GESTÃO & PRODUÇÃO

ISSN 0104-530X (Print)
ISSN 1806-9649 (Online)

Thematic Section

Digital transformation, intelligent manufacturing and supply chain management 4.0

Towards Industry 4.0: a SWOT-based analysis for companies located in the Sorocaba Metropolitan Region (São Paulo State, Brazil)

Rumo à Indústria 4.0: uma análise SWOT para empresas situadas na Região Metropolitana de Sorocaba (SP, Brasil)

Alessandro Silveira Firmino[1], Guilherme Xavier Perles[1], Juliana Veiga Mendes[1], João Eduardo Azevedo Ramos da Silva[1], Diogo Aparecido Lopes Silva[1]

[1]Universidade Federal de São Carlos – UFSCar, Departamento de Engenharia de Produção de Sorocaba, Sorocaba, SP, Brasil. E-mail: alefirmino_01@hotmail.com; guiperles@hotmail.com; juveiga@ufscar.br; jesilva@ufscar.br; diogo.apls@ufscar.br

How to cite: Firmino, A. S., Perles, G. X., Mendes, J. V., Silva, J. E. A. R., & Silva, D. A. L., (2020). Towards Industy 4.0: a SWOT-based analysis for companies located in the Sorocaba Metropolitan Region (São Paulo State, Brazil). *Gestão & Produção*, 27(3), e5622. https://doi.org/10.1590/0104-530X5622-20

Abstract: The concept of Industry 4.0 was first introduced in Germany in 2011. Also called as the 4th industrial revolution, this concept is based on digitization and integration of physical and digital media, focusing on the automation of production processes and integration across the value chain. Due to the fast development of Industry 4.0 in the last few years, this study performed a SWOT-based analysis to assess strategic points to develop and apply digital technologies in the companies situated at the SMR – Sorocaba Metropolitan Region (São Paulo State, Brazil). A literature review was developed on Industry 4.0 conception and its main technologies: Cyber-Physical Systems, Internet of Things, Intelligent Factories and Big Data. Findings from the literature review were used to develop an exploratory questionnaire (survey), which was applied to SMR's companies' representatives. After that, a SWOT matrix was applied, to generate action plans to facilitate the insertion of Industry 4.0 in the companies from the SMR, based on offensive, confrontational, reinforcement and defense strategies selection. The strategies proposed on this paper should be used as an input for public political issues in the SMR, and they could also be expanded to other regions in Brazil as short and long-term strategies.

Keywords: Cyber-Physical systems; Internet of things; Smart factories; Big data; Strategies selection; Decision-making process.

Resumo: O conceito de Indústria 4.0 foi introduzido pela primeira vez na Alemanha em 2011. Também chamado de 4ª revolução industrial, este conceito é baseado na digitalização e integração entre mídias físicas e digitais com foco na automação dos processos de produção e integração em toda a cadeia de valor. Devido ao recente e rápido desenvolvimento da Indústria 4.0 nos últimos anos, este estudo efetuou uma análise SWOT para avaliar pontos estratégicos para o desenvolvimento e aplicação de tecnologias digitais nas empresas situadas na RMS - Região Metropolitana de Sorocaba (SP, Brasil). Uma revisão de literatura foi desenvolvida na concepção da Indústria 4.0 e de suas principais tecnologias: Sistemas Ciber-Físicos, Internet das Coisas, Fábricas Inteligentes e Big Data. Os resultados da revisão de literatura foram

Received Jul. 1, 2019 - Accepted Dec. 17, 2019
Financial support: São Paulo Research Foundation (FAPESP) process number 2018/01978-8.

utilizados para desenvolver um questionário exploratório (survey), que foi aplicado com representantes de empresas da RMS. Em seguida, aplicou-se uma matriz SWOT, a fim de se gerar planos de ação visando facilitar a inserção da Indústria 4.0 nas empresas da RMS, com base na seleção de estratégias ofensivas, de confronto, reforço e defesa. As estratégias propostas neste trabalho devem ser utilizadas como motivadores envolvendo questões de políticas públicas na RMS, e também poderiam ser expandidas para outras regiões do Brasil como estratégias de curto e longo prazo.

Palavras-chave: Sistemas Ciber-Físicos; Internet das coisas; Fábricas inteligentes; Big data; Seleção de estratégias; Processo de análise de decisão.

1 Introduction

The concept of Industry 4.0 (I4.0) comprises a variety of technologies that can be integrated into production processes to enable the development of the value chain and new business models resulting in processes improvements, reduced manufacturing lead times and improved organizational performance (CNI, 2016a; Kamble et al., 2018). According to Beier et al (2020), I4.0 is a sociotechnical concept and not a single technology and involves the interaction among technological, social and organizational aspects (Beier et al, 2020).

The first discussions on the topic happened in Germany around the year 2011. The aim was to encourage the discussion of future technological issues in order to develop manufacturing and to strengthen the German industry (Hofmann & Rüsch, 2017; Kagermann et al., 2013). Laureth (2014) emphasizes that I4.0 emerged from the partnership between government, industry and academia.

Since then, the concept of I4.0 has spread worldwide and there are several technologies that underlie this concept. According to Liao et al. (2017), from a technological evolution perspective, there are four stages commonly identified (Kagermann et al., 2013). The first industrial revolution results from the introduction of water and steam-powered mechanical manufacturing facilities. The second, the application of electrically-powered mass production technologies through the division of labor and the third, the use of electronics and information technology (IT) to support further automation of manufacturing (Drath & Horch, 2014). The fourth industrial revolution or I4.0 is based on heterogeneous data and knowledge integration, and encompasses disruptive technologies through Internet of Things (IoT), big data, cloud computing and cyber-physical systems (CPS) (Rajput & Singh, 2019)

FIRJAN (2016) states that, in general, Brazilian industry is placed on the transition between the second and third industrial revolutions. CNI (2016b) conducted a survey with 2,225 companies in order to identify how much the Brazilian companies are prepared for Industry 4.0. The results revealed that 43% of companies didn’t know which new technologies could stimulate the industry’s competitiveness. The lack of knowledge about the issue is greater among small companies (57%) compared to large companies (32%). Also, 48% of companies use at least one new technology and, the greater the technological intensity of the company, the greater the use of digital technologies. It was found that 27% of them use digital industrial automation with sensors for process control, 9% collect and process large amounts of data, 8% have operating conditions for flexible autonomous lines, 6% use cloud services and 4% use the internet of things. Finally, cost of implementation (66%), lack of clarity in the definition of return on investment (26%) and the structure and culture of the company (24%) were mentioned as the main internal challenges for Industry 4.0. On the other hand, 30% of the companies pointed to the country's poor infrastructure and 28% highlighted the qualification of employees as the main external challenges. Regarding the infrastructure, Silva et al. (2017) showed that most companies in Brazil use electricity as their main source of energy. However, there are many problems related to generation, transmission and distribution, making this aspect to become a great concern for the diffusion of Industry 4.0 in the country. The development of industrial policies, their regulations and support by the initiatives of public and private institutions must be spread for the promotion and implementation of the Industry 4.0 technologies (CNI, 2016a).

The transition that is required by I4.0 not only challenges the capacity companies have to innovate, but also demands new strategies and organizational models, along with organization-wide changes in the entire physical structure, manufacturing operations, technologies, human resources and management of practices (Gilchrist, 2016; Ghobakhloo, 2018). The incoming innovations affect companies' performance and, therefore, to sustain competitive advantages, Ghobakhloo (2018) reinforces the need to formulate a technological strategy that supports planning for the adoption of future technologies.

Based on this context, the present paper has studied the application of I4.0 in the Sorocaba Metropolitan Region (SMR), São Paulo State of Brazil, in order to investigate the impacts and strategies to encourage its technological development in the region from short- to long-term. It was carried out the current technological characterization of the SMR's companies in the context of I4.0 and, afterwards, it was suggested a set of action plans based on SWOT matrix to facilitate the insertion of I4.0 in the evaluated companies, based on offensive, confrontational, reinforcement and defense strategies selection.

2 Literature review: technology trends and strategies in the I4.0

Cloud computing, IoT, big data, blockchain, augmented reality, cybersecurity, additive manufacturing, CPS, and smart factories, are technologies, concepts or associated components of the I4.0 phenomenon (Lu, 2017; Ghobakhloo, 2018; Vaidya et al., 2018).

To structure this study, four components of the I4.0 were considered, according to Hofmann & Rüsch (2017), namely: CPS, IoT, Smart Factories, and Big Data which are briefly discussed below.

CPS's are the first pillar of I4.0 according to Hofmann & Rüsch (2017). As reported by Kagermann et al. (2013), the incorporation of machines, storage systematization and production facilities describe a CPS. These systems are interconnected by global networks and perform an information exchange synchronized by IoT, enabling to generate independent, controlled and known actions. These systems are objects with integrated software connected to each other or through the internet, forming a single and intelligent system that allows physical communication between the digital and real world (Kamble et al, 2018). Their integrated elements and actuators are sensors and components used to move or control a mechanism in order to insert the CPS into the outside world. The sensors capture the data, allowing them to be processed and to be available in a network. According to Ghobakhloo (2018), the CPS is tightly integrated with its users (objects, humans and machines) via internet, and is controlled and monitored by computational algorithms. As reported by Schwab (2016), by the connection between the machines a CPS environment is created linking the real and the virtual world, which can result in amazing gains in productivity and decentralization in decision-making. It is also important to note that the digitization will increase the efficiency and other management indicators of industrial sectors to reach the needs of consumers, so the real-time response and large data storage capacity provided by Big Data will be another greater differential in the new future (Davies et al., 2017).

All these integrations result in the emergence of intelligent factories, or smart factories, which are environments where the efficiency of the process is optimized through the automation and self-optimization of machines and equipment (Gilchrist, 2016). Smart Factories represent a second pillar of I4.0, according to Hofmann & Rüsch (2017) and allow a greater capacity of autonomous control and extraction of production data, which generate better communication and make the decision-making process easier to companies. They are characterized by Benesová & Tupa (2017) as the connection of production with CPS, using also IoT as an interface between machine-machine, human-machine or human-human, simultaneously with a huge data acquisition being analyzed in real time by using Big Data technology. The efficiency of the process is optimized not only by automation, but also by the self-optimization of machines and equipment (Ghobakhloo, 2018). The smart factory combines smart objetcs with big data analytics and might be able to produce customized and small-lot products efficiently and profitably (Wang et al., 2016). A characterization generated by the DELOITTE (2014) consultancy has listed five crucial factors to the successful application of Smart Factories: connectivity, optimization, data transparency, proactive system and agile flexibility.

Another pillar of I4.0 is the IoT, whose concept, according to Trappey et al. (2017) refers to a way to create a connection between the real and the virtual world by connecting the user (real person) with a network of devices, through the use of intelligent sensors and software, working on transmitting data to the network. The devices have a unique identification through the computer system to which it is connected (Kamble et al, 2018). The IoT is formed by four layers: perception, transmission, computing and application layer. The perception layer is defined by sensors and actuators whose purpose is detecting physical and sensory changes by CPS use. The transmission layer collects the information from the perception layer and sends it to the next layer through a Big Data system. The computing layer receives the transmitted information, processes and models decisions that will be sent to the application layer. The last layer is the destination of the information and the end of the IoT cycle, where the ending goal is the application for a better experience to consumers.

Lastly, the fourth pillar of I4.0 is Big Data, and according to Witkowski (2017), a Big Data has the ability to collect and process data in a faster and more efficient way in comparison to current store systems. A Big Data can separate the most important information from the least important ones, to better support the decision-making process in a company level. Huxtable & Schaefer (2016) indicate various service trends derived from Big Data that can and have been used, such as data monitoring and maintenance, reselling data, pricing models and consulting and strategic partnerships. The Big Data is presented in four dimensions, called as 4 V's (Witkowski, 2017):

- Volume: refers to the ability to collect, store and analyze a huge amount of data;
- Variety: use of different types of data, which can be structured or unstructured;
- Velocity: speed of processing and storage of data, approaching to the real time data collection;

- Value: focus on isolating what is important from unimportant data related to the type of business and the variables of interest chosen to be analyzed in a company.

With these new technological advances in the I4.0 context, it is also important to study business strategies to better cope with this new reality in the industry. Some recent papers have been done in this area, with emphasis on sustainable production (Jabbour et al., 2018; Man & Strandhagen, 2017; Yang et al. 2018), product development and servitization (Akdil et al., 2018; Huxtable & Schaefer, 2016; Lee et al., 2014), and organization steering and control (Akdil et al., 2018; Zhou et al., 2015). However, to the best of our knowledge there is no studies relating I4.0 with strategic plans into Brazilian companies, and with special focus under the SMR area. According to data from EMPLASA (2014), the SMR is composed of 27 cities grouped into three sub-regions, with an estimated population of more than 2 million people, representing 4.6% of the state population with approximately 4.03% Gross Domestic Product (GDP) of the São Paulo state. Therefore, the SMR is an important industrial region to be studied because of its participation in the São Paulo state's GDP and to promote I4.0 in Brazil as a whole.

3 Methodology

This research can be classified as exploratory and descriptive with a qualitative-quantitative approach. By means of a literature review, the main technologies regarding I4.0 in Brazil and in the world were identified. In order to qualify and quantify relevant data on the application of the main technologies of I4.0 (Big Data, Smart Factories, CPS and IoT) in SMR's companies, a survey was applied as research procedure followed by SWOT analysis to investigate and gather relevant data input for developing strategic action plans. The methodological approach used for this research can be seen in Figure 1.

A total of ten steps is organized into three main phases for this research. Phase 1 was focused on describing the literature review and results were used to develop important theoretical issues to be used in the survey.

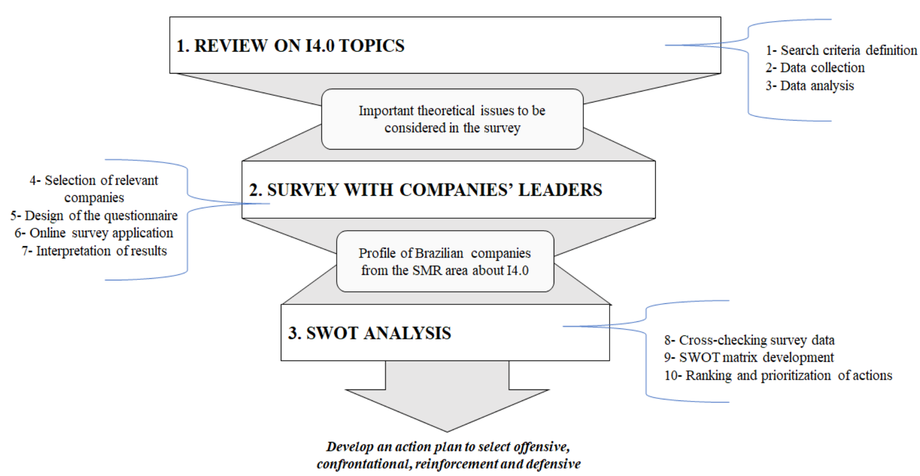

Figure 1. Methodological flow and steps for the research.

For the literature review, the search strategy was based on the four mentioned technologies of I4.0 to perform an exploratory analysis on them. The searches were performed in the Science Direct and Google Scholar databases looking for studies published from 2016 to 2018, using the following keywords: Industry 4.0; Industrie 4.0; Internet of Things; Cyber-Physical System; Smart Factories; Big Data; and strategy selection. Based on inputs found from literature, results were used to build a survey for application at the SMR area. Among relevant studies considered are Schroder (2016) who described Germany's I4.0 strategies; Chengula et al. (2018) that determined state of I4.0 across six French companies; Sung (2018) who elaborated strategies and policy implications based on survey results with manufacturing leaders to promote I4.0 in the Korea central government; and CNI (2016b) that conducted a survey with 2,225 companies in Brazil to elaborate a list of priorities for public and private investments in I4.0 topics.

Phase two of Figure 1 was composed of four steps dedicated to the survey design and application for the SMR area and its companies' leaders, and details about the strategies for data collection and analysis are shown in Table 1. The survey was performed on small, medium and large companies from the SMR, defined by intentional samples arranged through a list of companies provided by the City Hall of Sorocaba, a second list of companies provided by the São Paulo State Industries Center, at Sorocaba – CIESP Sorocaba (2020), and a third list of startups available on the company Startup Sorocaba (2020) website. The data collection instrument was a semi-structured form applied online via Google Forms platform. The questionnaire was sent to the companies, and some interviews with representatives of companies were scheduled for in loco data collection. The questionnaire had 22 questions with a large predominance of categorical closed questions and Likert scales with five levels.

The population studied was defined in 550 companies, but the sample size was obtained based on the finite population proportion. Based on Levine et al. (2000), it was determined that the sample size would be of 227 respondents, indicating that almost half of the population should respond to the survey. On the other hand, the response rate for this study was 21%.

Table 1. Main strategies for the survey data collection and analysis.

Collection instruments	Data
Companies' selection and sample size	• Email list of companies (small, medium and large sizes) from SMR • First contact approach: online submission of Google Form questionnaire • Second contact approach: in loco measurements with presential interviews
Survey with company managers and representatives using semi-structured questionnaires with open-ended questions	• Personal respondent data (name, email, position in the company, etc.) • Characteristics of the company (economic sector, size of the company, address) and products produced (type, production volumes, market served)
	• Process technological mapping, i.e., type of manufacturing physical and digital technologies already used by the company
	• Level of knowledge of respondents about I4.0 concepts and technologies • Set of strategies that the company already uses towards I4.0 advances at the company level

Finally, in phase three of Figure 1, through the results obtained with the survey, a SWOT matrix was applied. According to Batalha & Rachid (2008), the global strategic analysis of a company or sector can be carried out through the SWOT matrix, which is a tool obtained from the acronym of Strengths, Weaknesses, Opportunities, and Threats. The strengths and weaknesses are related to the internal environment and the opportunities and threats come from the external environment, being able to analyze the environment in macro and micro levels (Harrisson, 2010). The SWOT matrix was used to define the current scenario of the respondent companies. So, for each indicated issue related to strengths, weaknesses, opportunities and threats, a sequential numbering was given. The configuration of a future scenario of these same companies was defined through the intersection of internal and external factors in order to qualify action plans for the future development of the SMR. The crossing technique used according to Blog iBid System Solutions (2017) is characterized by:

- Offensive Strategy - Strengths x Opportunities: Determines the strengthening and the growth of positive aspects;
- Confrontation Strategy - Strengths x Threats: Evaluates how the strengths can reduce known threats;
- Reinforcement Strategy - Weaknesses x Opportunities: Aids to potentiate opportunities by reducing the impacts of a weakness; and
- Defense Strategy - Weaknesses x Threats: Aims to reduce the negative impacts and losses caused by weaknesses and threats.

To measure the relationship generated with the crossing of the elements from the SWOT matrix, it was established that the strategies would be classified in high, medium or low relations to facilitate the analysis of the collected survey data and the creation of action plans. Results from the action plan were also compared with other ones around the globe, as the Germany’s strategies for example, in order to providing a better comprehension about importance of each action in terms of national and international perspectives.

4 Results and discussion

From literature results, more than 500 articles were available in the period, but some of them are not directly related only to the four main technologies evaluated here (CPS, IoT, Smart Factory, and Big Data). Also, some publications do not integrate I4.0 technologies with “strategy selection” keyword, and, therefore, they were also excluded from the analysis. Thus, the results indicated that the combination with the largest number of publications are those related to Cyber-Physical Systems with 24 articles, followed by Internet of Things with 19 articles, Smart Factories with 13 articles and Big Data with 4 articles. Germany has the largest number of publications until here, with 28%. Italy was in the second place with 13% of the publications, followed by China and the United Kingdom with 8%. Therefore, Brazil was still an incipient country in the area, and more Brazilian researches should be developed to increase Industry 4.0 in the national context. On this sense, section 4.1 shows results of the survey with companies from the SMR.

4.1 Technological level and Industry 4.0 in the SMR

Regarding the survey results, 48 responses were collected through the online form. Considering the number of responses received, the study didn't reach a sample that represents statistical validation, according to Levine et al. (2000). However, the development of this survey can be considered an innovative and exploratory opportunity due to the quality of the data and the insights about the object of study under the companies that have filled the questionnaires. Regarding the size of the respondent companies, small, medium and large companies were represented, respectively by 27.1%, 35.4% and 37.5% of the responses.

The prevalent sectors in the survey were Services, Metallurgy and Miscellaneous Products, with, respectively, 10.4%, 10.4% and 8.3% of participation. The high diversity of respondent sectors is highlighted due to the variety of companies from more than twenty different sectors. Regarding the organizational level of the respondents, 40% are experts from the areas of Information Technology, Innovation and Research and Product Development, 41% belong to the Top Management, 21% are Trainees and 11% belong to the Middle Management. Throughout the data collection, it's observed that the companies tend to delegate the response of the questionnaire to specialists, as they become technical references in their area, closer to the pillars of the Industry 4.0.

The results indicated that half of the companies have dedicated areas focused on Research and Product Development (RPD) and Information Technology (IT), demonstrating their concern with market analysis and creation of new products, to increase competitiveness and innovation, and to keep up-to-date and integrated with the use of new digital technologies. Besides, 58% of the respondents reported having at least one IT area, and 33% reported that they don't have any of these dedicated areas (RPD or IT) in their organizational chart.

The predominant assembly process in 58% of the companies was classified as mixed, with both manual and automatic activities. Processes with a high level of automation have a 16% share and only 8% of the companies have fully manual assembling processes. These results indicate the presence of automation on assembly lines, however, also reflect the high use of manual labor. In other words, a great amplitude of technological level is revealed.

The use of electric power equipment in respondent companies is remarkable, as shown in Figure 2. Likewise, most companies have manual equipment, use statistical quality programs and integrated ERP systems.

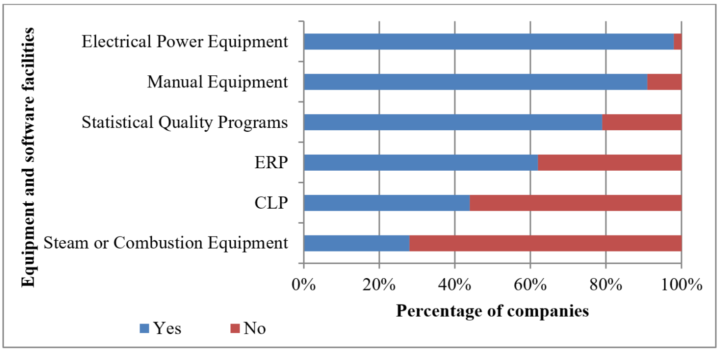

Figure 2. Representativeness of the use of equipment and software. ERP = Enterprise Resource Planning; CLP = Programmable Logic Controller. Source: Survey result.

The technological characterization of the process control is represented in Figure 3, where 83.3% of the companies said they are concerned on having adequate financial control and parameters, and 72.9% use statistical quality software. On the opposite direction, 10.4% of companies don't use any computer software.

In order to characterize the SMR's companies regarding the industrial revolutions, an analysis was performed with the results observed in Figure 3, comparing the equipment and software reported to the main aspects of each industrial revolution.

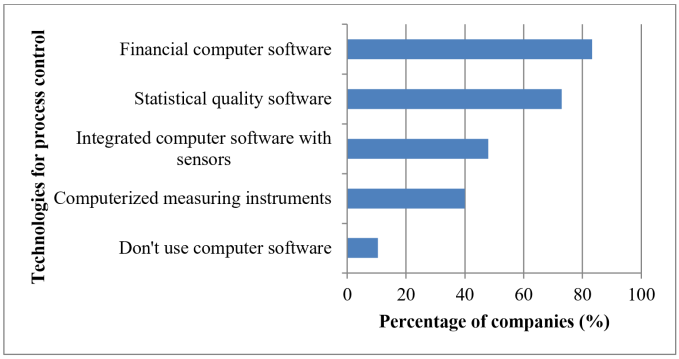

Figure 3. Technological characterization of the process control.

The usage of financial computer software was reported to be the most used technology, reported by more than 80% of the companies while just 10% do not use any computer software. Despite the low rate of companies that do not use any computer software, this fact reinforces that SMR has deep differences in terms of technological usage by firms. Table 2 present the technological characteristics associated to the second and third industrial revolutions being used in the companies from the SMR which suggests, on average, a current transition from the second to the third revolution yet.

Table 2. Technological characterization of the respondent companies.

Second Industrial Revolution	Third Industrial Revolution
Use of steam equipment	Use of electrical energy equipment
Manual assembly process	Mixed assembly process - manual and automatic
Non-use of computer software	Large use of computer programs for financial control, statistical process for quality
	Computerized measuring instruments

The survey indicated that 46% of the respondents know the concept of Industry 4.0, while 41.7% already started studies on the subject and just 12.5% had never heard about it. The results revealed that I4.0 was the most well-known expression for respondents, followed by IoT and Smart Factories. CPS was the lesser-known expression on the subject.

Eight statements were presented for respondents' evaluation, regarding impacts of I4.0 on businesses, according to a 5-point Likert scale related to respondents' agreement. The results are shown in Figures 4a and 4b.

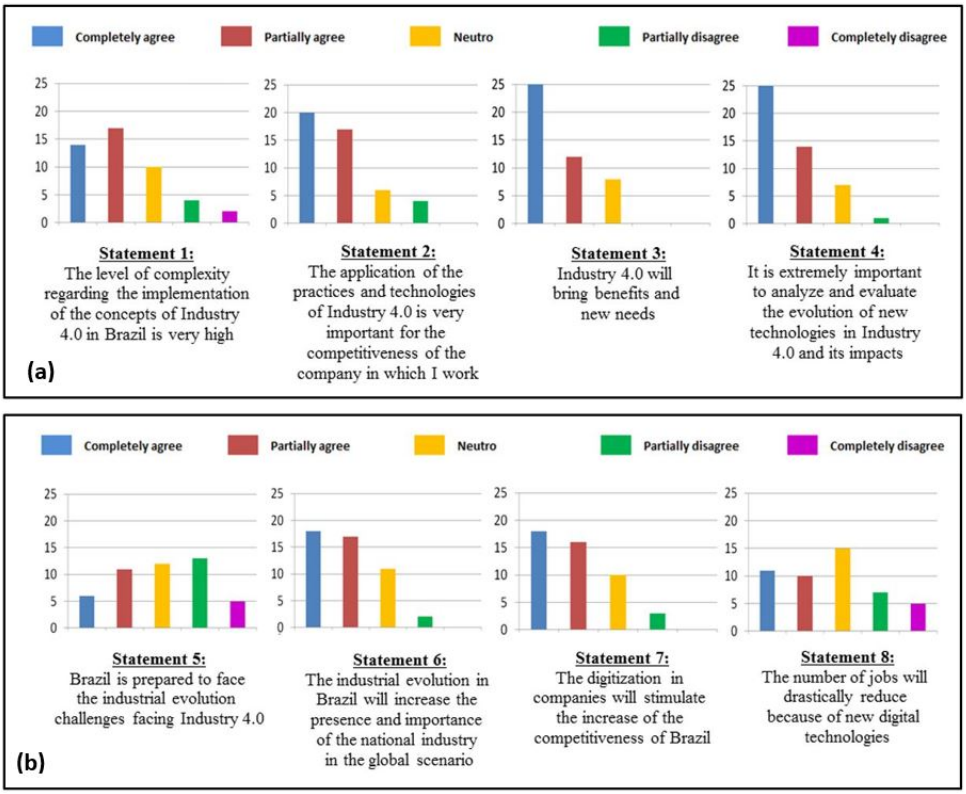

Figure 4. (a) Respondents' opinions about statements 1 to 4, on the Linkert scale; (b) Respondents' opinions about statements 5 to 8, on the Linkert scale.

Compiled results can be divided into three groups according to the level of agreement:

- Opinions with strong agreement: statements 2, 3, 4, 6 and 7;
- Opinions with partial or neutral agreement: statements 1 and 8;
- Opinions with strong disagreement: statement 5.

The statements with strong agreement reinforce the importance of new digital technologies to increase the competitiveness of national companies in the global scenario, as well as the importance of evaluating the impacts and evolution of such new technologies. Among the opinions of partial or neutral agreement, the complexity of the implantation of new technologies in Brazil and the high degree of uncertainty about the future of jobs with the intensification of these new technologies stands out. The only statement that has shown a degree of disagreement refers to the fact that Brazil is prepared to face the evolution challenges of I 4.0, indicating doubts of the respondents regarding the country's immediate suitability for this new era.

The survey indicated that 58.3% of the companies have already developed strategies to apply new technologies, and the departments identified as responsible for these developments and applications are Strategic Planning (35.7%) and Executive Management and Council (24%). In contrast, 16% of the companies indicated they didn't have departments to manage new technological projects.

The results also indicate that the most used digital technologies are: Digital Automation with process control sensors and CAD/CAM projects, with 44% of use; and Integrated Systems for Production and Research & Development, Digital Automation without sensors and Digital Automation with identification sensors, with 30%. It can be stated, therefore, that the use of automation for process control is a trend in these companies. Regarding the mapping of strategies for the implementation of digital technologies, Figure 5 show that, among the companies that applied some strategy focused on new technologies development, the most targeted field was data management. It's inferred that this occurs because of the companies' need to capture a large amount of data to trace monitoring, control and for strategic actions.

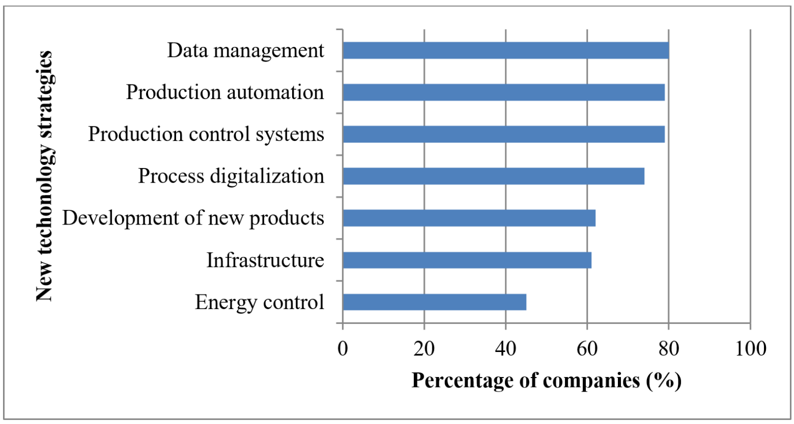

Figure 5. Application of new technology strategies.

The results obtained from our research confirms the statement of FIRJAN (2016) that classified Brazil in a transition between second and third industrial revolutions in terms of technological level. The use of manual assembly process, that is one characteristic of the second industrial revolution was mentioned in our survey in SMR, as well as the usage of electrical energy equipment, which is related to the third revolution.

CNI (2016b) showed that most of Brazilian companies didn't know the technologies associated to I4.0 and its potential for competitiveness. This statement is confirmed for SMR as it was evidenced that just 46% knew about I4.0 concepts and 12,5% had never heard about it. On the other hand, according to the survey's statements 2 and 3 (Figure 4a), there is a strong agreement that I4.0 is important for companies' competitiveness and will bring benefits and new needs.

As reported by Silva et al. (2017), most of Brazilian companies were based in electricity supply, which was also found in our survey at the SMR, with more than 95% of the reports. However, manual equipment is also pointed out for SMR companies, revealing a great diversity in terms of the organizations' processes. The survey reveals that the application of new technologies is used mainly for data management, production automation and production control systems, reported by near 80% of the respondents. From the pillars of I4.0, these applications suggest a stronger link to CPS, as this pillar enables the integration of objects, humans and machines (Ghobakhloo, 2018). These three applications are also supported by Big Data pillar that provides large storage capacity with real time response (Davies et al, 2017).

4.2 SWOT matrix and strategic action plans for SMR

The results regarding the expectations of the main benefits that I4.0 can provide are presented in Table 3. Potential benefits were indicated and classified on a scale from 1 to 5, where the classification 1 indicates high importance and the classification 5 indicates low importance. These data supported the development of the SWOT matrix.

Table 3. Main benefits assessed as high importance and low importance.

1 - High importance	5 – Low importance
Improvement of energy efficiency (58%)	Increased control and vision of process quality (23%)
Development of customized products or services (50%)	Improved worker safety (21%)
Better customer orientation (50%)	Creation of new businesses (21%)
Reduction of the time to launch new products (50%)	Culture focused on innovation (21%)
	Process optimization (21%)

Regarding the main barriers to the implementation of I4.0 technologies, the following results were obtained: 65% are related to the lack of qualified workers; 38% to the lack of information on new technologies; 38% to infrastructure; and 35% to the lack of technical standardization on the topic.

The main internal barriers pointed out were: high implantation cost (72%); lack of clarifying the return on investment (58%); lack of qualified labor (58%); training and improvement costs (48%); and software licensing and updating costs (44%).

The main threats caused by I4.0 and new technologies development were also highlighted. The responses listed three main threats: threat to lose the current jobs with 18.8%; lack of qualified labor with 12.5%; and organizational culture resistant to change with 4.2%.

The results of the SWOT matrix are shown on Figure 6.

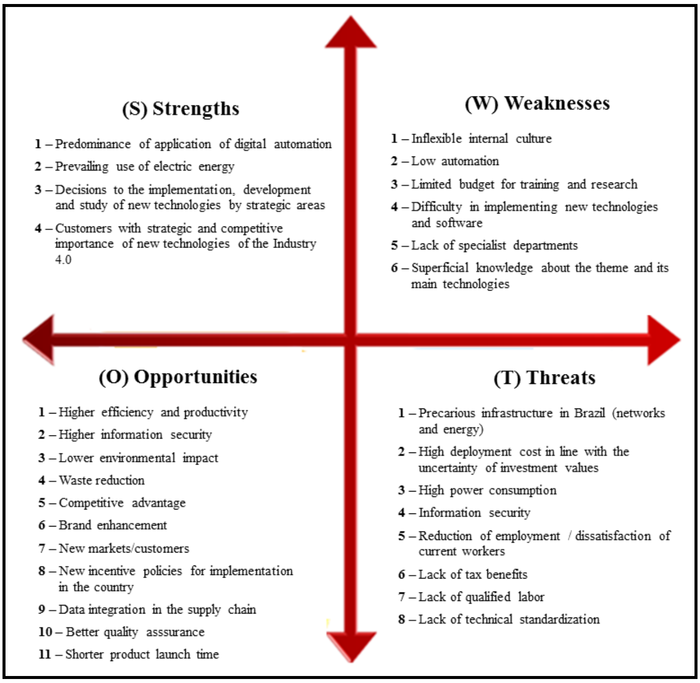

Figure 6. SWOT matrix for the Industry 4.0 implementation in SMR.

From Figure 6, action plans were proposed for the companies to achieve strategic goals related to I4.0 adoption in the SMR, as a way to the companies take a new path and strategic alignment for a common goal. The shortcuts to reach this path are presented by crossing the SWOT matrix results. The crosses were classified indicating high (H), medium (M) or low (L) relationships in order to make data analysis and creation of action plans more efficient.

4.2.1 Offensive strategy - strengths x opportunities

Chart 1 shows the results for the offensive strategy traced by crossing the strengths and the opportunities from the SWOT matrix.

Chart 1. Crossing of Strengths x Opportunities.

Strengths x Opportunities		Strengths			
		1	**2**	**3**	**4**
Opportunities	**1**	H	H	H	L
	2	L	L	H	L
	3	H	H	H	L
	4	H	L	H	L
	5	H	L	H	L
	6	M	L	H	L
	7	M	L	H	L
	8	H	H	L	H
	9	H	L	H	L
	10	H	L	H	L
	11	L	L	H	L

(H)igh, (M)edium or (L)ow Relationship.

In order to maximize the positive aspects through this cross, the following action plan was proposed:

- Make greater investment in industrial automation towards a greater technological integration;
- Perform benchmarking among companies which are already applying digital technologies;
- Create an association among companies focused on studying, exchanging information, holding events and discussing new fronts for the tactical level of strategies, to develop and apply new technologies;
- Invest collectively in Product Development laboratories with the participation of companies which are already applying Industry 4.0 technologies;
- Develop projects and establishing bilateral actions among the local government and industries, promoting advantages to companies with a high level of automation for generation and consumption of electric energy;
- Create departments with specialist areas responsible for coordinating innovation and technology application projects;

- Foment consulting projects to structure and support areas responsible for Industry 4.0 technologies.

4.2.2 Confrontation strategy - Strengths x Threats

Chart 2 summarizes the results regarding the confrontation strategy through the crossing of strengths and threats indicated by the SWOT matrix.

Chart 2. Crossing of Strengths x Threats.

Strengths x Threats		Strengths			
		1	2	3	4
Threats	1	H	H	L	L
	2	H	H	H	H
	3	H	H	M	L
	4	H	L	H	L
	5	H	L	H	H
	6	L	H	L	L
	7	H	L	H	H
	8	H	H	M	L

(H)igh, (M)edium or (L)ow Relationship.

The following action plan was established:

- Establish risk management projects and implementation and maintenance costs, coordinated by responsible areas;
- Stimulate risk management projects: analysis of network infrastructure in Sorocaba region and the quality of electricity distribution for industrial use;
- Perform financial projects about the costs involved in important topics such as: information security, electricity consumption, hiring people with focus on technology development, investment in training etc.;
- Perform studies on new forms of generation, maintenance and alternative energy replenishment, in case of central supply system fail.

4.2.3 Reinforcement Strategy - Weaknesses x Opportunities

Chart 3 presents the results from the crossing of weaknesses and opportunities of the SWOT matrix, which supports the establishment of the reinforcement strategy and its respective action plan.

Chart 3. Crossing of Weaknesses x Opportunities.

Weaknesses x Opportunities		Weaknesses					
		1	**2**	**3**	**4**	**5**	**6**
Opportunities	**1**	H	H	L	H	L	H
	2	H	H	L	H	H	H
	3	H	H	L	H	H	H
	4	H	H	L	H	L	H
	5	M	L	L	H	L	H
	6	H	L	L	H	H	H
	7	L	H	L	H	H	H
	8	L	L	H	L	H	H
	9	H	H	L	H	H	H
	10	H	H	L	H	M	H
	11	H	H	H	H	H	H

(H)igh, (M)edium or (L)ow Relationship.

By the analysis of this crossing, the following action plan was defined:

- Implement an organizational change project, aiming to change the inflexible culture and the difficulty of implementing new technologies and software, through feasible measures such as:
- Define mission, vision and values focused on organizational change towards Industry 4.0;
- Create a plan to provide training or replace managers that don't support the necessary changes towards Industry 4.0;
- Perform actions to disseminate information exchanges and internal studies, such as lectures, debates, recommendation of readings, short courses, workshops etc.;
- Define relevant criteria for selective processes to bring people with the company values;
- Create projects with the association of companies and the local government focused on a basic automation plan for companies without a good automation level to take knowledge and define implementation steps;
- Define as mandatory the existence of an IT department or an IT specialist area, depending on the size, budget and level of automation of each company, to define basic needs for Industry 4.0 with at least one specialist in industrial automation, and another specialist in data analysis, programming and information security.

4.2.4 Defense strategy - Weaknesses x Threats

Chart 4 crosses the weaknesses and threats of the SWOT matrix to elaborate the defense strategy for companies.

Chart 4. Crossing of Weaknesses x Threats.

Weaknesses x Threats		Weaknesses					
		1	2	3	4	5	6
Threats	1	L	H	L	H	L	L
	2	L	H	H	H	H	H
	3	L	H	L	L	L	L
	4	H	H	H	H	H	L
	5	H	L	H	H	L	L
	6	L	H	H	H	L	H
	7	H	H	H	H	H	H
	8	L	H	H	H	L	H

(H)igh or (L)ow Relationship.

The following action plan was established:

- Perform partnerships with universities and technological institutes to create projects and researches in order to obtain information on investments, training and internships, focused on preparing new professionals for the near future job market;
- Promote partnerships with software companies to gain training or discounts on licenses for software specialized in industrial automation, Internet of Things and Big Data;
- Lobby the government for fiscal benefit policies for: companies with investment in technical training of employees; companies with partnerships with universities for research projects; and companies with waste reduction and lower environmental impact polices;
- Stimulate the participation of companies in national and international events, looking for partnerships with institutions from countries that are advanced in the application of Industry 4.0.

In relation to SWOT matrix, the crossing technique reported by Blog iBid System Solutions (2017) enabled to draw a diagnosis on the SMR companies' position towards I4.0 and propose four action plans to accomplish the named strategies (Offensive, Confrontation, Reinforcement and Defense).

Based on the development of the SWOT analysis and the crossing of the discussed elements, it's possible to affirm that most of the actions should be taken in partnership among the private, public and academic sectors involving all the relevant stakeholders. This partnership among agents (government, industry and academy) was emphasized by Laureth (2014) as the fact that enabled I4.0 emergence. Due to this issues, the action plans for SMR regarding defensive strategy considers partnerships between universities and technological institutes to create projects/researches to prepare new professionals for the future job market as well as partnerships with software companies to provide specialized training in industrial automation, IoT and Big Data.

A closer look into SMR SWOT weaknesses show two issues that bring risks for the implementation of new technologies: the inflexible internal culture and the limited budget for training and research. As mentioned by Gilchrist (2016) and Ghobakhloo (2018), there is a need for organization-wide changes in human resources and management of practices, among others, to have a successful transition towards I4.0.

Additionally, CNI (2016b) revealed that for 28% of the companies highlighted the qualification of employees as one of the main external challenges for I.4.0. So, qualification of human resources and budget allocated to this purpose were reinforced as barriers for I4.0 on SMR. It can be noticed that, for reinforcement strategy, the action plans consider providing training or replacing managers that do not support the necessary changes towards I4.0 and also to define relevant criteria for selective processes to hire people aligned to the companies' values.

Some threats were identified in SMR SWOT analysis revealing lack of infrastructure and information security. These factors were identified previously at CNI (2016b) study when Brazil's poor infrastructure was pointed as a barrier for 30% of the companies. Aligned to confrontation strategy, the action plans for SMR considers risk management projects to analyze network infrastructure and the quality of electricity distribution for industries.

Electricity is the main source of energy in Brazil, which is considered a strength in SWOT analysis, but at the same time, problems related to generation, transmission and distribution of energy were previously reported by Silva et al (2017) as a barrier for I4.0 diffusion. This paradigm was also identified in our study. The precarious infrastructure in Brazil in terms of network and energy was considered a threat in SWOT analysis while the prevailing use of electric energy is a strength. According to the offensive strategy, that joins strengths and opportunities, among other actions to stimulate investments on technology, the proposed action plan stimulates the promotion of advantages to companies with a high level of automation for generation and consumption of electric energy.

Lastly, it is important to note that the proposed action plan is in line with other ones around the world. For example, Schroder (2016) who described Germany's I4.0 strategies also proposed some working groups with objectives very similar to those described on this paper. Some offensive strategies were investment-heavy industries (e.g., stocktaking and quantification of private and state investments) and some reinforcement strategies for Schroder (2016) were based on acceptance-attractive industry by strengthening citizen dialogue on I4.0 and developing new communication channels strategies. On the other hand, Chengula et al. (2018) determined I4.0 strategies across six French companies, based on six dimensions to strengthen product development process, steering and control, manufacturing operations, smart services, big data and organization structure. Results from Chengula et al. (2018) were like those found on this paper mainly in terms of the reinforcement strategies defined, such as investments required on specialist knowledge and implementation of advanced technology in all dimensions to achieve a high standard in I4.0. Finally, Sung (2018) elaborated strategies for I4.0 in Korea and results were classified in four groups of action plans with similar content than the proposed ones for SMR. However, it is important to note that some differences can be found as well when comparing the proposed SMR's I4.0 strategies with strategies from other countries and regions: 1) the abovementioned publications did not perform a SWOT analysis as we did on this paper, therefore, some external perspectives are missed specially in terms of establishment of defensive strategies; and 2) as I4.0 is still in an embryonic stage of development in Brazil, the need for training of qualified professionals is more necessary than in other countries and regions, with the exception of Sung (2018) who also highlighted this aspect as essential for the context Korean.

5 Conclusion

This study has evidenced the growth of the scientific interest about Industry 4.0, emerged from Germany, where the expression was launched. From the four components identified as the pillars of I4.0 (IoT, CPS, Smart Factories, Big Data). CPS was the most prolific term in literature, however, among the companies participating in the survey, the CPS was the least known expression by the interviewed people. Therefore, it’s possible to suppose that such misinformation, together with the importance of the integration of the physical and digital media proposed by the CPS, were the most relevant factors to develop the research.

The results of the survey indicate that some of the companies from the SMR are investing in new studies and new technologies, however, their mapped technological level, on average, presents a transition from the second to the third industrial revolution. This fact points out that the SMR is still far from the full implementation of the concept of Industry 4.0, including companies with superficial knowledge on this subject. The characterization of different levels of implementation of I4.0 configure an academic contribution of this study. It was also possible to identify in which processes I4.0 technologies are used, according to its technological level, and possible applications towards its full implementation.

SWOT analysis have supported the proposal of action plans to apply concepts and technologies related to I4.0 in the SMR’s companies, through the reduction of barriers and the creation of guidelines for greater engagement. The design of action plans for SMR companies can be considered a significant contribution for the society, as it points out strategies towards I4.0 implementation that can be followed by companies in different technological levels.

The action plans proposed from offensive, confrontation, reinforcement and defense strategies, derived from SWOT matrix, aim to strengthen in companies the focus on greater investments, benchmarking with companies in an advanced level in Industry 4.0, and with associations or partnerships with other companies, universities or technological institutes. Besides that, it was discussed about stimulating the development of studies and projects of management and organizational change towards Industry 4.0, aiming to the change of the culture of organizations. Also, the developed action plan shows some similarities with other ones developed some years ago for other countries, such as Germany, France and Korea.

Regarding the limitations of this research, it is important to register that the study was conducted with just 48 responses (21% of response rate), which restricts its amplitude. However, it can provide important insights for SMR as an exploratory study. The present paper allowed to achieve the main objectives proposed with emphasis on the mapping of the current scenario and the creation of action plans for a future scenario projection that stimulate the application and development of the I4.0 in the SMR’s companies.

Considering future possibilities of research, the contribution of this work in the academic and industrial scope of SMR presents a real possibility of replication in other regions, as well to follow the evolution of the SMR through the monitoring of application of the proposed action plans in practice from short- to long-terms.

Acknowledgements

The authors are grateful by the financial support provided by FAPESP (2018/01978-8).

References

Akdil, K. Y., Ustundag, A., & Cevikcan, E. (2018). Maturity and readiness model for Industry 4.0 strategy. In A. Ustundag & E. Cevikcan, *Industry 4.0: Managing The Digital Transformation* (Springer Series in Advanced Manufacturing). Cham: Springer.

Batalha, M. O., & Rachid, A. (2008). Estratégia e organizações. In M. O. Batalha & A. Rachid, *Introduction in production engineering.* Rio de Janeiro: Elseiver.

Beier, G., Ullrich, A., Niehoff, S., Reißig, M., & Habich, M. (2020). Industry 4.0: how it is defined from a sociotechnical perspective and how much sustainability it includes – A literature review. *Journal of Cleaner Production*, 259, 120856. http://dx.doi.org/10.1016/j.jclepro.2020.120856.

Benesová, A., & Tupa, J. (2017). Requirements for Education and Qualification of People in Industry 4.0. *Procedia Manufacturing*, 11, 2195-2202. http://dx.doi.org/10.1016/j.promfg.2017.07.366.

Blog iBid System Solutions. (2017). *Swot Cruzada o que é e como aplicar essa estratégia ao seu negócio*. Retrieved in 2018, April 26, from https://ibid.com.br/blog/swot-cruzada-o-que-e-e-como-aplicar-essa-estrategia-no-seu-negocio

Centro das Indústrias do Estado de São Paulo – CIESP Sorocaba. (2020). Retrieved in 2020, March 18, from http://www.ciespsorocaba.com.br/

Chengula, Z., Rubio Morato, M. A., Thurner, T., Wiedensohler, Y., & Martin, L. (2018). State of Industry 4.0 across six french companies. In *IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)* (pp. 1-8). Piscataway: IEEE. http://dx.doi.org/10.1109/ICE.2018.8436256.

Confederação Nacional de Indústria – CNI. (2016a). *Desafios para indústria 4.0 no Brasil.* Brasília: CNI.

Confederação Nacional de Indústria – CNI. (2016b). *Special Survey – Industry 4.0*. Brasília: CNI. Retrieved in 2017, March 18, fromhttp://www.portaldaindustria.com.br/estatisticas/sondesp-66-industria-4-0/

Davies, R., Coole, T., & Smith, A. (2017). Review of socio-technical considerations to ensure successful implementation of Industry 4.0. *Procedia Manufacturing*, 11, 1288-1295. http://dx.doi.org/10.1016/j.promfg.2017.07.256.

DELOITTE. (2014). *Industry 4.0 challanges and solutions for the digital transformation and use of exponential technologies*. United Kingdom: Deloitte. Retrieved in 2018, April 22, from http://www2.deloitte.com/content/dam/Deloitte/ch/Documents/manufacturing/ch-en-manufacturing-industry-4-0-24102014.pdf

Drath, R., & Horch, A. (2014). Industrie 4.0: hit or Hype? *Industrial Electronics Magazine*, 8(2), 56-58. http://dx.doi.org/10.1109/MIE.2014.2312079.

Empresa Paulista de Planejamento Metropolitano S/A – EMPLASA. (2014). *Região Metropolitana de Sorocaba*. Retrieved in 2018, May 25, from https://www.emplasa.sp.gov.br/RMS

Federação das Indústrias do Rio de Janeiro – FIRJAN. (2016). *Panorama da Inovação - Indústria 4.0*. Rio de Janeiro: FIRJAN.

Ghobakhloo, M. (2018). The future of manufacturing industry: a strategic roadmap toward Industry 4.0. *Journal of Manufacturing Technology Management*, 29(6), 910-936. http://dx.doi.org/10.1108/JMTM-02-2018-0057.

Gilchrist, A. (2016), *Industry 4.0: the industrial internet of things*. Heidelberg: Springer. http://dx.doi.org/10.1007/978-1-4842-2047-4.

Harrisson, J. P. (2010). Strategic planning and SWOT analysis. In J. P. Harrison, *Essentials of strategic planning in healthcare*. Chicago: Health Administration Press.

Hofmann, E., & Rüsch, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry*, 89, 23-34. http://dx.doi.org/10.1016/j.compind.2017.04.002.

Huxtable, J., & Schaefer, D. (2016). On servitization of the manufacturing industry in the UK. *Procedia CIRP*, 52, 46-51. http://dx.doi.org/10.1016/j.procir.2016.07.042.

Jabbour, A. B. L. S., Jabbour, C. J. C., Foropon, C., & Godinho, M., Fo. (2018). When titans meet – Can Industry 4.0 revolutionise the environmentally sustainable manufacturing wave? The role of critical success factors. *Technological Forecasting and Social Change*, 132, 18-25. http://dx.doi.org/10.1016/j.techfore.2018.01.017.

Kagermann, H., Helbig, J., Schuh, G., & Wahlster, W. (2013*). Securing the future of German manufacturing industry. Recommendations for implementing the strategic initiative Industrie 4.0. Final report of the Industrie 4.0 Working Group*. München: ACATECH.

Kamble, S. K., Gunasekaran, A., & Gawankar, S. A. (2018). Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives. *Process Safety and Environmental Protection*, 117, 408-425. http://dx.doi.org/10.1016/j.psep.2018.05.009.

Laureth, W. C. (2014). Convergência Tecnológica, Educação e Trabalho: do discurso social global aos desafios regionais. *Revista da Associação Brasileira de Estudos do Trabalho*, 13, 279-293.

Lee, J., Kao, H.-A., & Yang, S. (2014). Service Innovation and Smart Analytics for Industry 4.0 and Big Data Environment. In *Proceedings of the 6th CIRP Conference on Industrial Product-Service Systems* (pp. 3-8). USA: Elsevier. http://dx.doi.org/10.1016/j.procir.2014.02.001.

Levine, D. M., Berenson, M. L., & Stephan, D. (2000). *Estatística: teoria e aplicações usando microsoft excel em português.* Rio de Janeiro: LTC.

Liao, Y., Deschamps, F., Loures, E. F. R., & Ramos, L. F. P. (2017). Past, present and future of Industry 4.0 - a systematic literature review and research agenda proposal. *International Journal of Production Research*, 55(12), 3609-3629. http://dx.doi.org/10.1080/00207543.2017.1308576.

Lu, Y. (2017). Industry 4.0: a survey on technologies, applications and open research issues. *Journal of Industrial Information Integration*, 6, 1-10. http://dx.doi.org/10.1016/j.jii.2017.04.005.

Man, J. C., & Strandhagen, J. O. (2017). An Industry 4.0 research agenda for sustainable business models. *Procedia CIRP*, 63, 721-726. http://dx.doi.org/10.1016/j.procir.2017.03.315.

Rajput, S., & Singh, S. P. (2019). Industry 4.0 - challenges to implement circular economy. *Benchmarking*, BIJ-12-2018-0430. http://dx.doi.org/10.1108/BIJ-12-2018-0430.

Schroder, W. (2016). *Germany's Industry 4.0 strategy Rhine capitalism in the age of digitalization* (17 p.). Alemanha: Friedrich-EbertStiftung.

Schwab, K. (2016). *The fourth industrial revolution*. Geneva: World Economic Forum.

Silva, E., Coutinho, W., Fo., & Araújo, F. (2017). A qualidade da energia elétrica no contexto da quarta revolução industrial – Indústria 4.0. In *Anais do XXXVII Encontro Nacional de Engenharia de Produção*. Rio de Janeiro: ABEPRO. http://dx.doi.org/10.14488/ENEGEP2017_TN_STP_239_389_32636.

Startup Sorocaba. (2020). Retrieved in 2020, March 18, from https://startupsorocaba.com/

Sung, T. K. (2018). Industry 4.0: a Korea perspective. *Technological Forecasting and Social Change*, 132, 40-45. http://dx.doi.org/10.1016/j.techfore.2017.11.005.

Trappey, A. J. C., Trappey, C. V., Hareesh Govindarajan, U., Chuang, A. C., & Sun, J. J. (2017). A review of essential standards and patent landscapes for the Internet of Things: a key enabler for Industry 4.0. *Advanced Engineering Informatics*, 33, 208-229. http://dx.doi.org/10.1016/j.aei.2016.11.007.

Vaidya, S., Ambad, P., & Bhosle, S. (2018). Industry 4.0 – A Glimpse. *Procedia Manufacturing*, 20, 233-238. http://dx.doi.org/10.1016/j.promfg.2018.02.034.

Wang, S., Wan,J., Zhang, D., Li, D., & Zhang, C. (2016). Towards smart factory for Industry 4.0: a self-organized multi-agent system with big databased feedback and coordination. *Computer Networks*, 101,158-168. https://doi.org/10.1016/j.comnet.2015.12.017.

Witkowski, K. (2017). Internet of things, big data, Industry 4.0 – innovative solutions in logistics and supply chains management. *Procedia Engineering*, 182, 763-769.

Yang, S., M. R, A., Kaminski, J., & Pepin, H. (2018). Opportunities for Industry 4.0 to support remanufacturing. *Applied Sciences (Basel, Switzerland)*, 8(7), 1177. http://dx.doi.org/10.3390/app8071177.

Zhou, K., Liu, T., & Zhou, L. (2015). Industry 4.0: towards future industrial opportunities and challenges. In *Proceedings of the 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD)* (pp. 2147-2152). Piscataway: IEEE.