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# Technology transfer in the supply chain oriented to industry 4.0: a literature review

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# Technology transfer in the supply chain oriented to industry 4.0: a literature review

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**ABSTRACT**

In the supply chain oriented to Industrial 4.0 Scenario the scarcity of studies on Technology Transfer (TT) can be easily observed. TT is a fundamental process, because it steers the absorption and dissemination of technologies towards the various stages of supply chain. The objective of this study is to contextualise TT in the supply chain of Industrial 4.0 Scenario, focusing on the supply, manufacturing industry and final consumer stages. A review of the literature was carried out, using a structured protocol and criteria to compose the bibliographic portfolio. To support the questions presented in this study, the most relevant articles related to the researched topic were thoroughly analyzed. The results infers that in the Industrial 4.0 Scenario, the supply chain will go through changes, such as real-time visibility throughout the entirety of the supply chain, continuous collaboration between the stages of the chain, among other significant changes.

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Technology transfer; industry 4.0; smart manufacturing; supply chain 4.0

## 1. Introduction

Recently, numerous issues related to the next industrial revolution, mainly reported in German and denominated Industry 4.0 (Lee, Kao, and Yang 2014), have been discussed with the goal of creating industries with intelligent integrated processes, endowed with adaptability and efficiency characteristics (Jasiulewicz-Kaczmarek, Saniuk, and Nowicki 2017).

Industry 4.0 encompasses a variety of technologies, principles and methods, to make production systems more autonomous, dynamic (Tortorella and Fettermann 2017), flexible and accurate. In this context, the aim is creating a variety of new opportunities for the industries of the various market sectors (Hecklau et al. 2016).

The changes arising from Industrial 4.0 Scenario, characterised by the insertion of intelligent systems into the industrial environment, new technologies (Lalanda, Morand, and Chollet 2017), new tasks and improvement of human skills (Wittenberg 2016), diversified modes of management and control of production (Lalanda, Morand, and Chollet 2017; Moeuf et al. 2017; Pacaux-Lemoine et al. 2017) and logistic processes (Davis et al. 2012; Ivanov et al. 2016; Shamim et al. 2017), generate numerous amendments to the manufacturing industry (Tjahjono et al. 2017) and the supply chains to which it belongs (Szozda 2017).

Studies and research addressing TT focused on traditional Supply Chain (SC) and Industrial 4.0 Scenario, or on supply chain 4.0 are still very recent and available on very small scale on bibliographic databases. Although TT and SC are topics already consolidated in the literature, Industry 4.0 is a current new approach of industrial configuration and, therefore, a redirection of studies is needed.

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To adapt to the concept of Industry 4.0, an industry initially needs to undergo processes of TT with suppliers of the various branches of the technology industry, mostly. Subsequently, to keep up with the changes that have already been implemented in the manufacturing industry, it is necessary to develop supply chain networks that accompany these changes, characterised by the use of technologies such as the Internet of Things, Big Data, among others. Such technologies will be essential to facilitate the flow of information, mainly in the supply chain referred to by Schrauf and Berttram (2016) as the digital supply chain. Flows of products along a supply chain start being guided by these technologies, as well as by, according to Kovács and Kot (2016), more efficient logistic systems such as transportation optimisation (Kusiak 2017), warehouses management, resources planning, information security between stages of the chain (Barreto, Amaral, and Pereira 2017), and other technologies and practices.

TT is a fundamental process, because it leads to absorption and dissemination of technologies, equipment, resources and products (Kumar, Kumar, and Persaud 1999), and knowledge (Takahashi 2005; Davenport 2013), in addition to encompassing approaches to transfer barriers, mechanisms and models at the various stages of technological (systems, equipment and machinery, for example) and industrial (raw materials, unfinished and finished products, for example) supply chains. Therefore, it is a topic of great relevance.

Industries, in general, are not born with characteristics of Industry 4.0. They go through an evolutionary process, adopting new technologies from their own headquarters, subsidiaries, suppliers, and / or even through TT industry models. Thus, in order for an industry to be considered fit to accompany the Fourth Industrial Revolution, TT will be necessary in one way or another. According to Carvalho and Cunha (2013), new technologies must be developed and transferred to meet the needs of the market, which is increasingly competitive.

The objective of this study was to contextualise Technology Transfer (TT) in the supply chain of Industrial 4.0 Scenario, focusing on the supply, manufacturing industry and final consumer stages.

## 2. Theoretical approach

### *2.1. Technology transfer (TT)*

To understand the process of TT it is necessary, initially, to define the elements of the term technology. Technology is not limited to a machine or equipment, because depending on the nature and purpose of applying of product or other element, it can be considered a technology, as described in Table 1.

Based on the definitions presented, this work defines Technology Transfer (TT) as the process of dissemination and retention technologies of different natures, such as an applicable knowledge (intangible asset) and/or a result of its implementation, generating the product (tangible assets) and/or other infinity of applicable elements between two or more involved persons and/or industries and/or institutions and/or entities. According to Takahashi (2005) and Davenport (2013) the act of transferring a technology refers to the issues of sharing and absorption of it.

In its different natures and configurations, technology is a primordial element that must be transferred between the industries to achieve competitive market, economic growth and commercial performance (Wang and Blomström 1992), for it is essential for the development of any country (Rocha et al. 2016).

The TT process basically involves two minimum conditions, the donor, who is responsible for sharing technologies, and the recipient, who must be fit to absorb the technologies shared (Takahashi 2005). Although it sounds simple, this is an extremely complex process (Gibson and Smilor 1991).

Due to the complexity of the topic, in this study, the conceptual approaches to the main mechanisms involved in the process of TT are emphasised, as well as the barriers that inhibit this process related to the donor and recipient sources (Takahashi 2005; Szulanski 1996; Duan, Nie, and

**Table 1.** Elements of the term technology.

| Category | Element | Author |
|---|---|---|
| Tangible asset | Tool | Kumar, Kumar, and Persaud (1999) |
| | Machine and equipment | Gibson and Smilor (1991) |
| | | Sung and Gibson (2000) |
| | | Kumar, Kumar, and Persaud (1999) |
| | | Hidayat et al. (2009) |
| | | Swinner and Kuijpers (2016) |
| | Prototype | Gibson and Smilor (1991) |
| | Product | Kumar, Kumar, and Persaud (1999) |
| | | Swinner and Kuijpers (2016) |
| | Physical component and device | Hameri (1996) |
| | | Hidayat et al. (2009) |
| | | Davenport (2013) |
| | | Schlüter and Hetterscheid (2017) |
| | Hardware | \|Schlüter and Hetterscheid (2017) |
| Tangible and/or intangible asset | Results of scientific research | Gibson and Smilor (1991) |
| | | Sung and Gibson (2000) |
| | | Hidayat et al. (2009) |
| | | Abdurazzakov (2015) |
| | | Rocha et al. (2016) |
| | | Caramihai, Tănase, and Purcărea (2017) |
| | | Göllü (2018) |
| Intangible asset | Logical software | Schlüter and Hetterscheid (2017) |
| | Experiences | Hameri (1996) |
| | | Hidayat et al. (2009) |
| | | Davenport (2013) |
| | Knowledge | Hameri (1996) |
| | | Davenport (2013) |
| | | Hidayat et al. (2009) |
| | | Swinner and Kuijpers (2016) |
| | | Bliznets, Kartskhiya, and Smirnov (2018) |
| | Technical support | Hidayat et al. (2009) |

Coakes 2010), to the interactive context and to the technology to be transferred (Szulanski 1996; Duan, Nie, and Coakes 2010).

### *2.2. Industry 4.0*

As forerunner of the term Industry 4.0, Germany has been leading, in recent years, changes in the Industrial 4.0 Scenario, based on the production and innovation enabled by the Cyber-Physical Systems (CPSs) (Lee, Kao, and Yang 2014). According to Lee (2008), the CPSs consist of digital integrations with physical processes, where integrated computers and networks monitor and control physical processes. For Lalanda, Morand, and Chollet (2017), Industry 4.0 is based on the use of new production techniques, new materials and adoption of diversified digital technologies.

Within the framework of CPSs and other technologies, intelligent processes provide quick answers to changes in production, and to failures along the industrial production chain (Haddara and Elragal 2015; Jasiulewicz-Kaczmarek, Saniuk, and Nowicki 2017). Industry 4.0 requires an effective integration between personnel, processes, equipment and products (Gebhardt, Grimm, and Neugebauer 2015; Haddara and Elragal 2015), providing competitive advantages such as cost and time efficiency in production and improvements in the quality of the product (Albers et al. 2016).

In general, industries will be positively impacted by changes derived from Industry 4.0. In Germany, the automotive, food and components and systems production industries stand out (Rüßmann et al. 2015). According to Gorecky, Khamis, and Mura (2017), the automotive sector is one of the leaders in the adoption of technologies, such as the Internet of Things (IoT) and CPSs.

Industry 4.0, also called the fourth industrial revolution, future industry or smart industry, encompasses nine pillars with technological bases, listed by Rüßmann et al. (2015): High number of data for analyses; Autonomous robots; Simulation; Integration of horizontal and vertical systems; Internet of things; Cyber security; Cloud computing; Additive manufacturing, and; Augmented reality.

## 3. Methodological procedures

For realisation of this study, a review of the literature was carried out, using the protocols of Pagani, Kovaleski, and Resende (2015, 2018), which included the steps: i) Selecting bibliographic databases; ii) establishing keywords and keyword combinations; iii) defining search criteria in the databases; iv) carrying out the searches in the databases; v) eliminating duplicate articles; vi) defining and applying criteria for excluding articles that are incompatible with the proposed theme; vii) qualifying the articles from the calculation and analysis of InOrdinatio do Methodi Ordinatio values, and; viii) carrying out the complete reading of the selected articles.

Considering the research's objectives and proposal, four Groups of keyword combinations were structured, in Table 2. To facilitate the organisation of the information, keywords 'Industry 4.0', 'Smart Manufacturing', 'Fourth Industrial Revolution', 'Smart Industry' and 'Cyber-Physical System' (one of the primary technologies that best represents the applied concept of Industry 4.0), searched for in the databases, refer in this article to a single term: Industrial 4.0 Scenario.

Keyword combinations and search criteria were defined in the databases Science Direct, Scopus and Web of Science, using two requirements: i) Keywords in Abstract-Title-AND-Keywords, and; ii) AllYears.

The execution of the searches was carried out was based on the keyword combinations and criteria defined. The articles found were collected using the reference manager Mendeley®.

To select only articles directly related to the research topic, filtration procedures were applied individually for groups 1, 2 and 3, respectively, including: i) Eliminating duplicate articles; ii) Eliminating articles published in conferences, and; iii) Eliminating articles not related to the topic under study.

From the application of the filtering criteria, for selecting the final sample of articles, step 7 of the Methodi Ordinatio of Pagani, Kovaleski, and Resende (2015, 2018) was applied, called InOrdinatio. This phase allows qualifying and sorting the articles according to scientific relevance, equating the impact factor, year of publication and number of citations for each article. In this way, it is possible to obtain relevant studies with respect to the scientific criteria mentioned.

## 4. Results and discussion

### *4.1. Supply chain on the industry 4.0 perspective*

#### *4.1.1. Analysis of terms*

In this study, the term Industrial 4.0 Scenario corresponds to the terms used in the literature by researchers to define the recent industrial setting, as described in Table 3.

The most discussed terms in the world are Industry 4.0, '*Industrie 4.0*' (industry in the native language of Germany (Anderl 2014; Drath and Horch 2014; Thoben, Wiesner, and Wuest 2017; Wang et al. 2016), Advanced Manufacturing (Davis et al. 2012; Tjahjono et al. 2017) and Fourth Industrial Revolution (Park and Lee 2017).

**Table 2.** Classification of bibliographic groups.

| Keywords | Group |
|---|---|
| 'Technology Transfer' AND 'Supply Chain' | 1 |
| 'Technology Transfer' AND 'Industrial 4.0 Scenario' | 2 |
| 'Supply Chain' AND 'Industrial 4.0 Scenario' | 3 |
| 'Technology Transfer' AND ('Supply Chain 4.0' or ' Digital Supply Chain' or 'Smart Supply Chain') | 4 |

**Table 3.** Others terms for Industrial 4.0 Scenario.

| Term | Author |
|---|---|
| 'Advanced Manufacturing' | Davis et al. (2012) |
| | Tjahjono et al. (2017) |
| 'Digital Manufacturing' | Byrne et al. (2016) |
| 'Digital Age' | Küsters, Praß, and Gloy (2017) |
| | Bliznets, Kartskhiya, and Smirnov (2018) |
| 'Fourth Industrial Revolution' | Park et al. (2017) |
| *'Industrie 4.0'* | Anderl (2014) |
| | Drath and Horch (2014) |
| | Kagermann et al. (2016) |
| | Neugebauer et al. (2016) |
| | Thoben, Wiesner, and Wuest (2017) |
| | Wang et al. (2016) |
| 'Industry 4.0' | Gorecky, Khamis, and Mura (2017) |
| | Rüßmann et al. (2015) |
| | Ivanov et al. (2016) |
| | Sanders, Elangeswaran, and Wulfsberg (2016) |
| | Majeed and Rupasinghe (2017) |
| | Tortorella and Fettermann (2017) |
| 'Intelligent Manufacturing' | Bogle (2017) |
| | Zhong et al. (2017) |
| 'Smart Industry' | Tjahjono et al. (2017) |
| 'Smart Manufacturing' | Davis et al. (2012) |
| | Bogle (2017) |
| | Feng, Bernstein, and Hedberg (2017) |
| | Kusiak (2017) |
| | Sharp, Ak, and Hedberg (2018) |

Amongst the main countries interested in the concept of Industry 4.0 we can mention China, France, Germany, Italy, Japan, South Korea, the United Kingdom and the United States. These countries have national proposals and policies to drive the development of the industry in the medium and long term, as presented in Table 4.

### *4.1.2. Analysis of industry 4.0 technologies*

The increasing globalisation of the market and increasing competitiveness have generated the need of applying new technologies, procedures and business processes in industries (Kovács and Kot 2016). The technologies of Industry 4.0 are described in Table 5(a–g).

In view of the presented technologies, some of them are the basis of Industry 4.0, such as CPSs, IoT, Big Data, cloud computing, augmented and virtual reality, integrated wireless infrastructure and artificial intelligence.

On the other hand, other technologies are already used in various manufacturing industries, such as use of sensors in machines for data collected, data mining, real-time simulation, automation and robotisation of processes, and systems and network security, should be perfected for the Industry 4.0.

Schumacher, Erol, and Sihn (2016) report that for an industry to be considered 4.0, it is indispensable to meet technological requirements (focus of the present study). Nevertheless, a maturity model should also include other requirements, distributed in other groups of organisational and

**Table 4.** Countries national policies for developing the concept of Industry 4.0.

| Country | National programme | Source |
|---|---|---|
| China | *'Made in China 2025'* | http://www.china.org.cn |
| France | *'Aliance Industrie du Futur'* | http://www.industrie-dufutur.org/ |
| Germany | *'Plattform Industrie 4.0'* | https://www.plattform-i40.de |
| Italy | *'Piano Industria 4.0'* | http://www.sviluppoeconomico.gov |
| Japan | *'Connected Industries'* | http://www.meti.go.jp |
| The United States | *'Advanced Manufacturing USA'* | https://www.manufacturingusa.com/ |

**Table 5.** Technologies of the Industry 4.0.

| (a)Technology: Data Analysis | Author |
|---|---|
| Big Data | Almada-Lobo (2015) |
| | Rüßmann et al. (2015) |
| | Assad Neto et al. (2017) |
| | Grieco et al. (2017) |
| | Tjahjono et al. (2017) |
| | Witkowski (2017) |
| | Zhong et al. (2017) |
| | Kayikci (2018) |
| Data mining | Trstenjak and Cosic (2017) |
| Technology: Distribution of data | Author |
| Cloud computing | Almada-Lobo (2015) |
| | Rüßmann et al. (2015) |
| | Reddy, Singh, and Hariharan (2016) |
| | Assad Neto et al. (2017) |
| | Chen (2017) |
| | Majeed and Rupasinghe (2017) |
| | Tjahjono et al. (2017) |
| | Kayikci (2018) |
| | Molka-Danielsen, Engelseth, and Wang (2018) |
| (b) Technology: View data and scenarios | Author |
| Augmented reality | Rüßmann et al. (2015) |
| | Assad Neto et al. (2017) |
| | Tjahjono et al. (2017) |
| | Kayikci (2018) |
| Simulation | Rüßmann et al. (2015) |
| | Grieco et al. (2017) |
| | Mohammed and Ahmed (2017) |
| Virtual reality | Assad Neto et al. (2017) |
| | Tjahjono et al. (2017) |
| (c) Technology: Advanced robotisation | Author |
| Autonomous robots | Rüßmann et al. (2015) |
| Automation systems | Dossou and Nachidi (2017) |
| Artificial Intelligence (software) | Mohammed and Ahmed (2017) |
| | Tjahjono et al. (2017) |
| Cyber-Physical System | Davis et al. (2012) |
| | Ivanov and Sokolov (2012) |
| | Neugebauer et al. (2016) |
| | Reddy, Singh, and Hariharan (2016) |
| | Assad Neto et al. (2017) |
| | Bogataj, Bogataj, and Hudoklin (2017) |
| | Chen (2017) |
| | Trstenjak and Cosic (2017) |
| | Molka-Danielsen, Engelseth, and Wang (2018) |
| | Tuptuk and Hailes (2018) |
| Robots | Chen (2017) |
| | Dossou and Nachidi (2017) |
| | Tjahjono et al. (2017) |
| | Dieber, Schlotzhauer, and Brandstötter (2017) |
| | Kayikci (2018) |
| Vehicles autonomous | Chen (2017) |
| (d) Technology: Digital system / network | Author |
| Internet of Things | Rüßmann et al. (2015) |
| | Byrne et al. (2016) |
| | Neugebauer et al. (2016) |
| | Assad Neto et al. (2017) |
| | Barreto, Amaral, and Pereira (2017) |
| | Bogataj, Bogataj, and Hudoklin (2017) |
| | Dossou and Nachidi (2017) |
| | Jensen and Remmen (2017) |
| | Majeed and Rupasinghe (2017) |

(*Continued*)

**Table 5.** Continued.

| | |
|---|---|
| | Shamim et al. (2017) |
| | Tjahjono et al. (2017) |
| | Witkowski (2017) |
| | Zhong et al. (2017) |
| | Abdel-Basset, Manogaran, and Mohamed (2018) |
| | Kayikci (2018) |
| | Molka-Danielsen, Engelseth, and Wang (2018) |
| Machine-to-Machine communication | Tjahjono et al. (2017) |
| Wireless networks | Bogataj, Bogataj, and Hudoklin (2017) |
| | Chen (2017) |
| | Zhong et al. (2017) |
| (e) Technology: Data security system | Author |
| Cyber security | Annunziata and Biller (2017) |
| | Rüßmann et al. (2015) |
| | Mohammed and Ahmed (2017) |
| | Tjahjono et al. (2017) |
| | Tuptuk and Hailes (2018) |
| IPv6 protocol | Chen (2017) |
| (f) Technology: Data collection and control device | Author |
| Mobile app | Davis et al. (2012) |
| | Bogataj, Bogataj, and Hudoklin (2017) |
| RFID | Chen (2017) |
| | Majeed and Rupasinghe (2017) |
| | Tjahjono et al. (2017) |
| Sensors | Bogataj, Bogataj, and Hudoklin (2017) |
| | Chen (2017) |
| | Majeed and Rupasinghe (2017) |
| | Kayikci (2018) |
| (g) Technology: manufacturing system | Author |
| Additive manufacturing | Rüßmann et al. (2015) |
| | Tjahjono et al. (2017) |
| Integration of horizontal and vertical systems | Rüßmann et al. (2015) |
| | Grieco et al. (2017) |
| 3D printing | Tjahjono et al. (2017) |
| | Kayikci (2018) |

industrial dimensions, to highlight industry strategy, leadership issues, customers, products, operations, culture and people, and governance.

### *4.1.3. Advantages of technologies 4.0: perspectives and scientific discussions*

Industry 4.0, in its complexity, refers to a set of intelligent systems, which allow reaching a diversity of competitive and strategic advantages, with emphasis on the greater flexibility of decision-making processes, patterns of achievable quality, efficiency in production and increased productivity (Tjahjono et al. 2017). Moeuf et al. (2017), in their study, identified through a systematic review of the literature some production indicators that are influenced by digital technologies of Industry 4.0, including flexibility in production, cost reduction, improvement in productivity, improvement in the quality of the production process and reduction in the delivery time of the product to the final consumer.

Although the concept of Industry 4.0 has greater influence on manufacturing industries, other organisations are also influenced, such as retailers, businesses, service providers, among other (Tjahjono et al. 2017). In this context, an entire supply chain becomes affected by changes arising from this current approach to industrial configuration.

In supply chains, the application of the concept of Industry 4.0 becomes one of the essential factors to maximise the performance of industries in the market (Dossou and Nachidi 2017). Majeed and Rupasinghe (2017) report that many industries still feature malfunctions and poor performance due to technology and management deficiencies in their respective supply chains. In

Industry 4.0, digitisation leads to more agile, efficient and consumer-focused supply chains (Schrauf and Berttram 2016).

The integration of an entire supply chain can be obtained with the implementation of Cyber Physical Systems – CPSs, and employment of Big Data and technologies such as the Internet of Things – IoT (Guduru, Harpreet, and Hariharan 2016) and cloud-based data storage systems (Ivanov and Sokolov 2012). These technologies are paramount to facilitate the flow of information, mainly in the supply chain. To preserve the data and information generated in the industry and distributed throughout the entire supply chain, Cyber Security technology is essential.

CPSs are the base of Industry 4.0 seeing as they consist of digital integrations with physical processes, where integrated computers and networks monitor and control physical processes. In this context, it is possible to create smart industries through these systems (Lee 2008).

Data analysis using the Big Data aims to improve the quality of production and products, to ensure the efficiency of equipment and assist in real-time decision-making processes (Rüßmann et al. 2015). The Big Data is a set of data processed with analytic technology, including unstructured data without compatible formats, such as data from social networking services, blogs, news, pictures, among others (Park and Lee 2017). In this way, it is possible to provide personalised services to final consumers, assist in decision-making processes, among other advantages (Witkowski 2017).

The internet of things (IoT) consists of intelligent communication systems using IP addresses, which allows the interconnections of objects to the network (Anderl 2014; Haddara and Elragal 2015). Although certain technology industries are already connected to the machines and to the network, with the IoT, a larger number of devices and sensors will be incorporated into the processes and connected to the network, providing real-time answers (Rüßmann et al. 2015).

#### *4.1.4. Changes in the supply chain: perspectives and scientific discussions*

Due to changes in production, managerial and operating systems derived from CPSs, the IoT, the Big Data concept, among others, and to the ways in which the processes are executed and how the products are produced and sent to customers, likely changes emerge in the supply chain (Szozda 2017; Tjahjono et al. 2017).

Büyüközkan and Göçer (2018) define supply chain as a physical and digital network consisted of companies and their suppliers, who seek, through the management and coordination of a myriad of activities, to produce and distribute goods and services to final consumers. Abdel-Basset, Manogaran, and Mohamed (2018) define supply chain 4.0 such as a modern system with interconnected processes that expands from isolated applications to a broad relationship, integrated and efficient between stages of the supply chain.

According to Szozda (2017), the management of supply chain 4.0 moves from traditional relations between the stages of the chain to a data connection network, and use of technologies, systems and personnel. In this configuration of the chain, the supplier, manufacturing industry and final customer stages stand out, because they will have more interactions with each other, the remaining stages also being fundamental to its organisational performance.

In the industry, many components such as sensors, mechatronic devices and/or complex control subsystems that are connected to the network, when grouped into larger physical control devices (machines, for example), should collect data and information in real time (Harrison, Vera, and Ahmad 2016).

The collected data are processed through specific electronic systems (Picciano 2012), and stored in the cloud, to facilitate the collaboration between companies operating in the same supply chain. Through this connectivity and availability of data and information, these companies are better targeting their decision-making processes in different areas (Avventuroso, Silvestri, and Pedrazzoli 2017). The management of data and information is accomplished through the use of CPSs, the IoT and cloud computing, mainly (Trstenjak and Cosic 2017).

The set of data and information collected by different sensors and other components can be self-organized in networks, and it moves dynamically according to the real behaviour of production systems (Smirnov, Sandkuhl, and Shilov 2013). The smart manufacturing systems and the technologies involved need to be agile to keep up with the various oscillations of real problems that may arise in the industry, and the use of appropriate, detailed and accurate information and data becomes fundamental (Jung et al. 2015).

The CPSs are characterised by their autonomous and decentralised behaviour, and thus evolve through the adaptation and reconfiguration of their structures (Ivanov and Sokolov 2012). From these systems and the IoT, machine networks are able to exchange information autonomously and control themselves mutually (Tjahjono et al. 2017).

According to Tjahjono et al. (2017), the introduction of Industry 4.0 in the industrial context has impacts on the entirety of the supply chain and, therefore, requires collaboration between suppliers, the manufacturing industry and final consumers, especially in relation to information flows. Dallasega et al. (2017) report the importance of the availability of accurate, reliable and up-to-date information, whenever possible, throughout all of the supply chain, to generate a consistent and stable demand value.

In the traditional supply chain there is a limited vision that hinders the effective collaboration between the stages of the chain. The information admit delays for individually moving towards each of its stages and for having different planning cycles, resulting in delays and failures related to synchronisation of data and information. In supply chain 4.0, information is available for all stages of the chain simultaneously. The responses to changes in planning and the execution of operations occur in real time, and the changes in consumer demand are evaluated quickly (Schrauf and Berttram 2016).

The application of technologies of Industry 4.0 in traditional supply chain start being guided by six value drivers (Planning, Physical flow, Performance management, Order management, Collaboration and Supply Chain strategy). Consequently, it results in the best performance of services, cost, capital and agility in the supply chain (Alicke, Rexhausen, and Seyfert 2017). According to the authors, the six value drivers are influenced in the following ways:

- Supply chain planning: will be influenced by technologies as Big Data, Advanced analytics and automation of knowledge work;
- Physical flow: through better connectivity between supply chain stages, additive manufacturing, advanced automation, autonomous and smart vehicles and 3D printing aim to reduce costs;
- Performance management: control systems, performance indicators, Big Data and data mining techniques and machine learning aim to identify dysfunctions in the processes;
- Order management: the processing of orders can be performed by digital means, and re-planning, if necessary, in real time, aim to reduce costs and improved reliability of consumer;
- Collaboration: cloud technology creates digital platforms between suppliers, industry and customers, and;
- Supply Chain strategy: Customised products provide most value for the consumer and help reduce costs, through Big Data and other technologies and strategies.
- According to Schrauf and Berttram (2016), supply chain 4.0 basically consists of eight main elements, including: integrated planning and execution of operations; logistic visibility; smart storage; efficient management of inputs; autonomous logistics; prescriptive supply chain analysis; flexibility of processes; reduction of delays and efficiency, and; cost reduction.
- Büyüközkan and Göçer (2018) describe the fundamental characteristics that can be achievable in supply chain 4.0 in their study:
- Speed: Corresponds to the speed of delivery of inputs and products between stages of the supply chain, where more precise answers are provided to meet the clients' demands;
- Flexibility: Consists in the company's ability to respond to changes that arise in the supply chain, so that they are monitored and managed through data and information made available in real time;
- Real-time inventory: supply warehouses start being efficiently managed, and inventory levels start being monitored in real time, resulting in sufficient inventory levels whenever necessary;

- Transparency: The stages of the supply chain start having increased access to data and information from its partners, and therefore, more accurate and efficient information and material flows are obtained.
- Cost and benefit: With supply chain 4.0, better cost efficiency for companies and partners are obtained over the years, and;
- Proactivity: In companies, it is possible to apply actions to address and anticipate problems, to avoid disruption of flows between the stages of a supply chain.

To reach the expected advantages, the implementation of digital technologies and concepts and practices of Industry 4.0 in the supply chain must occur, and personnel must be qualified for work (Büyüközkan and Göçer 2018).

## 4.2. Technology transfer in the supply chain of industry 4.0

### 4.2.1. TT in the industrial 4.0 scenario: perspectives and scientific discussions

There are a variety of projections and actions for the development of smart industries, as well as for the development of supply chains 4.0, consisting basically of interconnections of stages of the chain to the network through advanced systems and technologies. However, so that the concept of Industry 4.0 becomes an effective reality in countries, with emphasis on the emerging countries that still have several limitations of resources, complex processes of acquisition and transfer of technology emerge.

To adapt to the concept of Industry 4.0, an industry initially needs to undergo internal and external processes of TT.

Internal processes of TT are those whose industry are limited to their resources, such as knowledge transfer between experienced collaborators and newly-hired employees. When an industry limits their TT to internal processes (from headquarters to branch, for example), it may face difficulties to remain in the market.

As for external processes, the industry interacts with resources from external suppliers, research institutions, the government, among other organisations. According to Hung and Tang (2008) with external technology transfer, industries save resources and research and development investments that would be infeasible otherwise, and attain competitible advantages.

In the process of TT, some issues need to be discussed, such as the required technology content analysis (dimensions, compositions and variables) (Szulanski 1996; Tatikonda and Stock 2003; Duan, Nie, and Coakes 2010), peculiarities and characteristics of the donor and recipient sources (Takahashi 2005), which may favour or compromise the success of the transfer, as well as its facilitating mechanisms. For Zhao, Tian, and Zillante (2014), technology is one of the main elements in the formation and development of supply chains, and become fundamental to achieving competitive advantage in industries. Nonetheless, the way the Transfer process is conducted becomes crucial for the effectiveness of the transfer and for organisational success.

***4.2.1.1. Analysis of TT barriers: perspectives and scientific discussions.*** A number of barriers can affect the effectiveness of TT between suppliers and industry in the Industrial 4.0 Scenario. These barriers are related to the donor and recipient sources, to the interactive context and to the technology to be transferred (Duan, Nie, and Coakes 2010), according to Table 6.

According to Tatikonda and Stock (2003), the technologies to be transferred admit different forms and compositions, and thus, while some can be easily embedded in production systems, others require more complex operations. In the case of the technologies that make up Industry 4.0, due to them being advanced technologies that are particularly new for many companies, their transfer becomes quite challenging.

A considerable portion of industries in developing countries understand the need for acquisition of new technologies (Jabar, Soosay, and Santa 2010), so that better production processes, efficient services, among other advantages are obtained (Kumar, Luthra, and Haleem 2015).

**Table 6.** Barriers that influence the technology transfer process, between suppliers and industry, in the Industrial 4.0 Scenario.

| Category | Barrier | Author |
|---|---|---|
| Barriers related to the technology | Complexity of technology related to knowledge embedded, to the compositions and to the complex operations. | Ford, Mortara, and Probert (2012)<br>Huang et al. (2012)<br>Blohmke (2014) |
| Barriers related to interactive context | Inefficient cooperation between donor and recipient sources | Gausemeier et al. (2016)<br>Kagermann et al. (2016) |
| | Insufficient communication and language | Desidério and Zilber (2014)<br>Kang et al. (2015)<br>Becker and Stern (2016)<br>Hecklau et al. (2016) |
| | Geographical location | Jude (2015) |
| | Inadequate physical and structural conditions | Duan, Nie, and Coakes (2010)<br>Firjan (2016) |
| | Financial investments | Huang et al. (2012)<br>Martínez, Galván, and Palacios (2013)<br>Sung (2018) |
| | Uncertainties with the application of technology | Gausemeier et al. (2016) |
| Barriers related to the donor source | Knowledge and experience about technology | Ford, Mortara, and Probert (2012)<br>Desidério and Zilber (2014)<br>Duarte and Martins (2016) |
| | Capabilities in sharing technology | |
| Barriers related to the recipient source | Decentralised capabilities to absorb technology | Kumar, Luthra, and Haleem (2015)<br>Schimith et al. (2015) |

The knowledge embedded in technology and the information inherent to it and to its operation/maintenance are owned solely by the manufacturing company, which understands in practice its technical and operational characteristics. This company, when negotiating this technology with other companies, starts assuming the role of supplier in the market. In this context, supply chains consisting of suppliers and other companies interested in technology sharing or absorption are created.

The technology to be negotiated having been defined and subsequently transferred, the recipient (manufacturing industry) can work in conjunction with the donor source (suppliers and other stages of the chain), so that the transfer of technology occurs in an effective manner (Tatikonda and Stock 2003). The success of TT is due to many factors, one of them being the joint cooperation between suppliers, research centres and industries (Gausemeier et al. 2016).

It is essential that the relationship bond to be created between both sources is not limited only to the knowledge and attributes of the technology, but also encompasses the experiences and capabilities to share technology of the supplier, as well as the company's capacity to assimilate and incorporate the technology in its organisational environment (Ford, Mortara, and Probert 2012).

In Technology Transfer, the absorption of technology must be carried out so as to prevent occurrences of anomalies in the industry caused by management and/or operationalisation failures (Schimith et al. 2015). However, an efficient absorptive capacity is meaningless if there are aggravating dysfunctions in the sharing of technologies by suppliers, due to the influence of a series of barriers. According to Kumar, Luthra, and Haleem (2015) the effective transfer of technology is hampered by some barriers, especially for developing countries.

In the literature, a number of barriers that inhibit Technology Transfer are described, however, in the context of Industry 4.0, some barriers stand out and show themselves to be influential due to their capacities to share and/or absorb technologies.

Sharing technologies can develop and maximise an organisation's workforce (Liao, Fei, and Chen 2007). Both industries and suppliers may benefit with TT.

The organisation interested in applying the concepts and practices of Industry 4.0 may face many challenges, depending on their resource limitations and the level of technological and management it presents. To minimise the deficiencies in the absorption of technologies, it is essential for the sharing to be carried out by qualified agencies that have the potential to introduce new knowledge and techniques associated with the technologies of Industry 4.0.

In the technological supply chain of Industry 4.0, as a result of the control over technologies being available to developed countries (Jude 2015), such as Germany and the United States, for example, it is up to emerging countries to import these technologies. Thus, another barrier inherent to the process of TT is the insufficient communication and language, requiring suppliers and the manufacturing industry to interact at a global level (Becker and Stern 2016; Hecklau et al. 2016).

Geographical location is another important barrier in this context, seeing as technologies (systems, components and knowledge) will shift from one region to another (between developed or emerging countries) (Jude 2015).

For the industries interested in the technologies and concepts of Industry 4.0, other barriers that can directly affect TT are those associated with the interactive environment, such as inadequate physical and structural conditions of the organisational environment (Duan, Nie, and Coakes 2010) and lack of financial investments (Huang et al. 2012; Martínez, Galván, and Palacios 2013), or uncertainty about the profitability of the investments to be made. According to the Federation of Industries of the State of Rio de Janeiro (Firjan 2016), Industry 4.0 requires a technological infrastructure that is capable of supporting complex virtual and physical systems. The industrial environment needs to be supported by a physical scenario that contributes to the implementation of technologies and concepts of Industry 4.0.

Other already consolidated TT barriers, which are mentioned in the literature by various researchers, do not have as much influence on the TT process of the supply chain (supplier, manufacturing industry and final consumer stages), such as lack of interest and/or motivation in the transfer, due to the strong commercial ties between both parties.

In this study, although the barriers described in Table 6 present a greater focus on the relationship of TT between supplier of technologies and industry, these barriers can also act in the TT between industry and final consumer of the supply chain.

***4.2.1.2. Analysis of TT for industry and supply chain 4.0.*** The Figure 1 was elaborated aiming to facilitate the analysis of TT processes in supply chains, whose transfer of technologies types (machine, tool, research results, among others) is presented considering the TT relations between suppliers – industry, and industry – final consumer.

TT may occur between the various stages of the supply chain, such as between supplier and industry (source and receiver of technologies, respectively or vice versa), or industry and final consumer (sources emitting and receiving technologies, respectively, or vice versa). Both sources involved might gain advantages with the TT, provided it is properly conducted. The TT is an essential process that governs not only the physical movement of technologies between stages of the supply chain, but also, the management of these in the organisational and industrial environment. According to Grange and Buys (2002), the transfer occurs only when the technology moved is used by the receiving source.

## 5. Conclusion

This study aimed to contextualise the topic of Technology Transfer oriented to the supply chain, in Industrial 4.0 Scenario. In addition to addressing TT, the Industry 4.0 is defined and basic differences between traditional supply chains and supply chain 4.0 are exposed.

Industry 4.0 is already a reality in countries like Germany, but there is much to be developed and applied in industries, primarily in emerging countries, which have limitations various resources. According to Tatikonda and Stock (2003), a technology can be easily embedded in production systems of industry. Others require more complex and detailed operations.

In order to adequate into the Industry 4.0 concept, an industry needs to undergo internal and external TT processes, which can occur simultaneously. Such processes can be complex and require efforts from all parts interested in the transfer.

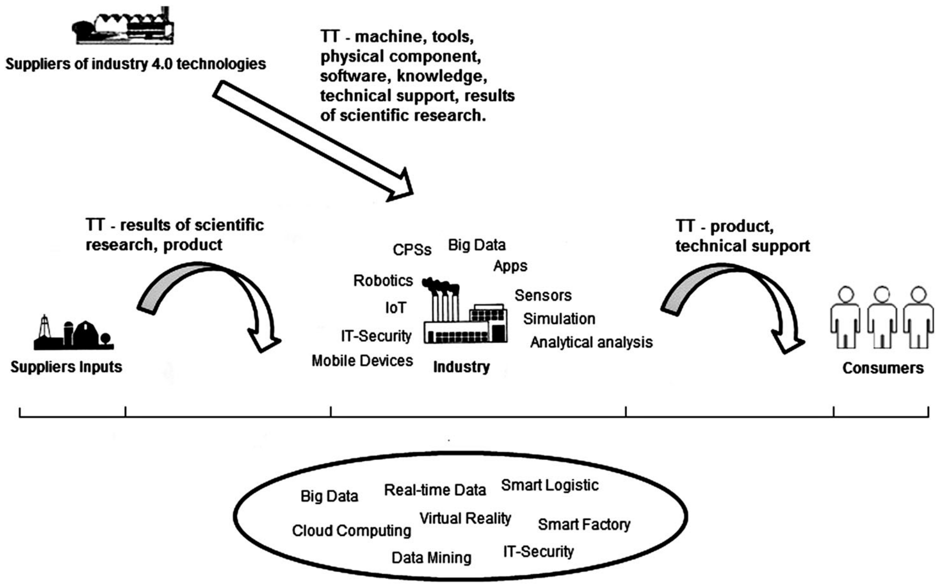


**Figure 1.** TT processes within major stages of supply chain 4.0.

Technology acquisitions involves people, financial resources and investments, efforts and commitment, which is expected from an efficient TT process in order to achieve favourable results.

The impacts of Industry 4.0 on industries around the world from different industrial sectors is notorious, however, when the focus is supply chain management, there are many limitations of studies.

In the Industrial 4.0 Scenario, the stages of a supply chain will undergo technological changes, which includes the manufacturing industries. Therefore, the elaboration of this research and similar studies is important for the enrichment of the subject, which has increasingly interests either from academicians or from industry sector.

This work is an attempt to contribute to the maturation of industries that seek technological development through discussions on the concept and technologies related to Industry 4.0. According to Herterich, Uebernickel, and Brenner (2015), with the increase in competition between businesses, exploring and managing new and potential technologies is becoming essential for industries.

The limitation of this study is that it is restricted to the technological aspects related to Industry 4.0, not addressing other aspects that should be discussed for the maturing of industries. Nevertheles, several research gaps can be spotted within the text, which can be furtherly studied.

In this sense, for further studies, we suggest that practical contributions from supply chain management in Industry 4.0, as well as applied approaches related to TT in the context of the supply chain in the scenario Industrial 4.0, could be developed.

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No potential conflict of interest was reported by the authors.

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