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TOWARDS SUPPLY CHAIN MANAGEMENT 4.0

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ABSTRACT

Highlights: A brief review of industrial, logistics, and Supply Chain Management evolution. A concept and the technological elements for Supply Chain Management 4.0 (SCM 4.0) are presented. Potential applications of SCM 4.0 are reviewed as well.
Goal: This paper aims at reviewing the historical development of the Supply Chain Management 4.0 concept and to propose an update for it.
Design/Methodology/Approach: The exploratory part of the paper started with a bibliometric analysis to identify relevant keywords and publications per year. Secondly, a historical review of the concepts of Supply Chain Management is presented. Additionally, the paper embraced a conceptual approach to propose a new definition of Supply Chain Management 4.0. Lastly, a research outlook and some initiatives to the practical application of the concept are presented.
Results: The bibliometric analysis about Supply Chain Management 4.0 reinforce the growing importance of the topic. The main keywords related to the subject indicate that Big Data, cloud computing, and Internet of Things are the most widely explored issues within smart supply chains. Analysis indicate that smart supply chains take advantage of communication and technological advances in order to build an adaptive, efficient, and transparent network. However, the application of such concept requires the development of knowledge, not only in the hardware and software fields, but also in the managerial field, to address the question of how to use that information and communication to benefit stakeholders.
Limitations of the investigation: The document reports an exploratory research applied only to the Scopus database. In addition, only English-language literature was considered.
Practical implications: The review showed a lack on the development of knowledge not only in the hardware field, but also in the managerial field. It is recommendable that studies focus on areas such as required data to be exchanged, potential financial benefits, and technological and managerial challenges.
Originality/value: An overview of the historical evolution of the supply chain to the Supply Chain Management 4.0 is presented. A concept of Supply Chain Management 4.0 is proposed. Application examples illustrated the practical implementation of the proposed concept.

Keywords: Supply Chain Management, Industry 4.0, Logistics 4.0, Smart Logistic, Smart Supply Chain.

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1. INTRODUCTION

The application of new technologies is pushing manufacturing to a new revolution. The outcomes of the so-called Industry 4.0, or smart manufacturing, are the object of high expectations. For Pfohl *et al*. (2017), Industry 4.0 is "the sum of all innovations derived and implemented in a value chain to address the trends of digitalization, autonomization, transparency, collaboration and the availability of real-time information of products and processes." The main characteristics of the smart factory, as connection and intelligent self-management, could be imagined working together as a network of several smart companies, jointly creating value to maintain competitive status. Pereira et al. (2018a) describes Industry 4.0 as integration of Cyber-Physical Systems and Internet of Things into supply chains. Maier et al. (2015) proposes that the application of Industry 4.0 technologies can lead to an innovation in supply chains and solve problems such as information asymmetry. Witkowski (2017) presents smart solutions that can be extended from the Industry 4.0 to the supply chain management (SCM).

Several initiatives can be found in the literature about the use of industry 4.0 technologies in SCM, which can be labelled smart SCM or SCM 4.0. However, there is an insufficiency of studies that collect the ideas of such initiatives and provide the definition of a concept. In order to contribute to this current debate, this paper aims at reviewing initiatives about smart SCM or SCM 4.0, to analyse potential or existing applications, and finally, to propose a new concept.

The paper is structured as follows: in section two, a review on the so called Digital Age is conducted to contextualize the Industry 4.0 rise as well as the evolution of SCM to the present day. Section three highlights the technical elements of the SCM 4.0. Section four presents a proposed concept for the smart SCM / SCM 4.0. Section five brings applications examples. The last section summarizes the main findings, conclusions, and research opportunities.

2. BIBLIOMETRIC ANALYSIS

A brief bibliometric analysis was conducted for a better understanding of the application of the 4.0 / smart concept in academic and business scenarios. The bibliometric analysis consists of generating and interpreting numerical data provided by scientific databases. The procedure is particularly applicable to verify relevance, tendencies, subtopics, and main sources in the area. The present section describes the data collection procedure, the methods for data treatment as well as the results and their interpretation.

The first step of the analysis is data collection. In this document, the database was limited to the Scopus collection, one of the most reputed databases, which covers the main journals on engineering, supply chain, and other science areas. It is also cited in other review articles (Hassini et al., 2012; Yadav and Desai, 2016; Glock, 2017; Pereira et al., 2018b), being compatible with the software used for data analysis. The search was done with the following terms: ("supply chain* management*" OR "Demand chain* management*") AND ("industr* 4.0" OR "supply chain* 4.0" OR "smart* factor*" OR "smart* manufactor*" OR "smart* supply chain*" OR "intelligen* manufactur*" OR "industrial internet" OR "integrated industr*" OR "physical internet" OR "Fourth Industrial Revolution"). The search was not limited to Supply Chain and 4.0 terms due to the fact that some authors produce works related to the technologies that support the fourth generation of supply chain or even related topics that surround the theme, but do not define their work according to the proposed concept. The keywords were labelled as "Topic" (they were searched not only in the keywords field, but also in the abstract and title). The database provided 119 papers within previously mentioned configuration.

Annual publication volume

The volume of documents published by year can lead to conclusions such as the topic's novelty and growing importance. The analysis of the number of publications per year was collected through tools provided by the database mentioned above, and the graphic gathering such number is presented in Figure 1.

Since no constraint was determined to publication date, the data indicates that the topics were first mentioned in 2000, with the use of the term intelligent manufacturing, aiming that some studies could foresee the fourth revolution. Over the next fourteen years the publication volume remained greater than 5 documents per year, which suggests the issue is recent. A significant increase on the growth rate can be noticed after 2014, highlighting the importance the topic currently receives.

Keywords Analysis

The keywords and topics found within the documents suggest especially significant topics on which work is being conducted. To generate such analysis, the software VOSViewer was utilized. The software reads data exported from the database and builds a network with the keywords found in the files. To build the network, the search was applied in the title, abstract, and keywords for all papers collected besides the keywords provided by the author. The network was built addressing the co-occurrence of the topics. A pair of keywords is considered to be "co-cited" when they both occur in the same

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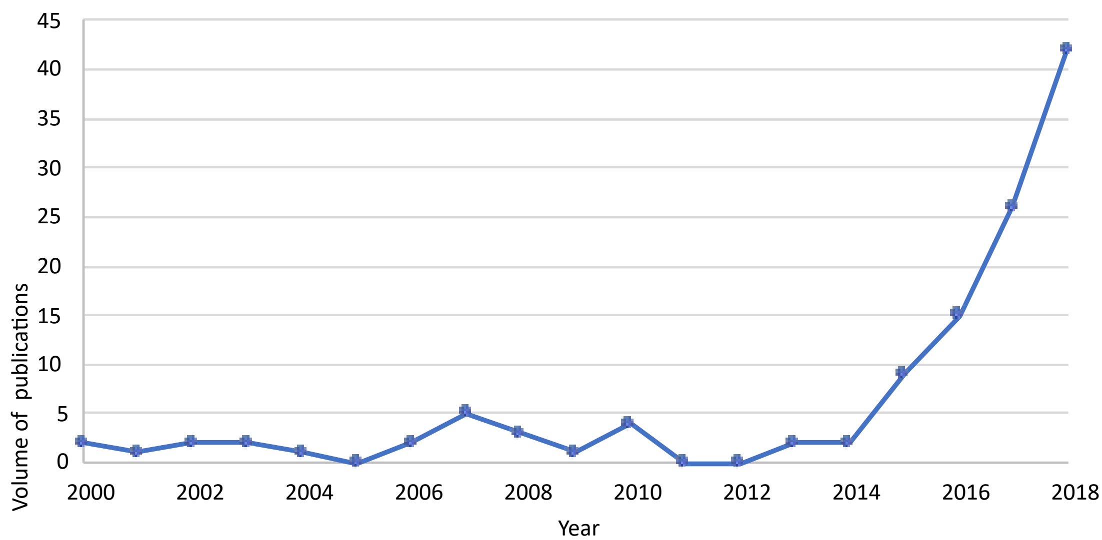

Figure 1. Annual publication volume
Source: The authors themselves.

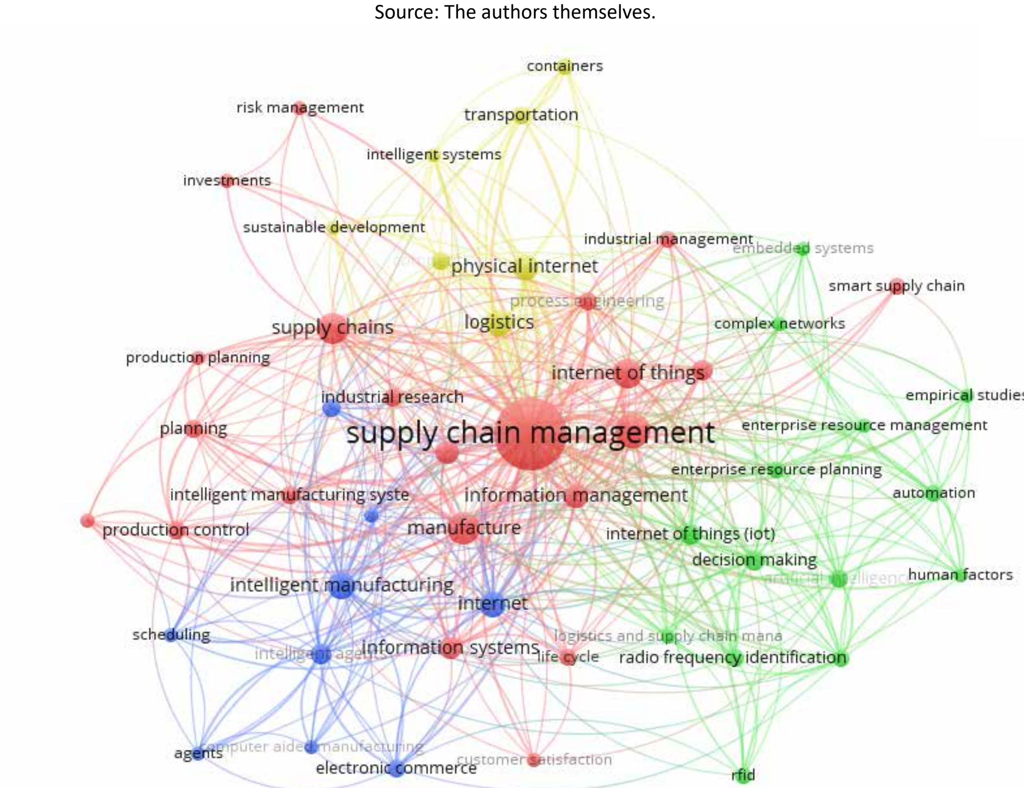

Figure 2. Network visualization of the keywords
Source: The authors themselves.

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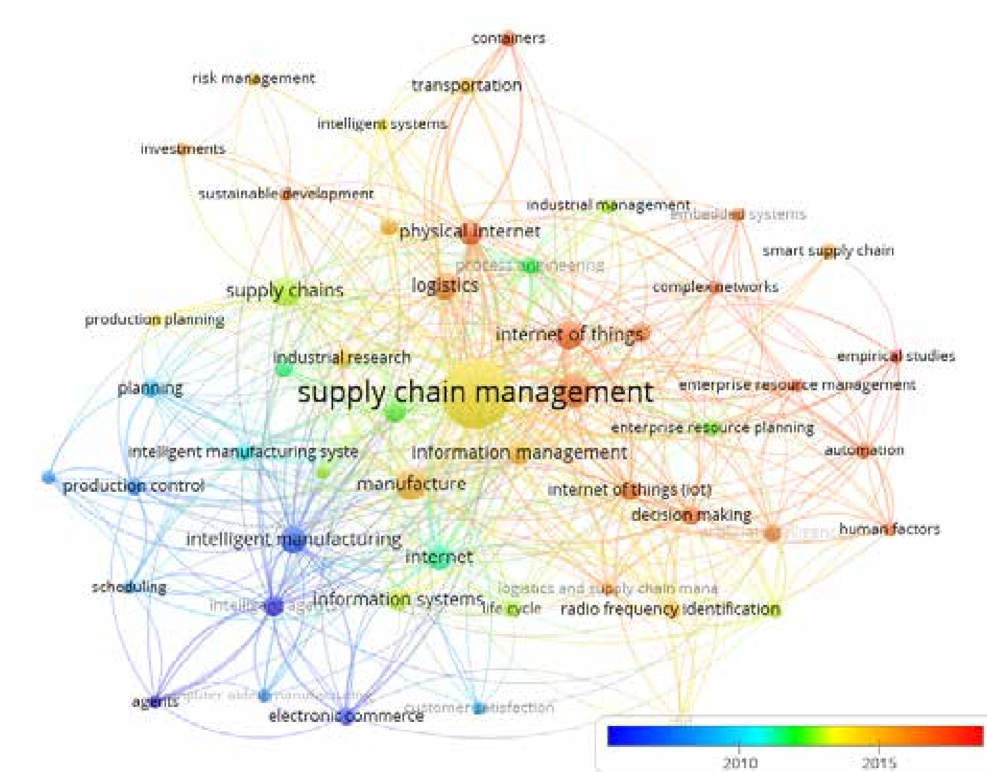

Figure 3. Overlay visualization of the keyword
Source: The authors themselves.

reference list of a third article. To limit the size and ensure the clarity of the network, only terms that appeared more than 3 times were considered. The network and overlay visualization were considered the best representation and are presented in Figure 2 and Figure 3.

An analysis of Figure 2 reveals that the size of the circles reflects how many times they were used as keywords by the articles, that is, their relevance in the research theme, and the proximity between the keywords portrays the affinity of the search in which the words were used.

Also, in Figure 2, it can be observed that keywords were classified into four clusters by the colours green, blue, red, and yellow:

- The green cluster can be analyzed as the one that represents all the factors such as human and technologies that support the supply chain management in the decision-making process. Moreover, the most relevant words in this cluster are “internet of things (IoT)” and “decision making”;

- The blue cluster can be characterized as the one that presents the intelligence applied in the manufacturing process. The most relevant words in the blue cluster are “intelligent manufacturing” and “intelligent agents”;

- The red cluster showed “supply chain management” and “industry 4.0” (behind the word “supply chain management”) as the most relevant words and with more connections. However, they were expected to be the keywords used to conduct the research. For this reason, the cluster is highly connected to all the others, presenting several topics linked to these two keywords and without a clear definition over the cluster;

- The yellow cluster can be represented by areas associated to logistics; the most representative words are “logistics” and “physical internet”.

In addition to the analysis of the standards and keyword relevance, the temporal occurrence of these was analysed with VOSViewer software in order to observe the trend of keywords usage and, consequently, tendencies of research areas, as illustrated in Figure 3. In the overlay visualization, the gradient from blue to the red color represents the temporal appearance of the keyword—red being the newest one. The most recent keywords are “empirical studies”, “embedded systems”, “automation”, “physical internet”, “inter-

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net of things," and "big data." They can be interpreted as the expansion of the application of industry 4.0 concepts and practices in the field of SCM. Nevertheless, as highlighted as one of the most recent words, this application still focuses on the field of empirical studies. Moreover, it is clear that Big Data, Internet of Things and Physical Internet are key factors to the next generation of SCM, according to the network. The presence of the Industry 4.0 term reveals the origin of the concept.

3. DIGITAL AGE

Smart production processes are preparing and modifying the way to a new technological age, which will radically transform industry, production value chains, and business models according to Lee (2018). Moreover, this revolution, based on Barreto (2017), is causing deep changes, not only to the industry but also to the society, to the economic rhythm and outlook, to how work is planned and operationalized; it also affects the way human-machine interactions should be oriented.

The digital age is one more way to name the fourth revolution. In order to summarize the impact of industrial evolution on inventory and physical distribution area, Figure 4 draws a parallel among industrial phases (Yetis et al., 2016; Thoben et al., 2017), logistics phases (Wang, 2016), and SCM phases (analysed within this study).

In Figure 4, some relevant highlighted aspects are:

- Logistics 2.0 starts almost one century after industry 2.0;
- The phase 3.0 has started almost in the same time for all areas (Industry 3.0, 1969; Logistics 3.0, 1980; SCM 3.0, 1985);
- Absence of the phases SCM 1.0 and SCM 2.0, due to the fact that the characteristics and techniques of SCM 3.0 (first phase of SCM) are more proper aligned with industry 3.0 and logistics 3.0;
- SCM 4.0 is still an idealized phase; the approach and opportunities for practical applications must be consolidated to address to the total network integration.

Industry 4.0

"*Industrie 4.0*" was publicly known in 2011, when an initiative called "*Industrie 4.0*"—an association of union representatives from business, politics and academy—promoted the idea as an approach to strengthen the competitiveness of German industry (Kagermann *et al*., 2011). The German Federal Government supported the idea, launching the "*Industrie 4.0*" as integral part of "High-Tech Strategy 2020 for

<table>
<tr><th></th><th>INDUSTRY AGE</th><th>LOGISTICS AGE</th><th>SCM AGE</th></tr>
<tr><td>2020</td><td rowspan="2">Industry 4.0
Strong products individualization under production conditions with great flexibility
(current...)</td><td rowspan="2">Logistics 4.0
Intelligent Transportation Systems (ITS), Real Time Locating Systems (RTLS) (current...)</td><td rowspan="2">SCM 4.0
Total network integration
(current)</td></tr>
<tr><td>2010</td></tr>
<tr><td>2000</td><td rowspan="3">Industry 3.0
Micro-processors. First programmable logic controller (PLC). Use of electronics and Information Technology
(1969 to 2000s)</td><td rowspan="3">Logistics 3.0
System of Logistics Management
(from the 1980s)</td><td rowspan="3">SCM 3.0
Integration between two channels
(beginning of the 1980s)</td></tr>
<tr><td>1990</td></tr>
<tr><td>1980</td></tr>
<tr><td>1970</td><td rowspan="4">Industry 2.0
Mass production using electrical energy
(1870 to 1969)</td><td rowspan="2">Logistics 2.0
Automation of handling system
(from the 1960s)</td><td rowspan="9">There is no SCM concept in this period</td></tr>
<tr><td>1960</td></tr>
<tr><td>1880</td><td rowspan="7">Logistics 1.0
Mechanization of transport
(late 19th century and early 20th century)</td></tr>
<tr><td>1870</td></tr>
<tr><td>1860</td><td rowspan="5">Industry 1.0
Mechanical weaving loom, water, steam power (1784 to 1870)</td></tr>
<tr><td>1850</td></tr>
<tr><td>1800</td></tr>
<tr><td>1790</td></tr>
<tr><td>1780</td></tr>
</table>

Figure 4. Digital age evolution
Source: The authors themselves.

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Germany", focusing on technological innovation leadership (Hermann *et al*., 2016).

Industry 4.0 is the German government program based on the assumption that in the near future the industrial production will be marked by strong products individualization under production conditions with great flexibility (large series), wide integration between customer and their business partners, and the link of production and services with high quality driving to hybrid products (Weyer et al., 2015). However, Industry 4.0 is being applied in many other countries as development programs under different names, as reported by Liao *et al*. (2017).

Thoben *et al*. (2017) states that industry 4.0 is characterized by the Internet of Things (IoT) and Internet of Services (IoS), enabling smart factories with production systems horizontally and vertically integrated. Liao *et al*. (2017) adds End-to-End Digital Integration as one of the three Necessary Integration Features for Industry 4.0. They describe End-to-End Digital Integration as "integration throughout the engineering process so that the digital and real worlds are integrated across a product's entire value chain and across different companies, whilst also incorporating customer requirements".

According to Hofmann and Rüsch (2017), the concept of Industry 4.0 still lacks clear understanding; it is not completely established in practice. Thus, his definition is:

- Products and services are flexibly connected via internet or other network applications;
- The digital connectivity enables an automated and self-optimized production of goods and services, including the delivering without human interventions;
- The value networks are controlled in a decentralized manner, while system elements make autonomous decisions.

Industry 4.0 is a program structured by cooperation from academic researchers, political, and industry representatives. The studies about this theme are advanced in relation to the practical applications; however, companies already look for the opportunities to bring the researches results to their operations.

Logistics 4.0

Due to the highly dynamic, uncertain, and complex logistics market and consumer behavior, logistics networks require new methods, products, and services, which lead to new logistics challenges and opportunities (Wang, 2016). In this sense, Lee (2018) argues that the traditional manual operation no longer responds to the customer requirements and leads to low warehouse operation efficiency instead.

For this reason, Industry 4.0 can bring significant changes and improvements to traditional logistics and its self-perception. This is due to the fact that aspects such as flexibility, adaptability, proactivity, and self-organization are gaining importance and can only be achieved through integration of new intelligent technologies (Wang, 2016).

Therefore, with the application of the concepts of Industry 4.0 to logistics activities, Logistics is now called Logistics 4.0/Smart Logistics, since "*Smart Logistics* is a logistics system, which can enhance the flexibility, the adjustment to the market changes and will make the company be closer to the customer needs." (Barreto, 2017, p. 1248).

Logistics 4.0 can also be conceptualized, according to Domingo Galindo (2016), as the progress of "labor saving and standardization by the evolution of Internet of Things (IoT)", and how physical objects are transported, handled, stored, supplied, and used can be reshaped by Physical Internet, affirms Lee (2018). Wang (2016) also proposed a definition for Logistics 4.0:

> *"Logistics 4.0 is a collective term for technologies and concepts of value chain organization. Within the logistics, CPS monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT, cyber physical system (CPS) communicate and cooperate with each other and humans in real time. Data Mining (DM) discovers knowledge to support decision-making process. Via the Internet of Service, both internal and cross-organizational services are offered and utilized by participants of the value chain". (Wang, 2016)*

In accordance with those concepts, Strandhagen *et al*. (2017) presents some examples as real-time Big Data analytics of vehicle, on-site, on-demand, autonomous robots and vehicles, real-time exchange of information among different actors and smart products, and cloud-supported network that describe the Logistics 4.0 environment.

Thus, Barreto (2017) affirms that "Smart Logistics" has a time dependency and will be driven according to the actual technology, relying and using the following technological applications: Resource Planning, Warehouse Management Systems (WMS), Transportation Management Systems (TMS), Intelligent Transportation Systems (ITS), and Information Security. Domingo Galindo (2016) also emphasizes six other technical components of Logistics 4.0:

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- Identification (Radio-Frequency Identification, RFID, systems): Use RFID systems to identify logistics objects;

- Locating (real time locating systems, RTLS): Combine the functions of real time objects identification and real time objects localization;

- Sensing (Cyber Physical System, CPS): Enable operations connection of the physical reality with computing and communication structures;

- Networking (IoT): Supervise every product in real time, and manage the logistics architecture;

- Data collection and analysis (Big Data and Data Mining): Collect and analyze large data as images or real time videos;

- Business Service (IoS, Enterprise Resource Planning (ERP), Billing, and Marketing): "IoS is the term used to name the concept of offering services over Internet so that they can combined into value-added services by various suppliers".

Strandhagen *et al*. (2017) presents the following trends of business operations related to Logistics 4.0:

- Individualization and personalization: Individualization of demand;

- Servitization: Selling an integrated product and service delivering value in use;

- Accessibility: Providing products or services to the customers anytime, anywhere and in any form;

- Autonomy: Autonomous production through merging of manufacturing, information technology, and telecommunications;

- Global network: Incorporation of machinery, warehousing systems, and production facilities in the shape of cyber physical system (CPS);

- Digitization: Convergence of the real and virtual worlds that is enabled by Information and Communication Technology (ICT);

- Green logistics/circular economy: Increasing efficiency through integrating technology and manufacturing systems, closing the material loops within an economic system.

Supply Chain Management evolution

The concept of SCM, according to Cooper *et al*. (1997) appeared for the first time in literature in the mid-1980s, incorporating existing fundamental assumptions based on interorganizational operations management, system integration, and information sharing. However, many authors believe that the concept of Supply Chain Management can be compared to physical distribution and logistics (Ballou, 2007).

In order to explain the concept of SCM, Ballou (2007) states that SCM emphasizes the coordination, collaboration, and relation among other members, and can be viewed in three dimensions: activity and process administration, interfunctional coordination, and interorganizational coordination. In this same sense, Maccarthy et al. (2016) affirms that the dominant theory supporting the supply chain is related to two major areas, the first being structure, configuration, and coordination; the second, strategy, governance, and power.

Lummus and Vokurka (1999) argue that the key point in the SCM is that the entire process must be viewed as one system, which encompasses the necessary processes to create, source, make to, and deliver to demand. In order to increase the whole supply chain's competitiveness, Lummus and Vokurka (1999) still sustain that all players must work together, and to achieve that goal they use technology to gather information on market demands and exchange information among them.

Hence, according to the Council of Supply Chain Management Professionals (CSCMP) (2017), SCM can be conceptualized as the management that encompasses all the activities involved in supply and acquisition, and in all logistics management activities. It also includes coordination and collaboration with channel partners, suppliers, intermediaries, third-party companies, and consumers.

Supply Chain Management 3.0

The term SCM was introduced in the beginning of the 1980s (Burgess *et al*., 2006). The history of supply chain starts with the textile industry and later the grocery industry. In 1985, Kurt Salmon Associates conducted a supply chain analysis; due to the study's results, significant changes were adopted by the industry as a set of standards for electronic data interchange (EDI) between companies (Lummus and Vokurka, 1999).

According to Verwijmeren (2004), the basis for the Supply Chain Management architecture are the ERP, WMS, and TMS systems. These aim at the processes coordination in-

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side the organization. They need the EDI interfaces to allow the communication inside the chain; however, the EDI does not add intelligence to the SCM.

This third stage is characterized by dynamic and flexible integration among the supply chain elements. The integration in this phase occurs between two agents; the total integration is laid down only in the fourth phase. The information technology is the most important factor of this phase, exemplifying the use of barcode. Although utopian, the pursuit for zero inventory is another trend noted at this stage (Novaes, 2015).

Based on the above information, the main characteristic of this SCM 3.0 is the integration between two chain elements. That is feasible through the intervention of computers and information technology, which drive automation and efficiency of logistics management. In order to facilitate the intercompany communication and agility, some techniques innovated at that time:

- Barcode: commonly used to identify products and monitor the inventory changes;
- EDI: the information flow became faster, more synchronized, and accurate;
- "Zero inventory": based on the Toyota Production System philosophy, inventory costs reduction was (and still are) continuously pursued;
- ERP: data integration for materials management;
- WMS: system used to maximize the warehouse space, working with real time information about shelf status. Useful for data reports for companies' partners;
- TMS: the system is designed to suggest routing solutions. It can be linked to ERP and WMS.

In this phase, individual elements of the chain understood the need to focus on final consumers, besides each network customer. Many companies remain in the beginning of this stage.

Supply Chain Management 4.0

Jayaram (2016) states that global supply chains can use Industry 4.0 concepts to develop four attributes: Connectivity, Visualization, Optimization, and Autonomy. While connectivity would link production and the supply chain in the same network, visualization would help to overview supply chain's performance and status. Meanwhile, optimization would increase the performance at a supply chain level and autonomy would represent the capability of the operations to handle themselves. This can lead to an adaptive and intelligent supply chain and can be especially interesting in a competitive environment. For Ivanov *et al*. (2016), these smart supply chain networks have dynamic structures, which evolve over time. Such characteristics would make the network more capable of adapting after sudden changes.

Hermann *et al*. (2016) identified several bigrams and trigrams in publication related to Industry 4.0; not surprisingly, supply chain was one of the terms, as well as Big Data, cyber physical systems and cloud computing. As it can be seen in Ivanov *et al*. (2016), a significant part of the contemporary manufacturing concepts share aspects of smart networking; additionally, supply chains must be considered collaborative cyber physical systems. The author also states that half the German enterprises already plan a network with smart factories attributes. Therefore, it is easy to notice the interest of both scientific and business areas to extrapolate the concepts of the fourth industrial revolution to the organizations network and work to deliver a final product.

According to the interpretation offered by Queiroz *et al*. (2017), the smart supply chain, or Supply Chain 4.0, can be defined as:

> *"a business system integrated which extends applications to supply chain by systematic smart implementations, including, but not limited to Internet of Things, intelligent infrastructure, smart products, smart machines, and interconnectivity that provides real-time communications in all supply chain stage with intelligent and responsive process". (Queiroz et al., 2017)*

For Wu *et al*. (2016) a smart supply chain would present the six distinctive characteristics:

- Instrumented: the smart supply chain will be equipped with an abundance of hardware able to provide real time information;
- Interconnected: the supply chain will not only collect real time information, but it will also provide it to the whole network;
- Intelligent: a supply chain 4.0 will be able to react, make decision and optimize its own processes;
- Automated: most of the processes in a smart supply chain will be automated and thus have minimum human interaction;

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- Integrated: the smart supply chain will use its intelligence to self-optimize in an integrated and collaborative way, aiming at a global optimum considering all the connected organizations;

- Innovative: the supply chain will be able to innovate and evolve over time to adapt and achieve new values.

Wu *et al*. (2016) applied a literature review over smart supply chains and collected five main research directions that are required for the maturity of the subject. They are: (i) Regarding data, what are the information needed, and how to use it; (ii) What is the financial benefit of implementing Industry 4.0 concepts and technologies in a network; (iii) How to use existing knowledge in the literature into the smart supply chains; (iv) Why supply chain partners are not collaborating so far and how to change this; (v) What are the technological challenges and management challenges in the implementation of the supply chain 4.0.

All the industrial revolutions took advantage from new technologies in order to evolve in the direction of the customers' requests. Some revolutions utilized new power sources, while the last one benefited from some automation. The fourth industrial revolution is favored by communication and intelligent technologies. Both technologies are particularly relevant to SCM, considering the communication and information nature of its activities. It is thus expected that this generation of SCM will profit from communication and intelligent technologies to build a smart, interconnected, and transparent network that can manage flows and optimize itself.

4. TECHNICAL ELEMENTS FROM SUPPLY CHAIN MANAGEMENT 4.0

As previously mentioned, the application of the Industry 4.0 concept may strongly benefit SCM. However, the evolution of an organization into a "smart organization" requires investments in technologies, and the diffusion of such concepts must consider some factors. Pfohl et al. (2013) defines five especially relevant characteristics from Industry 4.0 to be considered in the expansion to the supply chain. The first

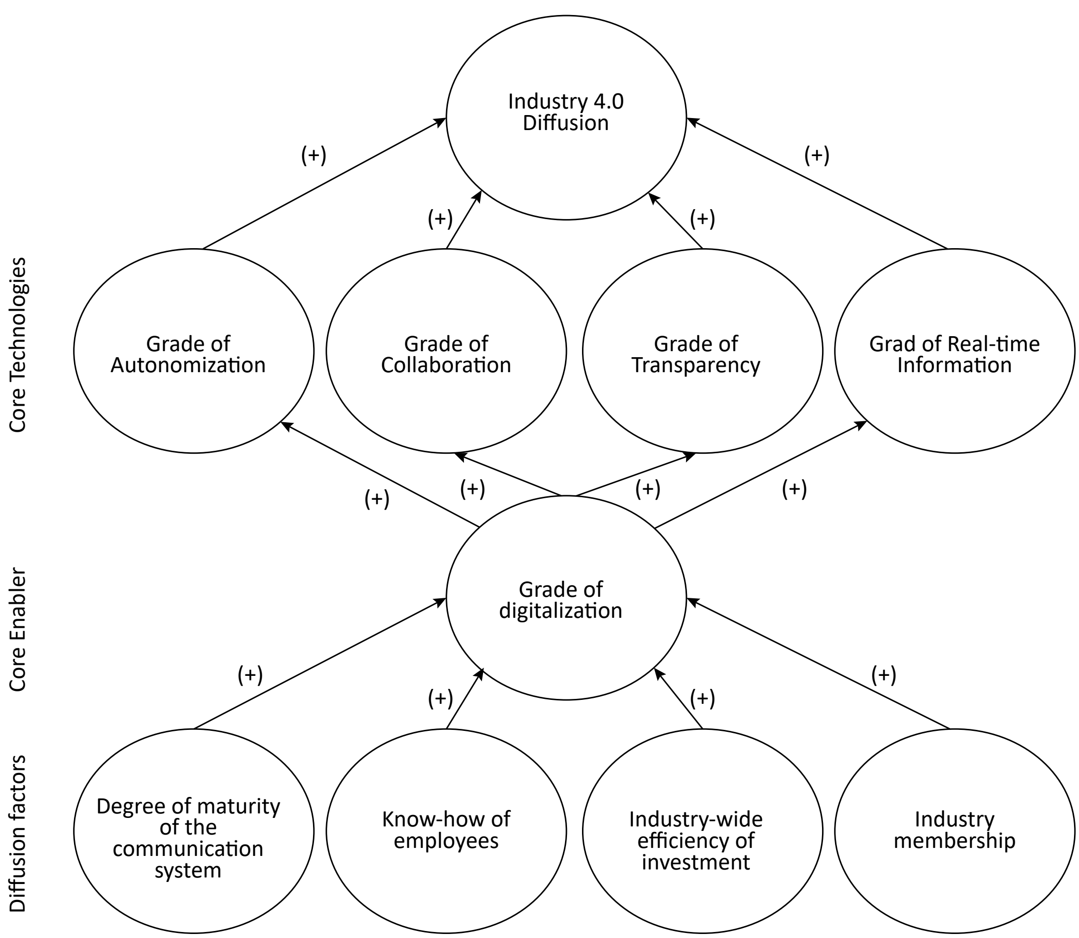

Figure 5. Structural model for Industry 4.0 diffusion
Source: Adapted from Pfohl *et al*. (2013).

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one is the digitalization of products and processes, wherein key components from supply chain as internal processes and communication channels are rapidly being digitalized—according to the author, that is a key element for others characteristics. The author considers the automation of processes and decision as second aspect, minimizing human interaction. The third aspect is transparency of organization and customers, whilst the fourth and fifth factors are collaboration ability and real time information availability. Figure 5 presents a scheme for the diffusion of Industry 4.0 concepts adapted from Pfohl et al. (2013).

Nevertheless, the grade of digitalization requires diffusion factors that are intrinsic to the organization, depending only on itself to be prepared for the evolution. Such fact boosts the importance of partnership selection.

From digitalization, several hardware items are required to build a 4.0 structure. Jayaram (2016) proposes a concept to the application of lean six sigma in global SCM using industry 4.0 concepts. For instance, this concept would require several implemented modules to run as: (a) Inbuilt equipment such as Radio-Frequency Identification readers and Wi-Fi transmitters/receivers; (b) Product sensors as passive RFID tag or Quick Response (QR) tag; (c) Logistics sensors to provide decisions and status; (d) Vehicle sensors to track, for instance, speed and location; (e) Black box, related to vehicle protection; (f) Package score, related to the priority of the product, to assist in optimization decisions (Jayaram, 2016).

However, gathering such a structure to work together and to efficiently be utilized requires some advances. Wu *et al*. (2016) states that the existence and management of a smart supply chain requires advances in the following main areas: (a) Information in supply chains; (b) Information technology; (c) Process automation; (d) Advanced analytics; (e) Process integration and innovation.

Therefore, the existence of a smart SCM depends on a series of individual organization efforts to digitalize themselves and to integrate and collaborate with others digitalized organizations.

5. SUPPLY CHAIN MANAGEMENT 4.0 CONCEPT

End-to-End Integration is the core of SCM 4.0. The use of Internet of Things, Internet of Service, and other technical elements allows a network that is integrated, synchronized, dynamic, and flexible. A possible general definition of SCM 4.0 is: *Supply Chain Management 4.0 is the integration and synchronization of the product's entire value chain across different companies, using smart technologies (IoT, IoS and others) to build an interconnected and transparent system with real-time communication that can manage flows and optimize itself, leading to an autonomous, adaptive, intelligent, agile, and dynamic network that focuses on customers' requirements.*

6. APPLICATIONS OF SUPPLY CHAIN MANAGEMENT 4.0

Pereira et al. (2018b) wrote a review about Industry 4.0 to study the current status of measurable results from industry, which evidenced the lack of industrial results within the academic context.

In this research, to improve the understanding of how the SCM 4.0 is being applied in the academia and organizations, an exploratory literature review was carried out on the cases applied in real scenarios. For this analysis, the articles used were classified by country in the Scopus's analysis database. The countries with five or more publications in the area were selected; they were: Germany (13), United States of America (12), Canada (7), China (6) and France (5), totalizing 43 papers. After the screening stage, only 2 papers reported real application cases of the SCM 4.0, one in China and the other in Canada. It was noticeable that both articles dealt with the application of Physical Internet (PI) in operations of Supply Chain Management:

Yao (2017), from China, applied the Physical Internet into the one-stop delivery mode in an online shopping platform, and with data from Physical Internet, constructed a mathematical model to optimize the delivery scheduling. It was concluded that the application of PI to the optimization of one-stop delivery scheduling in an online shopping platform supply chain has significant advantages. However, the experiment also indicated the need to explore multiple goals in the optimization and the fact that the no-load rate of the unit container should be seriously considered.

From Canada, Mohamed *et al*. (2017) explored the application of the operational urban transportation problem of PI containers under interconnected city logistics (ICL) considerations. For that purpose, a heuristic solution approach was developed to consider key features such as multiple time periods, heterogeneous fleets, multi-hub pickups, and delivery constraints. Through the experiments, which used real data, they showed the benefits of interconnectivity as an important lever to improve overall urban transportation performance.

7. CONCLUSIONS AND RESEARCH OPPORTUNITIES

This study presented a bibliometric analysis about SCM 4.0, which reinforces the growing importance of the topic through the volume of annual publications. With the main

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keywords related to the topic, it was possible to conclude that Big Data, cloud computing and Internet of Things are the most widely explored issues within smart supply chains.

Furthermore, this work reported an overview of the Supply Chain Management concept and the evolution of supply chain until the proposition of supply chain management 4.0, providing a historical view of the topic. The technological support to the revolution of supply chains was also presented. Analysis indicated that smart supply chains benefit from the communication and technological advances in order to build an adaptive, efficient, and transparent network. However, the application of such concept requires the development of knowledge, not only in the hardware field, but also mainly in the managerial field, on how to use such information and communication to benefit stakeholders.

This paper also proposed a new definition for Supply Chain Management 4.0. Many studies are being developed around the concepts, terms, and techniques related to the fourth industrial revolution in SCM. Still, practical researches remain scarce and often utopian. It is therefore noticeable that SCM 4.0 has already begun in theoretical studies, but it is an ideal yet to be implemented in real SCM.

Regarding future research opportunities, it is agreed that some points must be investigated in depth as required data to be exchanged, potential financial benefits, and technological and managerial challenges. The biggest challenge, however, are the practical applications of the techniques from industry 4.0 (CPS, Big Data, Data Mining, IoT, IoS, and others) to SCM.

Some limitations ought to be contemplated when the present paper is read. First, only literature produced in English was analyzed. Besides that, it is an exploratory research; a systematic selection of papers could be used to explore systematically the content of contemporary works.

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