Digital supply chain characterization: a review of the definition and main benefits.

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Abstract: Digitalization is overwhelming in every aspect of modern businesses. Already widespread and widely adopted by companies in the manufacturing sector, the Industry 4.0 paradigm is increasingly affecting all the firm's processes and, in particular, supply chain management. Often, one of the main expected goal for the companies after the implementation of the Industry 4.0 technologies is making the supply chains "digital". The impact of 4.0 technologies can be easily recognized in changing supply chain structure: the chain becomes an integrated actors' network, allowing for more effective information sharing and ensuring the end-to-end visibility, necessary in today's context. This change creates a global ecosystem where information travels quickly and easily in all directions, among all stakeholders. This new structure, which goes beyond the traditional linear one, makes the supply chain faster and more flexible, increasing its responsiveness and reliability. These last features are crucial in the current environment where customers' expectations are continually rising, and meeting them is the only way to survive in a highly competitive world. This is how the Digital Supply Chain (DSC) concept was born; although it is still in its infancy, it is starting to be a topic of relevant interest to many academics who are focusing on it. This paper aims to give an unambiguous definition of this new concept, highlighting its characteristics, and showing the benefits brought by the digitalisation of supply chains. In particular, eight typical characteristics of the modern chains are presented, showing how these bring important benefits to companies that implement this strategy. This article can also be taken as a starting point for further research, for example, to identify benefit clusters, linking them to roles or areas within a company or for a possible quantitative study in terms of cost savings.

Keywords: digital supply chain, technologies, innovation, logistics 4.0.

1. Introduction

Digitalization – intended as the changes in human society associated with the use of digital technologies (Parviainen et al., 2017) – is an inevitable process in progress today, as a result of the impetus given by the now well-established Industry 4.0 paradigm. The consequences of this process – also referred to as *digital transformation* – are manifested with important impacts on production systems and on the whole economy, in terms of significant opportunities and challenges for companies. Indeed, the digital transformation is putting companies under pressure, pushing them to innovate and redesign their business processes. In particular, in recent years, the wave of innovation involved one of the most complex business processes: Supply Chain Management (SCM). Industry 4.0 implies changes in the way companies organize themselves. Currently, however, there are many theories about the general implications of this phenomenon for manufacturing, while there are only a few on its impact on SCM (Tjahjono et al., 2017).

The idea that the supply chain is synonymous with purchasing, production and transport of goods from one place to another has long since been overtaken. Today people often talk about *supply network*, emphasizing the complexity of the relationships between the different actors that form a network, or *fulfilment network*, highlighting the focus on the satisfaction of market demand (with particular attention to the e-commerce channel) through a complex network of companies. By enabling a "network" view, digitization can help companies capturing huge savings and competitive advantages by developing networked processes, optimizing the whole enterprise instead of individual functions, and driving new ways of thinking. All this implies greater visibility, collaboration and innovation (Raj and Sharma, 2014).

With the diffusion of innovative technologies typical of the Industry 4.0 paradigm, supply chain management is changing significantly to better adapt to the continuous change of the surrounding environment (Ben-Daya et al., 2019). The drivers of digitalization include, in addition to technological innovations, changes in customer behaviour and expectations: their needs are becoming increasingly dynamic and changing (Farahani, 2017). For example, the increasing diffusion of e-commerce has led to an increase in expectations regarding the level of service required and higher product customization. These requirements boost companies to review their supply chain management, in particular by changing the classic linear model – where streams (especially information) flow from the supplier to the producer, from the distributor to the consumer – in favour of more integrated models, based on greater collaboration and communication between all actors in the chain in order to increase reliability, agility and effectiveness (Büyüközkan, Göçer, 2018). Such models exploit digital technologies to overcome rigid organisational structures,

inaccessible data, and unstable relationships between partners. Thus, the concept of Digital Supply Chain (DSC) was born and developed. This new concept includes notions ranging from process automation to organizational flexibility and digital management of company assets, necessary to remain competitive in a highly competitive market.

Starting from the methodology used, the article goes on to define the concept, the technologies used and the structure of the new supply chain. In the following sections, the characteristics and major benefits are then presented. Finally, conclusions and possible future research are shown.

2. Methodology

The methodology used in this paper is the literature review, with the objective to collect and analyse the existing literature on the concept. Usually, database queries are used to search for documents related to a topic. The first part of this research was carried out by entering keywords such as digital supply chain, technologies, innovation, logistics 4.0 in Scopus database and Google Scholar. The aim of the research was to collect information on the application of digital technologies in the supply chain, through the reading of peer-reviewed journal papers, conference papers, books, etc. The Digital Supply Chain could be seen as the result of the application of Industry 4.0 in the supply chain; for this reason, the timespan considered goes from 2011 to 2019. Although it is still in its infancy, this topic is starting to be attractive to many academics who are focusing on it but, at the moment, it is still difficult to find scientific literature available. There are, however, scientific articles dealing with the supply chain, but they are mainly focused on technologies and their applications in this field or, in general, on the relationship between supply chain and Industry 4.0. Currently, the literature available, focused on this topic, is "grey literature": mainly books or industry reports by consulting firm.

This search has shown that the DSC concept is still in its early years of research and development among academics, while it is widely discussed among professionals. For this reason, the search engine Google was also used to include industrial reports.

The information about DSC is fragmented: there is no unanimously adopted definition on the concept. For this reason, has been used the secondary data methodology to overcome the limit of data heterogeneity. Secondary data can be defined as data collected by others, not specifically for the research question at hand (Stewart, 1984). One of the most important sources of secondary data will be companies themselves (Cowton, 1998), with their industrial reports. In the Table 1 the industrial/consulting reports used in the paper are shown, detailing which information has been collected (D=definition, T=technologies, F=features, B=benefits).

Author	Year	Title	Information				Company
			D	T	F	B	
Alicke et al.	2016	Supply Chain 4.0- the next generation digital supply chain	X		X		McKinsey
Bailey	2015	Digital Supply Chains: A Frontsite Flip	X	X		X	The Digital Supply Chain Initiative
Ferrantino and Koten	2019	Understanding Supply Chain 4.0 and its potential impact on global value chains		X		X	World Bank Group
Ganeriwalla et al.	2016	Three paths to advantage with digital supply chains	X				Boston Consulting Group
Garg et al.	2019	Digitize the industrial machinery supply chain	X	X		X	IBM Institute for business value
Hackenberg	2018	Creating competitive advantage through a Digital Supply Chain			X	X	Infosys Consulting
Hanifan et al.	2014	The Digital Supply chain network, a new paradigm for SC management			X	X	Accenture
Raab M. et al.	2011	Digital Transformation of Supply Chains: Creating Value–When Digital Meets Physical				X	Capgemini Consulting
Raj and Sharma	2014	Supply Chain Management in the Cloud			X		Accenture
Robinson	2016	The Future of supply chain, logistics &manufacturing: how technology is transforming industries		X			Ceraris
Schrauf and Berttram	2016	Industry 4.0: How digitization makes the supply chain more efficient, agile and customer focused				X	Pwc

Table 1: Industrial reports on DSC

3. Digital Supply Chain: a definition

In this article, we try to overcome the literature gap presented in the previous section, illustrating the different definitions of DSC, and trying to clarify the concept in a univocal way.

McKinsey consulting (2016) defines the new supply chain (Supply Chain 4.0) as the application of IoT, advanced robotics, and analytics in supply chain management to improve efficiency and customer satisfaction. The Digital Supply Chain Initiative (2015) states that "*the Digital Supply Chain i is a customer-centric platform model that captures and maximizes utilization of real-time data coming from a variety of sources"*. Boston Consulting Group (2016) underlines that the new asset-utilization, resulting from the digitalisation of the supply chain, implies a switch to a customer-centred approach, based on demand and supply. Wu et al. (2016) report that the supply chains are becoming smarter, with more objects integrated with sensors and better communication, intelligent decision-making and automation capabilities, resulting in opportunities to reduce costs and improve efficiency. There is one scientific paper (Büyüközkan, Göçer, 2017) that deals entirely with the concept of the Digital Supply Chain, doing a literature review that shows literature limits, challenges and success factors for DSC.

In summary, nowadays, the term Digital Supply Chain (DSC) is used to indicate a supply chain that implements digital technologies – emerging or consolidated – in order to improve supply chain management processes compared to the traditional, non-digitalized model, in perceiving, responding and coordinating flows (from the distribution channel to the supplier networks and vice versa). More specifically, a Digital Supply Chain is an intelligent process that exploits innovative approaches using emerging technologies and analytical methods in order to generate new forms of revenue for organizations (Büyüközkan, Göçer, 2017). The adjective *digital* is about the way supply chain processes are managed: innovative technologies enable interconnected activities between all stakeholders and therefore, better collaboration and communication between them. New digital technologies ensure a level of visibility and sharing of information along the entire supply chain which, although at the basis of traditional supply chain management paradigms, has hardly been achieved in the past (Garg et al., 2019). The collaboration along the chain also makes it possible to reduce overall inventory through a more reliable exchange of planning data, a gradual reduction in delivery times thanks to the rapid provision of information along the entire chain, and an early warning system that enables a rapid reaction to unexpected changes (Alicke et al. 2016).

3.1 Technologies

The logistics, manufacturing, and transportation industries are going through a time of rapid and unique transformation. The future of these industries is paved with innovation and technology. Today, merchants and service providers of these industries are prudently adopting these technologies to provide faster, cheaper, more reliable and sustainable business practices.

In defining DSC, everyone agrees that it involves the use of technologies typical of Industry 4.0. While each of the "industrial revolutions" is generally characterized by a cluster of standard technologies, the technologies list for this revolution is not unique. The analysis of the literature reveals eight leading technologies implemented, although some in a limited way, within the traditional supply chains that are evolving in the digital direction (Table 2). The reported definitions are based on the references in the table, but have been revised by the authors.

In brief, digital technologies allow the automation of processes, both physical (such as in production or warehouse through the use of robots) and cognitive (for example, through the use of advanced data analysis systems to support decision-making processes). The latter appears to be the real revolution in the digitization of the SCM. The volume of structured and unstructured data generated from disparate sources across today's increasingly complex global supply chains is enormous and will continue to multiply with the advent of these new digital technologies (Gjendem and Deep, 2016). For this reason, all companies must be equipped with technologies capable of manipulating, structuring and exploiting this massive amount of data, to seize the full potential of digital.

3.2 Digital Supply Chain structure

Surely, Digital Supply Chain is based on the use of contemporary technologies (e.g. Internet of Things (IoT), big data analysis, autonomous robotics), but this is not the most relevant aspect. According to World Bank Group (2019), the most radical change lies in the structure of the supply chain: a DSC is about transforming the supply chain management model from a linear model, in which information flow from supplier to manufacturer, from distributor to consumer, and vice versa, to a more integrated model in which information flows omnidirectionally across the whole network. Traditional supply chains have a significant limitation: information is exchanged only with direct supplier/customer, in a siloed way, not connecting the actor with those further upstream/downstream. Digitization can bring down those walls, and the chain becomes a fully integrated ecosystem that is completely transparent to all the players involved. This transparency will enable companies not just to react to disruptions but to anticipate them, modelling the network to better adapt to new circumstances. For instance, through simulation - powered by the available data- companies can create the digital twin of the physical network to analyse supply chain risks or to study the development of emergency plan (Ivanov et al., 2019).

The rapid exchange of information also boosts the agility of the entire chain, while enabling much closer integration with customers. Consequently, there is an exchange of information between all the actors that guarantees higher reliability and a faster response to sudden changes in the context.

Technology	Definition	References
Additive Manufacturing (AM)	Commonly known as 3D printing, AM is a process for the creation of three-dimensional objects usually obtained by superimposing layers of material. It is used in production, to reduce delivery times thanks to fewer assembly operations required.	Farahani (2017)
Advanced Analytics	It is the analysis of data by applying techniques and tools such as machine learning, data mining, predictive analysis of big data in order to extract useful information in an analytical and predictive sense.	Awwad et al. (2018)
Augmented Reality	Considered as an extension of physical reality usually perceived by the human senses, to which artificial and virtual information generated by computers (e.g., text, graphics, video, sound) are superimposed. The most common form of augmented reality includes a visual display that, once worn, helps the operator in the execution of operations with a consequent improvement in performance.	Büyüközkan and Göçer, (2018)
Autonomous vehicles	They are vehicles able to perceive the surrounding environment and navigate without human intervention. An example of a widespread autonomous vehicle is the Automated Guided Vehicle (AGV) for material handling. Another example today is the Unmanned Aerial Vehicle (UAV), commonly known as drones, which have been attracting the attention of delivery companies in recent years.	Büyüközkan and Göçer (2018)
Blockchain	It is a distributed accounting technology that allows multiple parties to store copies of the same information in different locations, either openly or by requesting permission from individual entities to access the network. Thanks to blockchain, companies involved in a supply chain can have a kind of shared database.	Crosby et al. (2016)
Cloud Computing	It is a network of remote services connected to the Internet along various points to store, manage, and process data. Cloud resources include tools and applications such as data storage, servers, databases, networks and software to integrate processes within a supply chain.	Robinson (2016)
Internet of Things (IoT)	IoT allows connected objects to communicate with each other, through an existing Internet infrastructure, without the use of human intervention. The most widely used IoT technology at SC level is Radio-Frequency Identification (RFID), which provides for the application of tags, capable of autonomously storing data and information on real people and objects and therefore allows the management and control of resources, increasing not only operational efficiency thanks to the reduction of time but also the reliability of the information transmitted.	Ben-Daya et al. (2019); Robinson (2016)
Robotics	The scope of application is, above all, manufacturing, and involves the use of robots to replace human resources or to support the operator (collaborative robots) to perform certain operations (especially those that involve repetitive or heavy actions for the human operator).	Robinson (2016)

Table 2: Digital technologies in the supply chain

This supply chain information sharing is not bounded to the business process level but also includes a vast amount of data from devices and sensors (IoT). Integrated supply chain information models are essential in modern DSCs, and the role of information integration and service automation has been identified as an essential business driver (Korpela et al., 2017).

Integration, therefore, plays such a fundamental role in the new supply chain concept so that, for some, it represents a real "enabling technology" or a DSC capability (Junge, 2019). Today it is no longer the individual organizations that compete with each other but compete as a supply chain. In this context, the traditional way of working and the decision support from the old ICT function are no longer sufficient in the face of such complex global supply chain management problems of large international companies (Merlino and Sproge, 2017).

4. Digital Supply Chain main features

In order to better clarify the DSC concept, it is necessary to define the main features of modern supply chains. Also in this case, the literature is still in its infancy but, from the analysis of existing articles and technical reports, it is possible to identify eight recurring peculiarities in the Digital Supply Chains. In particular, in the existing literature, it is difficult to distinguish features from the benefits resulting from the digitization of the chain. In this paper a clear distinction is made: features (discussed in this section) means the characteristics that digitized supply chains must have, benefits (shown in section 5) means the improvement impact that this phenomenon has on the supply chain.

As already mentioned, today's environment is characterized by high volatility: customers' needs are continually evolving, and their expectations are increasing dramatically, requiring more and more customized products and services. The high internet penetration rate has significantly changed customers' buying behaviour and demand patterns, which impose high pressure on supply chain managers. For that reason, supply chain managers need to focus their attention to enabling new processes and make corporations more agile and connected to create value across the enterprise (Agrawal et al., 2019); thus, new supply chains need to be rapid, scalable and flexible. There must also be a focus on sustainability, an increasingly valuable asset for companies that today must be "green" in all their processes.
Accenture consulting (2014) has identified four characteristics of the digital supply chain network, defined as "advantages", which have been taken as a starting point of our study: connected, intelligent, scalable, and rapid. McKinsey (2016) states that the Supply Chain 4.0 will be faster, more flexible, accurate, granular and efficient.

Based on these and other information gathered from existing literature, 8 typical DSC features have been identified:

- *Rapid,* ability to carry out operations in a short time, thus being able to respond quickly to requests from other players or customers.
- *Scalable,* ease of optimizing and duplicating processes; technologies make it possible to increase/decrease the size of the SC quickly to better respond to the variability of demand.
- *Flexible,* ability to adapt to external changes and change production factors and/or the product/service itself (Wang et al., 2016).
- *Sustainable* - in the environmental sense of the term – the DSC must be able to operate in a way that does not damage the environment, conserving resources (e.g., water, energy, soli) (Büyüközkan, Göçer, 2018).
- *Connected*, the equipment and machine in the chain are connected to the internet, and this allows them to interact, exchanging information and data.
- *Intelligent*, capability of making intelligent decisions that take into account the surrounding environment and support decision making.
- *Autonomous*, ability of making decisions and implementing operations autonomously, without human intervention (Kayikci, 2018).
- *Automated*, DSC can perform the operations indicated by a human resource, autonomously (Wu et al., 2016).

In summary, these characteristics can be distinguished in *demand-pull*, when required by the context, and *technology push*, when they arise thanks to the diffusion of new technologies (Table 3).

Demand-Pull	Technology Push
Rapid	Connected
Scalable	Intelligent
Flexible	Autonomous
Sustainable	Automated

Table 3: Classification of Digital Supply Chain features

5. Digital Supply Chain main benefits

Although this transformation will have a significant impact on organisations, it is still unclear what benefits it will bring. Many different benefits are reported in the literature, but, at present, there is no precise classification of these benefits. This paper aims to show the main benefits of the digitization of the supply chain. The benefits mentioned in the text have been inductively extrapolated by the authors through reading the reports and existing scientific paper.

One of the most important benefits of the application of digital technologies is undoubtedly the responsiveness they provide. Through the use of advanced analytics, especially Big Data, organizations can gain a clear and comprehensive view of customer information and better predict their future needs, while also ensuring a more personalized offer. In this way, the company not only increases customer satisfaction but also its responsiveness to changes in customer needs and competitors' moves.

Advanced analytics is also able to provide the necessary decision-making support. With the big data support is possible to make smarter and more responsible decisions, since they provide a structured decision-making process (Awwad et al., 2018). They can also offer actionable Insights - the result of an analysis of information that provides managers with enough data to make an informed decision - that machines or operators can put directly into action. Finally, through predictive analysis, the organization can assess the probability of a problem occurring and its potential impact based on available historical data, thereby reducing business risk (Wang et al., 2016).

However, the ultimate goal of any organization remains to be competitive in the marketplace, making profits that will allow the company to survive in the long term. To achieve these goals, especially in the manufacturing realities, companies try to increase the productivity and efficiency of the plant, with a consequent cost reduction. The increase in operational efficiency in the production phase of a supply chain is made possible thanks to the use of robots, which perform operations (usually repetitive) by replacing or collaborating with human resources (cobots), and additive manufacturing. Thanks to the use of these technologies, it is possible to reduce errors and therefore ensure higher quality standards of the product, as well as achieve greater operational flexibility, adapting production factors to better respond to external changes. Also, an essential benefit of using 3D printing (the main application of additive manufacturing) is the ability to respond quickly

to the urgent demand for spare parts, as reported by Farahani in his book "Shaping the Digital Enterprise".

We have already talked about how integration - and therefore, the sharing of information between different stakeholders - is a fundamental aspect for modern supply chains. The role of technologies such as blockchain and cloud computing in this respect is crucial. An interesting application case is that of the IBM Food Trust: it is a collaborative network of growers, wholesalers, distributors, producers and traders who use blockchain technology to increase the visibility and reliability of the food supply chain. This solution connects participants, allowing them to indicate provenance, as well as share source controls and quality certifications, through increased access to information. These implementations allow visibility into each stage of the food supply chain, increasing transparency of information and allowing more comfortable sharing of information. In this way, actors can collaborate better with each other and operate more efficiently, reduce waste, quickly identifying process inefficiencies. Still, concerning information sharing, it is appropriate to talk about an inevitable need of today companies: the traceability of products (Hackenberg, 2018). This traceability is made possible by the technologies mentioned above and also by IoT with the use of RFID.

The last one is the reduction of the environmental impact of using innovative solutions: autonomous vehicles, for example, can reduce both emissions and congestion problems, which are fundamental in last-mile delivery (Kayikci 2018). In the future, 3PL companies will use drones to deliver small packages quickly in both urban and remote areas. Because of their high speed and precision, their use will shorten the supply chain and significantly reduce the costs of transportation. Finally, it is possible to match the benefits to the DSC features identified, as shown in Table 4.

DSC Feature	Benefits
Rapid	▪ Responsiveness
	▪ Operational efficiency
Scalable	▪ Customer satisfaction
Flexible	▪ Customer satisfaction
	▪ Operational flexibility
Sustainable	▪ Environmental impact
Connected	▪ Real-time visibility
	▪ Traceability
	▪ Information transparency
Intelligent	▪ Actionable insights
	▪ Business risks
	▪ Smarter decisions
Autonomous	▪ Actionable insights
	▪ Business risks
	▪ Reliability of decision
Automated	▪ Operational efficiency
	▪ Quality standards

Table 4: Match between DSC features and benefits

6. Conclusions

The supply chain is a fundamental process in every organization. It is, therefore, essential to increase collaboration between the various players in the supply chain in order to reduce ambiguities and facilitate communication between them. The diffusion of Industry 4.0 technologies and the exponential increase in the available data are two critical phenomena from this point of view, and their integration within the supply chain represents a turning point for companies.

In this paper we have tried to explain the emerging concept of "Digital Supply Chain", clarifying its definition, features and main benefits brought by the digitalization of supply chain management. In fact, in this context, is becoming increasingly important to be agile and know how to respond quickly to customer needs is a clear key to success. In doing so, the chain must also be particularly flexible, adapting quickly to changing circumstances. These are just some of the characteristics of the new supply chain, but what makes it truly "digital" is the use of modern technologies in the supply chain management. The supply chain becomes connected and intelligent, where machines and actors are connected through the use of sensors or cloud computing. The final goal is to create an integrated ecosystem among all the assets of the chain and create a global supply chain. The benefits that can be obtained from this integration are essential: from flexibility to operational efficiency, from decision support to the automated execution of the operations themselves. The most important benefits, however, are the visibility and the traceability along the entire supply chain, made possible by the data sharing between the different stakeholders. It is precisely in this perspective that companies are working and in which the first cases of real application of the supply chain 4.0 paradigm can be identified.

Despite all this, this paper has some limitations. First of all it is based almost entirely on "grey literature", which proved to be the first to deal with the topic of the paper. A further limitation is that it presents only the benefits, not showing the challenges that companies face in introducing such technologies within their supply chain or the possible risks of collaboration between actors. A possible further limitation may be the lack of a case study that can demonstrate the advantages outlined in the paper. For this reason, this paper could be taken as a basis for further research that can evolve mainly in two ways: it can be enriched by application cases and/or quantitative studies, or it can be thought of a clustering of benefits and challenges based on the areas of the traditional supply chain (supplier, production, distribution and customer) or roles within the companies.

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