

Supply Chain 4.0 Results: A Systematic Literature Review

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Abstract This study is a systematic review of the literature on the results of supply chain 4.0, considering the recent process of digital transformation suffered by companies. In addition, the study aims to identify the main tools used by companies and the results obtained by them in the various areas of Industry. Therefore, this research aims to fill a knowledge gap in the results of Supply Chain 4.0 and develop a framework that synthesizes the subject. Thus, two research questions were created: "What are the results obtained by the Supply Chain 4.0 in the various areas of Industry?" and "What are the technological and managerial tools that cause these results?". To answer these questions, the Systematic Literature Review was structured in three phases. In the first phase, or planning phase, they were established as key words, while in the second phase, sorting, extraction, data analysis and synthesis of the results obtained were performed. Finally, the third phase presents a content analysis in a structured way. As a first result, 22 articles were chosen and 31 concepts divided into 5 categories were identified, such as: "Digital Technologies", "HR Management 4.0", "Lean and Agile Management", "Strategic and Environmental Management" and "Supply Chain 4.0 Results". As a second result, a framework was generated according to the concepts and categories, indicating the relationship between them. As a theoretical implication, this research brings a relevant and significant contribution to the academic community, since the framework on the results of Supply Chain 4.0 is new. As a practical contribution, the framework can support and serve as a guide for professionals who are represented in Supply Chain 4.0 implementation programs.

Keywords: Supply Chain, Industry 4.0, Performance, Results, Digitization.

1 Introduction

According to Ghoobakhloo (2019), in the beginning Industry 4.0 (I4.0) was defined as the fourth industrial revolution that emerged in the manufacturing industry, although this definition is already out of date. Today, Indústria 4.0 involves the digital transformation of the entire industrial and consumer market, from the advent of intelligent manufacturing to the digitization of all possibilities for delivering value. For Vial (2019), digital transformation or digitization can be defined as "a process that aims to improve an entity through significant changes in its properties by combining information, computing, communication and connectivity technologies." Historically, this concept was launched in Germany, in 2011, during an event called "Hannover Fair" (Ghoobakhloo, 2019) and, from this, the subject has become a very interesting topic in industry and academia. According to Frederico et. al. (2019), currently the theme has gained importance for worldwide recognition and the reason for this high interest is that Industry 4.0 has the potential to add and transform the value of companies. The author also introduces the concept of Supply Chain 4.0 (SC 4.0) to facilitate the exploration and clarification of the applicability and impacts of Industry 4.0 in the context of the supply chain. Also according to the author, the strategic

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vision of supply chain 4.0 is evolutionary and requires resources and reconfiguration of supply chains, a clear understanding of how and where a supply chain is and where it could potentially reach in the future.

At a more detailed level, digital technologies related to sector 4.0 include Iot, Big Data, Artificial Intelligence, among others, which would have implications for a variety of business areas, leading to significant changes in the supply chain. In general, none of the disruptive technologies in Industry 4.0 operate independently and in isolation. Such independence and integration do not act as a limitation, but rather as a contribution to the interoperability feature, ensuring that various components of a value network connect and share data in a coordinated manner. The spread of technological innovations is transforming traditional supply chains, in order to better acquire and manage data, as well as the integration of information that can provide competitive differentiation to members of the corporation. (Ghoobakhloo, 2019)

As the theme Supply Chain 4.0 is still embryonic, it represents an opportunity for significant academic research and original contribution in the area. However, there are a variety of potential research areas within the SC 4.0 context. Considering the above about the potential of SC 4.0 in generating competitive advantage, and that there are few studies that explore digital transformation and its impacts (Vial, 2019), it is important to establish a study that identifies the results and performances obtained by this model. To this end, the objective of this work is to identify the main tools used by SC 4.0. Furthermore, this research aims to develop a framework that synthesizes the results of SC 4.0 in the various areas of the Industry. Thus, two research questions that represent such a research gap must be answered, namely:

RQ1: What are the results obtained by the Supply Chain 4.0 in the various areas of Industry?

RQ2: What are the technological and managerial tools that cause these results?

The focus on SC 4.0 performance was driven by the intention to be practical in guiding, focusing on elements that are possibly under the company's control. Thus, a practical basis was provided on which managers can build structures and systems that would design SC 4.0 in their respective companies. Additionally, in line with the definition, the difference between processes/tools and SC 4.0 results was outlined: the former clearly precede and generate the latter. Thus, the innovation/originality of this study consists of examining which are the technological and managerial tools of the supply chain 4.0 and what are the results obtained by them, generating then a framework that synthesizes the subject and relates the constructs of the first with the constructs of the second. Such a framework can serve as a guide for practitioners in the area to implement such a model in companies.

This article is structured as follows: this introductory section contextualizes the research as well as introducing the research problem, the objective and the originality of the work. Section 2 demonstrates the research methodology, presenting the search terms, filters and exclusion criteria used. The profile and data of the chosen articles as well as the theoretical framework are found in section 3. Finally, in section 4, main results, contributions, study limitations and opportunities for future research are presented.

2 Research Method

2.1 Research Planning and Identification of Search Terms

According to Frederico et al. (2019), the new disruptive or digital technologies related to sector 4.0 would have implications for a variety of business areas, including the development of new products and services, operations, work environments, people and organizational management, business model, among others, creating competitive advantage in the offer and availability of products, cost reduction and increase in market share. Thus, Frederico et al. (2019) propose in their article the concept of "Supply Chain 4.0" so that, together with the new conceptual framework, it can capture the essence of Industry 4.0 within the context of the supply chain. However, there is still no research that clearly conceptualizes Industry 4.0 in the context of the supply chain.

To fill this gap, Tranfield et al (2003) suggest that a good resource is the development of a systematic review of the literature, as these authors argue that this method is an important part of any research project, where the researcher maps and evaluates the relevant intellectual territory in order to specify a research question that will further develop the knowledge base. Comprehensive and impartial research is one of the fundamental differentials of this method, and the protocol is a plan that helps to protect objectivity, providing explicit descriptions of the steps that have been followed. Although it sometimes takes considerable time and often requires perseverance and attention to detail, systematic review provides efficient means and quality methods for identifying and evaluating extensive literature.

Thus, this study followed the method proposed by Tranfield et al. (2003), which is structured in three phases. The first phase, the planning phase, establishes the keywords of the research and identifies the database and the research period. In the driving phase or second phase, the research is carried out followed by sorting, extraction, data analysis and synthesis of the results obtained. Finally, the third phase, or reporting phase, presents the analysis of results in a structured way.

Thus, in the first stage, meetings were held by the authors of this study to create a review protocol which will determine the research topic within SC 4.0. Thus, based on the keywords used by Frederico et. al. (2019), as well as in his article that links Supply Chain, Industry 4.0 and Digitalization and proposes conceptual constructs for the SC 4.0, this study defined the current performance of SC 4.0 studies within the digital transformation context. Thus, once the theme was defined, the keywords or search terms were determined. Table 1 below shows the sequence or order in which the keywords were inserted in the search system, the connectors used (in capital letters), the keywords chosen (in italics) and the reason for each choice.

Table 1 Keywords used and the respective justifications

Order	Keywords	Reasons for choosing the keyword
1	<i>Supply Chain</i> AND <i>Indust* 4.0</i>	According to Frederico et.al. (2019), research exploring the relationships, impacts and applicability of Industry 4.0 in the context of the supply chain is still very limited. The asterisk was used between indust and 4.0, as there are authors who use variants for the word "industry", such as the word "industrie".
2	<i>Results</i>	Understand what are the results obtained by the companies that adopted the Supply Chain in Industry 4.0.
3	<i>Performance</i>	Understand the degree of maturity and performance of Supply Chain actions in Industry 4.0.
4	<i>Digitization</i>	Clarify the applicability and impacts of Industry 4.0 on the supply chain in several industrial sectors in the context of digital transformation. This term was chosen in place of "digital transformation", as most authors use it to refer to the concept, such as digitization of processes, digitization of services, etc ...

The database used was Scopus, as it helps to identify the most cited authors and offers coverage to other types of references, such as countries that offer more studies, as well as the various areas of knowledge related to the study theme. Some studies referred to publishers Elsevier and Emerald, among others, during the research. The filter used for the research period was: papers published between 2011 and 2020, provided that the concept of Industry 4.0 was launched in 2011.

2.2 Conducting the Search for Papers

First, a total of 566 documents were identified when applying the terms "Supply Chain AND Industr * 4.0" in the search. Second, the result obtained was restricted by including the word "Results", obtaining 178 documents. Then, the word "Performance" was added to the research group, resulting in a total of 117 documents. This was followed by the screening step, which consisted of applying filters over the database. Such filters were: articles from 2011, articles published in journals and English, which restricted the search to a total of 104 published articles. Finally,, the search term "digitization" was added at the end, obtaining 22 published articles related to the theme.

3 Results

3.1 Selected Papers

The 22 papers obtained by the screening process were listed by the table 2 below, together with their authors and respective journals.

Table 2 22 papers obtained after entering the term “Digitization”

Paper	Authors (Year)	Document Title	Title of Journal / Event
1	Ivanov et al. (2019)	The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics	International Journal of Production Research
2	Luthra, Mangla (2018)	Evaluating challenges to Ind 4.0 initiatives for SC sustainability in emerging economies	Process Safety and Environmental Protection
3	Dallasega et al. (2018)	Industry 4.0 as an enabler of proximity for construction supply chains: A systematic literature review	Computers in Industry
4	Telukdarie et al. (2018)	Industry 4.0 implementation for multinationals	Process Safety and Environmental Protection
5	Nascimento et al. (2019)	Exploring Industry 4.0 technologies to enable circular economy practices in a manufacturing context: A business model proposal	Journal of Manufacturing Technology Management
6	Manavalan, Jayakrishna (2019)	A review of IoT embedded sustainable supply chain for industry 4.0 requirements	Computers and Industrial Engineering
7	Bienhaus, Haddud (2018)	Procurement 4.0: factors influencing the digitisation of procurement and supply chain	Business Process Management Journal
8	Horvath, Szabo (2019)	Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities?	Technological Forecasting and Social Change
9	Liboni et al. (2019)	Smart industry and the pathways to HRM 4.0: implications for SCM	Supply Chain Management
10	da Silva et al. (2019)	Technology transfer in the supply chain oriented to industry 4.0: a literature review	Technology Analysis and Strategic Management
11	Muller et al. (2019)	Digitization in wood supply – A review on how Industry 4.0 will change the forest value chain	Computers and Electronics in Agriculture
12	Asdecker, Felch (2018)	Development of an Industry 4.0 maturity model for the delivery process in supply chain	Journal of Modelling in Management
13	Stank et al. (2019)	Toward a Digitally Dominant Paradigm for twenty-first century supply chain scholarship	International Journal of Physical Distribution and Logistics Management
14	Dallasega et al. (2019a)	Field study to identify requirements for smart logistics of European, US and Asian SMEs	Proceedings of the International Conf. on Industrial Engineering and Operations Management, 2019
15	Dallasega et al. (2019b)	An agile scheduling and control approach in ETO construction supply chains	Computers in Industry
16	Wang, Ha-Brookshire (2018)	Exploration of Digital Competency Requirements within the Fashion Supply Chain with an Anticipation of Industry 4.0	International Journal of Fashion Design, Technology and Education
17	Menon, Shah (2020)	Are SMEs Ready for Industry 4.0 Technologies: An Exploratory Study of industry 4.0 Technological Impacts	Proceedings of International Conf. on Computation, Automation and Knowledge Management, 2020
18	Omar et al. (2019)	Business analytics in manufacturing: Current trends, challenges and pathway to market leadership	Operations Research Perspectives
19	Pandey et al. (2019)	Cyber security risks in globalized supply chains: conceptual framework	Journal of Global Operations and Strategic Sourcing
20	Gjeldum et al. (2018)	Performance analysis of RFID systems for assembly line purposes in learning Factory	Mechanical Technology and Structural Materials
21	Dhamija et al. (2020)	Industry 4.0 and supply chain management: A methodological review	International Journal of Business Analytics
22	Bibby, Dehe (2018)	Defining and assessing industry 4.0 maturity levels – case of the defence sector	Production Planning & Control: The Management of Operations

3.3.1 Digital Technologies

The results of the content analysis identified digital technologies within the scope of Supply Chain 4.0 that build technological constructs for different areas of the business, such as risk management, reverse logistics, circular economy, product and service development, operations, transformation industry, among others. These technologies include Big Data, Internet of Things, Cyber-Physical Systems, Mobile Apps, Cloud Computing (cloud-based ERP solutions, for example), Interface Human-Machine (IHM), Web technologies, e-Value Chain, Cybersecurity, Smart Sensors (RFID, for example), Autonomous Robotics (Automated Guided Vehicles, for example), Additive Manufacturing, Advanced Tracking and Routing Technologies (GPS, for example), Simulation and Optimization of Operating Systems (such as the use of digital twins, for example). In terms of supply chain operations, these technologies, according to Ivanov et. al. (2019), bring: increased response capacity, mitigating the cascade effect, optimization of delivery deadlines, new quality of planning and risk management, ability to reconfigure resources and better data planning. Luthra and Mangla (2018) identify organizational, technological and strategic challenges associated with disruptive technologies, due to the lack of infrastructure and resources of Industry 4.0 for emerging countries.

The application of augmented reality systems supports workers in several ways. These technologies can assist in step-by-step processes, linking virtual reality and reality. Maintenance with augmented reality support can reduce lead times and human error rates. The technology also assists in measuring the performance of employees and allows checking whether each product meets the quality standards. Besides that, training guided by augmented reality is increasingly effective (Horvát and Szabó, 2019).

Software companies have developed what is called manufacturing execution systems (MES), to provide data management capabilities and a 'common user interface' for operators, who bridge the gap between automated production resources and organizations' ERP systems (Bibby and Dehe, 2018). The benefits of an MES are summarized below: Central repository of data/information throughout the company; support for regulatory compliance for safety, health, environmental and financial Standards; access throughout the company to accurate data in real time; role-based visualization, reducing information overload; key Performance Indicators (KPIs) generation to enable and support the decision-making process; better response to micro and macroeconomic factors; optimal use of equipment, personnel and material resources; and Ensuring that the quality standards of manufacturing operations are met. (Telukdarie et al, 2018).

3.3.2 Lean and Agile Management

According to Dallasega et al. (2019b), Industry 4.0 brings the need to obtain agile programming and total control to the Supply Chain, so that, with this, it can have a lean management, capable of customizing products without generating waste or unnecessary stock. According to Naylor et al. (1999), cited by Dallasega et al. (2019b), agile in this context means that a manufacturing system is able to respond quickly to changes in customer demand. Thus, a more frequent availability of information allows us to design agile supply chains, which adapt to market demand, delays in logistics chains and other disturbances, in order to reach the optimal values of the desired Key Performance Indicators (KPIs). According to Sivaman and Varghese (2016), cited by Dallasega et al. (2019b), pull planning is a basic concept in lean thinking. For Ghosh et al. (2017), cited by Dallasega et al. (2019b), states that pull-driven approaches are trying to complete the project optimally in terms of quality, time and cost, in order to provide maximum value to the customer. Improving productivity by reducing inventories is critical for approaches based on pull production.

According to Gilchrist (2016), cited by Manavalan and Jayakrishna (2019), in the context of industry 4.0 decentralization is the ability of digitally connected systems to make autonomous decisions and take appropriate actions. Human interaction is only necessary during exceptions, in conflict with the expected exit. Thus, Spath et al. (2013), cited by Dallasega et al. (2019a), state that another important transformation that accompanies Industry 4.0 is the shift from centralized control to decentralized control to achieve highly flexible production of personalized products and services. An individualization and

customization of products increasingly leads to customer interaction strategies, such as X-to-order (make-to-Order, Build-to-Order, Configure-to-Order and Engineer-to-Order) and finally, for the concept of “mass customization”, where products can be configured by the customer at costs similar to those of mass production. The growing fusion of the IT environment with production and logistics allows to obtain flexible and reconfigurable manufacturing and logistics systems.

3.3.3 HR 4.0 Management

As Horvath and Szabó (2019) state that to succeed in adopting the technologies of industry 4.0, it is necessary to create a common understanding of change, as well as to develop innovative forms of training that develop quickly employee skills in a changing environment. According to Liboni et al. (2019), HR management should encourage and develop technical, personal and social skills, and must be connected with the Supply Chain to promote these 3 skills. This happens since the work environment will change permanently according to the application of digital technologies in the various sectors of the economy. For Liboni et. al. (2019), the main limitation for the advancement of Industry 4.0 in HR Management is the lack of qualified labor, especially in emerging countries, which demands costs and growth of precarious work. However, the author argues that this can be solved if HR management encourages and develops technical, personal and social skills, in order to connect the Human Resources and Supply Chain sectors in these competencies in a fair alignment. According to Jackson et al. (2014), cited by Liboni et al. (2019), topics related to human resources can be understood to include the ways in which companies adapt recruitment, training, performance appraisal and employee rewards in light of external trends, such as technological changes and competitive forces. From a broader perspective, HRM relates to methods for keeping the workforce up-to-date, qualified and aligned with the expectations of stakeholders.

Horváth and Szabó (2019) discuss the different effects of driving forces and barriers on Small and Medium Enterprises (SMEs) and Multinationals (MNCs). For SMEs, the growing labor shortage is crucial, as they depend heavily on local human resources. Many SMEs are therefore using Industry 4.0 solutions as a way to solve human resources problems. MNCs have greater recruitment opportunities because they seek talent on a global scale. If they do not find adequate human resources in a certain region or country, they can move their productive activities to another region. However, the number of specialists in artificial intelligence, big data and Industry 4.0 is currently low globally and the number of vacancies in this area is high.

3.3.4 Strategic and Environmental Management

Companies that actively seek to develop their Industry 4.0 status and strategies should start by understanding their current level of maturity in their specific context or supply chain. This will allow them to determine their areas of weakness and strength, prioritize opportunities for improvement and manage development plans. This Industry 4.0 maturity structure should provide a roadmap for companies to assess their level and make relevant and informed decisions for the transition to the 4th Industrial Revolution. This greater technological KPIs awareness can lead companies to increase their productivity, innovation and sustainability. Finally, companies in the same supply chain can also see this assessment as an opportunity to transfer best practices and knowledge between key partners (Bibby and Dehe, 2018). A developed maturity model will provide not only a collection of best practices, but also a flexible and customizable modeling architecture that is capable of taking into account the specific characteristics and peculiarities of an organization. The concept of maturity can be used for descriptive, prescriptive and/or comparative purposes. It serves a descriptive purpose if applied to as-is assessments, a prescriptive purpose if used to establish a desirable development path and a comparative purpose if used for internal or external benchmarking (Asdecker and Felch, 2018).

The ‘People and Culture’ dimension is a key part of the implementation of Industry 4.0 due to the value and power of people within organizations. A culture of innovation and continuous improvement is one that embraces change and thrives on new opportunities. Finally, a robust and clear strategy, an

ambitious and well thought out technology investment plan and a vision of agility are also important characteristics of an organization for the maturity of Industry 4.0. (Bibby and Dehe, 2018) Organizational factors, such as top management, leadership and organizational culture play a significant role in the management of Industry 4.0 and sustainable manufacturing operations in value chains.

According to Nascimento et al. (2019), digital technologies can have a positive influence on business sustainability, reinserting waste into the supply chain to manufacture products on demand and develop a circular model to reuse electronic scrap integrating web technologies, reverse logistics and additive manufacturing. Besides that, a company can potentially profit from the use of end-of-life or reverse logistics, that is, "the process of planning, implementing and controlling the reverse flows of raw materials, in-process inventory, packaging and finished products, from manufacturing, distribution or point of use, to a suitable recovery point or disposal point". Reverse logistics involves recycling and remanufacturing, as well as product returns, material reuse, waste disposal, reconditioning and repair, and has developed as a response to product-oriented policies that oblige manufacturers to guarantee and finance the return and recycling of products, given the growing environmental concerns. In this sense, sensors in products can accurately predict the end of a product's useful life based on analysis of usage patterns, and the wireless connection can be used to inform appropriate stakeholders to coordinate efficient reverse logistics. Research suggests that predicting the rate of return of products and their demand will help to design and build reliable and profitable reverse supply chains. In fact, integrating data from all participants in the reverse supply chain can ensure greater profitability. In addition, companies can use this information in target marketing campaigns, improving resellers and the customer experience (Omar et al, 2019).

3.3.5 Supply Chain 4.0 Results

According to Dallasega et al (2019a), to obtain state data in real time, an infrastructure and digital feedback system are needed, which monitors the status of production, storage and shipping in real time. In particular, the short-term availability of information on the status of delivery is very important for proper supply chain management. In addition, visibility of supplier status in real time for quick access to information enables better supplier risk management. Downes and Nunes (2014), cited by Bienhaus and Haddud (2018), affirm that, in recent times, organizations face a radical change. On the one hand, global interconnectivity and the exchange of data and information in real time allows organizations to create new business models and concepts within their area of operation. On the other hand, a growing competition, due to new entries in the market, forces organizations to increase their innovation potential to maintain competitiveness within the new business models and concepts created.

The presence of accurate and always up-to-date data and information is becoming a prerequisite to support decision making in production planning and control in the civil construction sector. According to Telukdarie et al. (2018), several factors influence better decision making within a company, such as Total Business Optimization, Artificial Intelligence, Manufacturing Execution Systems (MES), generation of KPIs. Thus, the company's management will have a global visibility of the business, in a reproducible way, in real time, from the factory floor to the highest level, with all the data available for decision making.

Dallasega et al. (2019a) argue that with the introduction of Industry 4.0, leaving centralization and moving to decentralization, in order to make processes more flexible and generate new business, automatically generating value for the current market needs. The beneficiaries of Industry 4.0 will be small and medium-sized companies that have greater flexibility for new strategies, approaches, concepts and customized technological solutions for implementation. According to Ivanov et al. (2019), many studies provide evidence of increased demand and manufacturing flexibility, product diversification, greater market responsiveness, shorter delivery times and better capacity utilization using Industry 4.0 technologies. Control approaches can be applied to workshop scheduling in a customized manufacturing process and sequencing operations within tasks, in order to support distributed and flexible programming in the emerging field of innovative production systems based on Industry 4.0.

Industry 4.0 will alter the production, operation and complete maintenance of products and services through interconnected components, machines and humans. With the influence of Industry 4.0, industrial production systems are expected to perform 30% faster and 25% more efficient than before. (Rusmann, Lorenz, Gerbert, Waldner, Justus, Engel, & Harnisch, 2015, apud Manavalan and Jayakrishna, 2019) These innovative manufacturing technologies result in less Time to Market (TTM), product accuracy, customized output as required by the customer and greater overall efficiency. (Schweer & Sahl, 2017, apud Manavalan and Jayakrishna, 2019) Such technologies allow to achieve a diversity of competitive and strategic advantages, with emphasis on the greater flexibility of decision-making processes, achievable quality standards, efficiency in production and increased productivity. (Da Silva et al., 2019) In addition, the task of achieving efficiency and customer satisfaction in a value-added network of interdependent institutions is facilitated by information and communication technology (ICT) (Masteika and Cepinskis, 2015, apud Asdecker and Felch, 2018).

Digitization helps industries achieve sustainability, customer satisfaction, reduce costs, and conserve resources (Menon and Sahah, 2020). However, the consumer's contribution is crucial to the project's success for value. Open innovation, where customers take a leading role in the design of new offers, expands the pool of information about the needs and technological solutions, what would be most valued by a potential consumer. Traditional point-of-sale data and customer feedback are complemented with customer-company interaction on social media, changing the relationship between market players and strengthening brand involvement. In addition, shorter Time to Market was associated with greater flexibility to respond to changes in customer trends, leading to better levels of customer satisfaction and loyalty, which in turn can increase sales (Omar et al, 2019).

3.4 Proposition of a Theoretical Framework

Ivanov et al. (2019) argues that digital technologies bring increased responsiveness, mitigating the ripple effect, shorter delivery times, new quality of planning & risk management, ability to reconfigure resources and data coordination (Better Planning). According to Dallasega et al. (2018), connectivity and uninterrupted data exchange bring optimization and proximity between the actors in the supply chain. Manavalan and Jayakrishna (2019) states that the Internet of Things and Industry 4.0 bring competitive advantages to companies and enable sustainable practices through gain for customers, greater responsiveness to demand and faster and real-time decision making. According to Telukdarie et al. (2018), industry 4.0 is capable of increasing the information processing capacity, changing the way current mobile applications are implemented, fully integrating global businesses for optimization and mitigating uncertainties in decision making. According to Müller, Jaeger and Hanewinkel (2019), digitization brings an increase in performance in terms of time, cost and processing error, that is, fewer errors and less misunderstanding, in addition to a constant increase in the amount of storable data.

According to Dallasega et al. (2019a), the introduction of industry 4.0 promotes decentralization to become processes more flexible and generate new business, automatically generating value for current market needs, and may even generate mass customization. Dallasega et al. (2019a) also states that small and medium-sized companies will only benefit from Industry 4.0 following strategies, approaches, concepts and customized technological solutions for implementation. Dallasega et al. (2019b) states that agile programming and digitization generate an efficient database for quick decision making and elimination of waste and unnecessary operations. Through a case study, Dallasega et al. (2019) achieved a 2% reduction in delivery time and a 42% reduction in inventory with decentralization, pulled production and elimination of Buffer. This performance was obtained knowing the actual delivery time and planning the production/delivery according to that time.

Digitization leads to more agile, efficient and consumer-focused supply chains, increasing interaction with suppliers and the manufacturing industry, which is fundamental for organizational performance. Technology Transfer (TT) at various stages of the supply chain generates benefits for everyone provided it is used properly. However, there is a difference in the acquisition of this technology by emerging countries, which are obliged to import it from developed countries that have the domain of TT. In

emerging countries, there are several resource limitations, complex technology acquisition and transfer processes (TT's success is due to a number of factors, including joint cooperation between suppliers, research centers and industry). (Da Silva et al. 2019)

Wang and Ha-Brookshire (2018) argue that forecasting, consumer research and the design function in the fashion industry offer great potential for Industry 4.0. Wang and Ha-Brookshire (2018) also emphasize the points of product customization and the necessity to implement Big Data in the area, creating the term “fashion 4.0”. Regarding digitalization, Bienhaus and Haddud (2018) argue that it brings new business models, a high influence factor for organizational success and a positive character for procurements, since the alignment of processes towards the digital strategy creates the role of purchasing and strategic network node for organizations. According to Stank et al. (2019), the Supply Chain market needs business reformulation to generate value. Besides that, Nascimento et al. (2019) demonstrates that Industry 4.0 generates a positive impact on business sustainability, by integrating web technologies, reverse logistics and additive manufacturing to reinsert waste into the supply chain and manufacture products on demand.

Finally, it is clear that the selected articles mention customization of the concepts and approaches adopted for small and medium-sized companies (SMEs) and for emerging countries. However, such concepts are part of any and all management practices of a company. In SMEs the operating conditions are different and in emerging countries the companies face limitations of infrastructure, strategy and legislation, what demands the adoption of alternative solutions. Thus, it was decided not to include such ideas as two concepts extracted from content analysis, although they were added in the framework. Figure 1 below shows the developed framework that brings together all the concepts and categories identified together with the relationships mentioned between them.

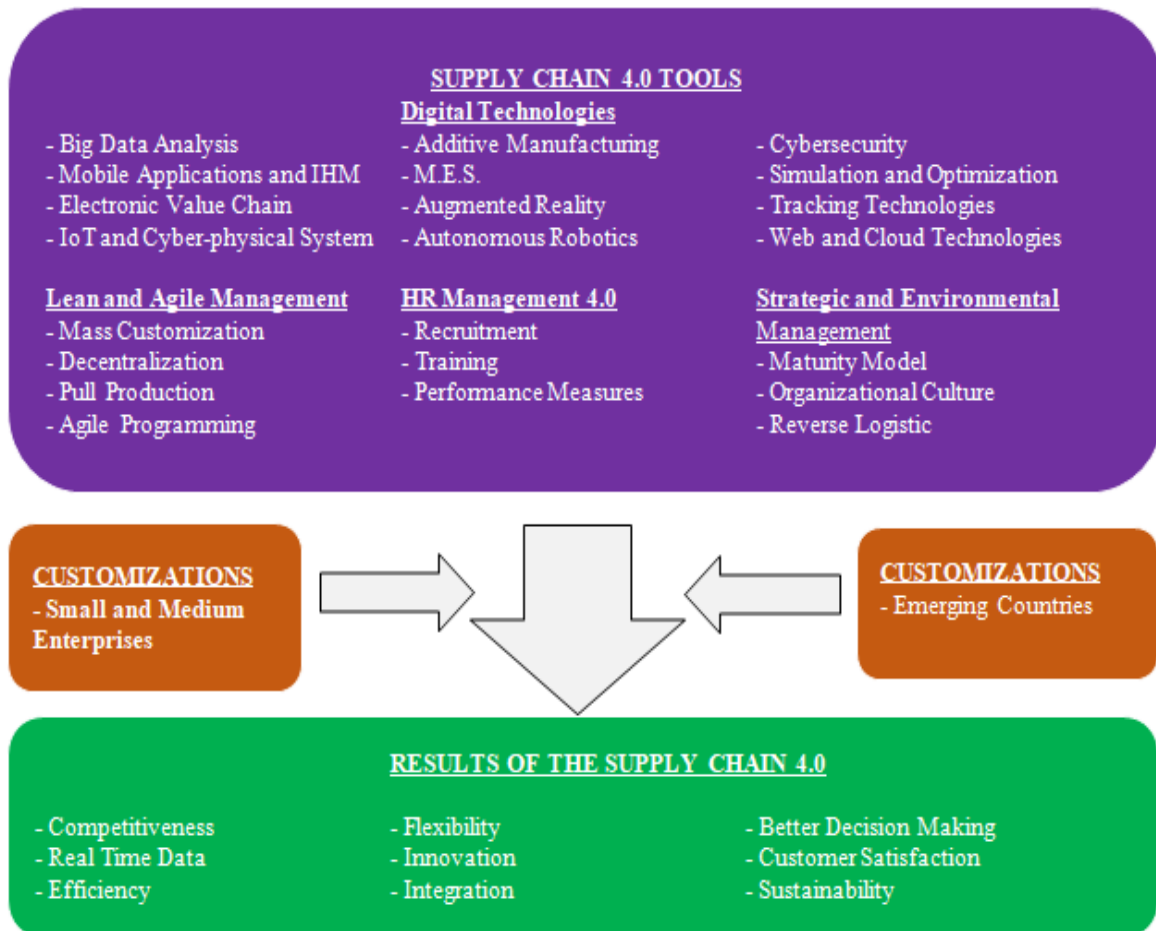


Fig. 1 Supply Chain 4.0 Results Conceptual Framework

4 Final Considerations

The objective of this work was to fill the knowledge gap for the results of Supply Chain 4.0, identifying the main tools used and the impacts obtained by them in the various sectors of the Industry, in addition to developing a framework that synthesizes the subject. To meet this objective, two research questions were created: “*What are the results obtained by the Supply Chain 4.0 in the various areas of Industry?*” and “*What are the technological and managerial tools that cause these results?*”. To answer these questions, a systematic literature review (RSL) was carried out, which identified 22 articles with 31 concepts divided into 5 categories, with their respective relationships: “Digital Technologies”, “Lean and Agile Management”, “HR Management 4.0”, “Management Strategic and Environmental” and “Supply Chain 4.0 Results”. This made it possible to build a theoretical framework that synthesizes the subject.

This research has theoretical and practical implications. In terms of practical contributions, the framework can effectively support and serve as a guide for professionals who are involved in Supply Chain 4.0 deployment programs. In this way, the structure of Supply Chain 4.0 offers a complete view of all dimensions that must be taken into account for successful implementation and management. Based on this, this survey provides a platform for future improvements with respect to Supply Chain 4.0. First, as Industry 4.0 is still seen as a new area, the structure of Supply Chain 4.0 presented in this document would facilitate engagement with relevant stakeholders to familiarize them with concepts and tools, leading to increase the interest and the adoption of Supply Chain 4.0. Second, for companies interested in further exploring the concept, the structures would provide assistance in formulating Supply Chain 4.0 policies and strategies. As more and more companies engage with the approach, more research and interests emerge, leading to improvements in tools and techniques. In terms of theoretical implications, this research brings a relevant and significant contribution to the academic community, since the framework that relates the constructs of SC 4.0 with the constructs of its results is new.

In addition, the proposed framework can strongly support future studies and assist in a deeper understanding of the various aspects of Supply Chain 4.0. As future research relevant to the theme, the following suggestions were made: Investigate each result individually in SC 4.0 according to technological tools (Digital Technologies) or management tools (HR 4.0, Lean, Agile, Strategic or Environmental Management); Directly relate SC 4.0 and the company's profitability in a quantitative way, in order to answer which technologies and which management practices lead to greater profitability; and Propose how SC 4.0 can be implemented in emerging countries or in small and medium-sized companies, considering a low budget. Finally, in order to empirically validate the research results and the proposed theoretical framework, as well as shedding light on emerging trends in the field of research, future research may consider conducting a Delphi study or a large-scale survey. This is considered part of the future research agenda derived from the present work.

References

- Asdecker, B., Felch, V. (2018) Development of an Industry 4.0 maturity model for the delivery process in supply chains, *Journal of Modelling in Management*, 13, 4, 840-883. DOI: 10.1108/JM2-03-2018-0042
- Bibby, L., Dehe, B., (2018) Defining and assessing industry 4.0 maturity levels – case of the defence sector, *Production Planning & Control*, 29:12, 1030-1043. DOI: 10.1080/09537287.2018.1503355
- Bienhaus, F., Haddud, A. (2018) Procurement 4.0: factors influencing the digitisation of procurement and supply chains, *Business Process Management Journal*, 24, 4, 965-984. DOI: 10.1108/BPMJ-06-2017-0139
- da Silva, V. L., Kovaleski, J. L., Pagani, R. N. (2019) Technology transfer in the supply chain oriented to industry 4.0: a literature review, *Technology Analysis & Strategic Management*, 31:5, 546-562. DOI: 10.1080/09537325.2018.1524135
- Dallasega, P., Rauch, E., Linder, C. (2018) Industry 4.0 as an enabler of proximity for construction supply chains: A systematic literature review, *Computers in Industry*, 99, 205–225. DOI: 10.1016/j.compind.2018.03.039
- Dallasega, P., Rojas, R. A., Bruno, G., Rauch, E. (2019a) An agile scheduling and control approach in ETO construction supply chains, *Computers in Industry*, 112, 103-122. DOI: 10.1016/j.compind.2019.08.003
- Dallasega, P., Woschank, M., Ramingwong S., Tippayawong K.Y., Chonsawat N. (2019b) Field study to identify requirements for smart logistics of European, US and Asian SMEs. In: *Proceedings of the International Conference on Industrial Engineering and Operations Management Bangkok, Thailand*. DOI: 10.1007/978-3-030-25425-4_5

- Dhamija, P., Bedi, M., Gupta, M. L. (2020) Industry 4.0 and supply chain management: A methodological review. *International Journal of Business Analytics* 7 (1), 1–23 (2020).
- Frederico, G. F., Garza-Reyes, J., A. Anosike, A., Kumar, V. (2019). Supply Chain 4.0: concepts, maturity and research agenda. *Supply Chain Management: An International Journal*. [ISSN 1359-8546]. DOI: 10.1108/SCM-09-2018-0339
- Ghobakloo, M. (2019) Industry 4.0, digitization, and opportunities for sustainability, *Journal of Cleaner Production*, 252 [0959 - 6526]. DOI: 10.1016/j.jclepro.2019.119869
- Gjeldum, N., Mladineo, M., Crnjac, M., Veza, I., Aljinovic, A. (2018) Performance analysis of the RFID system for optimal design of the intelligent assembly line in the learning factory. In: 8th Conference on Learning Factories 2018: Advanced Engineering Education & Training for Manufacturing Innovation, *Procedia Manufacturing*, v. 23, n. 2018, p. 63–68, Elsevier, Split Croatia (2018).
- Horváth, D., Szabó, R.Z. (2019) Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? *Technological Forecasting & Social Change*, 146, 119–132. DOI: 10.1016/j.techfore.2019.05.021
- Ivanov, D., Dolgui, A., Sokolov, B. (2019) The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics, *International Journal of Production Research*, 57:3, 829-846. DOI: 10.1080/00207543.2018.1488086
- Liboni, L.B., Cezarino, L.O., Jabbour C.J.C., Oliveira B.G., Stefanelli N.O. (2019). Smart industry and the pathways to HRM 4.0: implications for SCM, *Supply Chain Management: An International Journal*. 24:1 124–146. DOI: 10.1108/SCM-03-2018-0150]
- Luthra, S., Mangla, S.K. (2018) Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies, *Process Safety and Environmental Protection*, 117, 168–179. DOI: 10.1016/j.psep.2018.04.018
- Manavalan, E., Jayakrishna, K. (2019) A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements, *Computers & Industrial Engineering*, 127, 925–953. DOI: 10.1016/j.cie.2018.11.030
- Menon, S., Shah, S. (2020). Are SMSs Ready for Industry 4.0 Technologies: An Exploratory Study of I 4.0 Technological Impacts, 2020 International Conference on Computation, Automation and Knowledge Management (ICCAKM), Amity University, 203-208. DOI: 10.1109/ICCAKM46823.2020.9051550
- Müller, F., Jaeger D., Hanewinkel, M. (2019) Digitization in wood supply – A review on how Industry 4.0 will change the forest value chain, *Computers and Electronics in Agriculture*, 162, 206–218. DOI: 10.1016/j.compag.2019.04.002
- Nascimento, D.L.M., Alencastro, V., Quelhas, O.L.G., Caiado, R.G.G., Garza-Reyes, J.A., Lona, L.R., Tortorella, G. (2019). Exploring Industry 4.0 technologies to enable circular economy practices in a manufacturing context: A business model proposal, *Journal of Manufacturing Technology Management*, 30, 3, 607-627. DOI: 10.1108/JMTM-03-2018-0071
- Omar, Y. M., Minoufekar, M., Plapper, P. (2019) Business Analytics in Manufacturing: Current trends, challenges and pathway to market leadership. *Operations Research Perspectives*, 6, 2214 -7160. DOI: 10.1016/j.orp.2019.100127
- Pandey, S., Singh, R., K., Gunasekaran, A., Kaushik, A. (2019) Cyber security risks in globalized supply chains: conceptual framework. *Journal of Global Operations Strategic Sourcing*, 13, 1, 103-128. DOI: 10.1108/JGOSS-05-2019-0042
- Stank, T., Esper T., Goldsby T.J., Zinn W., Autry C. (2019) Toward a Digitally Dominant Paradigm for twenty-first century supply chain scholarship, *International Journal of Physical Distribution & Logistics Management*, 49, 10, 956-971. DOI: 10.1108/IJPDLM-03-2019-0076
- Telukdarie, A., Buhulaiga, E., Bag, S., Gupta, S., Luo, Z. (2018) Industry 4.0 implementation for multinationals, *Process Safety and Environmental Protection*, 118, 316–329. DOI: 10.1016/j.psep.2018.06.030
- Transfield, D., Denver D., Smart, P. (2003) Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review*, *British Journal of Management*, 14, 207–222. DOI: 10.1111/1467-8551.00375
- Vial, G. (2019) Understanding digital transformation: A review and a research. *Journal of Strategic Information Systems*. DOI: 10.1016/j.jsis.2019.01.003
- Wang, B., Ha-Brookshire, J. E. (2018) Exploration of Digital Competency Requirements within the Fashion Supply Chain with an Anticipation of Industry 4.0, *International Journal of Fashion Design, Technology and Education*, 11:3, 333-342. DOI: 10.1080/17543266.2018.1448459

Appendix

To access and obtain Table 4 in the Appendix, please send a request to the corresponding author's email: militello3@gmail.com