undergoes gradual variations. These are linked both to changes that permeate the internal structure and to changes in the organizational culture. The benefits in the use of BDs both at a strategic and operational levels are perceived as the degree of diffusion of the technology increases. The different benefits and barriers provided by BD are detailed in [Table 3](#). Despite the evidence provided, there is still a scope for more research about how this technology can be integrated with the other I4.0 technologies supporting SCOM, which led us to the definition of the first research question:

6.1 How does BD interact with other I4.0 technologies supporting SCOM?

I4.0 is based on IT systems that interact with the company's factory, boasting communication, control and computational skills. These interactions have brought numerous benefits, and so it

remains to be asked what additional benefits can be obtained in SCOM by exploiting the interaction between two or more I4.0 technologies. There is still a need for studies investigating SC communication processes between BD and I4.0 technologies such as IoT systems, cloud computing, artificial intelligence, additive manufacturing and deep learning. The SC will no longer be characterized by a limited network of technology devices but by a global network in which, at any time, each object is connected regardless of where it is located. Future research opportunities can investigate these relationships and evaluate if and how the benefits resulting from the interaction/integration of specific technological sets increase. Another interesting research direction emerges from the type of perspective used to analyse the diffusion and adoption of BD technology within the framework, and we have chosen the manufacturer as the FF and placed it at the centre of the network and the related diffusion process of the technology within the SC. This choice guided the subsequent discussion, and consequently the results achieved. Relationships expand and branch out from the manufacturer, and this leads to a streamlined and integrated network. It would be interesting to develop the model where the FF is polarized upstream (or downstream) investigating if there could be any mutations in the relational system between the different internal and external actors of the network and if new benefits and barriers can be detected. This assumption led us to formulate the second research question:

6.2 How would the benefits and barriers change if the FF were represented by an upstream or downstream member of the SC?

Finally, in this paper, we focused mainly on the evaluation of the relationships within the network – how they are composed, developed and the benefits they bring – without, however, deepening the process of external integration. The literature has shown how the external SC integration allows companies to obtain a competitive advantage in the current e-global environment (Das *et al.*, 2006; Aitken *et al.*, 2005; Briscoe *et al.*, 2004). High integration between external partners can lead to more resilient SCs capable of dealing with disruptive events such as the current COVID-19, thanks to the greater visibility and transparency of information in the network. These profoundly current reflections necessitate a broader assessment of how BD influences the relationship between the SC and the external environment through an integration process. The third research direction is:

6.3 How BD affect external SC integration?

The framework proposed focuses on manufacturing companies. Very few studies investigate the adoption of BD in the service industry. Therefore, future research can be conducted to analyse and compare the results achieved in this paper in the service industry. The fourth research direction and can expressed as follows:

6.4 What is the adoption process of BD technology in the service industry?

Finally, we investigated the diffusion and adoption process of BD in SC. The proposed framework can be used as a basic tool for evaluating the diffusion of I4.0 enabling technologies in the SC context. Therefore, it would be interesting to also investigate the diffusion process of the other I4.0 technologies within SC (e.g. cloud computing, artificial intelligence, augmented reality).

As for the practical and managerial implications, the taxonomy presented in Table 3 can be used to exploit the results of previous studies with particular emphasis on the benefits and improved performance achieved and the barriers and difficulties encountered. The results of our study can offer practitioners guidelines to promote the spread of BD in SC and to improve their impact on internal and external operations. The proposed framework supports companies in redesigning the processes mainly affected by the adoption of BD, helping them in identifying the critical elements, barriers, benefits and expected performance. Therefore, the framework could be an important model in using technologies that integrate partners into

SCM. The findings also show the importance of data-based DM skills, organizational learning, technical skills and management skills that managers must necessarily consider in redefining operational processes for the introduction of BD. The results of this paper particularly help those managers who face a constant problem of how and when BD can be used to improve the integration process with other SC actors. The results of our study also suggest that companies that introduce BD in SC build the culture of information sharing and are more successful in the vertical and horizontal integration processes that can help eliminate the complexities resulting in SCs from information asymmetry resulting from poor visibility and transparency. Despite the substantial insights of this study for researchers and practitioners, it is not without limitations. One limitation is the focus of the study on the analysis of the processes of adoption of BD technology in the SC considering a particular structure of SC characterized by only two levels of supply and by a reduced number of members. The impact of BD analysis on horizontal and vertical relationships could be expanded and explored in future research by introducing new SC actors (e.g. retailers) to integrate the current framework. As mentioned before, another potential limitation is that the study focuses only on the diffusion and adoption process of BD technology. It may be necessary to explore different I4.0 technologies by investigating the role they play in the technology adoption process. In this attempt, it may be useful to evaluate whether to integrate the tactical level to distinguish between short-range and long-range planning decisions when discussing SCOM. Finally, there is the need to empirically test the proposed framework.

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