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The Smart Supply Chain: A Conceptual Cyclic Framework

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Abstract:

Purpose: The objective of this work is to analyze the characteristics of the smart supply chain (SSC) and to propose a conceptual framework research. Given the pace of current technological change, there is a need to analyze the new features of the SSC, related to digital technologies and the incorporation of services.

Design/methodology/approach: A systematic review of the literature is addressed, analyzing the latest studies on the subject. This methodology allows to propose a conceptualization of the SSC and incorporate new elements of analysis.

Findings: The results show that much of the innovation and instrumentalization of supply chains involves incorporating digital services to expand their functionalities, especially in terms of agility and connectivity. The servitization of supply chains is therefore a key new feature. Put in relation to other characteristics identified in the literature, a conceptual cyclic framework is proposed for the SSC.

Originality/value: This study contributes to strengthening the theoretical foundations of SSCs and serves as a guide for researchers and practitioners.

Keywords: smart supply chain, systematic review, industry 4.0, digital technology, servitization

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1. Introduction

In today's competitive environment, companies face intense market pressure. In response to this pressure, they seek efficiency and effectiveness. Producing goods and services while minimizing costs is not enough; companies must also offer smart solutions that meet customer needs. Customers demand the fast delivery of more personalized products and services, which forces suppliers, manufacturers, and distributors to streamline the supply chain. Thus, supply chain management (SCM) is a crucial issue, and as such, it has attracted huge interest from both academicians and business practitioners (Sarkis, Zhu & Lai, 2011). The introduction of digital technologies, the increased degree of product customization, and the provision of customer solutions in the form of services have together led to a new way of approaching SCM (Porter & Heppelmann, 2015; Hasselblatt, Huikkola, Kohtamäki & Nickell, 2018; Frank, Dalenogare & Ayala, 2019). New digital technologies, which form the backbone of the

Fourth Industrial Revolution, are radically reshaping the way companies conceive the supply chain. Collectively, these technologies are referred to as smart supply chain (SSC) technologies because they make the supply chain "smarter" (Li, 2020).

The applications of digital technology have caused a paradigm shift. Competition no longer occurs between supply chains. Instead, supply services and the analytical algorithms behind supply chains compete. Services can be ordered in packages or as individual modules in the form of supply services, manufacturing services, logistics services, or sales services (Ivanov & Dolgui, 2019). Many of these services are digital. This digital facet has led to the emergence of servitized business models. The question is therefore, is there another step in the characterization of smart supply chains (SSCs)? Definitions of SSCs are incomplete in this context. A new approach that pays more attention to the relationship between SSCs, digital services, and servitization is needed.

A new stage in the evolution of SSCs by conceptualizing servitized SSCs is proposed. These servitized SSCs are characterized by the use of digital services that control the agility and connectivity of the chain. Here, the importance of product or service customization and the reduction of the product life cycle leads to a shift in the business model. Accordingly, services become more important by contributing to sustainability in all links within the chain. Servitized, sustainable SSCs thus emerge. The characterization of these servitized, sustainable SSCs is fundamental for the analysis and theoretical basis of SSCs.

The literature offers a number of definitions and key characteristics of SSCs (Butner, 2010a; Wu, Yue, Jin & Yen, 2016; Grzybowska & Lupicka, 2019; Tripathi & Gupta, 2020). The earliest reference to SSCs is attributed to Noori and Lee (2002), who found that SSCs can be characterized by the integration of all links in the chain, from product designers to end consumers. Since then, integration has been considered a differentiating aspect, and scholars have shown greater interest in characterizing SSCs by incorporating new identifying attributes. Butner (2010a) listed three core characteristics, arguing that SSCs are instrumented, interconnected, and intelligent. Wu et al., (2016) later cited two further core characteristics, adding that SSCs are automated and innovative. Ahn, Lim and Lee (2016) then included the sustainable nature of SSCs as a core characteristic. The last and most recent core characteristics were proposed by Tripathi and Gupta (2020), who added that SSCs are resilient, responsive, and traceable.

Two actions are central to these characteristics. The first is the pursuit of environmental sustainability. The second is the intensity and speed with which digital technologies are developed and applied. This intensity and speed means that SSCs are almost continuously evolving, incorporating digital services that enable transformation in terms of the operability and deployment of SSCs. There seems to be a need to analyze the current situation of SSCs in terms of their differentiating characteristics and to propose a unified definition and a conceptual framework that can serve as a basis for SSC research. This is the aim of our study.

To achieve this aim, a systematic literature review is performed. This review provides an in-depth description of the state of the art of SSCs and makes it possible to characterize SSCs in terms of their distinctive features. Our study complements the literature review conducted by Wu et al., (2016). In the seven years since that review, much progress has been made in SSC research, as reflected by the number of publications on this topic. Our study thus helps establish the conceptual foundations of the topic of SSCs. Our review reveals the importance of digital services in new SSCs and shows how companies are thus servitizing their businesses. We also find that sustainability is a core characteristic of SSCs. So, we propose a conceptual cyclic framework for SSC. This framework contributes to strengthening the theoretical foundations of SSC and serves as a guide for researchers and practitioners.

The paper is structured as follows. First, the systematic literature review method is described. Second, the findings are summarized. A conceptualization of SSCs is then proposed. Finally, the key conclusions are outlined.

2. Theoretical Background. Industry 4.0

Technology, and especially digital technology, has led to a rapid and intense transformation of all economic sectors. The changes affect practically all the variables involved in the business activity, as well, products, processes, systems; organizational structures and business models; to satkeholders and to the business functions, highlighting the production and logistics. The breadth of change is greater in those environments where information is most needed. All this has led to a deepen industrial revolution.

In the industrial sector, this revolution has been called Industry 4.0. Driven by the introduction of digital technology, it leads to a specialization of the value chain and connectivity between different actors. It is also identified as Industrial Internet (Evans & Annunziata, 2012), by integrating machinery and devices with sensors and software. Similar ideas are found in the terms Integrated Industry (Bürger & Tragl, 2014) and Smart Industry or Smart Manufacturing (Wiesmüller, 2014). The digital transformation in the industry leads to new ways of competing, to serve more demanding customers. The continuous exchange of data in real time allows to be more flexible and faster, which directly affects profitability and productivity. Industry 4.0 anticipates greater operational effectiveness and the development of new products, services and business models (Kagermann, 2014). The fourth industrial revolution is that of interconnected systems and digital transformation. The value chain is organized and managed throughout the entire life cycle of products.

In the Industry 4.0 environment, cyber-physical systems (CPS) appear. They are conceived as networks, where information technology connects with electronic and mechanical components, blurring the boundaries between the virtual and real worlds. Cyber-physical systems are formed by intelligent products and processes in a scenario of intelligent manufacturing, in connection with intelligent infrastructures. All this, for a market also interconnected (Rajput & Singh, 2019; Kagermann, Helbig, Hellinger & Wahlster, 2013).

The main objective of Industry 4.0 is to achieve precision as well as achieve a greater degree of automation (Thames & Schaefer, 2016). To achieve this goal, Industry 4.0 must bring together a set of key characteristics; following Marr and Strategy (2017), the main ones would be:

1. Interoperability: machines, devices, sensors and people that connect and communicate with each other.
2. Information transparency: Systems create a virtual copy of the physical world through sensor data to contextualize the information.
3. Technical assistance: both the ability of systems to support humans in decision-making and problem-solving, and the ability to help humans with tasks that are too difficult or unsafe for humans.
4. Decentralized decision-making: the ability of cyber-physical systems to make simple decisions on their own and become as autonomous as possible.

The development of these competencies allows Industry 4.0 to significantly influence the production environment with radical changes in the execution of operations. For example, technology such as IoT makes it possible to network the entire factory to form an intelligent environment. Intelligent machines, warehousing systems and digitally developed production facilities enable integration based on end-to-end communication and information systems throughout the supply chain, from inbound logistics to production, marketing, outbound logistics and service (Kagermann et al., 2013).

Industry 4.0 allows the manufacturing company to be connected in smart production networks with shared resources, such as raw materials, power plants and labor, ensuring better cooperation between the different actors in the supply chain (Sanders, Elangeswaran & Wulfsberg, 2016).

In this context of digitalization and interconnection, services are present in all areas, from information, big data and web services, to remote control and cybersecurity. All this means that industrial production is characterized by a very flexible manufacturing that facilitates a great individualization of products and a great integration between customers and business partners. The result is a close link between the production of goods and the generation of services. In general, services are incorporated into products, which is known as servitization of manufacturing. In a further step, products are conceived as services, because customers no longer want the product, but the use of the product. Solutions must be offered to the customer. In the new scenario of advanced manufacturing and industry 4.0, services therefore play a fundamental role.

Thus, company services, cyber-physical systems and human resources are available through internet services and can be used by different participants, both inside and outside the company (Hermann, Pentek & Otto, 2015). In short, the Smart Factory is based on a service-oriented architecture. And many of these services are based on the processing of a large amount of data, providing analytical models for decision making, becoming intelligent services. Smart services enable Industry 4.0 and will be key as a differentiating element (Marcos-Martínez & Martín-Peña, 2016).

3. Method

In order to respond to the research aims, a systematic literature review was conducted. This review provides an in-depth overview of the state of the art of the topic of SSCs, which can then be characterized in terms of its distinctive elements. A unified definition is thus provided.

Systematic literature reviews entail a rigorous review process that provides explanatory and/or interpretive findings. These findings can then help researchers to analyze the state of the art of an area of interest and reach clear conclusions (Denyer & Tranfield, 2009). As explained by Wu et al. (2016: page 397), "Smart Supply Change Management is a quickly evolving concept that is researched and discussed in many relevant disciplines, e.g., isolated smart hardware applications are often studied in engineering field, and advanced analytics is repeatedly investigated in data analysis and information system research. The research field has been quite fragmented and divergent." Given the rapid progress of all things related to technology, information systems, and data, there is a need to analyze the state of the art of SSC research, identify new elements of analysis, and infer the direction of this field of research.

Table 1 summarizes the systematic literature review process (Badi & Murtagh, 2019). Six stages were followed. In Stage 1, we initially considered the characteristics that make a traditional supply chain a smart supply chain (SSC). Previous literature reviews were used for this purpose as solid examples of systematic SSC research. We thus chose the search keywords, which led, as expected, to the choice of highly precise terms in Stage 2, namely "smart supply chain" and "digital supply chain".

To provide broad results, the search was performed with the Scopus and Web of Science (WoS) databases. These are the most comprehensive citation and abstract databases for peer-reviewed literature. They are considered effective tools for literature searches (Tukker, 2015; Annarelli, Battistella & Nonino, 2016).

The exclusion and inclusion criteria were defined in Step 3. Articles whose content did not relate to the research area or that did not contain exhaustive detail on the search topic were discarded. Conference articles and publications were accepted, whereas book chapters were excluded. The search period ran from 2000 to 2020. This period covers virtually all publications on the subject.

	Stage	Description of procedure in the present study
1	Define study aims	Analyze the state of the art of the smart supply chain (SSC) research
2	Define search terms and sources	Identify keywords Sources: Scopus and Web of Science – WoS (fields: title, abstract, and keywords)
3	Define exclusion and inclusion criteria	a) Written in English b) Published in journals and conferences c) Published before or during December 2020 d) Core topic of smart supply chains e) Full text available
4	Perform descriptive analysis	Search for, filter, and gather the set of studies for analysis
5	Perform descriptive analysis	Evaluate and classify the studies
6	Synthesize	Integrate characteristics found in keywords Design a research agenda

Table 1. Stages of the systematic literature review

The initial search returned 351 papers. After eliminating duplicates, we reduced the sample to 248. Once the exclusion criteria had been applied, the full text of all 188 remaining publications was read in full. Only the articles that were able to contribute to, answering the research questions were selected, 72 papers remained for analysis.

Citation analysis led to the inclusion of 15 additional papers in the sample. These helped with the conceptualization and the identification of core characteristics. Finally, a set of 87 papers were selected for analysis.

In Stage 4, descriptive analysis of the final sample of papers was performed (Seuring & Müller, 2008). We considered the number of publications per year (Figure 1). The results show that academic interest in SSCs has increased steadily since 2002, when the first bibliographic reference was found. In 2010, the first precise definition of the smart supply chain appeared (Butner, 2010a). The largest number of publications that explicitly reference SSCs can be found in research from the period 2016 to 2020 (58 papers). These papers formed the basis of the characterization of SSCs because they were not included in previous reviews (they had not yet been published).

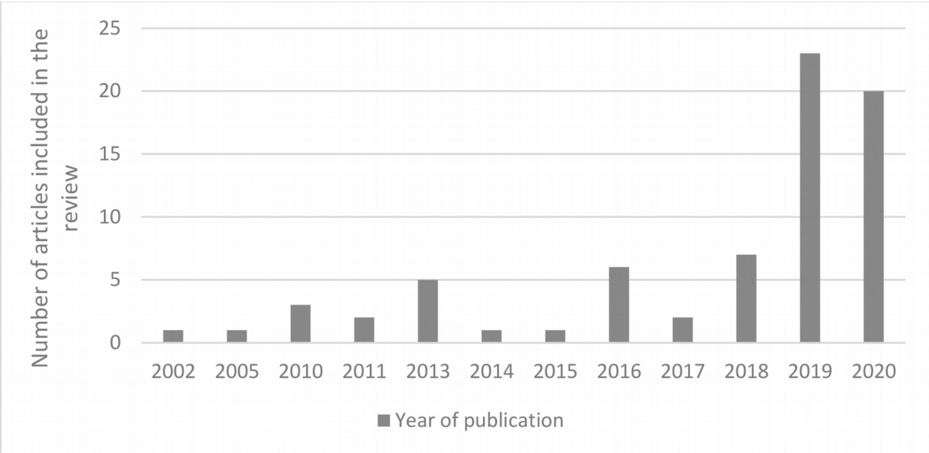

Figure 1. Distribution of papers by year of publication

Steps 5 (thematic analysis) and 6 (synthesis) are described in the following sections.

4. Findings

4.1. Thematic Analysis

The purpose of the thematic analysis is to clarify the state of the art of smart supply chains (SSCs) for proposing a conceptual framework, identifying those papers that define the concept SSC or propose core characteristics. Of the 87 papers, 26 provide a definition of an SSC and/or its characteristics (Table 2). The other documents help contextualize the topic, explain the interrelationship between key elements, and describe the evolution of this field.

Table 2 lists the references that explicitly define or conceptualize SSCs. For each characteristic, the authors who address it are cited. The in-depth analysis of these characteristics will provide the basis to give a unified definition of an SSC and to identify the core characteristics of SSCs and their evolution.

Author(s)	Definition/characterization	Characteristic
Noori and Lee (2002)		Integrated
Björk and Carlsson (2005)		Flexible
Bendavid and Cassivi (2010)	Collection of "smart processes" automatically triggered to perform specific transactions such as automated receiving and shipping, real-time cycle counting, assisted picking, etc.	Interconnected Collaborative Automated
Butner (2010a)		Instrumented Interconnected Intelligent Collaborative Flexible Visible

Author(s)	Definition/characterization	Characteristic
Pearsal, Steele and Zulpa. (2011)		Integrated Interconnected Collaborative Intelligent Visible
Valkokari, Kansola and Valjakka (2011)		Interconnected Collaborative
Lozano-Nieto (2012)		Instrumented Intelligent
Lu and Bowles (2013)		Integrated Instrumented
Novotny and Folta (2013)		Interconnected Collaborative Flexible Visible
Sundar-Raj, Lakshminarayanan and Forbes (2013)		Sustainable
Bowles and Lu (2014)		Instrumented Intelligent
Chung (2015)		Intelligent
Ahn et al. (2016)		Interconnected Collaborative Sustainable Visible
Dhondge, Shorey and Tew (2016)		Intelligent Interconnected Collaborative
Mezouar, El-Afia and Chiheb (2016)		Instrumented Interconnected Intelligent Collaborative
Wang (2016)		Automated
Wu et al. (2016)	New interconnected business system that extends from isolated, local, and single-company applications to supply-chain-wide systematic smart implementations	Integrated Instrumented Interconnected Collaborative Intelligent Automated Innovative
Yuvaraj and Sangeetha (2016)		Instrumented Traceable
Jabeena, Varma, Deepika-Reddy and Varma (2017)		Instrumented
Suri, Gaaloul, Cuccuru and Gerard (2017)		Instrumented Intelligent
Abdel-Basset, Manogaran and Mohamed (2018)	Modern and interconnected system that expands from separated, regional, and single firm applications to wide and systematic implementation of supply chains.	Interconnected Collaborative Intelligent

Author(s)	Definition/characterization	Characteristic
Do Chung, Kim and Lee (2018)		Interconnected Collaborative Flexible
Fajar and Utama (2018)		Interconnected Collaborative Sustainable
Gomes, Bordini, Loures and Santos (2018)	Broad application of technologies such as cloud computing, big data, and others, integrating all links in an industry value chain	Integrated Automated
Mital, Chang, Choudhary, Papa and Pani (2018)		Instrumented
Wazid, Das, Odelu, Kumar, Conti and Jo (2018)		Instrumented
Ayala, Gerstlberger and Frank (2019)		Interconnected Collaborative
Ben-Daya, Hassini and Bahroun (2019)		Integrated Intelligent Flexible Visible
Cimini, Pezzotta,Pinto and Cavalieri (2018)		Integrated Instrumented Intelligent
Chaopaisarn and Woschank (2019)	Technological integration in the supply chain has led to innovative systems in the different links of the chain, together with the knowledge of actionable intelligence.	Instrumented Intelligent
Crawford (2019)		Interconnected Collaborative
Frank et al. (2019)	Smart supply chains include technologies to support the horizontal integration of the factory with external suppliers to improve the raw material and final product delivery in the supply chain.	Interconnected Collaborative Automated Flexible Visible
Gorodetsky, Kozhevnikov, Novichkov and Skobelev (2019)		Instrumented
Grzybowska and Lupicka (2019)		Integrated Instrumented Sustainable
Gudlur, Shanmugan, Perumal and Mohammed (2019)		Instrumented
Gupta, Drave, Bag and Luo (2019)	The ability to synchronize and reconfigure in real time in such a way that it not only takes decisions based on the current scenario but also configures itself for future operations	Instrumented Interconnected Collaborative Flexible
Issaoui, Khiat, Bahnasse and Ouajji (2019)		Integrated Interconnected Collaborative Automated
Mezouar and El-Afia (2019)		Interconnected Collaborative

Author(s)	Definition/characterization	Characteristic
Oh (2019a,b)	Based on Fourth Industrial Revolution (4IR) technologies such as AI and IoT, an advanced and intelligent smart SCM solution has been developed, which has the objective of enhancing the visibility, safety, and efficiency of the supply chain, comprising manufacturers and suppliers, while complying with logistics standards.	Integrated Instrumented Automated Flexible Visible
Oh and Jeong (2019)	Smart supply chain converges with ICPT[1] such as the Internet of Things (IoT), cyber-physical systems, big data analytics, cloud computing, artificial intelligence (AI) and 3D printing, which provides a conventional supply chain with intelligence, flexibility, and sustainability ICPT: Information, Communication, and Production Technologies.	Interconnected Collaborative Intelligent Sustainable Flexible
Prause (2019)		Interconnected Collaborative Flexible Traceable
Prause and Boevsky (2019)		Flexible Transparent Traceable
Sabbagh and Djurdjanovic (2019)		Intelligent
Yanamandra (2019)		Instrumented Interconnected Collaborative
Abdullah, Stroulia and Nawaz (2020)		Instrumented Intelligent Automated
Chen, Ming, Zhou and Chang (2020)		Integrated Interconnected Collaborative Sustainable Flexible Transparent
Constante-Nicolalde, Pérez-Medina and Guerra-Terán (2020a,b)		Integrated Instrumented Automated Flexible Traceable Visible
De Giovanni (2020)		Interconnected Collaborative
De Vass, Shee and Miah (2021)		Integrated Instrumented Interconnected Collaborative Visible
Garay-Rondero, Martinez-Flores, Smith, Morales and Aldrette-Malacara (2020)		Integrated Instrumented Sustainable
Gorecki, Possik, Zacharewicz, Ducq and Nicolas (2020)		Interconnected Collaborative

Author(s)	Definition/characterization	Characteristic
Li (2020)	The smart supply chain must be based on information symmetries, thanks to digital technologies that allow interconnection in real time, reducing channel costs and improving operational efficiencies.	Instrumented Interconnected Collaborative
Nath and Sarkar (2020)		Instrumented
Nishi, Matsuda, Hasegawa, Alizadeh, Liu and Terunuma (2020)		Interconnected Collaborative
Sun, Yamamoto and Matsui (2020)	Smart supply chain is a large-scale business strategy that brings as many links of the chain as possible into a closer working relationship with each other. The goal is to improve response time and production time and reduce costs and waste.	Integrated Interconnected Collaborative
Tripathi and Gupta (2020)	Continuously improving, resilient, and agile supply chains that leverage technological innovations from various streams for process, service, and product enhancements to maximize customer comfort and satisfaction in a sustainable manner.	Integrated Instrumented Interconnected Collaborative Intelligent Automated Innovative Sustainable Flexible Resilient Traceable
Wan and Qie (2020)		Intelligent Automated Flexible
Wang, Liu, Liu and Xiang (2020)	Considering a smart factory supply chain consisting of a smart parts factory (SPF) and a smart assembly factory (SAF) with the support of high tech, it will facilitate the dynamic exchange of information between the SPF and SAF.	Interconnected Collaborative Intelligent
Xiang and Wang (2020)	The integration of some advanced technologies and equipment such as big data, intelligent equipment, uncrewed aerial vehicles, IoT, virtual/augmented reality (VR/AR) technology, blockchain, etc. into the supply chain to strengthen the information collection capability, interconnection capability, and intelligent application capability of the supply chain.	Integrated Interconnected Collaborative
Yonghui and Jiang (2020)		Integrated Instrumented Interconnected Collaborative Innovative
Yousif-Alsharidah and Alazzaw (2020)		Intelligent Sustainable Flexible
Zekhnini, Cherrafi, Bouhaddou, Benghabrit and Garza-Reyes (2020)		Intelligent Sustainable Transparent Responsive

Table 2. Definitions and characteristics of smart supply chains

As shown in Table 2, the characteristics attributed to SSCs in the literature are that they are integrated, instrumented, interconnected/collaborative, intelligent, automated, innovative, sustainable, flexible/perceptible, transparent, resilient, responsive, traceable and visible.

The literature shows a growing practice in SSC operations is to add services, especially digital services, enabled by digital technologies. Smart products, such as product-service systems, give rise to new business models in which manufacturers offer additional services as well as the product or even offer the product as a service (Zhong, Xu, Klotz & Newman, 2017; Ayala et al., 2019). Accordingly, digitalization helps manufacturers servitize (Martín-Peña, Díaz-Garrido & Sánchez-López, 2019). Thus, a new characteristic of an SSC is for it to be servitized. This finding has important implications, as outlined in the next section. It is incorporated in the evolution, the servitized characteristic, and is assigned 2021 to set the trend over time. Figure 2 shows the evolution of SSC characteristics.

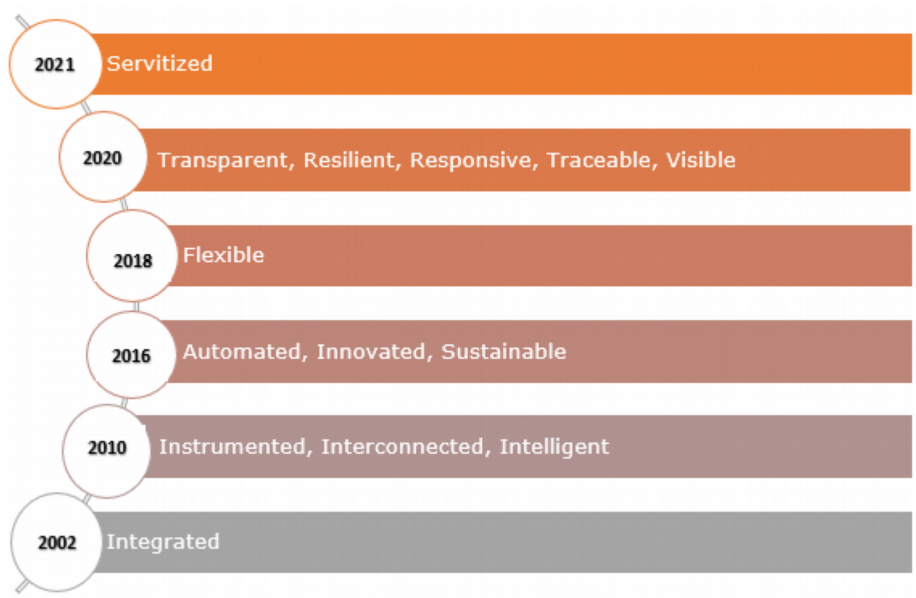

Figure 2. Evolution of the characteristics of SSCs

4.2. Synthesis: Conceptualization of the Smart Supply Chain

The analysis of the definitions and characteristics of SSCs found in the literature provides the basis to propose a conceptualization of SSCs. This conceptualization is based on the core characteristics of SSCs, and it provides the foundation for a conceptual cyclic framework (Figure 3).

The five dimensions of the proposed conceptual framework are: instrumented, interconnected, flexible, servitized, and sustainable. These dimensions contain the features that characterize the supply chain.

According to this conceptual cyclic framework, SSCs are characterized by the use of digital technology in an Industry 4.0 environment. These technologies instrument the supply chain so that data can be automatically provided by devices. Digital technologies also enable the automatic adjustment of production processes for multiple product types and time-variant conditions (Wang et al., 2020), leading to increased quality, greater productivity, and more efficient decision making.

Instrumentation leads to interconnectivity. For data to flow through all the links in the chain, the participating companies must integrate the technologies into their processes. This integration produces information symmetries and data transparency. Escalating the information exchange with the synchronization into the operations among supply chain partners, allows for the agility, efficiency, and total cost reduction throughout the entire supply network (Ghobakhloo & Fathi, 2019, Machado, Winroth & Ribeiro da Silva, 2020, Shao, Liu, Li, Chaudhry & Yue, 2021). Data are made visible to all members, and production is synchronized with suppliers to reduce delivery times and information distortions (Ivanov, Dolgui, Sokolov, Werner & Ivanova, 2016). This integration also enables the supplier-manufacturer dyad to interconnect, achieving smart manufacturing. This smart manufacturing makes it possible for them to share capabilities for the innovation of products into smart products and complementary services, providing additional value.

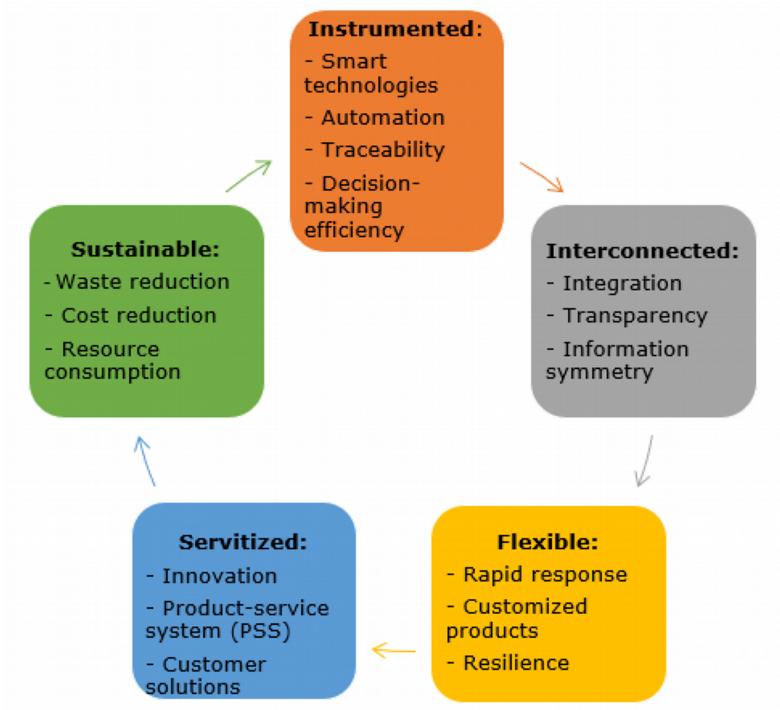

Figure 3. Conceptual cyclic framework of a smart supply chain

Interconnectedness leads to flexibility. The supply chain can respond quickly to changes by deploying and redeploying resources as and when necessary. Adopting technology and sharing data through collaboration, including the processing of customer feedback, the handling of customer complaints, and interactions with customers, enables companies to manufacture products and offer customized services and products (Jermsittiparsert, Kraimak & Boonratanakittiphumi, 2019). Flexibility enables resilience by detecting potential process disruptions and anticipating solutions for suppliers and customers (Tripathi & Gupta, 2020).

The above three dimensions drive servitization. Servitization can be described as the innovation of a manufacturer's capabilities and processes to shift from selling products to selling integrated offerings of products and services that deliver value in use (Tao, Cheng & Zhang, 2017). Smart products enabled by digital technologies provide huge volumes of data, which are fed back into the smart supply chain to provide new product-service systems such as customer solutions. This process enables the development of new business models based on these product-service systems, creating new opportunities for both manufacturers and service providers (Zhong et al., 2017; Ayala et al., 2019).

These dimensions result in lower consumption of resources (material, human, and energy), as well as the reduction of waste. In short, they drive sustainability. These cost savings are feed back into the system, creating a cyclic framework, as illustrated in Figure 4. The process resulting is characterised by reducing set-ups times, increasing production capacity and eliminating rework. Further details of each of the dimensions characterizing SSCs is now provided.

4.2.1. Instrumentation: The Instrumented Supply Chain

The information (data) needed to manage an SSC is generated by devices. This process involves instrumentation driven by the smart technologies associated with Industry 4.0. These smart technologies enable digitalization and automation at all levels of the production process. The main digital enablers that contribute to supply chain instrumentation are radio-frequency identification (RFID) technology, the Internet of Things, 3D printing, advanced robotics, virtual reality, big data, cloud manufacturing and blockchain (Mezouar et al., 2016; Gomes et al., 2018; Cimini et al., 2018; Hofmann, Sternberg, Chen, Pflaum & Prockl, 2019; Issaoui et al., 2019; Oh, 2019b).

RFID tags, sensors, and smart devices enable wireless data communication (Rymaszewska et al., 2017) making SSCs traceable (Tripathi & Gupta, 2020), enabling real-time traceability, monitoring the state and location of the product, allowing the automatic detection of processes in search of variations (Sanders et al., 2016) optimizing the flow of materials throughout the entire chain, from suppliers to final customers (Bendavid & Cassivi, 2010 ; Mezouar et al., 2016; Gomes, et al., 2018).The data provided are shared by all participants in the chain (supplier, manufacturer, distributor, retailer, and customer) using Internet of Things (IoT) technology. IoT incorporates sensors that transmit information in real time through a communication network between supply chain partners, on how customers use their products, which helps companies build improved product-service systems (Rymaszewska, Helo & Gunasekaran, 2017). IoT will allow the time between data capture and decision making to be reduced, allowing supply chains to react to changes in real time, enabling levels of agility and responsiveness never experienced before (Ellis, Morris & Santagate, 2015). This application helps optimize the planning and coordination of the logistics processes within an organization (Dev, Shankar & Qaiser, 2019).

Big Data technology enables the analysis of data from the application of the IoT (Yanamandra, 2019). The information shared by all members of the supply chain can be analyzed in real time. This analysis provides companies with, for example, knowledge of consumer habits, which can lead to better product design and demand forecasts. This valuable information can help companies use machinery more efficiently, reduce costs, and make decisions more quickly and effectively (Hasselblatt et al., 2018; Ben-Daya et al., 2019; Issaoui et al., 2019). This information also enables the development of smart products (Alcayaga, Wiener & Hansen, 2019) and personalized services.

Cloud manufacturing creates a virtual, global arena to create a shared network of manufacturing resources and capabilities over the Internet. Cloud technologies can be used extensively in Industry 4.0 to increase data exchange across company boundaries, improve system performance (such as greater agility and flexibility), and reduce costs when bringing systems online. (Tao, Zuo, Da-Xu & Zhang, 2014; Liu & Xu, 2017). The rationale behind cloud manufacturing is service based, which means that suppliers and customers interact to sell and buy services (Lopes de Sousa Jabbour, Chiappetta-Jabbour, Godinho-Filho & Roubaud, 2018; Lopes de Sousa-Jabbour, Rojas-Luiz, Rojas-Luiz, Chiappetta-Jabbour, Ndubisi, Caldeira de Oliveira et al. 2019). As indicated later, this model leads to servitization. Users can access a catalog of services where they pay for use, not ownership. They can thus meet their business needs while making substantial cost savings.

SSCs instrumented through digital technologies are vulnerable to cyberattacks. These threats can be mitigated by blockchain technology. A blockchain consists of a virtual chain of encrypted blocks that protects the security and allows greater transparency of the origins of the products. Each block is an ordered record that contains a reference to the previous block. The list of blocks within the database is constantly growing. It can help create a trusted environment with secure access to the data shared among the parties within the supply chain.

A company's ability to manage data processing is thus a key capability that can generate value throughout the entire supply chain and create a competitive advantage.

4.2.2. Interconnectivity: The Interconnected Supply Chain

When physical products are endowed with smart capabilities, the dimension of instrumentation lets companies generate real-time information for central monitoring and management. The interconnection between the members of the chain enables information symmetries. Companies have access to data on product conditions, location, use intensity, failures, availability, and so on. They can thus optimize the performance of products and processes. Companies can also gain insight into customer behavior, understand customer habits, and create more efficient collaboration between the manufacturer, service provider, distributor, and customer (Hofmann, 2019). This exchange of information enables companies to innovate when developing new products and services through hybrid offerings under a product-service model.

For optimal smart supply chain management, digital technologies must be integrated by all links in the chain. Doing so can take advantage of unprecedented levels of interaction, not only with customers and suppliers but also between objects that monitor (Butner, 2010a). All data are stored digitally and can be accessed in real time by all stakeholders, aiding transparency throughout the chain (Tripathi & Gupta, 2020).

Through collaboration and integration in the SSC, greater use of information and communication technology (ICT) makes it possible to digitally design products and production. Thus, different stakeholders (customers, workers, suppliers, and the manufacturing team) become integrated in a virtual network and exchange information in and between the different phases of the product life cycle.

The concept of the SSC highlights the role of end customers. Following Butner (2010b), fluctuations in customer demand and variations in customer requirements are among the biggest challenges in SCM. Customers' willingness to exchange information (Valkokari et al., 2011) enables the development of products and the launch of new designs.

This exchange of customer information encourages companies to engage in strategic supplier partnerships. Information sharing among suppliers lets them quickly respond and analyze information on delivery schedules, certification programs, joint decision making, and design teams. Strategic supplier relationships enhance the ability of supply chain partners to improve overall responsiveness.

Therefore, collaboration between manufacturers, customers, and suppliers is essential to improve transparency at every step of the chain, from shipping an order to the end of the product lifetime. Collaboration is also crucial so that automated and digitalized processes (Jermsittiparsert et al., 2019). This process enables smart decisions that improve productivity by reducing downtime and achieving cost reductions to become more profitable.

Thus, a key feature of the SSC is that all components are interconnected. Information is shared by all members of the chain.

4.2.3. Flexibility: The Flexible Supply Chain

Flexibility is essential to respond to variations in the environment (Oh & Jeong, 2019). As explained, interconnections enable information symmetries between customers and suppliers. These information symmetries in turn enable the development of customized products, ensuring supply chain flexibility. A smart factory can manage a complex, flexible manufacturing system that responds to sudden changes in customer demand, inventory, and production volume. Embracing technology and sharing data through collaborative supply chains enables companies to manufacture customized products and services, be flexible (Jermsittiparsert, et al., 2019), and increase supply chain agility. End-to-end connectivity allows supply chain members to respond more quickly (Gupta et al., 2019) to market changes through a configurable supply chain cloud network (Chaopaisarn & Woschank, 2019).

Do Chung et al., (2018) identified six types of flexibility: design flexibility, product flexibility, process flexibility, supply chain flexibility, collaboration flexibility, and strategic flexibility. As the importance of individual customer needs increases and the product life cycle becomes shorter, more and more companies focus on customized products, achieving greater flexibility.

A flexible supply chain must be resilient. SSCs can detect possible disruptions, anticipating solutions for suppliers and customers (Tripathi & Gupta, 2020). Melnyk, Closs, Griffis, Zobel and Macdonald (2014) reported that the resilience of a supply chain is based on two fundamental pillars. The first, the capacity for resistance, refers to the ability of the members of the supply chain to delay a disruption and reduce its impact on a product. The second, the capacity for recovery, refers to the effectiveness of analysis and decision-making based on the results in order to recover from a disruption.

4.2.4. Servitization: The Servitized Supply Chain

The increase in global competition has led manufacturing firms to search for customized solutions by adding services to products. This process is known as servitization. Servitization refers to innovation in an organization's capabilities and processes to create mutual value by shifting from selling products to selling product-service systems (Baines, Lightfoot, Benedettini & Kay, 2009; Cusumano, Kahl & Suarez, 2015).

In the supply chain, an interconnected network of organizations offers products and services. A key link in the chain is the manufacturer because it determines which products will cause upstream and downstream movements in the chain (Christopher, 2005). As the supply chain evolves into an SSC, this link adds a growing number of services, thanks primarily to digital technologies. Eventually, it will be able to offer solutions but will also demand solutions from the other links in the chain. The SSC can thus be said to be servitized. A servitized SSC allows for faster innovation, developing offers for different customers in a much more detailed and personalized way.

The above dimensions lead to servitization. In the instrumented dimension, digital technology underpins digitalization, which in turn underpins the addition of digital services and product-service systems (i.e., servitization). Information traceability makes it possible to innovate in the development of smart products and enables the creation of product-service systems in which manufacturers can offer additional services along with the product or even the product as a service (Zhong et al., 2017; Ayala et al., 2019). PSS systems take advantage of digital technologies and connectivity to improve resource efficiency in the use phase, extend the product lifetime, and close material loops (Alcayaga et al., 2019).

According to Schiffer, Luckert, Wiendahl and Saretz, (2018), one of the capabilities of SSCs is the availability of real-time production, product, and logistics process data at all stages of the chain. For instance, equipment suppliers, who help their customers digitalize with smart products and solutions, contribute by innovating in the development of new digital business models based on digital services.

Interconnections help companies get to know their customers, interconnecting in real time and being in remote control of the use, status, and location of their products. These interconnections give companies a great opportunity to learn how customers use their products. They can get close to their customers and sell customized solutions, transforming to a servitized business model (Hasselblatt et al., 2018; Lopes de Sousa Jabbour et al., 2018).

The increased customization enabled by flexibility is also conducive to the addition of services to products. As a result, digital innovation makes servitization part of the SSC. Wang et al., (2020) described servitization as the quality of shifting toward "a kind of service provider," which facilitates the state of the servitized SSC.

The remote operations allow equipment suppliers to retain ownership of their assets throughout their lifetime. Suppliers perform maintenance and replace or dispose of equipment (Bressanelli, Adrodegari, Perona & Saccani, 2018), charging the customer for use. Because the company retains ownership of a smart product and users' needs may change throughout the product's lifetime, companies can only upgrade digital components such as product software. They can thus enhance the product's upgradeability to extend the product's lifetime. Digital technologies are increasingly important (De Propris, 2016), as they enable upgrading of manufacturing activities and facilitate development of integrated product/service solutions (Baines, Bigdeli, Bustinza, Shi, Baldwin & Ridgway, 2017; Bustinza, Vendrell-Herrero & Baines, 2017) based on a better understanding of customer's needs (Windhal, Andersson, Berggren & Nehler, 2004)

Such integrated solutions in the digital domain are a symbiosis of smart products (Porter & Heppelman, 2014), digitization of supply (Coreynen, Matthyssens & Van Bockhaven, 2017) and advanced services including software and sensors (Baines & Lightfoot, 2013), in a process known as digital servitization (Vendrell-Herrero, Bustinza, Parry & Georgantzis, 2017). Therefore, the concept of digital servitization revolutionizes the conventional idea of products as standalone concepts, highlighting the connectivity between products and between companies (Frank et al., 2019).

Digital servitization can be defined as "the transformation in processes, capabilities, and offerings within industrial firms and their associate ecosystems to progressively create, deliver, and capture increased service value arising from a broad range of enabling digital technologies such as the Internet of Things (IoT), big data, artificial intelligence (AI), and cloud computing" (Sjödin, Parida, Kohtamäki & Wincent, 2020). Digital servitization involves the utilization of digital tools for transforming a product-centric business model to a servicecentric logic (Sklyar, Kowalkowski, Tronvoll & Sörhammar, 2019). This owes to the evolution of 'smart, connected products' – a combination of hardware, software, sensors, data storage, and connectivity – which have transformed manufacturing companies (Porter & Heppelmann, 2014, 2015).

The automation of warehousing, autonomous smart vehicles, human-machine interfaces, smart logistics planning algorithms, reliable online order monitoring, real-time re-planning, real-time vender inventory monitoring and no-touch processing (Brettel, Friederichsen, Keller & Rosenberg, 2014; Alicke, Rexhausen & Seyfert, 2016) are examples of digitally integrated solutions derived from a servitized smart supply chain.

As part of digital servitization, companies offer additional services associated with the reuse and recycling of materials. Accordingly, the servitized supply chain becomes increasingly sustainable. This sustainability is the last dimension of the proposed conceptualization.

4.2.5. Sustainability: The Sustainable Supply Chain

Digital technologies, together with information traceability throughout the supply chain, enable the design of smart products tailored to customers' needs. One of the key benefits of customization is the elimination of waste.

Focusing on consumer demand and preferences is crucial to achieve sustainability. The customized design of products and their associated services means lower resource consumption and reduced energy use. Companies have incentives to design products for which components can be reused at the end of the product lifetime. This approach to design results in higher efficiency and resource savings, with massive potential to increase the sustainability of manufacturing processes and products. Reducing the energy consumption of tools and machinery improves the environmental performance of manufacturing processes and systems (Cimini et al., 2018).

Industry 4.0 enablers mean that the entire supply chain can be monitored and analyzed to study waste and resource efficiency. The IoT can provide real-time information that helps improve data collection and aids the sharing of resource consumption and material waste. The design of smart products that can be tracked to aid their collection once consumed can achieve efficiency in production levels (Lopes de Sousa Jabbour et al., 2019), contributing to sustainability.

Design, production, and logistics decisions in sustainable operations management can be adapted according to the data provided by cloud manufacturing resources and the IoT (Lopes de Sousa Jabbour et al., 2018). Information on the condition of a product and the calculation of its remaining life are crucial for decisions on reuse, remanufacturing, and material recovery (Bressanelli et al., 2018; Dev et al., 2019; Li, 2020).

The impact of the IoT on environmental sustainability varies greatly. The most common outcome is reduced paper use, followed by carbon footprint reduction, electricity savings, and waste minimization. Integrating these technologies offers one way of reducing emissions and minimizing negative impacts, which is crucial in transportation and warehousing. The integration of logistics processes improves the performance dynamics of the supply chain in terms of cost, quality, delivery, and flexibility, which also affects a company's sustainability (De Vass et al., 2021).

SSCs entail a large-scale strategy that brings as many links in the chain as possible into a closer working relationship. The primary goal is to improve turnaround and production times and reduce costs and waste (Gold & Schleper, 2017; Fajar & Utama, 2018).

Synthesizing the proposed dimensions leads to a characterization of servitized SSCs as a smart infrastructure based on digital technologies and services, with interconnective capabilities that enable data collection and real-time data sharing between all members of the chain. Together, this promotes traceability in decision making and efficient processes, flexibility, which facilitates the integration of technologies in the chain to improve response times and create value at all stages of the chain, and sustainability by promoting the efficient use of resources and avoiding waste.

5. Conclusions

The present paper offers a conceptualization of SSCs based on a systematic literature review and propose a conceptual framework of SSC. In total, 87 articles were selected and analyzed. The analysis shows that scholars in this area characterize the SSC in terms of a set of core characteristics. A conceptual cyclic framework has been proposed with five dimensions that reflect the core characteristics of SSCs, which are instrumented, interconnected, flexible, servitized, and sustainable. This conceptual framework offers a cyclic model in which each dimension leads to the next. The model then feeds back in a continuous cycle. The cyclic process is characterized by reducing set-ups times, increasing production capacity and eliminating rework.

From the in-depth analysis of the different attributes of the SSC found in the literature, servitization emerges as a new characteristic, revolutionizing the conception of SSC. The incorporation of digital technologies, as enabling innovations for supply chains, contributes to the development of digital platforms as an interconnection tool between the different members of the chain. These digital connections encourage the development of digital services. Therefore, much of the innovation and instrumentalization of supply chains involves incorporating digital services to expand their functionalities, especially in terms of agility and connectivity. The servitization of supply chains is therefore a key novelty and constitutes the fundamental pillar of the proposed conceptual cyclical framework, in such a way that each dimension contributes to the servitization of the supply chain.

The findings of this paper have important theoretical and practical implications.

From a theoretical perspective, the review offers a guide for academic research, identifying the state of the art and the futures lines of research. The paper offers a new conceptualization of SSCs. This conceptualization is based on key characteristics, such as sustainability, and novel characteristics, such as servitization. Rapid technological advances create a world of solutions. Supply chains must adapt to this world.

From a practical perspective and as managerial implications, the proposed conceptual cyclic framework can help companies identify where they are and what the next steps should be to improve. Today, supply chains are sustainable and servitized. In this point, the incorporations of digital services are key in the way to the competitive advantage. Managers who consider these actions will put their firms in a better position for responding to changes. In sum, firms will have a better global value chain management. Moreover, it is important to consider that the digital transformations that occur at the firms' level and impact the supply chains, require policies that consider this phenomenon, highlighting the need for the creation of ecosystems to facilitate these changes. In this context, smart supply chain is strengthened.

This study has some limitations. First, we used the Scopus and WoS databases as the sources for the search. Although these databases include a large number of published studies, they may omit some. Second, we focused on the search keywords "smart supply chain" and "digital supply chain", as explained earlier. However, other terms such as "supply chain 4.0" also appear in the literature. Third, we only considered publications in English, even though some papers may be written in other languages such as Italian, French, German, and Russian. This decision may have prevented us from obtaining a complete list of related publications. In future research, we hope to validate the proposed conceptual framework through empirical analysis by identifying the dimensions and attributes in industrial sectors. An interesting line of work that emerges from this study is to reformulate the proposed structure under the principles of "continuous improvement". Both for the conceptual foundations and for the practical implications, this approach can offer a more solid approach to SSCM and its management.

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