

Indianapolis, IN –USA

Collaborative Research Network on Supply Chain 4.0

ISSC4²⁰¹⁹

October 24–28th, 2019.

III International Symposium on Supply Chain 4.0:

**Challenges and Opportunities of Digital
Transformation, Intelligent Manufacturing
and Supply Chain Management 4.0**

Additional information:

Network: <http://supplychain4.org>

Symposium: <http://supplychain4.org/issc4-2019/>

Joint-organized by
SC4 (Collaborative Research Network on Supply Chain 4.0),
Conexus Indiana www.conexusindiana.com, and
Butler University, Lacy School of Business www.butler.edu/lacyschool

Proceedings

of the

Third International Symposium on Supply Chain 4.0: Challenges and Opportunities of Digital Transformation, Intelligent Manufacturing and Supply Chain Management 4.0

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Annual Publication; v.03

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3rd International Symposium on Supply Chain 4.0

S53a Proceedings of the 3rd International Symposium on Supply Chain 4.0: Challenges and Opportunities of Digital Transformation, Intelligent Manufacturing and Supply Chain Management 4.0. Indianapolis, Indiana, USA, 24-28th Oct 2019 / Ed. SC4 - Collaborative Research Network on Supply Chain 4.0. Butler University, Lacy School of Business, 2019.

Theme: Challenges and Opportunities of Digital Transformation, Intelligent Manufacturing and Supply Chain Management 4.0.

ISSN: 2594-8342, v.03

1.Symposium. 2. Supply Chain 4.0. 3. 4th Industrial Revolution.

I. SC4 - Collaborative Research Network on Supply Chain 4.0 Butler University, Lacy School of Business.

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Welcome message

ISSC4 III – Welcome Message

On behalf of the Lacy School of Business at Butler University, I want to welcome all participants of the 3rd International Symposium on Supply Chain 4.0 (ISSC4 – 2019) to Indianapolis, Indiana. It is indeed a great honor to host the first ISSC4 in the U.S. during this beautiful fall weather. With four days of intense program, we are excited to share a little bit of what Indy and this great region has to offer.

In the first two days of the conference, we had the great opportunity to partner with Conexus Indiana, co-sponsoring their supply chain case competition that involved 200+ students and representatives of more than 50 different companies. The following two days were filled with 43 papers, presented by 32 scholars, from 22 universities in 5 different countries who all met in Indy, either in person or using virtual technology. The final day of the conference was full of real-world learning and networking opportunities with the visits to Toyota Material Handling and Faurecia Clean Mobility plants.

Prof. Janaína Siegler, Ph.D.
President of the Organizing Committee

Prof. Luis Antonio de Santa-Eulalia, Ph.D.
President of the Scientific Committee

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ISSC4 –2019| Detailed Program

Third International Symposium on Supply Chain 4.0: Challenges and Opportunities of Digital Transformation, Intelligent Manufacturing and Supply Chain Management 4.0
 October 26–28th, 2019, Indianapolis, Indiana, USA
 Joint-organized by SupplyChain4.org, Conexus Indiana and Butler University (Lacy School of Business)
 Website: supplychain4.org/issc4-2019/

Saturday, October 26th		Sunday, October 27th		Monday, October 28th
7:30 –8:30	Registration			
8:30 –9:00	Open Ceremony			
Thematic Session - Education in the era of Industry 4.0 (Chair: Prof. Fabiano Armellini)		Thematic Session - Humans and Environment (Chair: Prof. Elias Ribeiro da Silva)		Industrial Visit 1 (transportation is provided)
09:00 –10:30	Teaching Digital Transformation	Sven Packmohr and Kristin Vogelsang.	Theoretical framework the Industry 4.0 risks from sustainability perspective	Faurecia (Columbus, Indiana) Transportation is provided
	Analysis of the main categories of Skills oriented to the context of the Industry 4.0	Leonardo Breno Pessoa Da Silva, Joseane Pontes, Luis Mauricio Martins De Resende and Rui Tadashi Yoshino.	Historical perspective of the industrial revolutions: how we got here Industry 4.0	
	A Benchmarking Study of Industry 4.0 Initiatives in Engineering Education	Amanda Guerra De Araujo Cruz and Fabiano Armellini.	Marketing 4.0 and Social Responsibility: A Bibliometric Contribution	
	Proposal for a Systematic Literature Review on the Theme Education 4.0: a contribution to the improvement of Engineering teaching	Bernardo Perota Barreto, Joseane Pontes, Fernanda Tavares Treinta and Rui Tadashi Yoshino.		
10:30 –11:00 Coffee Break				
Thematic Session - Supply Chain 4.0 (Chair: Prof. Luis A. De Santa-Eulalia)		Thematic Session - Emerging Technologies (Chair: Prof. Fabiano Armellini)		
11:00 –12:30	The contribution of KPIs to build resilience in the supply chain in the context of Industry 4.0	Enzo Gabriel Nascimento Domingos, Heric Serafim Luciano, Luciana Rosa Leite, Andrea Lago Da Silva, Fabiano Armellini and Carla	The influence of blockchain in business ecosystems	Lunch Lunch with Keynote Speaker and Closing Ceremony
	The supply chain in the industry 4.0 context in small and medium enterprises: an international landscape	Marcelo Silva De Andrade.	Assessment of potentially attractive tasks to collaborative robotics application: A case study based on electronics industry	
	Digital Supply Chain: A literature review	Priscila Laczynskide Souza Miguel, Kenyth Alves de Freitas and Alexandre Vicente Bittar.	Blockchain in sustainable supply chains: a literature review about benefits and applications	
	Business Cluster Identification Leveraging Self-Organizing Maps	Francis Bowen and Janaina Siegler.	Big Data with Data Lake: A Case of a Paper Industry	
12:30 –14:00 Lunch				
Thematic Session - Digital Transformation (Chair: Prof. Elias Ribeiro da Silva)		SupplyChain4.org Meetings - registration required		Industrial Visit 2 (transportation is provided)
14:00 –15:30	Human Resources Management and Digital Transformation in SMEs: How to Manage Paradoxes?	Sandrine Berger-Douce, Elaine Mosconi and Luis Antonio De Santa-Eulalia.	Presentation of the SupplyChain4.org Network	Toyota Forklift (Columbus, Indiana) Transportation is provided
	Market of Rules: A new business through combination of people expertise and automation from Industry 4.0	Anibal Tavares De Azevedo.	Working Groups about the Network Development	
	Digital Business Transformation in the Fourth Industrial Revolution: A Systematic literature Review of Maturity Readiness	Martin Beliveau, Luis Antonio De Santa-Eulalia, Elaine Mosconi and Nathalie Cadieux.		
	The Effects of Industry 4.0 Implementation on Organizational Value Chain.	Thales Volpe Rodrigues, Luis Mauricio Martins De Resende, Rui Tadashi Yoshino and Joseane Pontes.	All participants	
15:30 –16:00 Coffee Break				
Thematic Session - Knowledge, Collaboration and Innovation (Chair: Prof. Janaina Siegler)		SupplyChain4.org Meetings - registration required		
16:00 –17:30	Implications of blockchain technology in Knowledge Management: a literature review	Talita Frozza, Edson Pinheiro De Lima, Elias Ribeiro Da Silva and Flaviana Casella Galli.	Planning the next Steps of the SupplyChain4.org	All participants
	Social Learning for the Industry 4.0 context	Leandro Feitosa Jorge, Emiliano Oliveros, Elaine Mosconi.		
	Startups and the usage of Social Media for co-innovation	Anna Laura Almeida, Elaine Mosconi, Jeremi Doyon-Rochand Leandro Feitosa Jorge.		
	Collaboration between startups and industry to face the challenges of the Fourth Industrial Revolution: a Systematic Literature Review	Ivan Caputo Nunes, Fernanda Tavares Treinta, Joseane Pontes, Rui Tadashi Yoshino and Rubia Carla Mendes.		
Linking Industry 4.0, Learning Factories, and Simulation Modeling: testbeds and proof-of-concept experiments	William De Paula Ferreira, Arun Palaniappan, Fabiano Armellini, Luis Antonio De Santa-Eulalia, Elaine Mosconi and Guillaume Marion.	Closing Session	Prof. Janaina Siegler, Butler University	
17:30 –19:30 Cocktail				
20:00 –00:00 Social Activity –Band Show: Steep Canyon Rangers (Schrott Center for the Arts –Butler University)				
All presentations will be at room LSB 203 (Lacy School of Business), Butler University				

Online transmissions: Join Zoom Meeting at <https://butleru.zoom.us/j/704666126> **Or dial by your location:** +1 646 558 8656 US (New York); +1 647 558 0588 (Canada); +5511 4680 6788 (Brazil); +46850 539 728 (Sweden)
Meeting ID: 704 666 126 **Find your local number:** <https://zoom.us/j/agnW4WCad>

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Thematic Session
Education in the era of Industry 4.0
(Chair: Prof. Fabiano Armelini)

Teaching Digital Transformation

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Abstract: Digital Transformation (DT) is a megatrend (Fitzgerald et al. 2013) which affects all parts of society (Parviainen et al. 2017) including education. An education in DT will prepare students to better cope with its opportunities and challenges. Missing skills is a barrier to DT mentioned rather frequently in research (Vogelsang et al. 2019). To come to full DT adoption, usage of its advantages, and a critical reflection of its disadvantages are substantial. A reflective approach to DT needs to find its way into the education of the current and future workforce (Frey and Osborne 2013). Study programs focusing on DT are evolving at the moment. A search on studis-online.de shows 124 programs for Digital Business and 6 for Digital Transformation in Germany.

This abstract reflects on how to design a course on a topic which is fast evolving and which might change the nature of education, too? A DT course was taught to working graduate students attending an evening program in Business Studies during the spring semester 2019 in Istanbul, Turkey. The course delivery was rather traditional with classroom lectures, including 70% of compulsory attendance. These restrictions were set by the program management. Content-wise the lectures focus on discussing cases of successful DT companies during the lectures. Assignments are done as case study, data collection from the field of DT, and final exam. We followed (Krathwohl 2002) to reflect upon the course development. Feedback data from participating students were collected to serve as a base for analysis. Feedback was collected from 9 out of 14 participants, which represents a rather small population.

Textbooks play an essential role in traditional teaching. A challenge the authors faced in the absence of a dedicated textbook. Instead, a more accessible book written by consultants was chosen. The students reported they liked the substitution of the classical textbook. An assignment for the students during the course was to interview company experts who were involved in the transformation of companies. This approach leads to a combination of teaching, research, as well as gaining practical skills in communication. One of the students reported back that “Only now, I understand the challenges companies face”. The course design based on consulting literature and own small research assignment seems to engage students in the topic. A more research-based lecture approach is a good fit for students with work experience in advanced studies.

The student body is not the regular one, as the participants were graduate students working for some years already. The whole master program was taught in the evening to attract part-time students. Future research needs to focus on bigger and regular populations like full-time undergraduate students as well as whole study programs. More digital-enabled forms of learning and instructional design need to be considered. During summer 2019 this course was held as an online version, introducing DT elements into the course delivery. For the delivery, Adobe Connect was used, and videos of the lectures were recorded. From this video material, further applications such as flipped-classroom concepts could evolve.

Keywords: Digital Transformation, Course Development, Higher Education

References

1. Fitzgerald, Michael, Nina Kruschwitz, Didier Bonnet, and Michael Welch. 2013. “Embracing Digital Technology: A New Strategic Imperative.” *MIT Sloan Management Review* 55 (2): 1–12.
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4. Parviainen, Päivi, Maarit Tihinen, Jukka Kääriäinen, and Susanna Teppola. 2017. "Tackling the Digitalization Challenge: How to Benefit from Digitalization in Practice." *Developing Offshore Outsourcing Practices in a Global Selective Outsourcing* 5 (1): 63–77.
5. Vogelsang, Kristin, Kirsten Liere-Netheler, Sven Packmohr, and Uwe Hoppe. 2019. "Barriers to Digital Transformation in Manufacturing: Development of a Research Agenda." In *Proceedings of the 52st Hawaii International Conference on System Sciences*.

Analysis of the main categories of skill oriented to the context of the Industry 4.0

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Abstract: The challenges arising from Industry 4.0 due to changes in the productive environment are the targets of constant investigations, mainly linked to the impacts generated by the means of production and the society affected by it. Not only linked to the productive systems, but the forms of work will have significant changes, mainly related to the skills needed to overcome these challenges. Thus, the objective of this paper is to analyze the main categories of skills oriented to the industry 4.0 by means of a content analysis. To achieve the objective, a systematic literature review was necessary, with searches in the databases Scopus, Science Direct and Web of Science, in order to raise the necessary bibliography. The selection of studies was structured by the PRISMA methodology. After selection, content analysis made it possible to categorize skills, subdivided into soft, hard and digital skills contextualized with Industry 4.0. With this structured knowledge, companies can leverage efforts in significant drills to strengthen the skills of their collaborators by inserting them in the context of Industry 4.0. This research enables a greater understanding of the skills necessary for the changes proposed by Industry 4.0, impacting directly on the human resource management of organizations on the point of view of potential trainings and management of its collaborators. It also enables knowledge for new professionals who will be inserted in this new reality. The paper presents a set of skills specifically geared to the challenges of Industry 4.0, structuring a series of studies already developed in this subject.

Keywords: Industry 4.0, Skills, Content Analysis, PRISMA.

1. Introduction

The challenges arising from Industry 4.0 are the result of the junction of new technologies of intelligent and autonomous devices. [1] It states that this new revolution will facilitate the interconnectedness of the traditional industry due to the proliferation of smart and connected devices.

The Industry 4.0 will have influence on important transformations in the industry, mainly linked to the digitization of production, due to management systems, control and planning will be autonomous and aided by the use of information technology [2]. Another influence will be the automation due to the use of intelligent machines and the linking of the production chain in various locations, and the data exchange allows the work to be carried out in different locations and, mainly, in collaboration with Several companies along the supply chain.

The impacts described with the adoption of the technologies employed in Industry 4.0 are diverse, being linked to the efficiency of the productive system, energy saving, quality improvement and cost reduction [3, 4]. But not only does this new revolution change the production process, the way employees perform their activities will also undergo changes, mainly due to the autonomy of machines, no more human resources are needed operating machines and yes collecting a set of data that will serve as a basis in decision-making.

The skill is the capacity to apply knowledge and use the know-how to perform a task [5]. In a sense, it is to identify whether the collaborator is able to develop a particular task within a specific context. Some scholars propose a categorization of skills, such as soft skills, being personal, as the ability to manage oneself and interpersonal, as a way of dealing with other people. The hard skills are technical skills that involve work with specific equipment, data and software [6, 7]. Already a new category, the digital skills, understands the basic skills of digital literacy and the specific for information technology professionals [8].

Given the new challenges required for the implementation and operation of the technologies employed by Industry 4.0 and how the forms of work will change over time, it is necessary to investigate the skills required to effectively comply with the Work-related activities. Therefore, the need to know more specifically which skills are oriented to the context of the Industry 4.0.

Thus, the objective of the present study is to analyze the main categories of skills necessary for the effective development of work oriented to the context of the Industry 4.0, through a content analysis. For this purpose, a systematic literature review was necessary in order to identify these skills and categorize them and contextualize them according to the context of the Industry 4.0.

The present study is structured in four phases, initially presenting the introduction with the contextualization, justification and objectives to be attained. Therefore, the methodology of applied research is presented, with the methods and procedures applied. Subsequently, the results of the content analysis will be presented, where the skills will be systate and categorizing them for better identification. Finally, the final considerations followed by the references used.

2. Methodology

The process of Systematic Literature Review (SLR) systematizes studies sought by means of a selection of keywords to identify more relevant studies on the subject investigated. For better organization, systematization and identification of the studies that were analyzed, the methodology was used PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), which uses the search in database pertinent to the theme Searched by selecting Keywords. After the initial search, we used a series of filters proposed by the methodology until reaching a specific final portfolio for the development of the study [9]. First, the research intentions were established through initial searches to identify the keywords that demonstrated the authors' intentions. Two research axes were identified: Industry 4.0 (Axis 1) and Skill (Axis 2). Due to a variety of words that pass the same translation, mainly related to axis 1, it was systate combinations of keywords to encompass to largest number of possible studies. This schematization is presented in Figure 1.

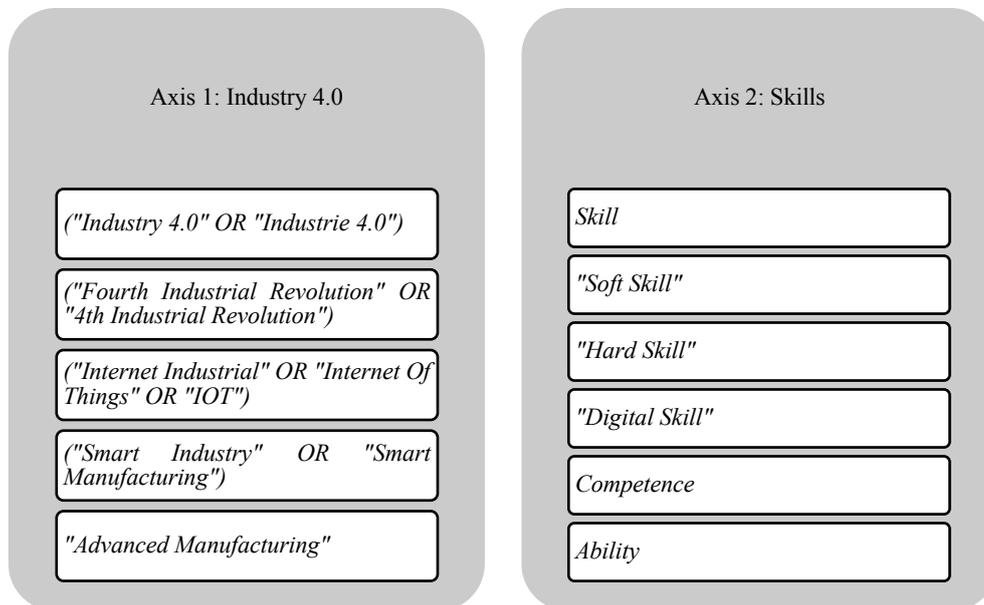


Figure 1: Axis of Research and Keywords.

Mainly related to Industry 4.0, there are many words describing this axis due to the countries that most study this new revolution have created their own terms. For example, Industry 4.0 and Industrie 4.0 is a German term, already in the United States is used Smart Manufacturing or Advanced Manufacturing. Thus, it was necessary to use the Boolean index (OR) to cover all the terms found. For the second axis, it was researched beyond only the term that represents skills, also used its categories that intended to organize in the present study, besides some variations found in preliminary studies.

As a database, the following were defined: Web Of Science, Science Direct and Scopus. These bases were chosen by the quantity of journals of great relevance in their collection, which present publications in the area belonging to Engineering III. As preliminary filters, only research articles and review articles were chosen, and the keywords searched should be in the title, abstract or keywords (title, Abstract or keywords). Subsequently, the articles were organized with the help of the Software Mendeley® and JabRef® for better ordering and beginning of the filtration process. Figure 2 organizes the data referring to the quantitative entry of the articles and their outputs according to the filters applied.

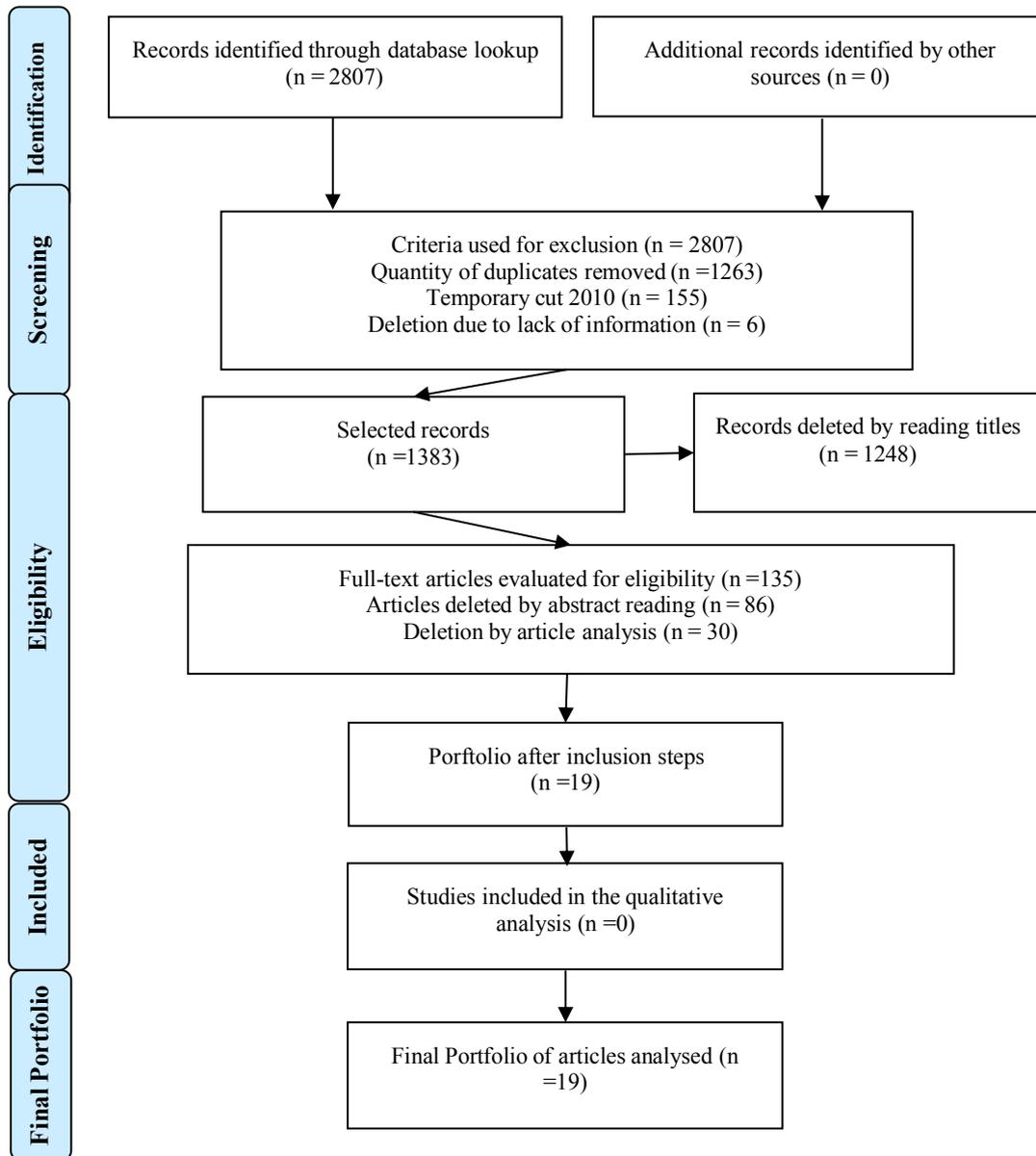


Figure 2: PRISMA Methodology

Therefore, it can be identified that from the initial search portfolio (2807 articles), the exclusion criteria proposed by the PRISMA methodology were applied. Among the exclusion criteria, such as temporal cut, cut by analysis of title, summary and complete article, a final portfolio of 19 articles to be analyzed and catalogued by content analysis was obtained. The focus of this analysis is to extract the skills cited therein and presenting a context and the authors who put those skills will be necessary for the effective development of the work in the context of the 4.0 industry.

3. Results

Content analysis focused on identifying the skills mentioned throughout the analyzed texts and bringing a contextualization focusing on the 4.0 industry. To select the studies used the methodology of selection of PRISMA studies, as presented previously.

Thus, table 2 presents the skills mentioned by the authors as important for the development of work in the context of the 4.0 industry. As a selection criterion and to corroborate the importance of such ability, we opted to present the skills that were mentioned minimally in two articles.

Table 1: Skill needed for the context of Industry 4.0.

SOFT SKILL		
Skill Required	Context	Authors
Communication Skill	The Industry 4.0 focuses mainly on multidisciplinary work and in teams that can extend along the supply chain. Thus, communication skills are required, mainly due to the increase of virtual work with globalized teams. Communication is also required in the ability to persuade and inspire people to a common goal.	[10]; [11]; [12]; [8]; [13]; [14]; [15]; [16]; [17]; [18].
Contact Skill	Multidisciplinary and collaborative teams, due to the work in the highly globalized and intertwined value chain, require people to have the ability to expand their contact networks. Networking is important to maintain contact, especially with professionals who can assist in the use of new technologies from the Industry 4.0.	[10]; [11]; [13]; [18].
Teamwork	Industry 4.0 will enable the work in multidisciplinary teams that transcend the business environment, and can be collaborative even with other companies in the supply chain. Thus, the ability of teamwork will be paramount to engage teams in function of a common goal.	[10]; [11]; [12]; [19]; [8]; [13]; [14]; [15]; [16]; [20]; [21]; [18]; [22].
Commitment and cooperation	The development with partners along the value chain incubate employees to be committed to their activities, especially if the company is in collaborative work with others along the value chain. It is necessary to create a win-win system between these collaborations and this is only done with commitment and personnel engagement.	[10]; [19]; [14]; [21]; [18].
Skill to work under pressure	The constant changes in customer requirements require companies to be in constant innovation processes. Thus, creativity is a necessary skill for the insertion of new products in the market. Not only to market products, but companies also need creativity to innovate their production process, mainly to achieve more innovative and sustainable solutions.	[10]; [11]; [16]; [18].
Creativity	The constant changes in customer requirements require companies to be in constant innovation processes. Thus, creativity is a necessary skill for the insertion of new products in the market. Not only to market products, but companies also need creativity to innovate their production process, mainly to achieve more innovative and sustainable solutions.	[10]; [8]; [14]; [16]; [18].

Entrepreneurial Thinking	Undertaking is not only opening a new business, but rather verifying solutions and taking advantage of previously unseen opportunities. Therefore it is necessary the ability of entrepreneurial thinking because employees will have greater strategic responsibilities in companies, and they should constantly seek new ideas of improvement, have initiative and seek opportunities to Growth.	[10]; [17]; [20].
Leadership skill	Employees will have more responsible tasks and will take on activities more related to decision making and data analysis. Thus, each employee needs to become leaders of their sectors so that commitment to work is effective and can accomplish successfully. By having the formation of several leaders throughout the company, the focus is the leadership by influence and not by authority, and the influence better builds collaborative work	[10]; [11]; [19]; [8]; [13]; [15]; [23]; [17]; [18]; [22].
Decision Making	As already mentioned, the tasks will have a higher level of responsibility, because although the new technologies are more autonomous, they have generated a lot of data. These data require a thorough analysis, mainly because they support decision making. Thus, the decision-making ability will be of great importance to the context of the Industry 4.0.	[10]; [24]; [14]; [15]; [25].
Flexibility	The increase in virtual work makes employees susceptible to being flexible and more independent of their functions, mainly due to their multidisciplinary aspect. Another aspect is the rotation of functions. Not only new skills will be necessary, but new functions that will be multidisciplinary are going to require flexibility on the part of the collaborators who occupy these positions.	[10]; [11]; [21]; [18]; [22].
Motivation to learn	Industry 4.0 will revolutionate the manufacturing environment and provide an environment that is more susceptible to change. Thus, in order to accompany the changes, the collaborators are obliged to accompany these changes and always have availability to learn. Constant learning keeps them inserted in the market and enables the creation of new products, technologies and processes.	[10]; [11]; [15]; [21]; [18].
Intercultural skill	The Industry 4.0 will not only allow the collaborator to work from different places to the manufacturing environment, but will allow the work to be in collaboration with several partners, whether national or international. Therefore, work with different cultures, habits and customs will be more common. Therefore, intercultural skill is necessary, that is, interaction with different cultures, always showing respect for habits and customs that may diverge from itself.	[10]; [11]; [14]; [23].
HARD SKILL		
Skill Required	Context	Authors
Technical skill	Changing the most operational tasks for more strategic tasks raises the need for more technical skills, mainly related to the implementation and operation of the new technologies proposed by Industry 4.0.	[10]; [11]; [26]; [21]; [27]; [18].

Understanding the process	The main changes related to industry 4.0 will happen in the production process, such as the use of Artificial Intelligence, Autonomous Robots and the use of sensors in the factory plant. Thus, the skill to understand the productive process will be of utmost importance both to understand the complexity that the new processes interconnected and to always seek the innovation of the productive environment.	[10]; [11]; [19]; [14]; [23]; [21]; [18].
Skill with media	The increase in virtual work through the use of augmented reality makes employees need to use smart media. The most common is the use of smart glasses that simulate productive environments and even product development processes.	[10]; [11].
Skill to transfer knowledge	The skill to transfer knowledge is of paramount importance to the improvement of the Organization in the realization of activities. Thus, organizational change is always driven by the generation of new knowledge and the transfer to the other members of the organization. The Industry 4.0 will bring a range of knowledge that has to be systate and transmitted to its collaborators.	[10]; [11]; [19]; [25]; [18].
Problem Solving	The ability to solve problems will be of paramount importance because employees will have to be able to identify sources of errors to improve processes. By identifying these sources, they will have to be able to solve problems by conducting critical analyses and questioning that can support decision making.	[10]; [8]; [26]; [14]; [15]; [17]; [21]; [18].
Analytical skill	Due to the automation of the production line, human resources will be shifted to activity based on analysis of data generated to support decision. Thus, it is extremely important to analytical skill, especially in structuring, examining and analyzing large amounts of data in complex processes.	[10]; [8]; [14]; [15]; [27]; [18].
DIGITAL SKILL		
Skill Required	Context	Authors
Data analysis	As already mentioned, the machines will be autonomous aided by information technology and will generate a large amount of data to be analyzed. Therefore, it will be of paramount importance the ability of data analysis, mainly because the jobs will be more related to this activity. These analyses are important because they will be based on decision-making.	[12]; [20].
Coding skill	The growth of highly digital processes, with the aid of machinery connectivities, makes the coding ability highly necessary for the future of work in the context of the 4.0 industry. Therefore, the professional who will dominate this skill, besides working with a lot of data and the use of cloud computing, is the highlight.	[10]; [11]; [21]; [18].
Understand IT security	The work with large amount of data stored on servers or digital platforms opens a worrying aspect to the industry, the cyber attack. They can be characterized by the operation of machines that can jeopardize employees for the theft of sensitive and important data. Thus, the ability to understand work safely with information technologies will be important for the context of the Industry 4.0.	[10]; [11]; [12]; [21]; [18].

Operate IT Device	With a highly connected and autonomous manufacturing environment, it is of great importance that the collaborators who work in it the ability to operate information technology (IT) devices. Among them are the main hardware that are physical parts of data processing and software that are set of products developed by computer programs.	[19]; [26]; [15]; [20].
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According to table 1, you can pick up 12 soft skills, 6 hard skills and 4 digital skills. The large number of soft skills is given that most studies have mentioned that the lightweight skills, that is, the most linked to personal development will be the most important for the context of the Industry 4.0. It is noteworthy the skills of teamwork (mentioned in 13 studies), communication (mentioned in 10 studies) and leadership (mentioned in 10 studies), were the most cited throughout the texts analyzed.

is mainly represented by new technologies that will allow to interconnect not only the manufacturing environment, but all companies in the supply chain. Thus, multidisciplinary teamwork and even "multi" will be quite common, because data can be accessed from anywhere in the world, supporting decision making and optimizing the chain as a whole. Therefore, these skills will be of extreme necessity for this new context.

Regarding the hard skills, the skills as problem solving (mentioned in 8 studies) and comprehension of processes (mentioned in 7 studies) are the most cited in the texts analyzed. Problem solving is of paramount importance because professionals will cease to be more operational and more strategic, so analyzing data and making decisions will be a common task in most jobs. Understanding the processes that will be in constant change is extremely important for professionals inserted in this context, mainly because they always need to continually improve the productive environment.

For the digital skills, the skill to operate IT devices (information technology) because the manufacturing environment will be more interconnected and autonomous. Thus, understanding and being able to operate such devices, the basis of specific software, is one of the indispensable skills for the new industrial context.

4. Final Considerations

The objective of this study was to analyze the main categories of skills oriented to the context of the Industry 4.0. To achieve this, a bibliographical survey was needed among the main databases related to the research theme. A satisfactory quantity of articles published in relevant journals can be gathered.

It is concluded that the use of the systematic literature review was of great importance to achieve the objective, since it can systematize the search for articles and can assist in the elaboration process of the present study. Content analysis Besides being able to categorize the skills mentioned throughout the texts read, in hard, soft and digital, one can have a brief contextualization of why that skill will be important for the context of Industry 4.0.

It was managed to catalog 12 soft skills, 6 hard skills and 4 digital skills, and the importance of the soft skills will be due to the fact that the autonomy of manufactures alienate the human resources of more operational work and will allow Multidisciplinary teams work together for data analysis. Thus, this study can serve as a basis for companies and universities that need to prepare to be employees or academics who will assume these new jobs with the skills that will be needed to meet the challenges that the Industry 4.0 will cause the business environment.

As proposals for future research, it is suggested to encompass more databases of articles and also to investigate new studies, as it is a theme that is in constant publications. We also suggest guided investigations in mature companies in Industry 4.0 to investigate whether the skills mentioned in the literature match the reality in which organizations are inserted.

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A Benchmarking Study of Industry 4.0 Initiatives in Engineering Education

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Abstract: The industry has already gone through three industrial revolutions in the past, driven by major technological and organizational innovation. The first revolution was the mechanization, followed by mass production, and the third was caused by automation. In these revolutions, the society and, more specifically, the education institutes managed to reinvent themselves to survive and to respond to the challenges imposed by these technological and organizational shifts. Today we face the next industrial revolution, driven by digitalization, connectivity and artificial intelligence, also known as Industry 4.0 (I4.0). Several technological paradigms changes are in progress, and their effect goes beyond production itself, as it will profoundly affect the labour market, leading to professions and jobs reformulation or extinction. This change will require a revolution in the fields of education and professional development, especially in the fields of technology and engineering. Even though the need for change is evident, different interpretations with respect to the necessary skills for the engineer of tomorrow makes it less clear which direction this shift should take. In this context, the general objective of this research is to identify what I4.0 competences should be incorporated or accentuated in engineering training to form well-prepared professionals for this new industrial era. The first objective is to identify the individual competencies required to perform well in the I4.0 context, through a review of publications containing description of skills associated with I4.0. The second objective is to perform a benchmarking study using multiple sources of data to identify current educational initiatives to cover the I4.0 emergence. Following the suggestions of some authors, we consider larger initiatives in the industrial engineering curriculum in the following areas: data science and advanced (big data) analytics; Advanced simulation and virtual plant modelling; Data communication and networks and system automation; Novel human-machine interfaces; Digital-to-physical transfer technologies (e.g. 3D printing); Closed-loop integrated product and process quality control/management systems; Teaching and learning demonstration infrastructure. As a result, from our analysis, we identify nine trends on Education 4.0, namely: classroom-free learning, flexibility, personalized learning, mentoring, practical application, project-based thinking, learning and working, ownership, evaluation instead of examination and data interpretation. It is expected that with these tools the institutions will find ways to combine technology and the newest industrial trends to provide well-prepared professionals to the labour market. Another important measure is to promote the union between institutions and industry, so they can share knowledge, data and work needs to fit the education on the companies' demands. In this paper, we present the characteristics of the education initiatives identified in this benchmarking study, as well as a trend analysis and a critical review of them, taking into account the scope of transformation 4.0 that is taking place in the industry. The major contribution of this research is to present a direction to engineering education professionals willing to review their learning platforms and methods so to adapt them to the I4.0 context.

Keywords: Industry 4.0, Engineering Education, Education 4.0, Skills 4.0.

1. Introduction

The industry was already affected by three majors changes due technological innovations, they are called industrial revolutions: the first was mechanization, followed by the use of electrical energy and the third was the use of electronics and automation.

All these paradigms affected more than just production itself, reaches the labor market and educational system as well, leading to professions and jobs extinction. These days, due digitalization and robotics development, we are facing the next industrial revolution, also known as the concept of Industry 4.0 [1]. The term emerged at the Hannover Fair in 2011 [2], is internationally usually known as Industrial Internet

of Things (IIoT) and comes from the High-Tech Strategy Action Plan of Germany government for High-Tech Strategy 2020 implementation [3].

The plan is being used as inspiration for countries world abroad, like: United States of America (*Advanced Manufacturing Partnership*), France (*La Nouvelle France Industrielle*), United Kingdom (*Future of Manufacturing*), Europe (*Factories of the Future*), South Korea (*Innovation in Manufacturing 3.0*), China (*Made in China 2025*) and others [4].

According to [5] decentralized intelligence helps to create an intelligent network of objects and process management in an independent way, where there is interaction between the real and virtual world through cyber-physical systems. These are considered an enabling technology, providing basis for the Internet of Things and that together with the internet of services, make the I4.0 possible.

There are some concerns that in the long term, Industry 4.0 will lead to technological unemployment [6]. That the profile of jobs and workplaces is changing, it is already possible to perceive, this requires an even greater change in the fields of education and professional development [7].

According to [8], companies are demanding new skills and therefore undergo a reduction of qualified employees to their jobs. Another aspect is related to age, keeping young employees requires to offer incentives and promotions or they can change jobs easily, while those of greater age carry difficulties and disinterest in learning new technologies or hinder in case of changing their work routines. This challenge is multiplied in the case of Industry 4.0 as scenarios and technologies can change at any time.

It is known that engineering disciplines follow technological trends and therefore it is easy to see that education will also go from 3.0 to 4.0, where real-world and virtual information will be combined through various resources such as reality goggles applied in classes and training of employees. since students will work in an industry context 4.0, it is important that they be embedded in virtual learning environments in order to gain experience with the technologies used, as well as making teaching and learning more collaborative [9].

To avoid a shock as great as the 1990s, because of the information technology revolution, a new challenge is to define the roles of the engineer in the industry environment 4.0 and then identify the potential reforms needed in the curriculum, so that graduates can work with these systems as well as in traditional enterprises. [9] developed this assessment in the face of the reality of the African institutions of industrial engineering teaching, proposing a set of items to contribute to the curricular reform.

Thus, the main objective of this ongoing research is to evaluate and propose improvements in the training of professionals to deal with I4.0.

1.1. Methodology

The first objective is to seek the state of the art regarding the competencies related to industry 4.0, through review of publications containing description of skills and/or skills. For the search was used terms as "Industry 4.0", "Industrie 4.0", "Smart Factory", "Internet of Things", "Education", "Formation", "Curriculum Industry 4.0" and possible combinations between them, in the title or subtitle of the publications.

Through online research, it was possible to find educational initiatives that introduce industry 4.0 concepts to their students, providing future professionals prepared for the job market. Such research allowed to reach the second objective initially, since it is a research still in progress.

To get an idea about institutions that have not yet prepared for Industry 4.0, a quick interview was made with a coordinating professor of the mechanical engineering course, where even with basic questions it was possible to notice some implementation difficulties.

1.2. Literature Review – Competences

According to [10], Industry 4.0 relies basically on nine pillars, namely: Big Data; Autonomous Robots; Simulation; Universal System Integration; Industrial IoT; Cybersecurity; Cloud Computing; Additive Manufacturing and Augmented Reality. Such integration represents a transformation of the workers' profile, being of great importance then, the partnership between companies and industries with educational institutions so that the academic formation is aligned with the present necessities.

[11] identifies 14 technologies associated with Industry 4.0: Simulation and Modeling; Cyber-Physical Systems (CPS); Semantic Technologies; Internet of Thing (IoT); Internet of Services (IoS); Internet of

People (IoP); Cloud Computing; Big Data Analytics; Blockchain; Cybersecurity; Augmented Reality; Automation and Industrial Robots and Additive Manufacturing.

The trend to automate repetitive tasks in an industrial environment leads employees to deal with complex and indirect activities, collaborating with the machines in their daily work, needing to solve unstructured problems, work with new information and deal with non-routine manual tasks [1].

The skills can be classified in personal and technical, being structured in "must have skills", "should have skills" and "could have skills", being presented in Table 1.

Table 1: Future qualifications and skills for workers [12]

	Must	Should	Could
Technical	IT knowledge and abilities	Knowledge Management	Computer programming and coding abilities
	Data and information processing and analytics	Interdisciplinary/generic knowledge about technologies and organizations	Specializes knowledge about technologies
	Statistical knowledge	Awareness for IT-Security and data protection	Awareness for ergonomics
	Organizational and processual understanding	Specialized knowledge of manufacturing activities and processes	Understanding of legal affairs
	Ability to Interact with modern interfaces		
	Self and time management	Trust in new technologies	
Personal	Adaptability/ability to change	Continuous improvement and lifelong learning	
	Team work abilities		
	Social Skills		
	Communication Skills		

According to [8], some challenges are encountered by companies in relation to I4.0, the first of which relates to data, since they are generated and collected from several machine sensors, as well as process, product, quality, plant, logistics, infrastructure, among others. This situation creates demands for new methods of storage, processing and management. The lack of a standard is the biggest concern of companies, since inconsistent data lead to wrong decisions.

The second challenge is to exchange data with external partners and departments, for example for good logistics management. Skills training and development is the third challenge since most of the workforce has resistance to the introduction of new technologies, techniques, handsets and work routines.

The life cycle of a product in this decade is less than before, since individual customization is a reality, which leads to a greater need for production flexibility, defined as the fourth challenge. In most cases the technology currently employed on the factory floor is inadequate or does not support flexibility and its upgrade needs to take into account the complexity and the cost for it to be implemented effectively.

Last but not least, security is a top concern today and will be for future factories as well, as they need to keep employees, products and plants safe, despite the increased use of smart devices, which require regular updates so that they are external threat insurance.

[9] cites areas that for many authors need larger initiatives in the industrial engineering curriculum for industry 4.0:

- Data Science and advanced (big data) analytics
- Advanced simulation and virtual plant modelling
- Data communication and networks and system automation
- Novel human-machine interfaces
- Digital-to-physical transfer technologies, such as 3D printing
- Closed-loop integrated product and process quality control/management systems
- Teaching and learning demonstration infrastructure.

The importance of the subject, the different interpretations regarding the necessary skills and the interest in seeking a more efficient preparation of the engineers for the labor market, leads the question: *What Industry 4.0 competencies are needed in training well-prepared professionals?*

1.3. Results

According to the evaluation of publications, it was possible to come up with a list of technical skills deemed necessary for the new labor market within Industry 4.0, such skills were organized by affinity into two groups and their subgroups, as follows.

Table 2: Industry 4.0 Skills

Systems	Data
Cyberphysical	IoT
Robots	Cloud Computing
Augmented Reality	Big Data
Simulation	Cyber Security
Artificial Intelligence	

For the second objective described, it is necessary first to state the difficulty in obtaining more detailed information about the courses on the Internet in a public way and to mention that this article is part of a broader research that is underway. That said, the initiatives found in Canada, the United States, and Turkey will be presented.

An example is Polytechnique Montreal, located in the province of Quebec, Canada, which has a discipline applied to the master's and doctorate degree in industrial engineering, to be started in the fall of 2019, called Industrie 4.0. Addressing Industry 4.0 definition, tools, technologies and concepts to implement digital business and process transformation by applying the concepts of: Internet of Things (IoT), Big Data, Cloud Computing, Cloud Manufacturing, CyberPhysical System (CPS) and Artificial Intelligence, Augmented Reality, Cybersecurity, among others. A microprogram in Industry 4.0 is also to be implemented.

Still in Canada, it is possible to mention the University of Sherbrooke which has a microprogram called Gestion et Intelligence Manufacturière aggregating five required disciplines: Industry 4.0 and digital business models, Internet of Things in Business Applications, Management Challenges related to collaborative robotics, Analysis business in the Manufacturing and Diagnostics sector and moving to the digital age.

An initiative to be held annually by ETS in Montreal, had its first edition in August 2019, the Summer School - Industry 4.0, featured lectures from various areas such as educational institutions, industries, startups, representatives of government departments, related to industry, among other lectures aimed at presenting the concepts, examples and how and why achieving Industry 4.0 is important.

In terms of management, some courses have been identified at MIT, such as the executive certificate, a two-day course aimed at manufacturing executives and leaders who want to implement technology changes in their companies to keep up with new trends.

Examples of these courses: Implementing Industry 4.0: Leading Change in Manufacturing and Operations, Understanding and Predicting Technological Innovation New Data and Theory, Machine Learning for Big Data.

Another type is the professional certificate, for example: Machine Learning & Artificial Intelligence that has in the core courses Machine Learning for Big Data and Text Processing: Foundations and Advanced Machine Learning for Big Data and Text Processing.

Also at MIT, in several engineering courses there are disciplines related to I4.0 technologies, such as the Mechanical Engineering course, the Introduction to Robots, Learning Machines, Process Data Analytics, Software and Computation for Simulation, among others.

In Turkey it is possible to find a master's degree in Industry 4.0, whose justification cites the interdisciplinary and multidisciplinary need of the workforce in the new industrial context as its main objective.

From the six main initiatives presented an assessment was made in terms of concepts used, among the skills mentioned above and can be completed and presented through the following table, which also presents the percentage of skills addressed in the sample used.

Table 3: Presence of I4.0 initiatives in researched courses

Subject	Initiatives	%
CyberPhysical Systems	4	66,6%
Robots	2	33,3%
Augmented Reality	3	50%
Simulation	1	16,6%
Artificial Intelligence	3	50%
IoT	6	100%
Cloud Computing	3	50%
Big Data	3	50%
Cyber Security	2	33,3%

Through this analysis it can be seen that the most commonly applied concepts are: Internet of Things and Cyberphysical Systems and that of the nine concepts, only three were present in less than half of the samples, representing, therefore, two thirds of the concepts present in at least one. minus half of the samples. In the future when more institutions are analyzed, it will be possible to have a larger application of concepts, as well as the concepts that need a little more attention and through interviews try to understand the reasons why it may be easier to deploy compared to each other.

To complement the data acquired online, contact was made with a coordinating professor of the mechanical engineering course. He said that he does not yet have these I4.0 initiatives in his curriculum but is aware of them and that despite the efforts to add new technologies, he finds some difficulty with the older teachers. This information confirms the difficulties that exist also in the job market in relation to employees with more time in the company who do not want to change their way of working to adapt to new technologies, being one of the biggest difficulties of implementation.

2. Conclusion

As a conclusion of this article, which is part of an ongoing research, it was possible to present that Industry 4.0 is a current reality and that demands adaptation from both companies and professionals. Adaptation involves, in relation to educational institutions, reaching the necessary competences for professionals to be trained in the best way, making it possible to deal with current concepts of the new industry 4.0. Technical skills include: Cyberphysical Systems, Robots, Augmented Reality, Simulation, Artificial Intelligence, Internet of Things, Cloud Computing, Big Data and Cyber Security.

Some educational institutions already seek to offer such principles as compulsory subjects in undergraduate courses, others such as postgraduate, professional certificates, short courses, summer school, while others still try to overcome the human difficulty related to change so that they can offer new concepts in their courses.

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Proposal for a Systematic Literature Review on the Theme Education 4.0: a contribution to the improvement of Engineering teaching

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Abstract: The Education 4.0, concept which relates elements of the Industry 4.0 and education, appears as an ascendant and actual theme, improving engineering teaching through skill polishing. Basing on the presented context, this paper seeks to perform a content analysis about Education 4.0, applied to Engineering. For this, Literature will be systematically reviewed through specific methods, in order to reach the most recent Education 4.0 related articles that applies to Engineering. Though research on Scopus and Web of Science databases, an initial portfolio will be obtained, later filtered based on quantitative and qualitative criteria. The most relevant articles to this paper will be analyzed qualitatively with the help of the Nvivo software, intending to investigate its content. In this way, this paper seeks to clarify Education 4.0, collecting information about its characteristics, keywords, variations, countries and scholars; analyzing changes brought with it and helping the scientific community through proposals to improve engineering learning, even with industries that look for qualified labour to suit the new organizational, digital and technological tendencies.

Keywords: Industry 4.0; Education; Bibliometric Analysis; Systematic Literature Review; NVivo.

1. Introduction

The term Fourth Industrial Revolution, also known as Advanced Manufacturing or Industry 4.0, became publicly notorious in 2011, when the initiative of a representative's association from companies, politics and academy called "industrie 4.0" supported the idea as an approach for competitiveness strengthening in the German industrial market.

The goal of Industry 4.0 is to establish smart value creation, self-regulatory and interconnected (LIAO at al., 2017). Lee (2008) believes that a core issue of the Industry 4.0 is the link between both physical and virtual environment, that it is possible thanks to the integration between physical and computational processes, called cyber-physical systems. The organizations that utilize these concepts are named Smart Factories, and constitute the base of the Industry 4.0 (HOFMANN & RÜSCH, 2017).

From these concepts, it can be noted that other industry sectors are stimulated to follow, and even evolve or innovate from the new concepts of Industry 4.0. One example of this is the influence of digitalization in the areas of health, service and even in Industrial Engineering education, which is the scope of this article.

Thereby, through the review of recent published articles, this article aims to accomplish a content analysis over the subject Education 4.0, applied to Industrial Engineering.

The study about the subject intends, through its comprehension, contribute with the scientific community and industries, which aim at obtaining qualified labor to be suited to the new technological and organizational trends.

With this intent, a portfolio with 168 articles was assembled to perform a bibliometric analysis, and then, through qualitative analysis and the InOrdinatio Methodology (PAGANI et al., 2015), the ten most relevant articles were filtered, sorted and utilized in this study. These were prioritized and qualitatively analyzed by the software Nvivo.

In the next sections, the main concepts for this study will be detailed, as well as the methodology and the bibliographic review results regarding the Industry 4.0 and its relation with Education 4.0, in addition to its relation to Industrial Engineering.

2. Advanced Manufacturing or Industry 4.0

According to Chung & Kim (2016), the term Industry 4.0 or Industrie 4.0 was introduced initially in 2011 by the Fraunhofer-Gesellschaft Institute and by the Federal German Government as being a collective term capable of defining the set of technologies for automation, information flow and manufacture.

According to Paprocki (2016), the 4th Industrial Revolution is linked to three phenomena, they are:

- a. Common digitalization and assurance of constant communication between people, people and devices, and between the devices themselves;
- b. Growing increase of the implementation of disruptive innovation, which are able to provide the global increase of operational efficiency and effectiveness of socioeconomic systems;
- c. Development of machines able of autonomous behavior through the utilization of artificial intelligence.

Rüßman et al. (2015) was able to identify nine fundamental pillars that comprehend the 4th Industrial Revolution. Chart 1 presents each one of the nine pillars and their respective definitions according to the perspective of several authors.

Chart 1 – Fundamental pillars of the 4th Industrial Revolution

Pillar	Definition
Big Data	Big set of data, generally not structured, needing real-time analysis (MELL et al., 2015).
Autonomous Robots	Robots that act in a collaborative, flexible and autonomous manner (PONCELA et al., 2009)
Simulation	Physical world simulation in a virtual world of either machines, products or humans (RÜBMANN et al., 2015).
Horizontal and Vertical Integration	The horizontal integration happens in accordance with the cooperation and competition between companies. The vertical integration occurs between physical and functional sectors of the company itself (WANG et al., 2016)
Internet of Things	Connection between physical objects and the Internet, allowing the real-time communication between smart objects and the Internet (KOPETZ, 2011)
Cybersecurity	Methods used to recognize vulnerabilities and keep the process integrity (GILCHRIST, 2016)
Cloud	Responsible for the data sharing and storage (GILCHRIST, 2016)
Additive Manufacturing	Manufacturing method that adds material layer by layer to fabricate an object. (VAYRE, VIGNAT & VILLENEUVE, 2012)
Augmented Reality	Fusion of physical and virtual reality, allowing real-time information to assist decision making (RÜBMANN et al., 2015)

Font: Adapted from (RÜBMANN et al., 2015).

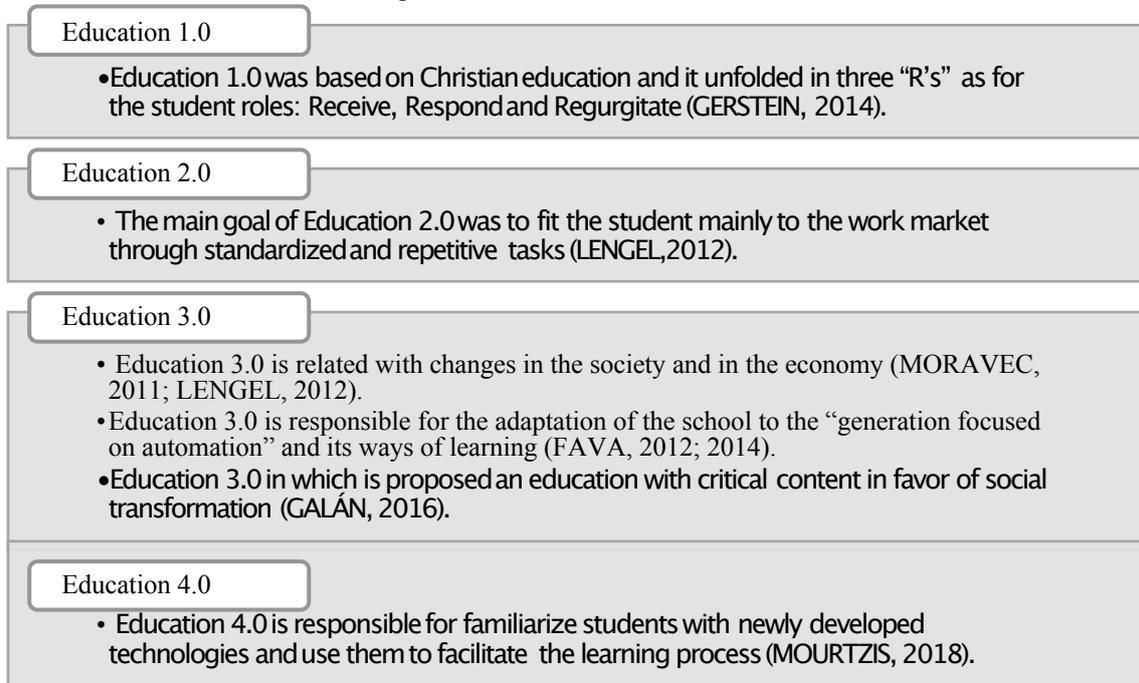
Jabbour et al., (2018) believes that the characteristics of the Industry 4.0 will affect the manufacturing processes, the customer perception and the products' added value. The connection between machines, devices and parts of the supply chain aided by shared information will provide opportunities to alter the order priorities, monitor and control the efficiency of production lines and logistic routes, thus, the needs of the customers will be readily fulfilled.

3. Industry 4.0 and the revolution of education

According to Romanelli (1960), education came from the Latin verb *educare*, meaning "to raise, to nurture, to make grow". As the society and the industry evolve, changes are noticeable in the context of education, main subject of this study. From the analyzed literature (GERSTEIN, 2014) (LENGEL, 2012) (MORAVEC, 2011) (GALÁN, 2016), (MOURTZIS, 2018), it is possible to observe the influence of each Industrial Revolution

on the current education model in the respective time periods, this is demonstrated in Figure 1.

Figure 1 – Evolution of Education 4.0



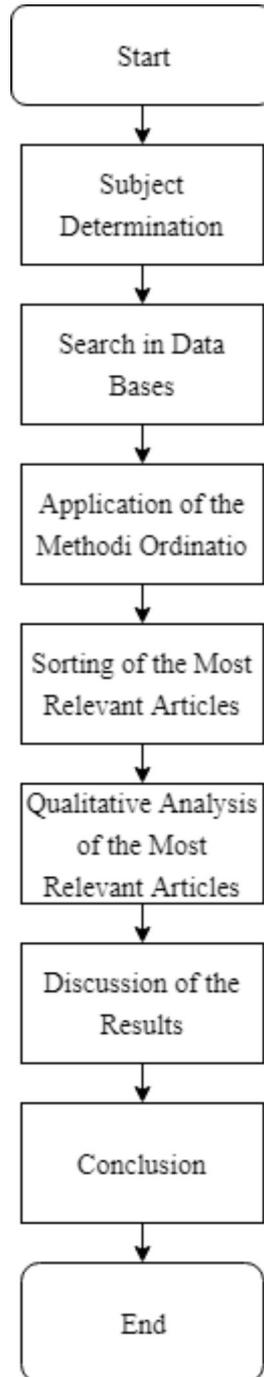
Font: Own Authorship (2019)

According to Figure 1, changes and characteristics unique to each phase of education are observed depending on the historic moment where each one of them are situated. The evolution of education does not exclude the way in which preview phases operated, they complement and adapt according to the new reality, that is, in a constructive way, they appropriate what is useful from preview phases and alter the aspects that are not fit to the new scenario. In this sense, Education 1.0 covers a moment when the Christian religion had an exacerbated power and for this reason it controlled inclusively information transfer. In Education 2.0 and 3.0, it can be noted a great industry influence on the education context, causing to fulfill industrial demands and to orient the learning process. Education 4.0 reflects the modernization of the uses of technologies from the pillars of industry 4.0 pointed out in Chart 1, as well as in section 5.2 of this article, where the analysis of the articles’ contents will be discussed, these articles will be presented on the systematic review, in the following section.

4. Methodology

According to Fonseca (2002), *methodos* means organization, and *logos*, systematic study, investigation or research, in other words, a methodology represents the study of organization, the paths to follow, to accomplish a research or a study. Starting from these concepts, Figure 2 is presented next, showing the research strategy adopted to the development of this article.

Figure 2 – Research Strategy



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In this sense, a Literature Systematic Review was made intending to obtain a general view of the relationship between Industry 4.0 and Education. According to Counsell (1997), a good systematic review is based on a question of a well formulated research that can be answered, because it will guide the review, defining which studies will be included, what search strategy to use to identify the main studies and the data that needs to be extracted from each study.

The chosen data bases with more relevance, multidisciplinary, efficiency on obtaining and treating data for the research were Science Direct, Scopus and Web of Science. The key words related to the study subject and the initial filters applied to the searches are demonstrated in Chart 2.

Chart 2 – Search of the key words in the data bases

Keywords and Combinations	Science Direct (Review Articles e Research Articles)	Web of Science (Journals)	Scopus (Journals)	Total
"education 4.0"	Results: 3 Title: ("education4.0")	Results: 10 Title: ("education 4.0")	Results: 13 Title: ("education 4.0")	168
"industry 4.0" AND "education"	Results: 5 Title: ("industry 4.0" AND "education")	Results: 43 Title: ("industry 4.0" AND "education")	Results: 84 Title: ("industry 4.0" AND "education")	
"education 4.0" AND "methods"	Results: 7 Title("education 4.0" AND "methods")	Results: 0 Title("education 4.0" AND "methods")	Results: 3 Title("education 4.0" AND "methods")	

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Initially, 168 articles were found, with the search being restricted only to scientific articles. On Science Direct's case, filters were used to limit the search to Review Articles and Research Articles. With Scopus and Web of Science the search was made only on Journals.

Subsequently, a qualitative analysis was made on the found articles with the goal of excluding possible duplicates from the three different data bases for each key word with the help of the software Mendelev. After the analysis, articles with title or abstract incompatible with the study subject were excluded, leaving 41 articles remaining. These

remaining articles went through the Methodi Ordinatio filtering method to form the final portfolio. The Methodi Ordinatio is a multicriteria methodology for decision making and scientific article selection, designed to compose a bibliographic portfolio (PAGANI, KOVALESKI & RESENDE, 2015).

To sort the relevance of the studies, the equation based on the InOrdinatio was designed:

$$\text{InOrdinatio} = (Fi/1000) + \alpha * [10 - (\text{AnoPesquisa} - \text{AnoPublicação})] + (\Sigma Ci) \text{ Eq. (01)}$$

Where:

Fi: Impact factor of the journal in which the article was published;

α : Value attributed to year by the researcher;

AnoPesquisa: Year in which the research is being made;

AnoPublicação: Year the article was published;

Ci: Total number of the article citations.

The articles with InOrdinatio values under 50 were excluded, so that the bibliographic base formed after the Methodi Ordinatio application contains ten relevant and consistent articles, detailed in the next section, Results and Discussions.

5. Results and discussions

5.1 General view of the articles

After the Methodi Ordinatio's application, ten final articles were obtained and are shown in Chart 3.

Chart 3 – Articles selected by Methodi Ordinatio

Author	Title	CI	FI	Year	Inordinatio	Journal/ Proceedings
BENESOVÁ A.; TUPA J.	Requirements for Education and Qualification of People in Industry 4.0	46	0,7	2017	86,0007	Procedia Manufacturing
MOTYL B.; BARONIO G.; UBERTI S.; SPERANZA D.; FILIPPI S.	How will Change the Future Engineers' Skills in the Industry 4.0 Framework? A Questionnaire Survey	18	0,7	2017	58,0007	Procedia Manufacturing
MOURTZIS D.; VLACHOU E.; DIMITRAKOPOUL OS G.; ZOGOPOULOS V.	Cyber- Physical Systems and Education 4.0 –The Teaching Factory 4.0 Concept	12	0,7	2018	57,0007	Procedia Manufacturing
COSKUN S.; KAYIKCI Y.; GENCAY E.	Adapting Engineering Education to Industry 4.0 Vision	5	0	2019	55	TECHNOLOGIES
SACKEYS.M.; BESTER A.; ADAMS D.	Industry 4.0 learning factory didactic design parameters for industrial engineering education in South Africa	14	0,409	2017	54,000409	South African Journal of Industrial Engineering
STACHOVÁ K.; PAPULA J.; STACHO Z.; KOHNOVÁ L.	External partnerships in employee education and development as the key to facing industry 4.0 challenges	3	2,075	2019	53,002075	Sustainability (Switzerland)
MASELENO A.;; TANG A.Y.C.; MAHMOUD M.A.; OTHMAN M.; SHANKAR K.	Big Data and E-Learning in Education 4.0	6	0	2018	51	INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND NETWORK SECURITY
SALAH B.; ABIDI M.H.; MIAN S.H.; KRID M.; ALKHALEFAH H.; ABDO A.	Virtual reality-based engineering education to enhance manufacturing sustainability in industry 4.0	0	2,075	2019	50,002075	Sustainability (Switzerland)
MOURTZIS D.; VASILAKOPOULO S A.; ZERVAS E.; BOLI N.	Manufacturing System Design using Simulation in Metal Industry towards Education 4.0	0	0,7	2019	50,0007	Procedia Manufacturing
SETHAKUL P.; UTAKRIT N.	Challenges and Future Trends for Thai Education: Conceptual Frameworks into Action	0	0	2019	50	INTERNATIONAL JOURNAL OF ENGINEERING PEDAGOGY

Font: Own Authorship (2019)

Chart 3 presents the author of each article selected by Methodi Ordinatio, sorted in a descending order, followed by the title, number of citations, impact factor, year of publication, Ordinatio value and the Journal in which the article was published,

highlighting Journal Procedia Manufacturing as the one with biggest publications about Education 4.0.

With the goal of showing the country and university of origin of the authors with publications amongst the selected articles, there is Chart 4.

Chart 4 – General view of the selected articles

Author	Author's country	Author's University
BENESOVÁ A.; TUPA J.	Itália	University of West Bohemia in Pilsen
MOTYL B.; BARONIO G.; UBERTI S.; SPERANZA D.; FILIPPI S.	Itália	University of Udine, Udine, Italy; University of Brescia, Brescia, Italy; University of Cassino and Lazio Meridionale, Cassino, Italy
MOURTZIS D.; VLACHOU E.; DIMITRAKOPOULOS G.; ZOGOPOULOS V.	Grécia	University of Patras, Rio Patras, Greece
COSKUN S.; KAYIKCI Y.; GENCA YE.	Turquia e Alemanha	Turkish German University, Istanbul; Universität Tübingen, Tübingen, Germany
SACKEY S.M.; BESTER A.; ADAMS D.	África	University of Science & Technology, Ghana; Cape Peninsula University, Cape Town, South Africa
STACHOVÁ K.; PAPULA J.; STACHO Z.; KOHNOVÁ L.	Eslováquia	Faculty of Management Comenius University, Slovakia
MASELENO A.; TANG A.Y.C.; MAHMOUD M.A.; OTHMAN M.; SHANKAR K.	Malásia e Índia	Universiti Tenaga Nasional, Malaysia; Kalasalingam Academy of Research and Education, Krishnankoil, India
SALAH B.; ABIDI M.H.; MIAN S.H.; KRID M.; ALKHALEFAH H.; ABDO A.	Arábia Saudita e Palestina	King Saud University, Saudi Arabia; Birzeit University, Palestine
SETHAKUL P.; UTAKRIT N.	Tailândia	University of Technology Bangkok, Bangkok, Thailand

Font: Own Authorship (2019)

From Chart 4, it is possible to see that the continents with the biggest interest by the study of Education 4.0 and its relation with Industrial Engineering are Europe and Asia, with Italy and Greece standing out with a total of ten articles selected. That does not mean that countries such as Germany, precursor of the term Industrie 4.0, are not on the search ranking of the subject. It only shows that between the ten articles with the biggest impact factor, Italy and Greece stand out.

5.2 Definitions and characteristics of Education 4.0

There are two big subjects for education in Industrial Engineering, related with industrial automation and product digitalization. The first is the role that Industry 4.0 technologies will have on the way resumes are developed and implemented, considering the development of adaptable and inclusive investigation and problem-solving skills. The second, intimately connected to the first, is the role that learning factories of Industry 4.0 have in helping to develop creative, collaborative, communicative and innovative engineers that have a connection with the digital-industrial world and a critical sense to deal with unexpected situations (SACKEY, 2017).

Mourtiz (2018) believes in the direct connection between the education and industry through the learning factories. To Sackey (2017), a learning factory is a realistic model of a production environment that offers the students the opportunity to implement improvements in the process and see immediate results. Its main goal is to bring the real world to the education environment, allowing the students to have a practical experience through real life projects.

To Mourtiz (2018), Education 4.0 considers the exploration of developed technologies, such as advanced techniques of visualization in which virtual reality is integrated to facilitate the learning process and the methods that will habituate the engineering students to these technologies. As technologies advance, such concept for education is becoming necessary and multinational organizations consider its integration, specifically the institutions will need to stablish new ways of connecting theoretical knowledge from the academic environment with real cases of cyber-physical spaces being implemented on industries, creating an advantageous situation for both parts.

According to Masaleno (2018), Big Data, fundamental industrial tool of Education 4.0, by providing new chances to increase information gathering and connection to web-based learning systems, is capable of assisting the personalized learning process, taking into account the uniqueness of each person.

According to Benešová (2017), the skills of new engineers vary from technical and linguistic abilities (hard skills) and interpersonal skills (soft skills). This way, Education 4.0 does not only need to limit itself to technical requirements and knowledge, but expand its horizon and act personally, encouraging the development of soft and hard skills.

5.3 Quantitative content analysis

Based on the ten articles (Chart 3), a quantitative analysis was made with the help of the software Nvivo, from its sorting functionalities, coding and visualization of the search data. First, an auto coding of sentences was made to provide the main subjects in the downloaded articles. Figure 3 presents the hierarchy chart of the main subjects brought up.

Figure 3 – Hierarchy chart of subjects



Font: Own Authorship (2019)

The main subjects marked by the software are: systems, production and learning. As for “systems”, there are the main sub-topics: “human resource development systems”, “physical systems” and “augmented reality systems”. These highlight the importance of cyber-physical systems and augmented reality systems, that is, the pillars of Industry 4.0 in the construction of Education 4.0.

With the subject “production”, there are: “production process”, “production environment” and “production engineers”. It is relevant to note the importance of the industrial engineers to the subject, reinforcing the intent of the research and showing the proximity of the industry to Education 4.0.

When talking about “learning”, there are: “learning environments”, “learning method” and “learning theory model”. Once more reinforcing the learning environment as a key factor in Education 4.0, together with models and methods that allow the replication of the learning processes.

From the coding generated by Nvivo, it was possible to identify and map the main subjects and words that are being discussed in the articles, with the goal of obtaining an overview about the articles related to Education 4.0. With the help of the software, it was possible to make a content analysis that shows the main topics and definitions of Education 4.0. This way, it becomes possible to guide not only the academic research, but also the organizations that aim to align with the requirements of the Industry 4.0, the students who seek to research or to work in businesses 4.0 and the professionals that work or want to specialize in the field.

5.4 Main Author's Contributions

Considering the analysis of the selected texts, it was possible to raise the authors' main contributions to the current context and scenario, in parallel with Industry 4.0. Such considerations are expressed in Chart 5.

Chart 5 - Main Author's Contributions

Autor	Título do Artigo	Main Contributions
BENESOVÁ A.; TUPA J.	Requirements for Education and Qualification of People in Industry 4.0	It presents in detail each phase of Industry 4.0 implementation and therefore indicates how the environment, technologies, work and the changes generated in this new industrial revolution work. It also presents qualifications and skills of professionals focused on the industry.
MOTYL B.; BARONIO G.; UBERTI S.; SPERANZA D.; FILIPPI S.	How will Change the Future Engineers' Skills in the Industry 4.0 Framework? A Questionnaire Survey	With the help of a questionnaire and its analysis, we sought to investigate which skills are necessary for professionals who want to work in the Industry 4.0 scenario, from their pillars.
MOURTZIS D.; VLACHOU E.; DIMITRAKOPOULOS G.; ZOGOPOULOS V.	Cyber- Physical Systems and Education 4.0 –The Teaching Factory 4.0 Concept	It addresses the theme of Learning Factories 4.0, relating Cyber-Physical Systems with the education of the 4th Industrial Revolution, Education 4.0. The evolution of Teaching Factories 4.0 is evidenced compared to the conventional model of Learning Factories, with active use of technologies as tools that increase the perception of the approached content.
COSKUN S.; KAYIKCI Y.; GENÇAY E.	Adapting Engineering Education to Industry 4.0 Vision	It presents a generic structure for education in Industry 4.0 in script form, pointing adaptations in the engineering curriculum to the new demands of Industry 4.0, involving curriculum, physical spaces and activities. In addition it uses a practical application of the script in a University to reinforce the study.
SACKEYS.M.; BESTER A.; ADAMS D.	Industry 4.0 learning factory didactic design parameters for industrial engineering education in South Africa	It presents a didactic model, applied in Universities of South Africa, of Learning Factory using concepts, pillars and tools of Industry 4.0 as a way of instructing and adapting industrial engineering students to scenario 4.0 in a practical way.
STACHOVÁ K.; PAPULA J.; STACHO Z.; KOHNOVÁ L.	External partnerships in employee education and development as the key to facing industry 4.0 challenges	It contributes to a better understanding of the value of external partnerships in training and personal development, as well as providing insight into the sustainable development of human resources within the context of Industry 4.0.
MASELENO A.; TANGA.Y.C.; MAHMOUD M.A.; OTHMAN M.; SHANKAR K.	Big Data and E-Learning in Education 4.0	It addresses the relationship of education with E-Learning, ie, it highlights the relationship of education with new technologies, especially digital devices, pointing out their benefits and limitations, strengths and weaknesses, their role in universities and the importance of Big Data in this new context.
SALAH B.; ABIDI M.H.; MIAN S.H.; KRID M.; ALKHALEFAH H.; ABDO A.	Virtual reality-based engineering education to enhance manufacturing sustainability in industry 4.0	Provides an innovative teaching and training vision, suited to the context of Industry 4.0, to prepare students for the challenges and unpredictability of the real manufacturing environment. To validate the ideas presented, the article addresses a case study using Virtual Reality and the results and opinions of the people involved.
MOURTZIS D.; VASILAKOPOULOS A.; ZERVAS E.; BOLI N.	Manufacturing System Design using Simulation in Metal Industry towards Education 4.0	It discusses the importance of Education 4.0 linked to Teaching Factory in the scenario of the fourth industrial revolution, to present a case study in a metallurgical industry, in which simulation tools and ICT technologies are mainly used.
SETHAKUL P.; UTAKRIT N.	Challenges and Future Trends for Thai Education: Conceptual Frameworks into Action	The article discusses the evolution in the education scenario in Thailand from said education 1.0 to education 4.0 highlighting the main changes and challenges, emphasizing the importance of education in the structure and organization of the country.

Font: Own Authorship (2019)

6. Final Considerations

From what was demonstrated, it was verified that the goal of this study, that is, make a content analysis around the term Education 4.0 applied to Industrial Engineering, was accomplished. Based on this, the contribution of the obtained results is highlighted, specially the subjects brought up from the content analysis, to a general view of the literature and publications related to Education 4.0 and its relation to Engineering, more specifically Industrial Engineering.

It is important to remind that the subjects explored in this article is contemporary and the research and the related applications are still in an initial stage. This is why the analysis allows a wide understanding about the subject and about what has been studied and published about Education 4.0. Due to the increasing interest of the scientific community and the industries that aim to adapt to the new technological, digital and organizational trends with the use of qualified labor, this study contributes with the explanation of the main subjects of Education 4.0, disseminating its study. Besides that, it allows the stimulation of future research, since the subject is recent and urge industries and universities to prepare to the changes caused by the 4th Industrial Revolution.

With Education 4.0, the industries will be able to benefit through the intake of more qualified engineers, with better communication and automation, in the context of Industry 4.0. The universities will benefit by promoting the improvement of learning and the encouragement of the development of soft and hard skills from environments more similar to the industry reality, like the simulation environment, consequence of the pillars of Industry 4.0. The approximation between industry and university will be a positive consequence to the learning of future (university) and current engineers (industry).

As possible suggestions for future studies related to Education 4.0, there are the making of more studies related to this subject, in which they comprehensively analyze each one of the possible subjects and key words that were discussed, besides searching for new lines of research or words, aiming to expand the horizon of the relationship between Industry 4.0 and education.

It is also suggested that, in future studies, searches that connect industry 4.0 with the term “learning” are made, since this was the most frequent word according to Nvivo, among the articles selected by Methodi Ordinatio.

Lastly, it is important to stress the importance of the subject Education 4.0 in an environment of constant change, whether it is in the social, production or academic context. Education 4.0 is able to provide the necessary skills to Industrial Engineers that want to work with Industry 4.0, as well as the Industry 4.0 is able to provide the necessary tools to develop engineers efficiently, from the improvement of pedagogical projects or of environment of academic development, that is, the communication between industries, society and universities is crucial for both education and industrial production.

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**Thematic Session
Supply Chain 4.0
(Chair: Prof. Luis A. De Santa-Eulalia)**

The contribution of KPIs to build resilience in the context of Industry 4.0

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Abstract: Efforts to align aims, ensure good performance levels, and integrate resources across organizational boundaries are commonly known as Supply Chain Management (SCM) initiatives. To better monitor and manage supply chains, companies need to identify which critical factors help them to achieve competitive position in comparison with their competitors. To do so, key performance indicators (KPIs) are normally used as a set of metrics to quantify organizational actions. However, choosing "what to measure" is not an easy task and must always be tied up to a strategic orientation. This summarizes the challenge for companies in identifying which indicators would conveniently measure the efficiency of its operations and, consequently, its supply chain performance. This challenge is aggravated by today's complex technology scenario dictated by the Fourth Industrial Revolution, or simply Industry 4.0. Initially, the challenge for organizations was to identify assertively the most appropriate KPIs for measuring the supply chain performance. Now, taking into consideration the multiplication of data collecting points and the amount of data generated (with the advent of the Internet of Things, for example), and the technological advancements that allow real-time analysis and automatic decision-making, the challenge is to structure data analytic systems that can extract useful knowledge for a more efficient SCM. Additionally, knowing that the supply chain efficiency depends on internal operations and on external events, companies need to be prepared to deal with untoward events so as to anticipate, adapt, respond, recover and learn from any disruptive event. These therefore lead to a resilience capability. Given this context, the goal of this project is to investigate whether Industry 4.0 requires standard KPIs to monitor its operations along the supply chain; if so, assess which are them and how they could help supply chains to become more resilient. To that effect, we conduct a systematic literature review (SLR) to identify what is known so far about these major topics (KPIs, industry 4.0, and resilience). To conduct a thorough SLR, we developed a protocol for performing a search in two databases (Scopus and Web of Science) from 1995 to 2019. After applying the inclusion and exclusion criteria, ten papers were analyzed using the qualitative approach through a critical content analysis. As a result, a discussion was developed through the main aspects of resilience, KPI and Industry 4.0 found in the selected papers. This study found many KPIs related to 4.0 technologies, however none of them clearly explored particular KPIs emerged from Industry 4.0 that helped to create supply chain resilience. In the current results, six out of ten articles found in the third filter could not respond the proposed questions (Table 2), since they did not approach KPIs (Figure 2). In any case, those studies reveal attention to resilience within the context of Industry 4.0 technologies, which help in the sense of deepening the knowledge about the contribution of resilience in the context of Industry 4.0.

Keywords: supply chain resilience, industry 4.0, KPI, systematic literature review

1. Introduction

Efforts to align aims, ensure good performance levels, and integrate resources across organizational boundaries are commonly known as Supply Chain Management (SCM) initiatives. To monitor and

manage those supply-chain initiatives, companies need to identify which critical factors help them to achieve competitive position in comparison with their competitors. To do so, key performance indicators (KPIs) are normally used as a set of metrics to quantify organizational actions. However, choosing "what to measure" is not an easy task and must always be tied up to a strategic orientation. Initially, the challenge for organizations was to assertively identify the most appropriate KPIs for measuring the supply chain performance. At this moment, it is required to know how these KPIs can help organizations to be competitive in the complex global scenario.

Regarding overall technological advances, organizations tend to renovate their production resources in order to optimize and support the creation of new demanded services and products [1]. Upon the third industrial revolution (focused on developing applied technologies to the industrial production, such as automation and the computerization of productive lines), the fourth industrial revolution (Industry 4.0) arises with the purpose of combining various technological tendencies that unify the virtual and the physical world. That is capable of improving the efficiency in whichever industry's sector, enhancing the competitiveness of enterprises in the international market through the integration of multiple data from the manufacturing's equipment and machine. Thus, new concepts arise to support such revolution - for instance IoT (Internet of Things) and Big Data (management of high volume of information and data).

As this concept keeps on evolving and bolstering itself as the future of today's manufacturing, challenges emerge to be solved. One of them is the multiplication of data collecting points and the amount of data (most of them, real-time data) generated by production systems, which might make it harder to choose the proper data and to grasp information when it comes to decision-making. Thus, another challenge is to structure data analytic systems that can extract useful knowledge for a more efficient SCM.

Additionally, knowing that the supply chain efficiency depends on internal operations and on external events, companies need to be prepared to deal with untoward events so as to anticipate, adapt, respond, recover and learn from any disruptive event. These therefore lead to the resilience capability. This is defined as the capacity of an organization to prepare itself to cope with unexpected events, and so to better respond to disruptions along the flow of goods, information or services, in order to maintain its operations at a desirable level of connectivity as well as the control of the structure and the functions of one or more enterprise [2].

Given this context, the goal of this paper is to investigate whether Industry 4.0 requires standard KPIs to monitor its operations along the supply chain and, if so, assess which are them and how they could help supply chains to become more resilient. To that effect, we conduct a systematic literature review (SLR) to identify what is known so far about these major topics (KPIs, Industry 4.0, and resilience).

The subsequence of the article's structure is defined by the following steps. The theoretical overview will summarize the studied subjects in order to explain thereupon the replicated research method of the SLR. Afterwards, the findings will be presented according to the intersections of the discussed themes so the conclusion can return to the questions of the research to be answered.

2. Theoretical overview

2.1. Industry 4.0

According to Roblek, Mesko and Krapez [3], the concept of "Industry 4.0" was first mentioned in 2011 at a Technological Conference in Germany to promote industrial automation. The country is now considered a model to follow, as it is a world leader in automation follow-up and one of the exponents for Industry 4.0. The term "Industry 4.0" expresses cyber-physical arrangements and autonomous machines that connect over the internet, decreasing production costs that increase productivity [4]. Among many tools used in Industry 4.0, we can highlight the Internet of Things (IoT) and Big Data, which are the pillars of this concept. IoT is a network of Internet-connected devices that exchange information with each other in real time, allowing the management and collection of various data that facilitate decision-making [4]. Whilst Big Data deals with a vast amount of data and information that is generated by cyber-physical systems, concerning to how to store information, how to analyze large data and how to use it to add value to the industry [5].

Although these are well-known tools with applications in Germany and other highly industrialized countries, there are barriers that must be faced, especially in the context of developing countries, to finally

become a general-purpose model. A critical challenge is the level of security demanded, which increases with the volume of data and the criticality that information becomes for the industry. In this regard, the FTC (Federal Trade Communication) brings together information system improvement studies for privacy, system neutrality, and data security [4]. Due to increasing demand for data analysis and security, the concept of blockchain (decentralized distributed database for information logging) brings the solution to the problem of lack of security for large data. The reason is that each block is cryptographically linked to the previous one after validation and undergoing a consensus decision. As new blocks are added, older blocks become more difficult to modify, taking the information security to another level, improving the information technology for organizations [6].

2.2. Key Performance Indicators (KPIs)

Asgari et al. [7], describe supply chains as a network of organizations that are involved through a stream of processes' linkages that produce value in the form of products and services to the ultimate consumer. To monitor and manage these linkages, organizations' KPIs play a significant role in helping managers to visualize operations and having support for making decisions, which will certainly impact the whole supply chain. Therefore, KPIs are commonly known as a set of tools that help managers to evaluate the organizational performance, such as processes and activities (local and global).

According to Nagyova and Pacaiova [8], KPIs are quantifiable (metric) aspects that reflect key factors which organizations must track the operations and manage the resources to achieve success. Thus, to measure the operations performance is fundamental to understand the current scenario in order to effectively coordinate operations and keep organization on track [9]. In the supply chain context, companies generate and specify their own KPIs in terms of functional context, responsibilities and goals [10;11]. However, there is a need to integrate the supply chain members objectives at their different levels so as to select proper KPIs to provide a broader view of the business.

2.3. Resilience in the supply chain

To Holling [12], resilience is defined as the capacity of a system to adapt to change, and deal with surprise while retaining the system's basic function and structure. Since then, its concept has evolved to an important factor to supply chain risk management and vulnerability regarding the market instability and the occurrence of environmental and manmade disasters [2; 13; 14]. Considering that most of supply chains are susceptible to a broad variety of disruptions [13], it is imperative to the organizational success the development of capacities to efficiently and effectively anticipate, respond to and prevent any disruptive event [15]. Hence, this concept is understood as a responsive capability for a firm's performance, as well as a key dimension of a firm's survival. Accordingly, to obtain adaptive capacities and better responses to disasters, companies must develop proactive and reactive actions to overcome impacts and thus remain competitive [16].

3. Research Method

According to Tranfield et al. [17], the systematic literature review (SLR) allows the researcher to portray and explore the existing intellectual territory about a certain theme. The results can certainly help researchers to deep their knowledge into a specific topic, considering the process of this method is composed of structured phases to guarantee consistent, robust and replicable results [17]. Thus, this study follows the three key phases: planning, conduction, and critical analysis.

3.1 Planning of the Review

The aim of this method is to identify studies that can bring information about Supply Chain Resilience, KPIs and Industry 4.0. To do so, an SLR protocol (Table 1) was developed by clearing up all the phases and steps took in this study [17]. To achieve the goal of this study, academic articles were searched in two widely recognized databases, starting in 1995 - mark of key publications of the oldest theme in study (KPIs).

Table 1. Systematic Literature Review Protocol

Steps	Details
Question formulation	- Which are the KPIs used in the management of the technologies of Industry 4.0? - What is the role of the KPIs within the Industry 4.0 to build to resilience in the supply chain operations?
Locating studies	- Develop search strings; - Search on SCOPUS and Web of Science databases; - Search in 24-year period (1995-2019).
Study selection and evaluation	- 1st filter: title, abstract and keywords screening; - 2nd filter: introduction, conclusion and searching for the paper's content; - 3rd filter: full paper's reading and assessment about four main points: quality of journal, accessibility, theoretical and empirical content, and unit of analysis;
Analysis and synthesis	- Carefully read papers;(Full paper's reading and assessment) - Use Nvivo software to code and organize the content based on what is intended to answer from the research questions; - Content analysis of the selected papers by crossing data and observing the co-occurrence between KPI, Industry 4.0 and Resilience.
Results presentation	- Answer the review questions based on what is known in the literature. - Critical analysis from the findings observing what is the role of the KPIs within the context of Industry 4.0 to build resilience in the supply chain operations.

3.2 Conducting the review

Initially, articles were searched in the databases through strings (rigorously defined and tested on the databases) to be sure that relevant articles will not be missed. After the first search, filters were used as criteria (Table 1) to select only key articles for the full reading and analysis. These steps follow Tranfield et al. orientation [17] and are displayed in Figure 1.

Search string

(supply chain* W/5 (resilien* OR risk* OR disruption* OR vulnerab*)) AND (supply chain* AND (performance W/5 (indicator* OR measur* OR metric*)) AND (industr* 4.0 OR fourth industrial revolution OR "4th industr* revolution*" OR smart factor* OR smart manufact* OR smart product* OR cloud manufact* OR technolog* innovation* OR "internet of things" OR "IoT" OR "big data" OR cyber securit* OR cyber-physical system* OR learning factor*))

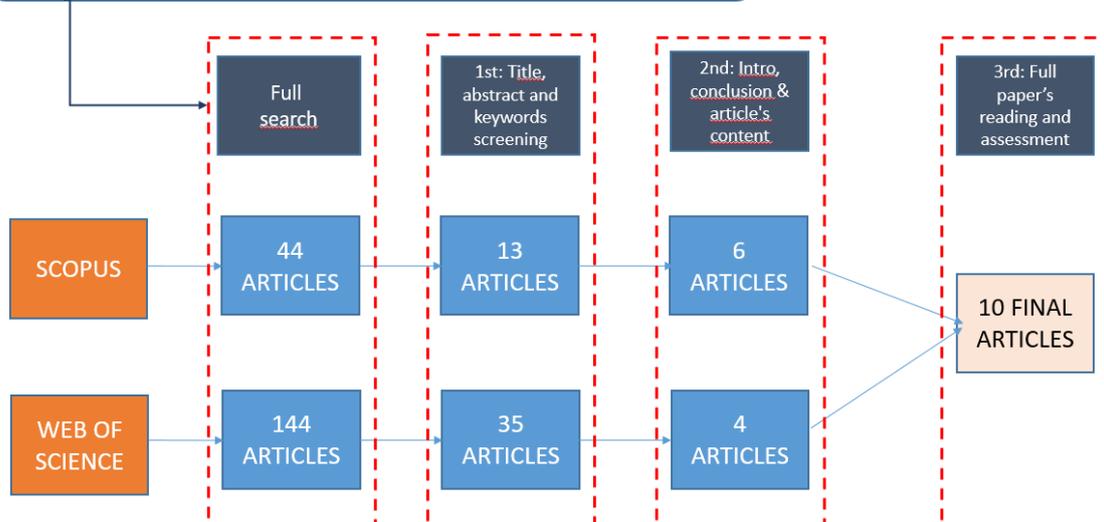


Figure 1. Systematic Review Process

3.3 Critical analysis

In total, 10 articles were selected and added to the NVivo software for the process of coding and data analysis. Two researchers started the process of coding, which were reviewed by the rest of the team to guarantee that important information was not missing. Theoretical data was analyzed by following the content analysis method. According to Bardin [18], the content analysis is composed by systematic procedures that provide a set of indicators (qualitative or quantitative), which allows researchers to extract the key parts of the text and then make inferences of knowledge, considering the whole content in study. In doing so, it became possible to observe whether the article's content might contribute to answering the review questions, and consequently the aim of the study. By using the NVivo software, it helped in the process of qualitative analysis as it crosses the concepts in analysis and provide a better relationship among them.

4. Findings

By reading the title, abstract and keywords screening of the 48 articles found in the first search, a noticeable result was the different sectors explored by the articles within the Industry 4.0 literature. Apart from the manufacturing sector, articles of tourism marketing [19] and lean hospital [20] were also identified. None of the articles approaches exclusively only one subject. Righteously on the contrary, all of them explore relations among the studied themes as Figure 2 shows. Overall, it is interesting, because it might characterize a multi-stakeholder's scenario that goes beyond the studies of supply chains.

Thereby, Figure 2 portrays the key subjects of the selected articles from the SLR: four articles approaching the three themes, five only discussing Resilience and Industry 4.0, and only one mentioning a relation between KPIs and Industry 4.0.

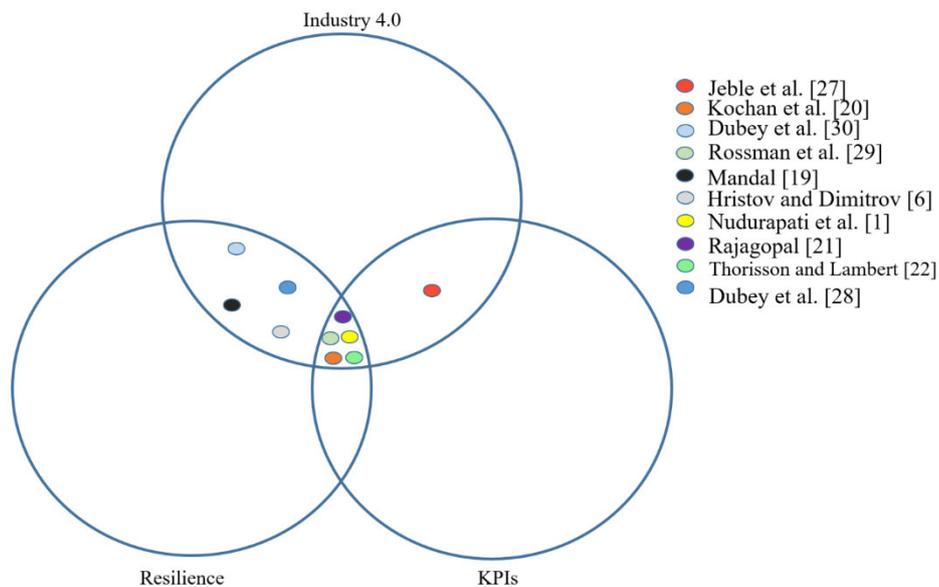


Figure 2. Subjects approached in the selected papers

After the full reading of these articles, we could identify which one can help answering the two proposed review questions (Table 2).

Table 2. Selected articles vs. review questions

Question Formulations	Nudurupati et al. [1]	Rajagopal [21]	Thorisson and Lambert [22]	Kochan et al. [20]	Jebble et al. [27]	Hristov and Dimitrov [6]	Rossmann et al. [29]	Mandal [19]	Dubey et al. [28]	Dubey et al. [30]
Which are the KPIs used in the management of technologies of Industry 4.0?		✓	✓	✓	✓	✓				
What is the role of the KPIs within the Industry 4.0 to build resilience in the supply chain operations?		✓		✓						

4.1 Fourth Industrial Revolution, KPIs and Resilience

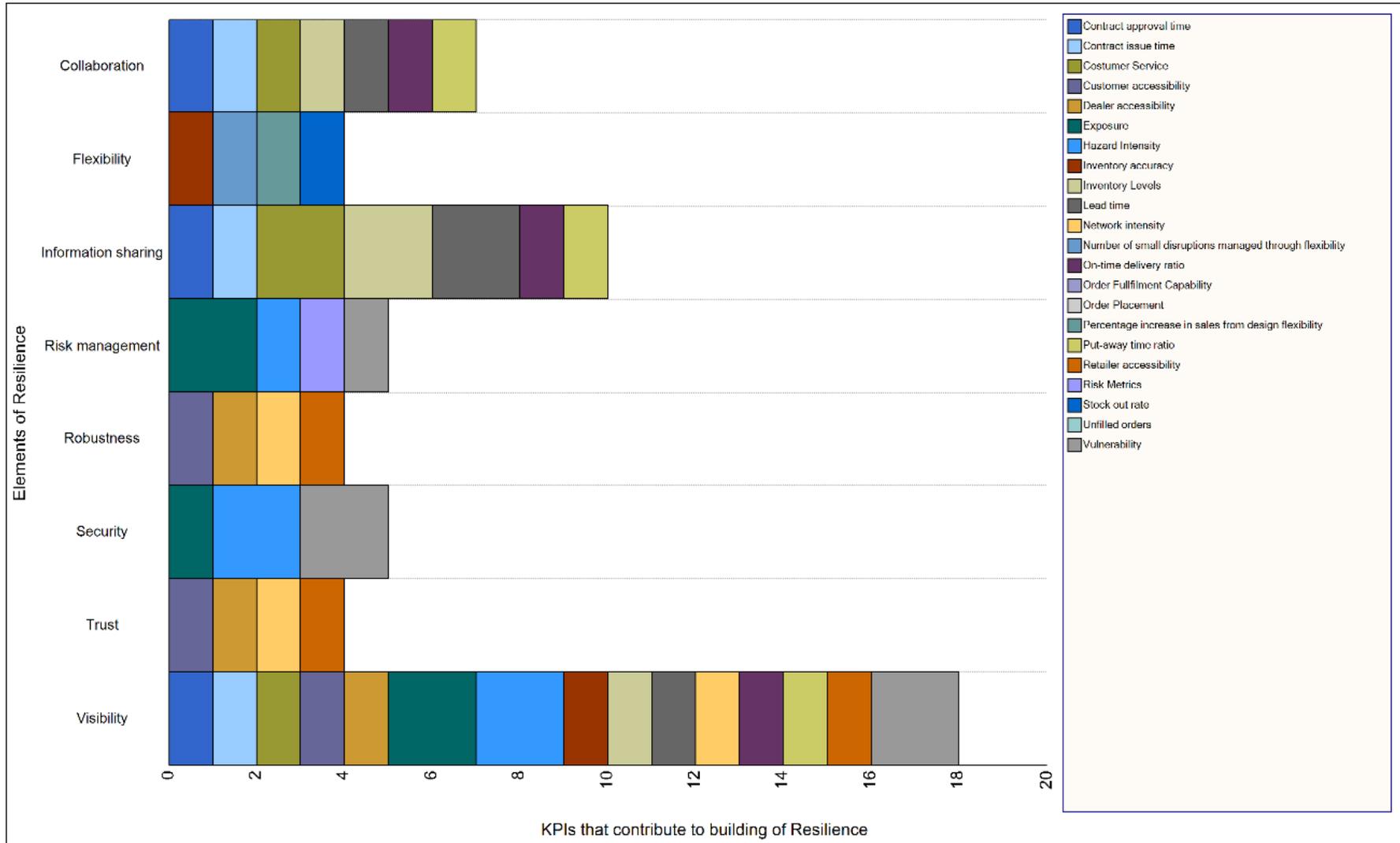
Figure 3 illustrates the existing relation between elements of resilience (vertical line) and KPIs (horizontal line; label indicates the color of each KPI). This helped in better understanding how the KPIs can help generate resilience to then depth the discussion on the Industry 4.0. The size of each block represents the frequency of which KPI were identified and related to elements of resilience.

Nudurupati et al. [1], firstly presents the scenario studied about new technologies to improve performance measurement and management, besides some challenges to become resilient. In contrast, Rajagopal [21], Thorisson and Lambert [22] and Kochan et al. [20] discuss which KPIs are used in the management of technologies in the era of Industry 4.0, as well as how they contribute to the building of resilience. Visibility, collaboration, information sharing, risk management, security, trust and robustness were elements of resilience highlighted by these authors, which were used to monitor the different KPIs (exposure, inventory accuracy, unfilled orders, network intensity, among others).

The study of Nudurupati et al. [1] presents the scenario and challenges of performance measurement and management in the digital era. By then, they claim an urgent need of empirical research and propose how models and practices should be transformed to become resilient and reflect advances in the digital economy. In this context, the participants of their case study highlighted key factors to the collaboration along the supply chain, such as trust, security and responsibility (the formers are also elements of resilience). Additionally, interviews in this study revealed the agreement of implementing technologies, such as the IoT and Big Data to improve the activities of the nuclear service company in the UK.

Yet, Nudurupati et al. [1] also draw the attention to the carefulness to implement these technologies so as to avoid often redundant and overloaded information. They therefore suggest the need for capturing data, processing data and communicating it to decision makers in a simple and easy way to use tools and techniques effectively. According to them, Nudurupati et al. [1] argue: “while it is argued that technological developments (IoT or social media) are inundating organizations with huge amounts of data, it will be in the interest of organizations to discover how that data could create competitive advantage” [1]. This is an interesting affirmation, as it supports the gap we aim to explore in this study.

Figure 3 – Relation between elements of Resilience and KPIs.



Rajagopal [21], proposes a grey prediction model for forecasting periodic indicators of resilience performance and points out the value and needs for Big Data analysis. His article highlights some elements of resilience, such as flexibility, responsiveness, quality, productivity and accessibility, in which KPIs are approached within each of them - quality of forecasts, inventory accuracy and customer accessibility are some examples of the KPIs. Different from a remarkable study in resilience supply chain, Ali et al. [23] summarize different concepts widely discussed in resilience from many authors [24;25;26]. In Rajagopal's study [21], quality, productivity and accessibility are not considered elements of resilience. The latter (accessibility) may be correlated to visibility; nevertheless, the formers tend to be characterized more to KPIs than elements of resilience.

It is important to highlight the reasons why Rajagopal [21] finds a union among the three studied subjects. He states that Data Analytics has enormous potential to improve business benefits and have a major impact on overall operating and financial performance. He also suggests its major benefits, including order-to-delivery cycle times, improved demand-driven operations, better customer and supplier relationships, effective decision-making, quicker reaction to issues, optimized inventory and asset productivity. Accordingly, the mentioned advantages can build resilience because of the improved agility and trust. His study indicates a high demand for innovative data analytics to improve strategy, operation and performance of modern supply chains. This claim is directly linked to the first review question (Table 2) as it presents the answer to supply chains handle disruptions and a variety of unpleasant operational events, which can be guided through appropriate analysis of the right KPIs (improving the accuracy of decision-making).

Even though the study of Thorisson and Lambert [22] is not in the supply chain context (as it is on the transportation networks context), they bring some interesting discussions about building resilience through KPIs and Big Data. Overall, they focus on risk management and the awareness of vulnerabilities that the emergent and future corridors of transportation networks might be exposed to. This study highlights three indicators, such as hazard intensity, exposure and vulnerability. Through these KPI, the intention is to map how they can help mitigate some of the disruption risks, such as climate change, land-use development, economic and social development, changes in policy and regulations. Finally, Thorisson and Lambert [22] claim that "advances in technology will enable the collection of data with respect to existing and additional metrics which characterize the performance of the system. Leveraging big data analytics for asset risk management is becoming increasingly important, and processes on how to store, manage access and utilize this additional information must be developed".

It is worth mentioning the inclusion of Industry 4.0 technologies. The study of Kochan et al. [20] is emerged in healthcare supply chains and intends to examine cloud computing as an enabler of electronic supply chain management systems, which enhances collaborative information sharing in a multi-echelon hospital supply chain. Their challenge is to determine the impact of cloud-based information sharing for the hospital's order fulfillment, inventory control, order placement and production supply chain processes. Excluding the last one, those are considered supply chain performance metrics.

Kochan et al. [20] conclude that "sharing accurate and timely data through effective collaboration with supply chain partners is important to respond quickly to supply chain changes, especially as supply chain complexity increases". Furthermore, the utilization of cloud-based information sharing improves demand and inventory visibility, reduces lead-time levels and variability, and improves customer service. These results can clearly be associated with practices to building resilience in the supply chain. Nevertheless, it shows a valuable result of the use of these KPIs and Industry 4.0 technologies to offer competitive advantage to the enterprises within the supply chains; although there is still the challenge of managing those technologies to achieve assertive utilization of the huge amount of data collected along the supply chain.

4.2 Fourth Industrial Revolution and KPIs

The study of Jeble et al. [27] is the only article found in this SLR that correlates Industry 4.0 and KPIs. This article portrays the impact of Big Data and Predictive Analytics (BDPA) on KPIs related to economic, environmental and social issues.

In the economic aspect, for instance, it highlights that companies' primary goal is to keep their business generating profits in the long term, competing and standing out from other companies in order to capture market share. However, due to social change and technological advances, companies are surviving less time in recent years, needing to measure more results in addition to profitability. According to Jeble et al. [27] economic success must be measured through profitability, competitiveness and brand equity; and for this to happen, they need robust analysis of the indicators to reach the intersection of the

three concepts. Analyzing environmental performance related to ISO 14001, it shows that reducing the environmental impact of production processes, the result of environmental performance can be enriched using the BDPA to optimize the environmental management system (EMS) present in the organization. Furthermore, environmental concerns have been discussed in different ways as the effects of global warming are visible today. According to this study, the effects of BDPA are sought by industry scholars to find out if implementing BDPA can help decrease the CO₂ emissions, for example. Finally, the authors explain that social performance is not measurable because the variable used to be intangible and complex. Nevertheless, the variables are qualitatively measured, which makes them still a complex phenomenon for predictive analysis.

4.3 Fourth Industrial Revolution and Resilience

Dubey et al. [28] introduce BDPA as the means to create more visibility in the supply chain, especially from upstream of the supply chain (suppliers). On the other hand, Hristov and Dimitrov [6] highlight the advantages of using blockchain in conjunction with any type of data analysis software to verify the impact of technology on organizational resilience. They argue that the confidentiality and security that comes from blockchain is a key part of resilience, because in using this technology, organizations can (i) fulfill contractual obligations and share private information with secure encryption, (ii) increase credibility with other organizations in securing data exchange and, (iii) increase the veracity of your data to customers/suppliers.

In order to build resilience, Mandal [19] argues that invests in BDPA are like investing in visibility. In his article on the tourist sector, he explains that visibility connects companies to customers, and this influences the extent to which companies can gain data for their decision-making. This author adds that BDPA offers many benefits in data collection and tourist experience. For example, BDPA does analysis and reporting that enables tourism companies to be more secure in their strategies and develop more form of monitoring within the supply chain. This is correlated to resilience, as security and visibility are elements of resilience.

At the point about the future of organizations, Rossmann et al. [29] talks about the difficulty of applying smart systems to companies and how BDPA transforms the supply chain and will continue to transform in the coming years. In his study, predictions for 2035 demonstrate how quality data analysis will improve demand forecasting and bring confidence to management decision-making. The Delphi study by Rossmann et al. [29] found that BDPA applications enable the reduction of uncertainty in the context of supply chain activities, building transparency in supply chain, increasing the agility of the organization in the supply chain landscape.

According to Dubey et al. [30], resilience is the ability of the organization or the supply chain to cope with unexpected events whilst remaining firmly structured. Resilience requires that risks are best anticipated and managed to mitigate them with strategies previously developed. Through the intersection of resilience and Industry 4.0, organizations can effectively leverage new insights gained from predictive data analytics. Reliable data organizations are better able to deal with environmental uncertainties, bullwhip effect, and other complex phenomena to deal with.

5. Conclusion

Through the critical analysis of the selected papers, there was a great appeal by companies to increase their level of technology so as to gain or keep competitive on the market. Predictive analytics on BDPA were found in all 10 articles as a primary tool for analyzing the sheer volume of information that organizations are currently navigating. The key issue to create resilience is to discover how that data could create competitive advantage within the organizations. To this end, this study found many KPIs related to 4.0 technologies, however none of them clearly explored particular KPIs emerged from Industry 4.0 that helped to create supply chain resilience. In the current results, six out of ten articles found in the third filter could not respond the proposed questions (Table 2), since they did not approach KPIs (Figure 2). In any case, those studies reveal attention to resilience within the context of Industry 4.0 technologies, which help in the sense of deepening the knowledge about the contribution of resilience in the context of Industry 4.0.

As any research, this study has limitation. It is purely focused on literature from two databases. For that matter, the same SLR will be conducted in other databases (EBSCO and ABI/Proquest) to raise more information and better explore what kind of KPIs are used by organizations that incorporate 4.0

technologies on their operations, and how these KPIs can help create resilience. In this matter, another limitation of this study was the identification of particularities and similarities of each of the selected paper. Through this analysis, it would be possible to raise common KPIs from industry 4.0, and then further discuss them to the resilience capability. This is also a future step of this research, as well as validating and/or complementing the theoretical knowledge of this research through empirical case studies.

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The supply chain in the industry 4.0 context in small and medium enterprises: an international landscape

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Abstract: In this century, business and scientific community are witnessing a velocity of technological development that, looking history, can be characterized as another industrial revolution. Knowledge and technological solutions are evolving fast, favoring all kinds of enterprises worldwide. This fourth industrial revolution, usually named as industry 4.0, unite concepts and technologies that can be applied in varied areas of business (industrial or services) and science. Therefore, the proposal of the present article is to understand how scientific works have approached supply chain issues in industry 4.0 context specifically when it concerns small and medium enterprises (SMEs). The interest in this strand of the theme is based on the fact SMEs have a significant influence on the economic and social context of most countries in the world. In addition, based on the fact supply chain activity goes beyond organizational boundaries, enterprises can be highly benefited by the concepts and technologies of industry 4.0, as already shown in recent studies. Consequently, understanding how science has directed its questions to this theme shows the tendency and maturity of the subject, allowing to reach new horizons. To obtain this thorough overview, two main scientific databases (Scopus and Web of Science) were searched, with keywords that would lead to work on this topic, considering the procedures of the systematic bibliographic review, which guides the search for keywords connected by boolean operators. The methodology also includes the definition of filters for the selection of articles linked to the research objective, as well as the rules of inclusion and exclusion. Thus, the search string and three filters were defined, in which the first one includes the reading of the title and abstract of the works, the second consists in the reading of the introduction and conclusion, and the third in the reading of the complete article. As an exclusion criterion, was defined that only english-language works would be selected. The number of articles initially returned from both databases (19) led to draw the first conclusion, that this topic of study still very incipient. By reading the works, could be inferred that most of them seek to show the best appliance possibilities of concepts and technologies from the fourth industrial revolution. This is the main aim of the present work as well.

Keywords: Industry 4.0, Fourth Industrial Revolution, Supply Chain, Small and Medium Enterprises, Literature Review.

1. Introduction

As the topic supply chain in the industry 4.0 context arises as a revolution not just in the way products are made, but on how information and material flow through the supply chain and value chain networks. It is important to look forward on how technologies and concepts interact. For instance, the communication between the various areas, internal or external of the organization, for production or administrative purposes.

For small and medium enterprises (SMEs) in special, the theme is treated with more attention and care, once investments in tech represents responsibility and commitment of budget. Thus, in this article, after a previa about industry 4.0, supply chain 4.0 and correlated topics in the background section, will be explored the current scenario of this trend and the best ways of tech applicability for SMEs, glimpsed from most recent scientific productions. Followed by pertinent discussion that guides the final conclusions over the theme.

The study was conducted based in the systematic bibliographic review methodology, guiding the overview obtaining. Relevant scientific databases were searched, with keywords well selected and connected, and filters defined aligned to the research objective. Consequently, this paper was organized as follow: introduction (section 1), background (section 2), methodology (section 3), findings and analysis (section 4), discussion (section 5), conclusion (section 6), references (section 7).

The present work aims to emphasize the relevance of this matter and its dominant aspects, mostly because of increasing competition worldwide and fast technological evolution. For SMEs, principally, adaptative and flexibility capacities are relevant for growing or remaining competitive. And, presently, the best enablers are technological developments and related capabilities.

2. Background

2.1. Industrial Revolutions

The first industrial revolution is characterised by the fast introduction of the power of steam. The second is marked by the advent of electricity use in production. The third, in the 20th century, for the use of information and logic with electronic devices, capable of programmable logic.

By fourth industrial revolution, or industry 4.0, is understood the use of hi-tech, such as devices with high processing and database capabilities and cybernetics, not just for automation, but decentralization of production decisions as it seems useful. Since this revolution is characterised by the bond between physical and virtual grounds, current instruments used to this goal are sensors, databases, processors, actuators and sometimes wireless access.

2.2. Value Chains and Supply Chain in Industry 4.0

Firstly, value chain can be described as a collection of activities performed to design, produce, market, deliver, and support products, creating value for customers. Industry 4.0 englobes what is newest in concepts and technologies of nowadays value chains, sometimes referred as global value chain in order of last decades' globalization progress, and consequently possible involvement of machines and activities worldwide for value creation.

Industry 4.0 attempt to connect multiple areas with concepts as IoT (internet of things), that comprehend the joining of virtual and physical spheres, with interconnectivity and proper infrastructure. That permit the decentralization of decisions as it seems necessary, along faster communication. Moreover, this interconnection allows to follow the products through their lifecycle, among use and relevant decision making, by clients or producers, according to who it concerns.

These technologies and concepts coined as industry 4.0 goes beyond the value chain of a single organization, truly embracing industries and supply chain links worldwide. In this concern, it is valid to remember the existence of the worldwide connection of computers, devices, and applications, as cloud services for example. Furthermore, considering supply chain links, it is important to highlight that currently producers can deliver to diverse markets worldwide. Therefore, can be presupposed that value creation in recent years has being impacted by globalization matters.

As the velocity of information evolve along communication technology, multiple actors are progressively involved internationally. For the supply chain management, the advent of industry 4.0 technologies led to a higher complexity in the treatment of information and production processes. Real-time communication; expanded access to suppliers and clients; quality management through all product lifecycle; adaptability; interchangeability; cloud computing; digital twins; big data storage and analytics are some of the new factors introduced recently.

Those factors elevate some benefits related to value creation, as: customization and flexibility in production, efficiency and optimization in the use of resources, in addition to information transparency, that can result in better decision making along the value chain.

2.3. Industry 4.0 and Supply Chain 4.0 for Small and Medium Enterprises

The main aspect to focus in this concern, of industry 4.0 and supply chain 4.0 for SMEs, is the lack of accessibility or capital to invest for major technological solutions. So, in a competitive way, when compared smaller and bigger firms alongside, they usually distinguish by disponsible resources (or capital). That

translate into different grounds of hi-tech capabilities, as: big data capacities and analytics, sensors and actuators, connectivity, or security. On the other hand, for SMEs, the integration of areas and activities in vertical and horizontal ways are facilitated, specially by the size of the enterprises itself.

Anyway, the biggest challenge for SMEs is to achieve interconnectivity and interoperability, the creation of such rapport enables the key capacity of flexibility in production and customization, which usually translate into optimization and effectiveness, with cost reduction and more agility, since the typical focus of enterprises are the customer satisfaction.

For that objective, networks must be improved with better communication and modularity in production means. The as real as possible digital representation of products and production resources (sometimes called digital twins) helps to simulate and plan to perform with more quality, enhancing SMEs' competitiveness. For SMEs, to be competitive mean been well adaptative and able of continuous improvement maintaining attractive prices.

Through holistic view, of internal and external environments of the organization, more accurate decisioning regarding new technologies can be reached, fulfilling the aim to upgrade the quality of products and processes, eying lower costs, profit increase and bettering quality.

To achieve those purposes, technologies must be applied the best way possible, in order to: connect different kinds of devices interactively; fasting communication in the value chain; empowering customization in manufacturing, after sales services, corporate strategies and decisioning. Some of the best technologies to be chased and applied related to industry 4.0 are: cyber physical systems; cloud computing; internet of things; big data and analytics. Which innovate business networks, flexibility in processes and production management.

3. Methodology

Supply chain activity goes beyond organizational boundaries and can be highly benefited by the concepts and technologies of industry 4.0, especially in relation to SMEs. Understanding how science has directed its questions to this theme shows the tendency and maturity of this paradigm, allowing to seek and reach new horizons.

To obtain the overview, two main scientific databases (Scopus and Web of Science) were searched, with keywords that would lead to work on this topic, considering the procedures of the systematic bibliographic review, which guides the search for keywords connected by boolean operators. The methodology also includes the definition of filters for the selection of articles linked to the research objective, as well as the rules of inclusion and exclusion.

After considering the search string (("industry 4.0" OR "fourth industrial revolution") AND "supply chain" AND ("small and medium enterprises" OR SME)). Three filters were defined, the first one included the reading of the title and abstract of the works, the second consisted in the reading of the introduction and conclusion, and the third in the reading of the complete article. As an exclusion criterion, was defined that only works in english language would be selected. The number of articles returned in both databases were 19, with total document access to 11 of the 19 articles, which led to the development of this work.

4. Findings and Analysis

Most of the works explore and show the possibilities related to the advancements from fourth industrial revolution, trying to demystify the understanding and explain what can be done with the new theoretical and technological development. Some of them focus on more technical topics (as specific projects), while others try to elaborate a taxonomy for this area.

This findings and analysis resulted from the 11 articles selected with the methodology described. The research was realized in mid-June 2019. Most articles are dated from 2018 or 2019 (Figure 1). That explicit the actuality of the theme and the growing interest on it. Searching on how the thematic has evolved, it was evidenced that the applicability of concepts and technologies are spreading across varied areas of knowledge and industries, even agriculture.

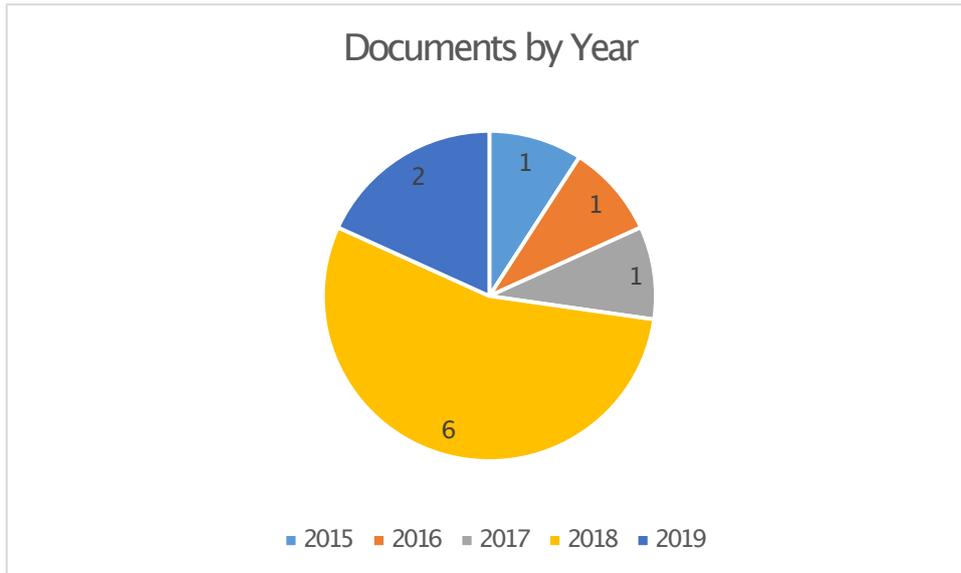


Figure 1: Number of publications per year, considering the 11 final articles selected.

5. Discussion

The number of articles returned in both databases (19), and mainly the 11 selected, led this discussion to claim that the topic still very incipient. Bellow, a brief presentation of the contribution of each work:

Table 1: Brief resume of the main selected articles.

Autor	Year	Contribution
Chen	2019	Creation of value in industry, using advanced technologies in SMEs, with a textile industry case study
Zambon et al.	2019	Compare and explore the application of industry 4.0 technologies in agriculture, possible impacts and solutions
Bär et al.	2018	Determination of company limitations and opportunities, for consequent application of industry 4.0 solutions
Lazarova-Molnar et al.	2018	Highlight the relevance of data analysis to achieve success in SMEs, and the implementation challenge
Din et al.	2018	Implementation of concepts and technologies of industry 4.0
Marty et al.	2018	Industry 4.0 LED projects for SMEs and other sized companies
Dossou	2018	Application of industry 4.0 for SMEs, especially metallurgy
Wang et al.	2018	Modelling of industry 4.0 implementation systems, for engineering projects
Qureshi et al.	2017	Implementation and control of ERP and company data collection systems
Prause	2016	Development of e-business, the integration between cyber and business worlds, by industry 4.0 means
Prause	2015	Structuration of business models in order to integrate company activities and supply chain in the present industry 4.0 scenario

All works in some instance try to study or develop ways to apply industry 4.0 advents to business. Mostly, regarding SMEs or supply chain activities.

The main challenge identified in this study is the accurate determination of company limitations, for adequate industry 4.0 implementations. Was evidenced that the acceptance of opportunities is key to initiate

the planning for implementing technological solutions. To fulfil that objective, the understanding of the supply chain and the own enterprise concomitantly may guide to the best results.

6. Conclusion

Although the debate still incipient in regard of SMEs in general terms, in this work could be gauged that the interest is crescent in the scientific community, as well as in business, once the positive results of recent technologies are already confirmed. While the prices of investments and costs still high, small and medium enterprise players are trying their best to make accurate decisions when it refers to financial commitment for industry 4.0 kind of solutions.

The comprehension of the theme guided to the understanding that the knowledge related to implementation and applicability is as important as the pursuing of technological artefacts. Modelling and implementing industry 4.0 projects require specialized capabilities and personnel, as well as digital structures, a staff capable to continue the enterprise activities and maintaining the quality of processes are required during and after implementations.

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DIGITAL SUPPLY CHAIN: A literature review

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Abstract: There is no common ground on what a Digital Supply Chain (DSC) really is, what technologies are associated to it, the extension of these technologies' application into the chain, or the value created (Buyukozkan & Gocer, 2018). The research was guided by the following questions: 1) What is the most appropriate definition for DSC? 2) What technologies have been used at each stage of supply chain management and what is the value created for the companies that adopt them? A Systematic Literature Review was conducted focusing on three highest ratings of ABS Guide 2018, in the fields of Operations and Technology Management, Information Management, and General Management, Ethics, Gender, and Social Responsibility. Using a combination of keywords related to supply chain and digital* (OR smart OR intelligent), a list of 134 papers were identified in the Web of Science database. The first aim of our analysis was to define DSC. To expand the discussion, we adopted the process known as snowball to incorporate the definitions cited in the paper of Büyüközkan and Göcer (2018). A concept of "Digital Supply Chain" with a chain management perspective and not of technology was proposed. Thus, the present study defines "Digital Supply Chain" as: "a supply chain that uses digital platforms, digital technologies and data analytics, connected in intra/inter-organizational systems, to promote integration, collaboration and synchronization and increase efficiency, service level, visibility, sustainability and resilience, resulting in consistent value creation in the chain and for the end customer." Furthermore, the analysis showed three important dimensions: the unit of analysis, technology, and values. The first dimension, unit of analysis, allowed us to identify that the studies apply the concept of DSC in a restricted way, within a company, or in a wide way, in the supply chain. The application of broad form occurs in the dyads and the chain, involving multiple partners. There is also a variety of digital technologies for collecting, transmitting, and analyzing data applied in different processes of the supply chain. The proposed framework suggests an evolutionary stage to be adopted by organizations. Nevertheless, companies do not necessarily need to go through all stages. The stage at which the entire chain becomes digital consists of a high degree of maturity, where all processes and all organizations would be connected by these technologies. This study proposes an integrative definition for a digital supply chain and also allowed to identify the most cited digital technologies in each area SCM and the gains by function within the chain.

Keywords: "Digital Supply Chain", "Technologies", "Value"

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Business Cluster Identification Leveraging Self-Organizing Maps

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Abstract: The importance of industry clusters as sources for regional development have been widely studied and explored. Business cluster identification is an important topic for helping understand regional and global supply chains, establishing economic policies, and logistics. We propose the use of self-organizing maps (SOM) to identify clusters using large multiple-datasets. SOM is an artificial neural network that achieves dimensionality reduction by projecting a feature space into two dimensions. Due to the effectiveness of the SOM for recognizing correlations within datasets, we propose using SOMs for the automatic mapping and identification of business clusters. The proposed method is advantageous over previous work in that the algorithm is unsupervised and makes no assumptions about the number of clusters for a given feature set (Vesanto and Alhoniemi, 2000; Costa and Netto, 1999). The proposed algorithm was evaluated using recent datasets for US metropolitan cities from the Indiana Business Research Center (Innovation 2.0) and the Occupational Employment Statistics Survey. Data involving innovation metrics, education levels, economic wellbeing, connectivity, local GDP, and STEM, are leveraged to demonstrate the effectiveness of the proposed machine learning algorithm. The clustering results are compared to common approaches including K-means clustering and manual regression techniques using a data visualization tool and which results were compared to the results generated by the SOM outputs. The unsupervised nature of the proposed SOM approach and acceptable computational complexity of the overall algorithm suggest that self-organizing maps offer several advantages over traditional methods. Preliminary results confirm the viability of self-organizing maps as an unsupervised approach for identifying business clusters.

Keywords: Self-Organizing Maps, Clusters, Artificial Neural Networks, K-means

1. Introduction

Understanding the landscape of business clusters is a critical endeavor that affects all aspects of logistics, supply chain management, and regional economic analysis. A detailed perspective on clusters allows businesses to gain knowledge of competition as well as understand strategic partnerships for achieving a competitive advantage. New ventures are compelled to look towards business clusters for a complete picture on where innovation is more prevalent or where opportunities may exist. Moreover, policy makers take into account business clusters and their concentrations to make decisions on infrastructure and resource allocation (Ketels, 2013). Despite the critics (Martin and Sunley, 2003), due to the myriad of benefits of understanding how businesses may be clustered, much research has been conducted to analyze the wealth of data available from numerous public databases in order to group businesses and define clusters (Porter, 1993, 2000; Feser, 2005; Yusuf et al., 2014; Delgado, Porter, and Stern, 2016).

Different authors have proposed a variety of methods to identify and group business clusters, and the importance of the use of Artificial Intelligence (AI) in Management Science and Operations Research has been long highlighted (Simon, 1987; Mora et al, 2005). However, there is not a definitive automatic approach for identifying business clusters for a given dataset. Therefore, we propose the use of a modern algorithm based on artificial neural networks for unsupervised clustering of business units. With the ever-increasing availability of data, and the dynamic nature of business clusters, an automatic solution will provide a means for consistent analysis of business units. This work also provides a reliable tool that avoids any pitfalls associated with requiring prior knowledge of the underlying clusters which allows one to understand business clusters without bias. The proposed three-phased approach outlined in this work is compared to the traditional machine learning method of K-means clustering, as well as the manual identification of correlated groups. This work leverages current public databases to illustrate the

effectiveness of the proposed deep learning algorithm. The method outlined is shown to be successful for datasets with large dimensionality, and differently from previous works (Porter, 1993, Feser, 2005, Delgado, Porter, and Stern, 2016), it makes no prior assumptions about the characteristics or the number of resulting clusters.

Quantitative and qualitative methods have both been applied for analyzing clusters in previous work. A thorough review of the most common methods will be presented in the next section, which is then followed with a detailed description of the proposed approach, an analysis of the results from employing the automated method, and finally a conclusion will be provided, along with a description of the future direction of this work.

2. Theoretical Background

The definition and methods to identify and group industries into clusters as well as the importance of industry clusters as sources for regional development have been widely studied and explored over the last three decades. Porter (1990) presents one of the first theories to illustrate the concept of regional clusters and their role shaping national and regional competitiveness in a global scenario. The definition of business clusters has evolved, but the essence remains the same. Clusters are, “Geographic concentrations of industries related by knowledge, skills, inputs, demand and/or other linkages” (Delgado et al, 2016). Examples of clusters include the financial services in New York (Wall Street), aerospace in the Seattle region, IT and software industries in the Silicon Valley, and automotive industries in the Detroit region amongst many others.

Business cluster identification is an important topic for helping understand regional and global supply chains, establishing economic policies, and logistics (Rivera, Sheffi, and Knoppen, 2016). Extensive research has been conducted to extract meaningful business clusters from the vast data available for each region because of the immense value in understanding the proximity and correlations of neighboring clusters. Different authors have challenged the main theoretical basis (Martin and Sunley, 2003; Alexandros and Metaxas, 2016), some have tested different ways to identify and group clusters (Porter, 2003; Feser, 2005; Delgado et. al. 2016) but few have challenged or used artificial intelligence methods in regional business cluster identifications. The most common methods are either manual or require prior knowledge about the clusters.

Different authors have proposed a variety of methods to identify and group business clusters. Porter (2003) develops one of the first attempts to measure how pairs of industries were related to each other. The author uses four-digit SIC codes of 1996 industry employment data across states through pairwise correlation. The goal was to identify co-location patterns of employment and thus recognize different types of inter-industry connectedness. Using the narrow approach for cluster definition (clusters that are mutually exclusive), Porter’s (2003) analyzed a dataset of 685 industries that were then grouped into 41 clusters. Feser (2005) evolved on the works of Feser and Bergaman (2000) based on Input-Output (IO) data. Rather than the factor analysis method proposed by Feser and Bergaman (2000), Feser (2005) developed a methodology based on hierarchical clustering using IO matrix for different manufacturing and service industries. The former authors had faced issues related to highly uneven clusters created using principal component factor analysis with a large number of IO codes grouped into a few clusters. Feser’s (2005) included a dataset of 910 industries that were then grouped into 44 clusters. Delgado et al (2016) a more comprehensive methodology involving five inter-related steps to identify, group, and compare clusters. The initial step is the construction of a multidimension similarity matrix. Next, due to restrictions of the method, the authors had to establish the initial number of clusters for the data to be organized considering two parameters of choice: starting value and the type of normalization. The third step is the clustering function for continuous data using the hierarchical function (with Ward’s linkage) and centroid-based clustering functions (k-mean and k-median). Step four develops an overall validation scores to identify the most appropriate set of clusters among 713 possibilities generated. Finally, the last step involves an expert judgement for final tuning and correction of possible anomalies within different clusters.

The aim of this work is to leverage the benefits of the self-organizing map to identify business clusters which are described with high dimensionality feature vectors. The extensive amount of data available today

on businesses makes SOM an ideal candidate for performing the clustering operation. Since modern algorithms are largely manual, or require prior knowledge of the number of clusters, an automated algorithm involving SOM will offer advantages of unsupervised learning that can be accomplished using less computational time. Inspired by Costa and Netto's segmentation approach, it is believed that an automated system can be used for the automatic detection of business clusters given high-dimensionality datasets.

Conceived in 1982 by Kohonen (Kohonen, 1982, 2001), the self-organizing map (SOM) is a special artificial neural network (ANN) which does not contain a hidden layer that achieves dimensionality reduction by mapping input vectors into one- or two-dimensional space. Aside from lacking a hidden layer, the SOM differs from traditional ANNs in that the weights connecting the input and output layers are updated using a competitive learning method for a given neighborhood pattern, as opposed to minimizing a cost function using back propagation. The original SOM algorithm is designed to mimic the neurons of the brain where correlated signals maintain spatial relationships. The power of the SOM is the ability to project high dimensional, non-linear data to a low dimensional map while preserving spatial relationships for easy visualization.

Since the SOM is capable of compressing information while maintaining spatial relationships based on correlations, SOMs are frequently used in machine learning applications involving clustering. Vesanto and Alhoniemi (2000) provide strong examples of utilizing hierarchical and partitive clustering techniques in conjunction with SOMs that perform clustering on large datasets that is as accurate as traditional approaches but uses less computational time. Their results illustrate the effectiveness of reducing the dimensionality of the inputs prior to clustering without sacrificing the critical information needed for grouping the data, however their work relies on understanding the number of clusters to search for within the SOM. To overcome this restraint, Costa and Netto (1999) propose an automated method for identifying the number of clusters based on the unified distance matrix of a SOM using region-based image segmentation. The examples presented in Costa and Netto's work are trivial with low dimensionality but serve as a basis for identifying business clusters.

3. Proposed Approach

The following section describes the three-phased approach for automatically identifying business clusters without any prior knowledge of the clusters. Figure 1 summarizes the components of the proposed method which will be defined in more detail in the subsequent sections. A formal definition of the self-organizing map is given, then a region-based image segmentation approach is described, and finally an appropriate centroid clustering algorithm is presented.

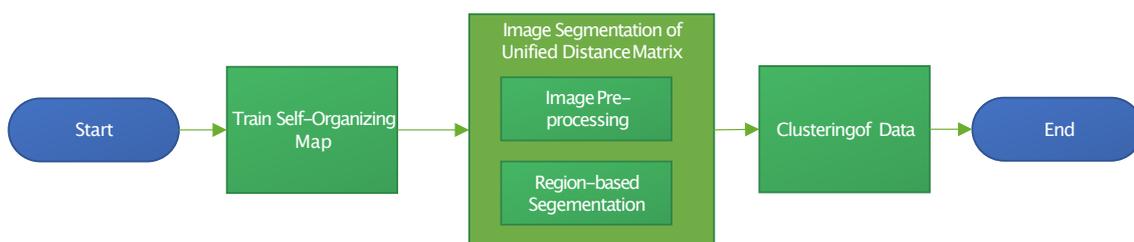


Figure 1: The propose method illustrating the three primary phases for unsupervised business clustering

3.1. Self-Organizing Maps

Given a dataset of n input vectors, $I = \{x_1, x_2, x_3, \dots, x_n\} \in \mathbb{R}^m$, $x_j = [x_{j1}, x_{j2}, x_{j3}, \dots, x_{jm}]^T$ is defined as a input vector with m features. Each node of the SOM is represented by a vector of weights, $w_j = [w_{j1}, w_{j2}, w_{j3}, \dots, w_{jm}]^T$ with the same dimensionality as the input vectors. These weights are initialized with random values and are compared to every input vector. Figure 2 illustrates the input and output layers of

the SOM along with the weighted connections between the input layer and output layer. For simplicity, the connections are only shown for the first two columns of the SOM.

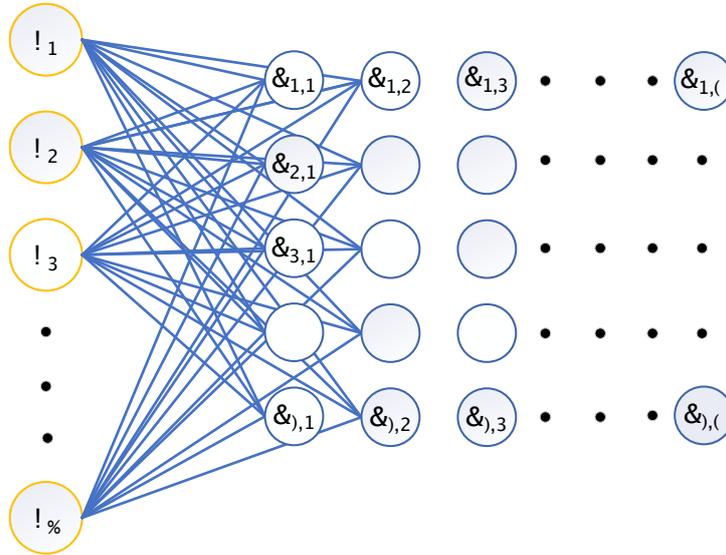


Figure 2: General illustration of mapping a dataset X to the nodes of an $i \times j$ Self-Organizing Map

When an input vector is presented to the SOM, the assigned neuron is determined by considering the distance between the input and all nodes. The best matched unit (BMU) is selected as node $(g, @)$ of the SOM if the distance between node $(g, @)$ and input vector is less than the distance between the input vector and all other nodes.

$$BCD_{g,@} = \underset{g}{\operatorname{argmin}} \sqrt{\sum_{N=1}^N (x_N - w_{g,N})^2} \quad (1)$$

The premise of SOM is built on the assumption that an input vector is assigned a neuron whose neighbors share similar characteristics. This fundamental property of SOMs is the basis of why SOMs are leveraged for clustering high dimensionality data. Once a BMU is determined for a given input vector, the weights of the BMU and neighboring nodes are updated using the input vector's features. If two vectors are assigned to neighboring nodes, the weight update operation will be in direct competition with each other. The weights of the BMU at node $(g, :)$ and neighboring nodes are updated according to the following,

$$w_{g,:}(S+1) = w_{g,:}(S) + h_{g,:} * x_{g,:} - w_{g,:}(S) \quad (2)$$

$$h_{g,:} = W \frac{X_{g,:}^2}{2Y_{g,:}^2} \quad (3)$$

The typical neighborhood is a Gaussian function where $X_{g,:}$ and $Y_{g,:}$ is the distance and standard deviation, respectively, between two nodes. The standard deviation of the nodes controls the radius of the neighborhood. For a given input vector, the Gaussian function provides a means to emphasize the weights of the winning BMU while suppressing the weights of the neighboring nodes. The competitive learning aspect of the SOM algorithm is in reference to the fact an input is mapped to a specific BMU while reducing the weights of neighboring nodes, as determined by the neighborhood function given in Formula (3). The suppressive nature of this function is based on distance and increases exponentially so that local maximums are realized. On each successive iteration of training, the standard deviation is decreased to allow convergence of local maximums for competing input vectors. Figure 3 demonstrates the competitive learning of BMUs to two input vectors that have overlapping neighborhoods. The dark circles indicate the assignment of two inputs while the lighter circles denote the reduction of weights for the neighboring nodes. The two nodes that exist in the area where two neighborhoods overlap represent nodes that are reduced

based on the effect of two competing nodes, as shown by the highlighted nodes of Figure 3. When many observations are projected to a SOM, the competitive nature of the algorithm will alter a BMU's weights frequently so multiple iterations of the learning phase are necessary in order to converge. The weights of the darkest nodes are most affected by the assignment of a BMU, whereas the lighter color nodes illustrate a diminishing effect on neighboring nodes after assignment.

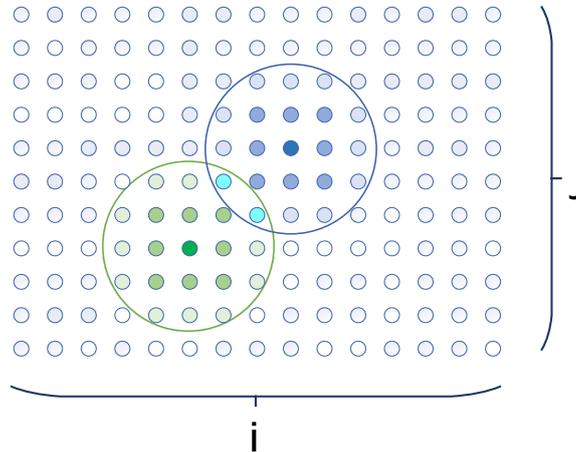


Figure 3: Example depicting the effects of the competitive learning phase using a Gaussian neighborhood

The work completed by Vesanto (2000) suggests the number of neurons in the SOM grid be a function of the number of samples. For this work, the grid dimensions are chosen from n observations, to be a square with dimensions $i \times j$,

$$i = j = \lceil \sqrt{n} \rceil \quad (4)$$

The number of training iterations can be varied to control quantization error with diminishing returns but is necessary for convergence. The proposed approach in this work uses 1,000 iterations which produces low quantization error while remaining computationally reasonable. Several iterations ranging from 500 to 2,000 were tested where 1,000 provided an average error of 16.0% with a standard deviation of 9.9%. Iterations as high as 2,000 risk overtraining the model and take several magnitudes of time longer than the chosen parameter of 1,000 for a marginal improvement of quantization error. This parameter is application specific and could be explored further, however the value chosen for this work represents a reasonable tradeoff between low error, being computationally efficient, and low risk of overtraining.

3.2. Segmentation of the Unified Distance Matrix

After training the SOM, a unified distance matrix (U-matrix) can be generated to visualize the data groups. A grayscale image is constructed by mapping the quantizing the Euclidean distances between features, where lighter pixels represent neighboring nodes with similar features and hence smaller Euclidean distances, and darker pixels are dissimilar characteristics. Traditional U-matrices are depicted in grayscale; however, the U-matrix can be mapped into other color spaces for easier analysis. Figure 4 provides an example U-matrix with overlaid contours to visualize the local maxima.

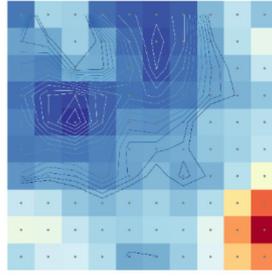


Figure 4: Resulting unified distance matrix used for visualizing a Self-Organizing Map

Cluster boundaries are identified by analyzing the U-matrix from a SOM, which can be automated using image segmentation, as demonstrated in Costa and Netto (1999). The purpose of segmentation is to partition an image into broader groups of pixels. Because a U-matrix defines the boundaries of clustered data, the intention of segmentation of the U-matrix is to clearly detect the borders of the data to identify the number of unique clusters in the SOM. The following section describes the image pre-processing and region-based segmentation method for automatically detecting the number of clusters from a U-matrix.

3.3. Image pre-processing

Prior to segmentation, an image is often pre-processed to emphasize features and remove noise. A common set of tools to do so are called morphological operators. More specifically, erosion and dilation operators are performed on binary maps. Erosion is defined as,

$$_-' = _- \ominus W \quad (5)$$

When a binary image is filtered with an erosion kernel, W , the resulting binary image, $_-'$, will reduce an image feature for a given neighborhood. This operation helps reduce noise or insignificant features from a binary image. Conversely, the dilation morphological operator increases boundaries and is defined as,

$$_-' = _- \oplus c \quad (6)$$

Application of the dilation operator will fill small gaps and emphasize features but may also amplify noise. The usage of both operators is common practice to remove noise and accentuate large features, however this is not a general rule as to how many times an operator is applied or the size of the kernels. For this work, we used kernel sizes of 5x5 on a binary image that was produced using the Otsu thresholding method. The erosion operator was applied successively three times to eliminate noise and weak features, then the dilation operator was used three times to enhance the remaining binary structures. Without pre-processing images, the problem of over-segmentation can arise where redundant and disjoint partitions are formed.

3.4. Region-Based Segmentation

The resulting binary map after pre-processing acts as a template for significant features in the image. After suppressing all nonsignificant features of the U-matrix, the image is segmented using a region-based approach called watershed segmentation. Originally proposed by Digabel and Lantuejoul (1978), the watershed segmentation process is an excellent candidate for analysis of the U-matrix because its core premise is to identify peaks and valleys within an image which is exactly how a U-matrix is formed from a SOM. The segmentation algorithm has been employed in a myriad of image analysis applications, such as computer vision (Patras, Hendriks, and Lagendijk, 2001), natural language processing (Mathivanan, Ganesamoorthy, and Maran, 2014), and medical imaging (Yu-LenHuang and Dar-RenChen, 2004) due to its versatility.

The premise of watershed segmentation is to identify catchment basins within an image that represent an object or area of interest. In the case of the U-matrix, catchment basins are the local maxima from data

clusters. By treating the U-matrix as a topographic image, the pixel intensities provide insight into the local maxima where the darkest pixels whose values are closer to 0 represent low points, or the catchment basins. From the perspective of the SOM, these catchment basins are areas that have been suppressed during the competitive training. Conversely, the areas of interest will have larger pixel intensities and represent the local maxima. Figure 5 illustrates a U-matrix and the resulting region-based segmentation after pre-processing. The images exemplify the isolation of significant data clusters of the SOM.

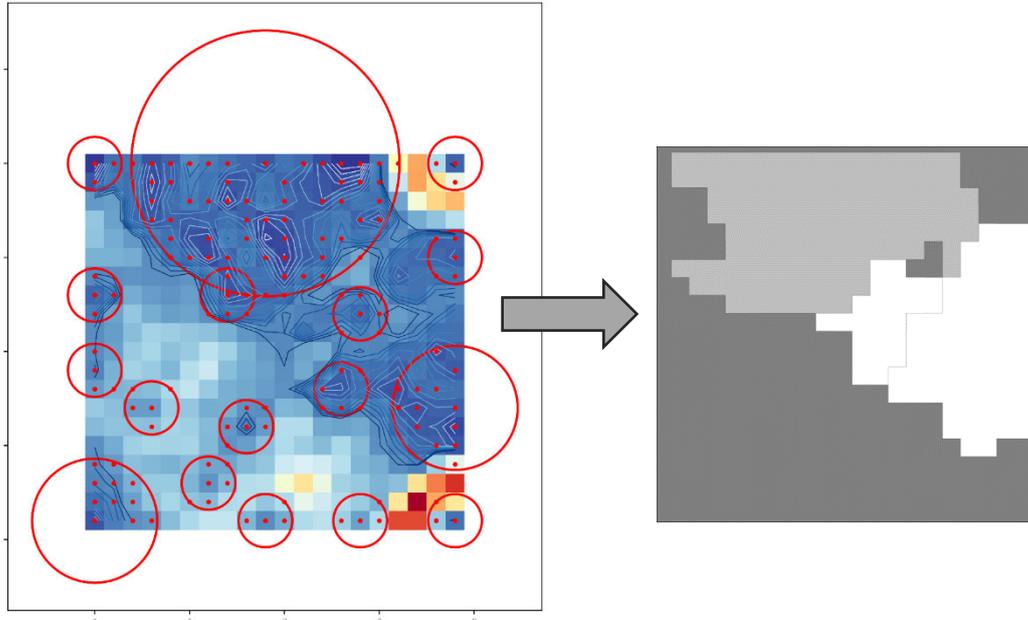


Figure 5: Example U-matrix and resulting watershed segmentation, identifying unique clusters

3.5. Clustering

The output from the segmentation phase identifies the number of clusters identified from the calculated U-matrix of the SOM. This value drives the clustering phase which is executed on the SOM then projected back to the original dataset. K-means clustering is a widely used cluster analysis algorithm to map / data points into ? clusters, where / ≤ ?. Stated formally, let $\mathcal{I} = \{I_1, I_2, \dots, I_k\}$, with $I_g \in \mathbb{R}^5$. The algorithm is initialized with randomly selecting ? datapoints from \mathcal{I} . Let the set of vectors $\mathbf{d} = \{e_1, e_2, \dots, e_k\}$ represent the feature vectors of the ? clusters, and $I_g \subseteq \mathcal{I}$ is the subset of datapoints in \mathcal{I} , where e_g is defined as,

$$e_g = \frac{\sum_{I_g \in \mathcal{I}} I_g}{\|I_g\|} \quad (7)$$

For iteration N, an unassigned data point I_j is assigned to the cluster k that minimizes the distance between the data point and the cluster vector.

$$k = \underset{i}{\operatorname{argmin}} \sqrt{\sum_{I_j \in \mathcal{I}} \|I_j - e_i\|^2} \quad (8)$$

After assignment, the cluster vector is updated according to Formula (7). The algorithm is repeated until all data points are assigned. Convergence is guaranteed but inter-cluster distances are not guaranteed to be minimal for a given number of initial clusters ?.

4. Results and Discussion

4.1. Datasets

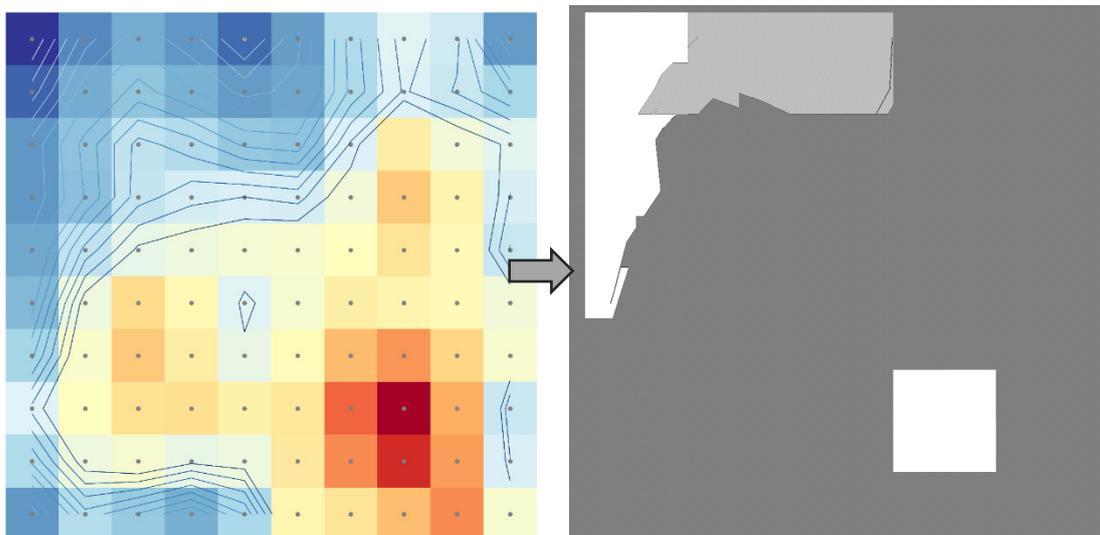
This work employed datasets from the 2016 Innovation 2.0 database, retrieved from StatsAmerica (2019) and 2016 Occupational Employment Statistics (OES) from the Bureau of Labor Statistics (2019). Data from both data sets were used concurrently to generate feature vectors for 380 metropolitan cities. A total of ten datasets were created for judging the viability of the proposed approach. Table 1 summarizes the datasets and provides the dimensionality of each data point for the given topic. For example, each metropolitan city in the GDP dataset is described by ten features, such as the economic wellbeing index, per capita income growth, income inequality, average poverty rate, average unemployment rate, dependency-based income sources, net migration, compensation core index, average salary growth rate, and gross domestic product. No assumptions are made about the correlations of the data point's features.

Table 1: Test datasets and the dimensionality for each input

	Topic	Dimensionality
1	GDP	10
2	Connectivity	5
3	Economic Wellbeing	10
4	Education	5
5	Foreign Direct Investment	6
6	Occupations in Education Sector	4
7	Occupations (Managerial Positions)	15
8	Occupations in Technology Sector	14
9	Patents and STEM	5
10	Venture Capital	8

4.2. General

For each of the ten datasets, the proposed approach was used to group the data and project the clusters back to the original data which is finally visualized on a map for manual inspection. We found the final clusters to be reasonable based on regional proximities and expected correlations in the data. For example, Figure 6 illustrates the U-matrix, segmentation, and back projection for the economic wellbeing dataset. Each metropolitan city in this dataset contains ten attributes that is mapped to a SOM, segmented to identify the number of clusters, then clustered. The five clusters are visualized on a map.



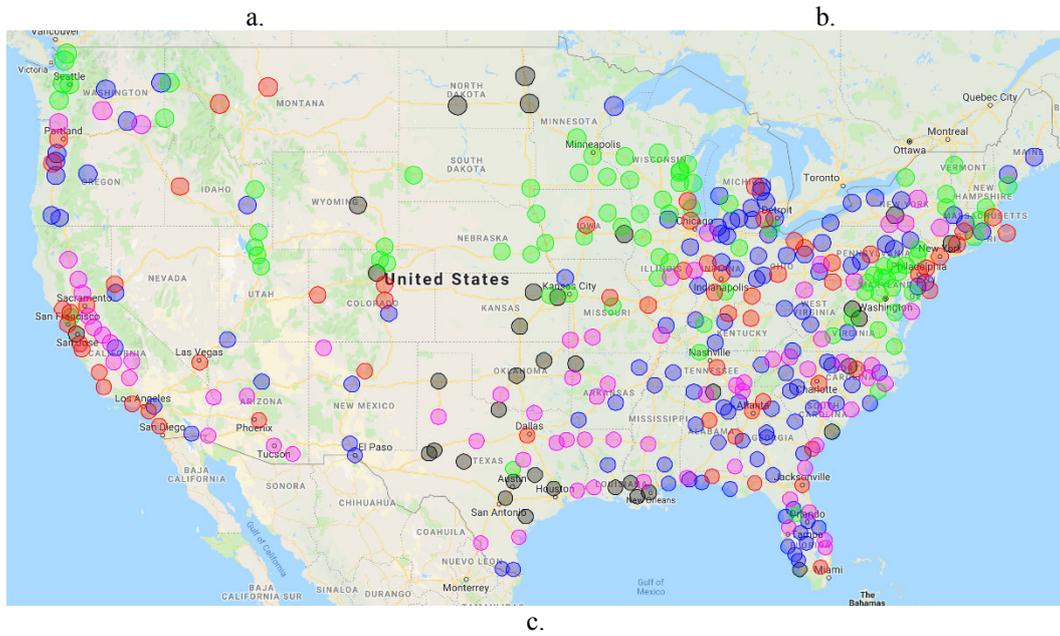


Figure 6: U-matrix (a), corresponding segmentation of the u-matrix (b), and back projected clusters of metropolitan cities for the economic wellbeing dataset.

4.3. Compared to K-Means Clustering

Judging the effectiveness of a clustering algorithm can be application-specific in the absence of a ground truth. However, much research has been done to develop techniques for evaluating an algorithm against itself as well as other approaches by looking at similarity measures within clusters and between members of a cluster as compared to members outside of the cluster. For this work, we have leveraged the Davies-Bouldin Index (1979) and the Silhouette score (Rousseeuw, 1987) for understanding the accuracy of the proposed approach when grouping business units as well as the dispersion of a cluster and the dissimilarity between two clusters (Halkidi, Batistakis, and Vazirgiannis, 2001). Moreover, the proposed approach was judged against a modified k-means method that attempts to identify the ideal number of clusters based on minimizing the Within Cluster Sum of Squares (WCSS).

The Davies-Bouldin Index (DBI) is a similarity measure that considers the intra-cluster and inter-cluster distances. A successful clustering result will minimize intra-cluster distances while maximizing inter-cluster distances. An ideal DBI is 0 which represents maximum similarities within clusters that are far apart from other clusters. Formally, the DBI is defined as,

$$DBI = \frac{1}{n} \sum_{r=1}^f \max_{t \neq r} \frac{u_r + u_t}{\min_{r \neq s} \|e_r - e_s\|} \quad (9)$$

u_g is the average distance between all members of cluster g to the feature cluster vector e_g , as defined in Formula (7). The index calculation assumes that the second average distance, u_t , is from cluster t , which is the most similar cluster to g . The Euclidean distance is the typical cost function used for computing both intra- and inter-cluster distances.

The Silhouette Index (SI) is an alternative metric that is prevalent in the analysis of clustering algorithms. The SI will range from -1 to 1 where values close to 1 represents excellent partitioning and separation amongst the datapoints, whereas as a score of -1 indicates that datapoints are incorrectly assigned to the wrong clusters. A score close to 0 signals that the data itself does not have clear separation in terms of features. The Silhouette Index is defined as,

$$xp_8 = \frac{u'_8 - u_8}{5y(u'_8 u_8)} \quad (10)$$

where u'_8 is the minimum average distance of datapoint 8 and all other datapoints from neighboring clusters. The SI score for the entire dataset is then the mean of all xp_8 . Similar to the DBI, the SI will provide insight into the intra- and inter-cluster similarities.

Both indices are employed to compare the proposed method and WCSS-adapted K-means algorithms for clustering business units. The results are outlined in Table 2, which indicates the proposed method outperformed K-means in 70% of the datasets when evaluated with the DBI and 60% if compared using the SI score. The self-organizing map method was shown to outperform K-means by an average improvement of 14.75% of the DBI and 38.68% of the SI. For the datasets where the proposed approach underperformed, K-means saw an improvement of only 8.13% and 15.33% for DBI and SI, respectively. Manual analysis of the proposed approach's images reveals that poor image pre-processing and image segmentation of the U-matrix may have contributed to incorrectly identifying the number of clusters. The issue of over-segmentation is observed for the GDP dataset where the proposed approach identified ten clusters while the K-means algorithm calculated four. As a result, the DBI index for the proposed approach is significantly larger than K-means and suggests the inter-cluster distances are minimized which ultimately increases the score. The two biggest limitations of the proposed method are the possibility of overtraining SOM by selecting too many training iterations, and the accuracy of the image processing used to extraction of the clusters. The use of morphological operators for filtering and the segmentation algorithm contribute to the long run-time which makes the proposed algorithm suitable for real-time applications.

Table 2: Summary of results comparing the proposed approach with a WCSS-adapted K-means algorithm. The Davies-Bouldin and Silhouette indices are presented for comparison.

Dataset	Proposed Method						K-Means				DB Index % Difference	Silhouette % Difference
	Grid Size	Quantization Error	Num Clusters	DB Index	Silhouette Index	Processing Time (s)	Num Clusters	DB Index	Silhouette Index	Processing Time (s)		
GDP	10	0.261472	10	1.756528	0.145494	20.3	4	1.624464	0.200705	2.5	-8.13%	27.51%
Connectivity	10	0.197307	7	0.932823	0.365396	18.3	3	1.056094	0.33413	1.7	11.67%	-9.36%
Economic Wellbeing	10	0.083824	11	0.780148	0.444278	17.4	4	1.644985	0.199465	2.5	52.57%	-122.73%
Education	10	0.237596	6	1.020492	0.314047	16.5	5	1.074963	0.310944	2.1	5.07%	-1.00%
Foreign Direct Investment	10	0.100223	6	0.844092	0.514046	18.9	4	0.908154	0.479813	2.1	7.05%	-7.13%
Occupations in Education Sector	10	0.082515	6	0.818234	0.38353	26.2	5	0.866004	0.388677	2.5	5.52%	1.32%
Occupations (Managerial Positions)	10	0.394724	3	2.026457	0.130485	26.5	3	1.819534	0.177824	2.8	-11.37%	26.62%
Occupations in Technology Sector	10	0.341274	2	1.172554	0.400464	21	3	1.48806	0.241334	2.5	21.20%	-65.94%
Patents and STEM	10	0.135485	8	1.085294	0.328263	18.9	5	1.034804	0.348777	1.9	-4.88%	5.88%
Venture Capital	10	0.035735	10	0.846349	0.69233	18.6	3	0.847708	0.549953	1.6	0.16%	-25.89%

5. Conclusion and Future Work

In the presence of the wealth of information available on businesses today, the ability to accurately identify business unit clusters is becoming more critical and difficult. The high-dimensionality of the data is posing a challenge for manual analysis, therefore the need to pursue automated machine learning algorithms is becoming clear. The analysis of business unit clusters may drive key decisions for supply chain, innovation, entrepreneurial, and even policy makers. This work investigated the viability of using a Self-Organizing Map to cluster high-dimensionality data from an eclectic range of data on businesses in the metropolitan cities of the United States. In doing so, the effectiveness and limitations of the technology were realized. SOMs have been used in many other clustering applications but have not yet been applied to the identification of business clusters. The SOM map's strength lies in the ability to visualize the relationships of the datasets after dimensionality reduction, however the ability to automatically extract the number of clusters from the map is not straight-forward. We implemented and tested a proposed method where common image processing techniques are used to isolate and extract key information from the SOM's unified distance matrix. The accuracy of the proposed method was compared to the standard K-means algorithm using the Davies-Bouldin and Silhouette Indices. We found that the proposed method outperformed the K-means algorithm for 70% of the datasets using the DBI and 60% of the dataset when comparing using SI. It should be noted that for the datasets where K-means performed more favorably, the improvement of the indices are marginal. The biggest drawback as compared to the K-means approach is

processing time. We found the proposed approach to take 9.15 times longer. The discrepancy in computation time can be attributed to the training of the SOM model and the image segmentation phases. The initial results from this work indicates that the self-organizing map is a viable technology for clustering high-dimensionality data for identifying business units. The future direction of this work will explore larger datasets from national databases. The underlying model parameters, such as grid size and segmentation characteristics will also be explored.

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**Thematic Session
Digital Transformation
(Chair: Prof. Elias Ribeiro da Silva)**

Human Resources Management and Digital Transformation in SMEs: How to Manage Paradoxes?

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Abstract: The existence of multiple tensions is clearly inherent in the life of organizations, but additional modern challenges still exacerbate this situation. Today, companies face major societal challenges such as the commitment to Corporate Social Responsibility (CSR) and more recently the digital transformation and Industry 4.0. The specificities of Small and Medium-Sized Enterprises (SMEs) make these challenges even more complex for these organizations. In this context, a research question arises: how to balance the digital transformation with CSR commitment? Both the engagement in CSR and the digital transition appears as potentially strong tensions in organizations. Consequently, we postulate that both strategic approaches are paradoxes requiring inherently limited resources in businesses, particularly in SMEs. The paradox perspective developed since the 1980s was designed to simultaneously meet competing demands (Smith and Lewis, 2011). This theory seems inspiring for better understanding how to articulate these two challenges. A strategic paradox refers to the situation in which the requirements of internal and external stakeholders are integrated into the strategic objectives of a company (Iivonen, 2018). The literature on change management and innovation also widely recognizes the existence of paradoxical tensions in interdependences (Smith et al, 2017). The literature on the paradoxes invites to focus on longitudinal approaches (Schad et al., 2016; Cuganesan, 2017, Simsek, 2009). In order to better understand how SME manage this paradox, we performed an exploratory case study (Yin, 2003; Langlely et al., 2013) in a French industrial company. The objective was to appreciate how an industrial SME can implement a strategy inspired by the theory of the paradox in order to preserve its CSR commitment when facing the challenges of the digital transition. This case study was based on a combination of several data sources. We gathered secondary data consisting of articles in the economic press, the website of the SME and professional events testimonials. In addition, we collected data through observation in the industrial site and through non-structured interviews with the human resources manager. The main source of data comes from in-depth face-to-face interviews with 12 internal interlocutors in the industrial SME, including managers, technicians and operators. All the interviews have been fully transcribed and thematically analyzed, representing a material of around 200 A4 pages. The results focus on Human Resources Management practices regarding needed skills, recognition of the employees and redefinition of jobs. The arrival of digital tools creates a sense of exacerbated isolation among employees. A more formal communication replaced the direct and informal communication; thus the challenge is now to preserve the place and role of the human. To summarize the digital transition in this SME, profound changes in the organization of work with consequences on jobs emerged. Aware of these challenges, the human resources manager multiplies initiatives to try to anticipate the changes taking place, particularly regarding the employability of production operators.

Keywords: CSR, Digital transformation, Industry 4.0, Paradoxes, SMEs

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Market of Rules: A new business through combination of people expertise and automation from Industry 4.0

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Abstract: This paper describes a framework which incentives human and machine cooperation to improve the operation of any productive complex system [3] like a factory, a port, or supply chain through the institution of a Market of Rules. For such purpose, first step is to make a digital copy of equipment's operation, environment, and people practices as Digital Twins [2]. Second step performs a map of this knowledge into a digital environment which consists of a combination of discrete-event and agent-based simulation [1, 6]. Third step employs a simulation-optimization approach to evaluate the best combination of practices proposed by the people, under the form of rules, and proposes a proper reward for them [1, 4]. In the proposed framework automation does not mean elimination of jobs for people, but a change of focus on what can be done: from repetition tasks to creativity activities [5]. This framework helps the alignment of people creativity, expertise and experience to provide a better operation for machine and equipment's of any complex system in a manner that a proper reward could be computed. The suggested framework depends on the solution of combinatorial optimization problem which can demand a significant computational effort to be solved [1]. An interesting research question for future works is how to reduce this computational effort using previous results from the system, maybe employing a machine learning technique. The practical implications is that better practices identified in one factory can be easily and quickly distributed and employed for other similar factories or even other environments like ports or distribution centers. Furthermore, there will be economical incentives for people to perform and create better practices. A study case on port logistics will be presented [1]. The potential impact on society of this research is scalable since it will help to promote a continuous improving by the fast adoption of best practices and experience through and outside organizations. The adoption of best practices and experience is based on a proper scientific background with a proper analysis of impact estimation done by simulation [6]. Various papers in the literature treat simulation, optimization, distribution of knowledge and practices as separate practices leading to a common thinking that the advance of automation will result into a reduction of human occupation and jobs. Although, the roots of treating these topics as separate research questions is related with the representation of decisions for machine operation in terms of numbers like binary or real variables. Instead, a representation that resembles to human reasoning facilitates the incorporation of human knowledge, experience and creativity into the automatic decision system [1]. It also helps on the institution of a monetary reward system based on continuous improvement, and automation provided by Cyber-Physical Production Systems from Industry 4.0.

Keywords: Cyber-Physical Production System, Optimized Control of Production Systems, Discrete-event simulation, Agent Based Simulation, Digital Twins, Market of Rules.

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DIGITAL BUSINESS TRANSFORMATION IN THE FOURTH INDUSTRIAL REVOLUTION: A SYSTEMATIC LITERATURE REVIEW OF MATURITY READINESS

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Abstract: New business models like servitization, mass customization products, unscaling production and virtualization have been emerging because of the possibilities of Industry 4.0 (I4.0) technologies. Success stories of business using new technologies come from young companies like Uber, from startups like Biz Biz share, from digital natives like Alphabet and from technology giants like IBM. What is common from these companies is that they are now venturing out into new, non-traditional markets, with innovative products. As an example, the *Uptake Company* is an Asset Performance Management application that uses AI technology to increase productivity, reliability and safety to equipment from industrial makers like General Electric, creating loss revenues for GE. Compared to the past 30+ years of industrial trends (quality management, lean, etc.), digital transformation is not only the most complex, but also the most critical challenge any manufacturer has had to face. One mistake is to think that digital transformation, the act of integrating the digital and physical components of operations into a new business model, is to focus solely on technology. “In a digital transformation, digital is not the answer, transformation is”¹. Being ready for I4.0 requires far more profound changes than merely investing in the latest digital technology. The digitalization of a company involves and affects multi-dimension of a business. This presentation is part of a research to seek out how existing businesses prepare for a digital transformation in the context of I4.0. For existing companies, one of the first steps is to assess its own readiness to embark on a digital transformation in an Industry 4.0 context. As such, there is an emerging literature by academics and consultants on new maturity models so that business leaders know their weakness and build upon their strengths. The objective of this presentation is to understand how and what a business needs to assess to successfully embark on a digital transformation in the Industry 4.0 era. This is the first time a Systematic Literature Review (SLR) of I4.0 maturity model has been made. The methodology used is a six-step SLR: 1) establish research questions, 2) determine primary characteristics, 3) retrieve articles in 4 databases, 4) select literature and allow snowballing into grey literature, 5) syntheses and 6) report 39 maturity models. Findings cover current trends in this field and a comparison of the dimensions maturity models measure into five macro-dimensions: 1) business models and products (goods and services), 2) operations, 3) data and information, 4) organizational behavior, 5) industry 4.0 technologies. This work will also point out general limits on existing models to give a baseline for future research and development.

Keywords: Digital transformation, Industry 4.0, Maturity assessment, Strategy, Systematic Literature Review

¹ Westerman, G., *Your Company Doesn't Need a Digital Strategy*. MIT Sloan Management Review, 2018. 59(3): p. 1-5

The Effects of Industry 4.0 Implementation on Organizational Value Chain

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Abstract: Companies are continually looking for innovative opportunities to explore new sustainable business models and stay competitive. Many of these organizations are finding this opportunity through modern technologies like Additive Manufacturing, Internet of Things, Big Data, among other so-called pillars of Industry 4.0. However, many of these technologies are still little explored by organizations, especially small and medium enterprises, thus generating uncertainty for investment and possible social, environmental and economic impacts generated by them. Based on this context, this research aims to investigate, through a systematic review, the influence of Industry 4.0 principles on sustainability dimensions, from an organizational value chain perspective. The literature research process was supported by Scopus, Science Direct and Web of Science databases, which allowed the creation of a portfolio of articles similar to the proposal in question. For the organization of the selected documents, PRISMA methodology was used, which helps authors to improve the systematic review reports. Finally, a bibliometric analysis was performed to present relevant research information, such as the main authors, countries and journals with the largest number of publications as well as the effects found. Industry 4.0 has considerable potential to affect the value chain of organizations, even if it is a new concept, its effects are already having an impact on the nature of competition and corporate strategies in many industries. Some authors oppose certain impacts of Industry 4.0 on the value chain, especially regarding the social dimension of sustainability. Thus, this work links the effects of new technologies on the organizational value chain, related to the three dimensions of sustainability. Through this, we sought to provide answers to uncertain questions about the implementation of Industry 4.0, allowing companies to improve the quality of their services to the benefit of all. In addition, the study contributes to scientific evolution in the quest to minimize negative impacts and maximize the advantages of the implementation of Industry 4.0. Industry 4.0 research points to a growing interest from researchers around the world, but work that presents the impacts of its implementation across the value chain is still scarce. Due to this large research gap in the context of industry 4.0, this paper is relevant for future research, as it presents the effects of implementing Industry 4.0 on the organizational value chain, based on Porter's value chain model. It can thus contribute to future debates.

Keywords: Industry 4.0, Sustainability, Triple Bottom Line, Value Chain.

1. Introduction

In order to remain competitive, manufacturing companies must constantly evolve their production systems and accommodate new market demands. [21]. One of the key drivers of this change is the emergence of new technologies that enable more cost and resource efficient production. Adoption of these manufacturing technologies heralds a future with shorter, more localized, more collaborative value chains and significant sustainability benefits [7].

Industry 4.0 is a term commonly used to refer to the development of cyber-physical systems and dynamic data processes that use large amounts of data to drive smart machines. More specifically, it refers to the emergence and diffusion of a number of new technologies in which smart products and devices can communicate and interact with each other [30].

Rüßmann et al. [27], presents nine technologies that characterize Industry 4.0, including tools and technical methods. These include automated robots, simulation, horizontal and vertical system integration, industrial IIoT, cyber security, cloud-based services, additive manufacturing, augmented reality and big data analytics. However, Industry 4.0 represents a “new paradigm” in manufacturing, which leads to “faster and more accurate decision making” and a “completely new approach to production”. This new approach leads to the industrial value chain that is not only automated, especially within individual factories, but also interconnected between objects, products and human beings [20].

Porter [25] states that the competitive advantage of an organization cannot be seen in general, it is necessary to understand the internal structure of the company, that is, how individual elements contribute to the delivery of the product or service at a lower price or higher quality. This structure depends on the implementation of the strategy and corporate traditions.

The value chain includes the processes that Porter [25] classifies as primary activities in value creation for the company, encompassing the information captured in the support activities performed during the value creation stages. Enabling organizations to be able to monitor the entire process and perform value-adding activities more efficiently and effectively [30].

Industry 4.0 represents an unprecedented fusion between digital, physical and biological entities that interact with each other creating this industrial value, which aims to transform work environments and create social, economic and environmental advances. To achieve this integration, traditional industrial machines and products are equipped with sensors and software for data collection and analysis. This can be done between products, production facilities and supply networks, achieving a value chain that is interconnected in real time. Potentially, Industry 4.0 can bring a shift from isolated manufacturing activities to automated, optimized and fully integrated data flows and products within organizational value chains [20].

Establishing an intelligent, self-regulating, interconnected industrial value chain where intelligent machines, storage systems and production facilities can exchange information, initiate actions and control each other. This leads to technological leaps in engineering, manufacturing, material flow and supply chain management [7]. Organizing suppliers, manufacturers and customers into an integrated value chain. Its implementation requires horizontal integration of the value chain with networked production systems and vertical interactions [33].

However, the effects of this implementation have not yet been sufficiently explored from the point of view of sustainability [7]. To date, investigations related to the implications of Industry 4.0 have been done at a broad level. As a nascent area of research in which the impacts on the value chain are unclear, the aim of this paper is to conduct a literature review presenting the effects of implementing Industry 4.0 on the organizational value chain in a sustainable context. Thus providing a broader understanding of the implications of Industry 4.0 for improving the sustainability of industrial systems.

This article is structured as follows, in the beginning the introduction briefly introduces Porter's value chain concept and Industry 4.0 concept and its tools. The second section describes the materials and methods used for the analysis, as well as a brief bibliometric analysis. In the third section, the research results are presented, and Porter's value chain exposes the advantages and challenges of implementing Industry 4.0. Based on the results, the main conclusions were presented.

2. Methods and Procedures

To achieve the objective proposed in this research, the literature review began by defining the research axes, being defined by: Industry 4.0; Value chain; Sustainability. Then, to search the articles in the databases, keyword combinations were performed through Boolean operators, which help in the search enabling the use of word variation.

After defining the keywords and their combinations, it was possible to start the search in the established databases, namely: Scopus (SC), because it is considered "The largest database of abstracts and citations in the literature. "; Web of Science (WoS), which for many years has been used as the primary means of assessing the evolution of world scientific production; Science Direct (SD), which is "a vital scientific ecosystem that facilitates collaboration, rewards innovation, and accelerates the research process itself" [34].

In order to delimit the research, the authors used database filters searching only for (Article or Review), which contain the keywords only in (Article Title, Abstract, Keywords). As this is a recent theme, it was decided not to apply the temporal cut. Table 1 shows the combinations of the keywords used and the number of articles identified per database.

Table 1 - Database Search

	Keywords Combinations	SC	WoS	SD	Total
1	("Industry 4.0" OR "Industrie 4.0") AND ("sustainable development" OR Sustainability OR sustainable) AND "Value chain*"	12	10	3	25
2	("Industry 4.0" OR "Industrie 4.0") AND ("triple bottom line" OR economic* OR Environmental OR Social) AND "Value chain*"	22	10	3	35
3	("Smart Factory" OR "Smart Industry") AND ("sustainable development" OR sustainability OR sustainable) AND "Value chain*"	0	1	1	2
4	("Smart Factory" OR "Smart Industry") AND ("triple bottom line" OR economic* OR Environmental OR Social) AND "Value chain*"	1	1	0	2
5	("fourth industrial Revolution" OR "4th industrial Revolution") AND ("sustainable development" OR sustainability OR sustainable) AND "Value chain*"	1	1	0	2
6	("fourth industrial Revolution" OR "4th industrial Revolution") AND ("triple bottom line" OR economic* OR Environmental OR Social) AND "Value chain*"	6	5	1	12
7	("Internet of things" OR "IIoT" OR "IoT") AND ("sustainable development" OR sustainability OR sustainable) AND "Value chain*"	13	10	4	27
8	("Internet of things" OR "IIoT" OR "IoT") AND ("triple bottom line" OR economic* OR Environmental OR Social) AND "Value chain*"	18	16	3	37
		73	54	15	142

The classification phase of the articles was based on the PRISMA methodology, where 78 out of 144 articles were excluded by duplication, 39 excluded by reading titles and abstract, as they were outside the scope of the research, thus resulting in a portfolio of 27 articles relevant to the study. In the course of reading the articles, 4 more papers were added to the portfolio, resulting in a final portfolio of 31 articles. Figure 1 presents the filtering steps of the articles based on the PRISMA methodology.

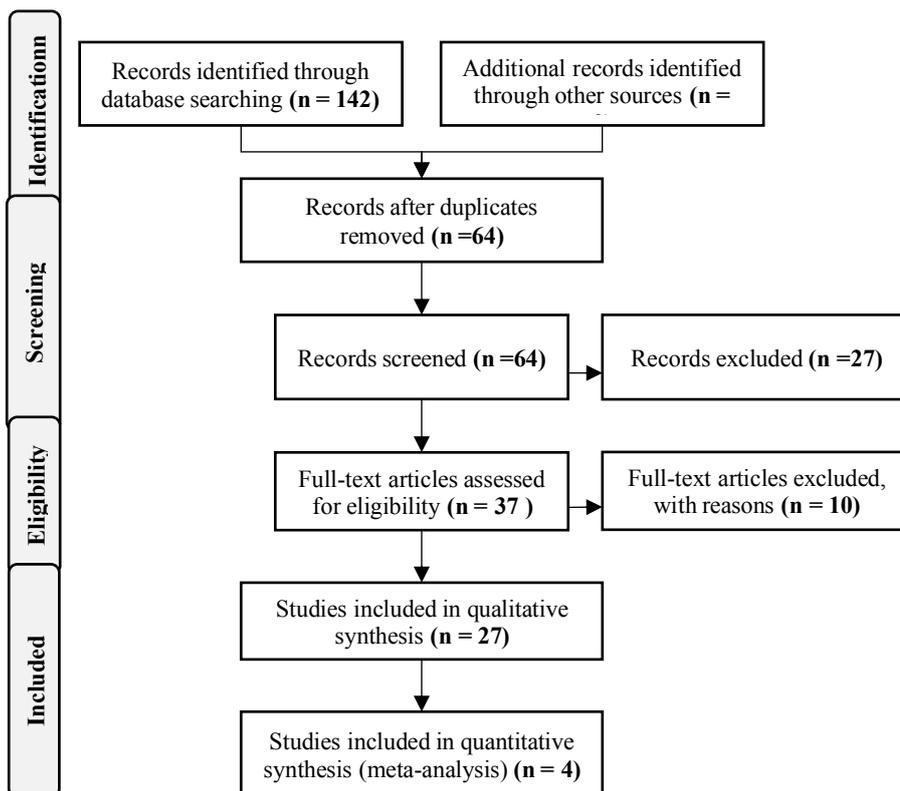
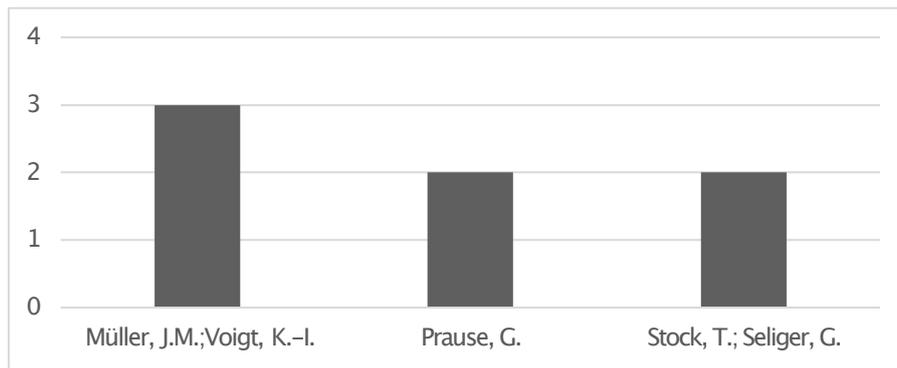
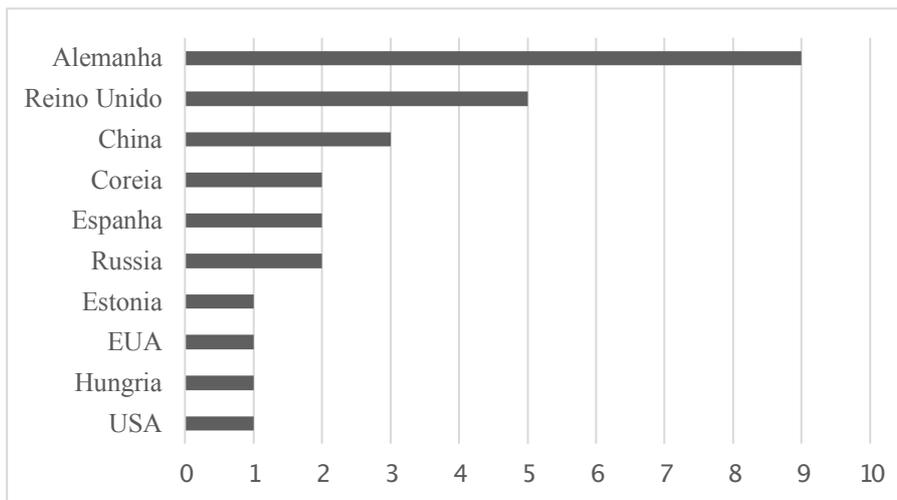


Figure 1 - Articles filtering steps based on PRISMA methodology Source: Adapted Liberati [16]

After the filtering phase, all articles were systematically read, allowing the analysis of the main authors, graphic 1, who published the most on the subject, also analyzing their countries of affiliation. As shown in graph 2.

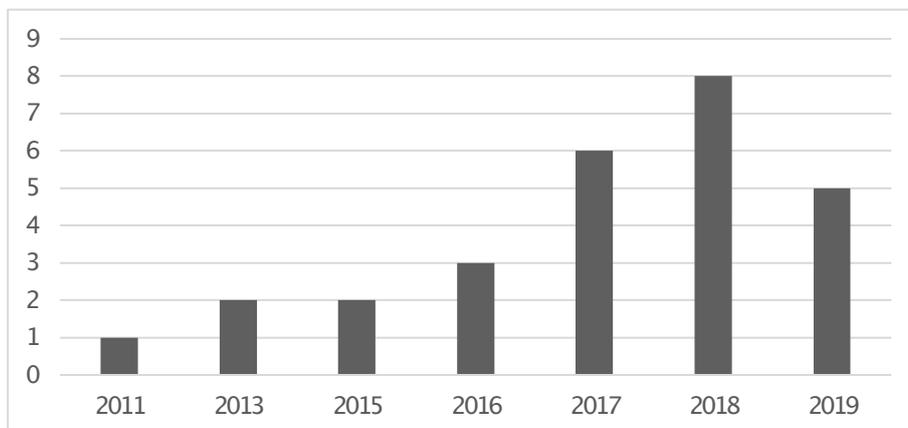


Graph 1 - Top authors who published on the topic



Graph 2 - Countries that most published on the topic

Of the articles found, the author who published most on the subject was Muller, J. M .; Voigt, K. I., followed by Prause, G. and Stock, T .; Seliger, G., the other authors have published only one article so far. With the elaboration of the graphs it can also be analyzed that Germany appears as the country that contributed the most to this research, with 9 publications, followed by the United Kingdom and China with 5 and 3 publications each. Next you can see Korea, Spain and Russia with 2 publications. To present the relevance of the theme to the present day, Graph 3 presents the evolution of publications each year.



Graph 3- Years of publication

Of the 27 papers analyzed, 8 were published in 2018, 6 in 2017 and 5 in 2019 (showing that this research was conducted in August 2019). This may demonstrate a growing evolution in the level of interest of researchers on the subject. Then graph 4 shows the most published journals on the topic.



Graph 4 - Periodicals that most published on the topic

Related to the most published journals on the subject, we can highlight the “Journal Sustainability (Switzerland)” with 4 articles, “International Journal of Advanced Manufacturing Technology” and “Journal of Cleaner Production” with 3 articles published. The reading phase also made it possible to survey the advantages and challenges that may accompany the implementation of Industry 4.0, related to the organizational value chain, in a sustainable context.

3. Results and discussions

Industry 4.0 impacts the company as a whole, so it is very important to understand how its various elements are able to exploit the opportunities it offers. Industry 4.0 impacts the company as a whole, so it is very important to understand how its various elements are able to exploit the opportunities it offers. Therefore, it is important to consider how the implementation of Industry 4.0 impacts the creation of industrial value in a sustainable manner. Thus to structure its effects, it was decided to use Porter's value chain model, a theory by which the company's core process is the creation of value, mainly related to operations. Figure 2

presents the challenges and uncertainties that the implementation of Industry 4.0 brings to the organizational value chain, as well as the authors who discussed them, based on Porter's model.

		Source:				
Support Activities	Firm Infrastructure					[7; 10; 11; 13; 17; 18; 19; 20; 21; 26; 29]
	• Big investments and uncertain profitability		• Lack of a digital strategy			
	• New competitors with innovative business models					[2; 3; 4; 7; 10; 12; 17; 19; 21; 22; 24; 29]
	• Employee Qualifications and Acceptance		• Badly Defined Responsibilities			
	• Reduction in the number of employees in the industries					[5; 6; 8; 9; 12; 17; 18; 19; 20; 21; 23; 25; 28; 29]
	• Ignorance of technologies					
Technology Development					[1; 7; 12; 17; 18; 19; 21; 26; 29]	
• Risks of Cyber Attacks						
• Development of new technologies					[1; 4; 7; 8; 10; 11; 12; 15; 17; 18; 19; 21; 26; 29; 30]	
Procurement						
• Change of suppliers					[1; 4; 7; 8; 10; 11; 12; 15; 17; 18; 19; 21; 26; 29; 30]	
Inbound Logistic	Operations	Out. Logistic	Marketing & Sales	Service		
• Cross-border work	• Unknown Raw Materials		• Change in consumption patterns • New business models			
Primary Activities					Margins	

Figure 2- Challenges of industry value chain implementation 4.0, based on Porter's model

The uncertainties related to costs, return on investment and implementation schedule often result in an initial reluctance of companies to adopt innovative technologies [10]. But this investment should increasingly be considered, as new business models, in which physical products are replaced by digital, and even the emergence of new organizations that embrace new digital technologies, can directly affect how consumers behave and may affect conventional manufacturing. [7], [12].

The dimension related to the social aspect presents a larger number of uncertainties, mainly regarding the qualification of employees and number of jobs. But for Industry 4.0 to enable companies to develop and create jobs, governments and organizations need to invest in training to create a skilled workforce. Developing or outsourcing these skills is a major challenge and obstacle for manufacturers, both in terms of cost and skilled personnel to deliver training, and in the context of employee acceptance of new technologies. [2], [18].

The high level of transparency also exposes manufacturers to the risks of cyber attacks and industrial espionage. Nevertheless, access to real-time data at different points also has a positive effect on strategy, financial planning and the process. Data generated in each area is also available for other areas and provides transparency in information. These tools contribute to system and process-based thinking and process integration within the organization [7]. Therefore to eliminate this risk organizations must invest in secure systems.

Technologies help increase the agility, and adaptability and alignment of companies that cooperate in a value chain network to gain competitive advantage [18], [21]. Thus the implementation of new technologies in organizations present a significantly greater number of advantages within the value chain, as shown in Figure 3.

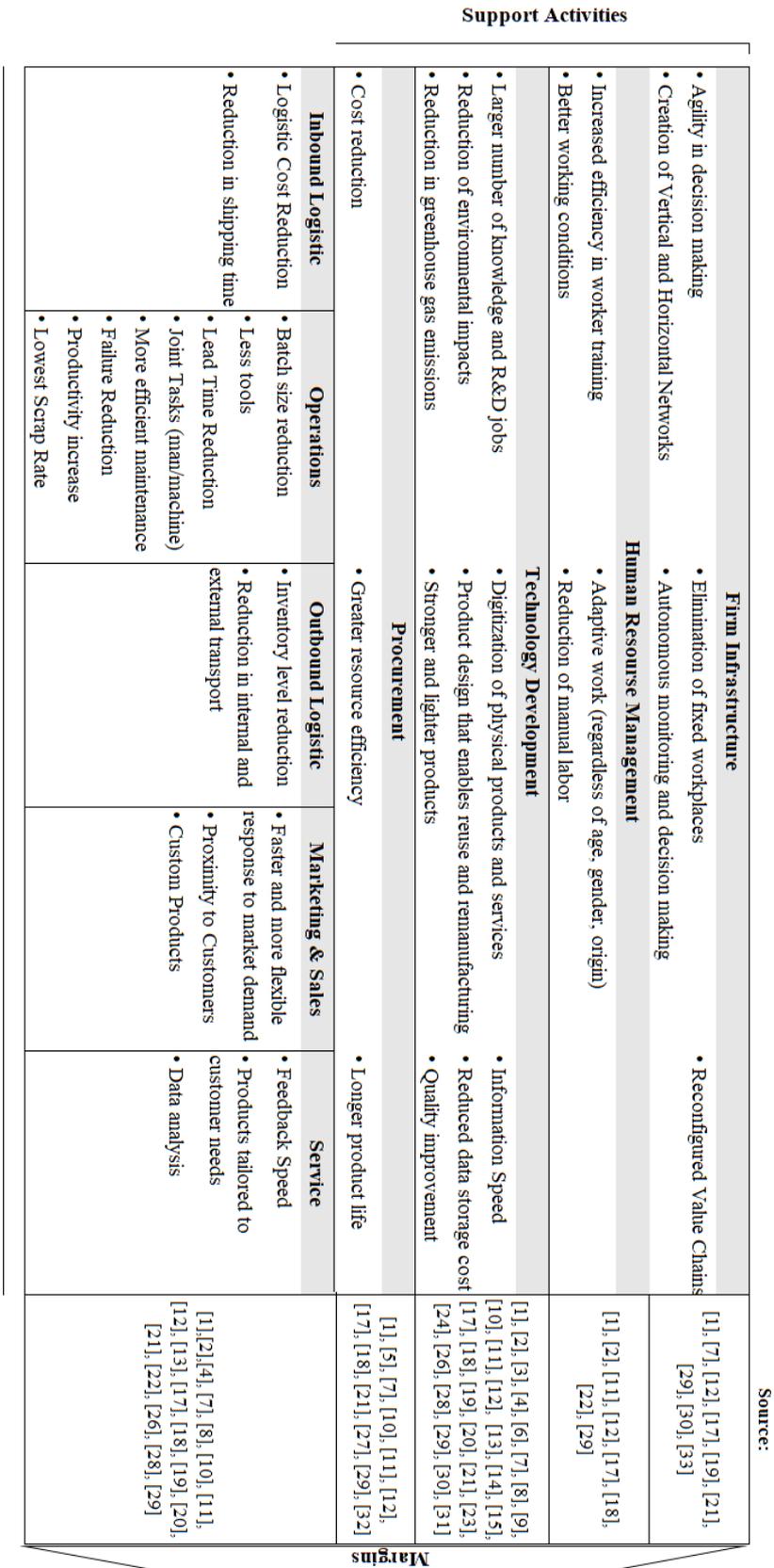


Figure 3- Advantages of industry value chain implementation 4.0, based on Porter's model

In the social aspect it can be emphasized that human beings will still be the organizers of value creation in Industry 4.0, due to the adoption of new technologies that require a specific level of knowledge, which requires the continuous development of new knowledge and skills [1], [20]. In the future, it will be perfectly normal to work in teams that are mixed according to age, gender and origin. This could trigger major improvements in creativity and productivity, but it also poses a greater risk of conflict. The equipment will be able to flexibly adapt to changes in other value creation factors, in which robots will be working together with workers on joint tasks. In addition to improving the quality of work, which through intelligent devices and robot assistance systems ergonomically assist in preserving health and long-term employee productivity [1], [7], [30].

In the economic aspect, the terms related to efficiency, time, quality and inventory levels are directly and positively related to significant cost reductions [9]. Value creation processes help reduce both manufacturing and raw material costs while increasing speed and accuracy, leading to reduced logistics costs. [1], [29].

Industry 4.0 enables the reduction of greenhouse gas emissions through data-centered and traceable carbon footprint analysis. If digitization of industrial processes reduces total energy consumption, positive impacts can indirectly arise in the areas of air quality and reduction of greenhouse gas emissions, with positive implications for social aspects such as public health [7].

An innovative and sustainable process where conscious and efficient use of resources, product reuse and recycling, waste disposal and process digitization all contribute to the reduction of environmental impacts [26]. A decentralized, sustainability-oriented organization in a smart factory focuses on the efficient allocation of products, materials, energy and water. Consequently, leading to reduced waste, improved resource consumption and new production technologies.

Overall, it can be concluded that Industry 4.0 penetrates the entire enterprise value chain. As a phenomenon that, through technology assets and activities, maximizes process transparency, exploits digitization possibilities, and integrates the corporate value chain and supply chain into a new level of customer value creation [21].

4. Conclusion

Industry 4.0 can provide an important competitive advantage for businesses, as it is a strategy that organizations seeking to become sustainable adopt to increase productivity, reduce maintenance costs, and reduce energy consumption. This study therefore focused on exploring how new technologies affect the value chain in a sustainable context.

Searches were made in databases in order to gather relevant and current articles to build the review portfolio. To fulfill the objective of this study was used as reference the PRISMA methodology to identify the most relevant articles for the research. In which it was possible, through a literature review, to identify 39 advantages and 14 challenges that Industry 4.0 can bring to the value chain. This work also sought to expand knowledge and show how new technologies can impact the future of organizations and even society as a whole.

It is noted from research that this is a very recent topic and therefore research is still under development. It was possible to identify the small volume of literature review articles and field research articles. In addition to technical research and current research that looks at how Industry 4.0 affects value creation in manufacturing.

According to the researched literature, it is clear that several impacts directly or indirectly affect other dimensions of the value chain. Based on this information it is suggested that for future work be investigated what the links and effects of impacts to the other dimensions of the value chain. This study was limited to articles from only 3 databases, so it is recommended to increase the number of databases for more robust analysis. The research contributed to show how the implementation of industry 4.0 will affect the layers of the organizational value chain.

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Thematic Session
Knowledge, Collaboration and Innovation
(Chair: Prof. Janaína Siegler)

Implications of Blockchain technology in Knowledge Management: a literature review

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Abstract: Organizations' needs for the protection of their experts' knowledge and copyright have led to greater relevance and challenges for Knowledge Management, and this is where Blockchain technology can be seen as a facilitating factor. Thus, this article aims to identify the applications and implications of Blockchain technology in Knowledge Management. To achieve this goal, the Fast Systematic Literature Review data collection technique was used. The information gathered demonstrates that the most frequent applications of Blockchain in Knowledge Management are related to three functions: Retention, Identification, and in particular Sharing and Distribution, due to factors such as the deconcentration of activities in value chains, where companies outsource part of their value chains in multiple places around the world, emphasizing the importance of knowledge as a competitive factor. In this sense, Blockchain has the potential to solve some challenges faced by Knowledge Management. However, it was identified that because the technology is still in the early stages of development, few applications were found in the domain studied. There is still a gap in the application of blockchain in order to enable and generate value to KM functions. Finally, this research provides an original contribution analysis on the implementation of blockchain technology in knowledge management, allowing the visualization of a new field of research and application.

Keywords: Knowledge management, knowledge sharing, blockchain, distributed ledger

1. Introduction

The revolution in communications technology has brought economic changes that underline the importance of knowledge. Global competition has become “borderless” as traditional boundaries such as national boundaries have diminished in significance. Companies no longer concentrate their value chain activities in one place, rather they establish strategic alliances, outsourcing their value chains in multiple places around the world. However, coordinate these activities geographically dispersed to obtain and maintain competitive advantage is one of the challenges of companies competing globally. In this perspective, the knowledge-based economy and knowledge as a competitive factor have gained importance [1, 2].

Thus, in order to obtain a competitive advantage from the knowledge, Knowledge Management (KM) is defined in this study from the perspective of their functions. However, considering the current scenario, KM implementation within companies has faced some challenges. To survive in such a competitive environment, they must promote their ability to learn and incorporate new practices and technologies to improve their long-term organizational performance and success [3].

Blockchain technology, which has become especially known for its application in cryptocurrencies, however, has the potential to be applied to any online digital asset transaction and has become a significant source of disruptive business innovations. and management. This technology also has the potential to overcome some problems faced by KM and it is in this sense that the purpose of this work arises [4-7].

Thus, the aim of this research is to identify the applications and / or implications of Blockchain technology in KM. For this, KM will be worked based on its functions, while Blockchain will be studied from the perspective of its main features, and to achieve this goal, a systematic literature review was performed using the Fast Systematic Literature Review method.

2. Theoretical Foundation

This section will cover Knowledge Management topics, focusing on the challenges facing economic and technological changes that include Blockchain, addressing its key features.

2.1 Knowledge Management

Regarding Knowledge Management (KM), there are numerous definitions presented by several authors, but there is no single definition universally accepted. In this sense, KM will be considered here as the set of processes that aims at the identification, acquisition, development, sharing and distribution, use and retention of knowledge. These processes consist of [1,8]:

- Knowledge Identification*: Knowledge, both internal and external, is not automatically visible, so organizations need to create transparency in order to know where to find the knowledge they need, that is, to locate knowledge inside and outside the company;
- Acquisition*: Companies can buy knowledge they cannot develop, so a substantial part of their knowledge comes from outside sources such as customers, suppliers and competitors;
- Development*: involves all consciously directed administrative efforts to produce new capabilities, and its focus is on generating new skills, new products and more efficient processes;
- Sharing and distribution*: They are considered as vital factors for transforming single information into something that every organization can use; Distribution consists of sharing and disseminating knowledge that already exists in the organization.
- Utilization*: The organization should ensure the application of knowledge to its benefit, and to this end, take steps to ensure that skills and assets are fully utilized;
- Retention*: Consists of the processes of regularly selecting, storing, and updating knowledge to protect the company from loss of knowledge.

It should be noted that KM is not restricted to company boundaries, but covers customers, suppliers, partners and other external users, thus meaning a simultaneous opening out and in. Besides that, Knowledge resource management is not limited to managing knowledge itself, but rather enabling an environment in which knowledge can be mobilized and used for the benefit of the organization [9, 10].

Regarding knowledge, it should also be noted that it has two essential economic peculiar characteristics that differentiate it from other goods: knowledge increases when it is exchanged or consumed and intellectual assets have high costs at the production stage (fixed costs) and very low costs at the stage. imitation or copy. These two characteristics are examples of why security in knowledge production and transfer is so important [11].

In addition to security in the production and transfer of knowledge, organizations have faced three main challenges regarding KM implementation in the current scenario [7, 12]:

1. Knowledge storage issues, as storing data on private servers brings high costs for transactions or processes between companies. This and the increased knowledge generated in companies, forces them to employ new storage strategies;
2. Insecurity of databases and loss of private information, especially when databases are configured on a central server;
3. Knowledge sharing issues and motivations, especially copyrights, as companies need to ensure that their specialists, under their rights, share their knowledge. In addition, lack of incentive and security can also be considered challenges, requiring knowledge owner copyright protection and access control schemes.

Problems related to knowledge sharing are also related to trust, as when entering and increasing the number of participants in a system, issues related to ownership, access and control arise, and lack of trust is one of the main reasons for not sharing knowledge among members. Still, there are problems with current knowledge sharing methods, as they are designed based on centralized structures [7, 13].

Lack of trust is also related to the lack of a mechanism to ensure the functioning of the parties to a contract. In the economy and in markets, for example, the state has historically played the role of a mechanism for forcing market players to respect agreements and avoid opportunistic behaviour [11].

More generally, without specifically considering the business environment, KM also faces problems involving knowledge erosion, quality and prevention against manipulation. These problems, however, can also hit organizations. The erosion of knowledge is associated with an explosion of information and an excessive number of interpretations of established theories and concepts. The increasing amount of information inevitably leads to distortions, involuntary or deliberate errors and inaccuracies during rewriting and replication, which may be intentional or unintentional in nature. On the other hand, quality and prevention against manipulation are part of the concept of data provenance, which describes where the data of interest originated, who owns it, and what transformations were made. In this regard, the main challenges for a provenance system are secure collection and storage, protection against unauthorized access and privacy violations. Also, as knowledge systems become increasingly autonomous, provenance and responsibility become more relevant [14-16].

In general, the challenges encountered in KM can be attributed to their roles. In this sense, Table 1 seeks to present what are the challenges faced by KM and what function of KM this challenge can be related to:

Table 1: Challenges in KM and its functions

Issues	KM functions
Knowledge storage	Retention
Insecurity and data/information loss	Retention
Knowledge sharing and copyright	Sharing and distribution
Lack of trust among members	Sharing and distribution
Erosion of knowledge	Utilization
Quality challenge and handling prevention	Retention
Provenance and responsibility for knowledge	Identification

From this it can be inferred that the challenges faced by KM have focused on the Sharing and Distribution and Retention functions, which may be justified, in particular, by the potential value of the knowledge held.

2.3 Blockchain

Commonly discussed for being the technology behind Bitcoin, blockchain - or distributed ledger - technology is well known due to the current cryptocurrency hype. However, the technology has applications well beyond financial markets for simplifying business processes and sharing data. Generally and simply, a Blockchain is a data structure that combines blocks of information that are chronologically chained and recorded in encrypted form, such as a distributed ledger, using consensus algorithms to generate and update data, ensuring secure data transmission, as transactions on the network cannot be tampered [6, 17, 18, 19]. Blockchain main features are:

1. *Decentralization*: The basic feature of Blockchain is decentralization. It means that information is automatically shared and distributed between nodes without third party intervention, i.e. Blockchain is not dependent on a centralized node and data can be recorded, stored and updated in a distributed manner [18, 20];
2. *Detrusting*: This feature derives from the previous feature, decentralization. Trust is an important factor that worries participants in traditional network negotiations. In Blockchain, data transfer between nodes does not require mutual trust between participants. Using a hash function and a consensus protocol, a trust relationship is formed between network nodes and distributed system structures [18];
3. *Transparency*: being it a decentralized technology, data records and operations within the network are transparent to all nodes. Through encryption techniques, all nodes are able to inspect and track logged data. For this reason, Blockchain can be considered a reliable technology [18, 20];
4. *Traceable and immutable*: Blockchain has the traceability feature because it uses timestamp to identify each transaction, which allows the node to keep the order of transactions and makes the data traceable. This registration guarantees the originality of the data, reduces the cost of traceability of transactions, as well as reinforces irreversible modifications to the data or

information, which sets the immutability characteristic. Transactions need to be reviewed by most nodes before they can be recorded. All valid blocks and transactions recorded in the ledger are virtually unchanged due to the need for verification by other nodes and change traceability [18, 21].

5. *Anonymity*: in a blockchain system, each node (user) has an alphanumeric address that serves to identify it, and each node can choose to remain anonymous or provide proof of their identity to others. Also, through encryption, digital signatures are made possible: the security of the transaction data, which is transmitted over the network and digitally signed to indicate the identity of the signer, and whether the transaction has been identified is ensured [18, 22].
6. *Credibility*: Participants may complete transactions in a harmful environment under conditions of complete anonymity. Technology protects the privacy of all parties involved in transactions and increases the security and credibility of transactions [18].

Since its development, dating back to 2008, Blockchain has evolved significantly, and has gradually added other technologies. One of the latest technologies incorporated into Blockchain are the smart contracts, which emerged long before Blockchain itself. An intelligent contract can be considered as a series of commitments defined in digital format, and contract execution is performed automatically when the conditions imposed in the contract are met. From the user's perspective, a smart contract is an automatic guarantee plan [18]. In the next section the links between blockchain and knowledge management will be

3. Research Design

Systematic Literature Review (SLR) is comprised of a set of time-consuming tasks, such as defining search terms, content analysis, and written reports. Thus, to conduct this research, the Fast Systematic Literature Review (FastSLR) method was used, which supports the diagnosis, validation and evaluation of the research content and seeks to minimize errors, both in terms of quality of work for planning and designing the research, as well as reducing the execution time of the review. The method consists of three steps: (i) research activities and search of articles; (ii) process of refinement for articles gathered in the previous step, using a reference manager, sample calculation and reading of the articles, partially and fully; and (iii) the use of MC3R software to obtain bibliometric reports and matrices [23, 22].

Thus, following the guidelines proposed for the method, the steps performed in this research are presented as follows. For this research the Scopus database was selected, and the search terms selected, considering the research proposal, were: “*knowledge management*”, “*Blockchain*” and “*distributed ledger*”. The operators used were *AND* and *OR*, according to Table 2. Also, in relation to the type of document, only “*articles*” and “*conference paper*” were selected, and in relation to the year of publication, works published between 2017 and 2019 were selected. Based on these criteria, the first data set consists of thirty-six publications.

Considering the low number of articles found for the research, the sample calculation technique was not used. Thus, the second step was straight done, importing the data set into the reference manager “Mendeley” for analysing the keywords, abstract and title looking for adherence to the theme. This analysis returned a data set composed of nine publications. Table 2 presents a summary of the FastSLR performed:

Table 2: FastSLR criteria

Search Criteria	
Database	Scopus
Type of documents	Article / Conference paper
Years	2017 / 2018 / 2019
Search Terms	“knowledge management” / <i>Blockchain</i> / “distributed ledger”
Operators	AND / OR
Database search	
“knowledge management” AND “ <i>Blockchain</i> ” OR “distributed ledger”	
Results	
Full portfolio	36 publications
Final portfolio	9 publications

The nine publications composing the research portfolio were analyzed in full. In the next section the results and discussions about the findings are presented.

4. Results and discussions

As discussed earlier, Knowledge Management presents some challenges for its implementation, as presented in Table 1, and blockchain has been applied for addressing these challenges. Based on the results obtained, the use of blockchain for KM has been performed, in many cases, based on the development of knowledge management models.

For instance, in the *Block Chained Knowledge Management Model (BCKMM)* model, each user is considered a node in the network and each piece of knowledge added to the network is considered a transaction. When someone needs some piece of knowledge and gets it from the network, all previous transactions related to that knowledge will also be available. In this model, all network participants will be able to record and share their knowledge with all members, and their knowledge will be retained and maintain ownership and tracking issues in a secure environment. In addition, other benefits of using blockchain are related to the high speed of knowledge transfer over the network, and any point of the network that requires a specific knowledge will be available in the shortest possible time. Considering the network security, the possibility of distortions and unwanted changes in information is minimized, the knowledge obtained is protected and there is no possibility of unwanted dissemination of information outside the organization [7].

Another example refers to a platform that aims to be a secure and reliable way for knowledge sharing in untrustworthy environments using two advanced technologies: private cloud and blockchain. The former technology is implemented as a distributed network to share knowledge and record transactions, reducing the risk of sharing on the platform. It was essentially designed to minimize risks of data modification, as it seeks to provide a secure method to ensure data immutability. In addition, verifying membership through blockchain also makes it possible to ensure the validity of the information, as it highlights the quality and accountability of each member involved in knowledge sharing [13].

A third example of a proposed model is called *Reputation Based Knowledge Sharing (RBKS)*. It aims to explore the copyright protection of the knowledge owner. Among other configurations, the system consists of a blockchain and a reliable storage server, which are jointly employed to share and store knowledge, the main procedures being implemented through smart contracts to ensure safe execution. In this case, blockchain is used to manage user interaction, ensuring transparent and reliable delivery of messages while the digital address must ensure a degree of anonymity. Finally, smart contracts are used for knowledge creation and knowledge sharing [12].

Regarding knowledge erosion, blockchain can be seen as a way of record keeping, preserving records and preventing unwanted changes, enabling only specialists to edit critical information while given access to a wide range of people without permission to edit it. In this sense, blockchain can provide a balanced solution for access control and protection [14]. Regarding provenance data, blockchain is seen as a tool that allows knowledge owners to be held accountable for complying with statements issued in the blockchain. It is viewed as a means of providing traces of provenance data, based on access controls, where only authorized users can verify changes made to any data file. In addition, it provides proof of change using digital signatures and time stamps [15, 16].

Other approaches applying blockchain to KM seek to exploit its potential to provide security in knowledge production and transfer, as well as use it as a mechanism to ensure the functioning of parties involved in a contract by using smart contracts. This is because knowledge and organizational best practices need to be protected from unauthorized copying, as data privacy and the fair exchange of value for knowledge are increasingly important to both customers and organizations [11].

Based on it, KM challenges are related to blockchain applications regarding their intrinsic characteristics. Table 3 presents the challenges already listed in Table 1, and which feature of blockchain has been explored in the applications of this technology for facing such challenges:

Table 3: Relationship between KM and Blockchain features

Challenges	Related blockchain's feature	KM function
Knowledge storage	Decentralization Immutability	Retention
Insecurity and data/information loss	Decentralization Immutability	Retention
Knowledge sharing and copyright	Traceability Immutability Anonymity	Sharing and distribution
Lack of trust among members	Detrusting Smart Contracts	Sharing and distribution
Erosion of knowledge	Transparency Immutability	Utilization
Quality challenge and handling prevention	Immutability	Retention
Provenance and responsibility for knowledge	Transparency Traceability Immutability Anonymity	Identification

Most applications of blockchain in Knowledge Management seek to exploit the potential of the technology regarding immutability and traceability characteristics, as well as the smart contracts feature. Immutability has gained prominence in KM as it assists to solve many of the challenges and has been applied to various KM functions such as Retention, Sharing, Distribution and Identification, as shown in Table 3. This characteristic of blockchain avoids that information on the network is corrupted or unwanted changes are made, which provides organizations with a high degree of transparency, security and protection of knowledge, especially related to its share and distribution. Traceability has also been seen as a catalyst for the Retention, Sharing and Distribution, and Knowledge Identification functions. It allows the copyright protection of the knowledge, first for the knowledge holder who will receive credits (or liability), and also for the organization that guarantees the copyright to the owner, facilitating experts to share their knowledge under their rights.

On the other hand, smart contracts have assisted in KM due the lack of trust between network members, which mainly interferes with the Knowledge Sharing and Distribution function. Smart contracts, by allowing contract execution automatically when their conditions are met increases confidence in the transfer of knowledge in networks with large number of participants mitigating risks for those involved in the contract.

In short, for solving challenges in KM the immutability and traceability characteristics as well as the smart contracts feature have been strongly used. However, despite many other characteristics and features of blockchain also allow to add value to organizations through KM's functions, it have not been currently used.

6. Conclusion

This study aimed to identify the applications and implications of blockchain technology in KM. This was analyzed based on KM functions while blockchain was approached from the perspective of its features. From the data set was possible to identify that blockchain has been mainly applied in KM regarding knowledge sharing and distribution, retention and identification.

In this sense, the main gains in applying blockchain in KM are related to immutability and traceability characteristics, as well as the use of smart contracts for automatizing decision-making. It was also identified that one of the main characteristics of blockchain, decentralization, has not been used a catalytic for KM even some challenges related to centralization have been identified. Thus, future works could focus in this aspect for better understanding the potential of blockchain for decentralising KM. Besides that, even blockchain characteristics being able to change standard KM processes, it was identified that most studies are applying blockchain to meet KM challenges rather than exploring new opportunities or innovative processes.

The two main limitations identified in this study are related to the use of only one database for applying the literature review method, restricting the number of articles found, and the maturity of blockchain technology field being quite low since, since the technology has been just recently applied beyond financial areas. Even best practices can be found and several learnings, having a low number of studies make difficult generalizations.

This study demonstrates the feasibility and value of applying blockchain technology in KM by citing models and frameworks that have been developed for this matter and also by showing several ways that blockchain may solve KM related issues and add value to organizations.

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Social Learning for the Industry 4.0 context

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Abstract: Traditional supply chains are becoming smarter and connected with more objects embedded with sensors and autonomous decision making. To prepare the workforce to this new smart environment, social media erupts as an affordable and intuitive tool, creating the opportunity to learn without time and location barriers. Besides, this kind of platform fosters knowledge share and creation through countries, industries and institutions. The professional consolidation of the generation Y (born 1980-1990s), and the arrival on the labor market of the generation Z (born after 1995), expanded the social media tools to the formal context of organizations and educational institutions. Lately, this subject has attracted the attention of practitioners and scholars, due to the necessity of improving formal learning process as a response to this everchanging business process and environment, reflecting on Social Media's positive capabilities and characteristics. Using a case study methodology, the purpose of this paper is to present the potential of an Enterprise Social Media platform to reduce the learning time of the students in a University's robotics course, allowing greater quality and practicality in the execution of tasks. This study presents academic and managerial potential contributions. First, as main academic contribution, we highlight the possibility to measure a concrete benefit of Social Media for superior education: to reduce the number of classes required to safely carry out the basic operations in an industrial robot for the Sherbrooke's University robotics course. Second, as main managerial contribution we expect to illustrate an example of ICT's integration on formal learning improvement, which might be adapted for the organizational environment. To carry out this ongoing research, we've created an interactive environment through a series of tutorials using an Enterprise Social platform. Throughout this platform, students and professors can have access to this digital learning content before the beginning of the course and find easily and in the right place the information that they need to be guided in their own learning process. The tutorials are mostly based on how to operate two kind of robots, digitally conducting students step by step with videos and instructions. Further tutorials can be added for all concerned participants, creating a solid and interactive environment among the complete line of production. According to Martindale and Dowdy (2010) social media learning platforms make easier and more accurate the learning process. Reinforcing this idea, a report from the World Summit for Innovation in Education (WISE) conclude that the educational systems around the world will undergo major changes by 2030 due to the 4th industrial revolution. This means that in the next 11 years the internet is going to transform the Universities into interactive environments. Around 645 experts were interviewed for a survey and they define that the internet will be the main source of knowledge and the teacher will guide the student through their own learning process. This help us to sustain that internet and social media are the path for learning in the digital age, through a digital and interactive environment, which allow informal interaction and formal learning.

Keywords: Social Media, Education, Case Study, Digital Transformation, Industry 4.0

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Startups and the usage of Social Media for co-innovation

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Abstract: Sustainable development is dependent on significant improvement in supply chain resource utilization and efficiency. It requires a holistic Product Life Cycle (PLC) perspective from producer to end consumer. This perspective includes to reduce waste, to reuse and recycle materials, and to extend the PLC through remanufacturing, resulting in a closed-loop supply chain. These aspects become more relevant in the context of Industry 4.0, which brings many emergent technologies to support digital transformation, value co-creation, and propel operational excellence. The use of Social Media (SM) in the Industry 4.0 context has the potential to transform traditional linear supply chains to closed-loop ones. This might be possible since SM are being used to support PLC phases and connect stakeholders throughout the value chain. Having all players connected offers the opportunity to co-innovate in different perspectives: product, process and business model. Co-innovation is a new paradigm in the field of value creation; it can be argued that innovation is derived by integrating external and internal resources to generate co-creation of value. This paper aims to investigate how Social Medias are being used to support the co-innovation and new product development on startups in the perspective of closed-loop supply chain and Industry 4.0. To better comprehend the usage of SM, we conducted a systematic literature review to study which SM tools are being used in each phase of the PLC. We selected 127 articles published between 2005 and 2018, which match our criteria mentioning at least one phase of PLC and a SM platform used to support at least one of them. Our findings highlighted significant trends in academic literature. Most of the studies focus on the earlier phases of the PLC, which is planning and imagination, introduction and definition, and growth and realization. Ten papers pointed out the usage of SM to support the retirement and recycling phases and no mentions about closed-loop supply chain. SM has been adopted to support idea generation, co-creation, open innovation, crowdsourcing, new product development, marketing strategies, and product launch. These aspects were analyzed by academics mostly in large companies, but seldom in SME's. Only four papers discussed SM and PLC in a startup context. These findings showed us three main gaps in the literature: (1) how are startups using SM in their PLC processes? (2) how are companies using SM to support the tasks of the mature, declining and retiring phases? and (3) how can social media support the integration of the stakeholders to generate a closed-loop supply chain? Our findings and understanding allowed us to better define the next phases of this project. We are conducting an exploratory case study via semi-directed interviews to collect data from four startups. These startups are participating in an open innovation program sponsored by a large multinational company that is looking for co-innovative initiatives using rejects from their iron mining processes. Our literature review helped us to identify and define efforts and new ways to use SM in startup's co-innovation process.

Keywords: Social Media, Co-innovation, New Product Development, Startups, Closed-loop Supply Chain, Industry 4.0

Collaboration between startups and industry to face the challenges of the Fourth Industrial Revolution: a Systematic Literature Review

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Abstract: The 4th Industrial Revolution has been responsible for numerous transformations in the industrial sector, thus promoting various challenges and opportunities for organizations, especially regarding the incorporation of new technologies along the entire production chain. In this context, the connection between startups and industry emerges as an efficient strategy for the implementation of the concepts of Industry 4.0. From this scenario, this study aims to understand how startups can help the productive sector to solve the challenges of Industry 4.0. For this, a Systematic Review of Literature was carried out in order to identify the main publications that correlate the themes Industry 4.0 and startups. Based on the research carried out in the Scopus and Web of Science databases, it was possible to structure a portfolio of articles that deal with these issues for qualitative analysis with the support of Nvivo software. In this way, it becomes possible to understand the important role of startups in the competitiveness of the industry, making it more agile to incorporate new technologies from Industry 4.0, promoting innovation, enabling the emergence of new business models and, thus, contributing to greater efficiency, productivity and stimulation to the innovation of the productive sector.

Keywords: Industry 4.0; Startup; Systematic Literature Review; NVivo.

Linking Industry 4.0, Learning Factory, and Simulation Modeling: testbeds and proof-of-concept experiments

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Learning factories have an important role in the development of Industry 4.0, providing a rich environment where researchers and companies can collaborate and test (in multiple scenarios) the application of cutting-edge technologies (e.g. the internet of things, big data, collaborative robots, additive manufacturing, simulation modeling). The purpose of this paper is to identify and describe testbeds and proof-of-concept experiments, mainly related to simulation modeling, developed in learning factories to support Industry 4.0 deployment. It also aims to present the lab shared by *Produit Québec* and the Center of Excellence in Innovative Manufacturing Enterprise Management (CEGEMI), located at Sherbrooke, Canada, identifying its potential to conduct simulation modeling research and to promote the digitalization of manufacturing companies. This research combines a literature review with a case presentation. For the literature review, data were collected through electronic data sources to analyze the development of Industry 4.0 learning factories and to identify existing Industry 4.0 testbeds and proof-of-concept experiments documented in the scientific literature. As for the case presentation, site visits and interviews were conducted to understand how the lab can support applied research and companies' transition to Industry 4.0. The literature review and case presentation show the relevance of learning factories to develop applied research and to deploy Industry 4.0, especially in small and medium-sized enterprises (SME) that tend incrementally to move towards digitalization. Moreover, it describes how learning factories can incorporate and test a wide range of Industry 4.0 technologies through testbeds and proof-of-concept experiments, supporting experimental validation of different artifacts, such as simulation modeling frameworks.

Keywords: Industry 4.0, Learning Factory, testbeds, proof-of-concept, Agent-Based, Digital Twins.

1. Introduction

On the one hand, Industry 4.0 (I4.0) is one of the main strategies to improve the competitiveness of the manufacturing sector over the next years [1], [2]. It will lead to the emergence of dynamic, real time optimized, self-organizing systems, making the creation of new business models based on mass customization possible [1]. However, I4.0 (or the Fourth Industrial Revolution) is still in its infancy [2]. Moreover, most legacy systems are not Industry 4.0-ready [3], [4], and companies tend to deploy I4.0 incrementally, especially small and medium-sized enterprises (SME) [5]. Therefore, the development of empirical and applied research on I4.0 with real cases are still limited, an issue to further advance the research field. On the other hand, learning factories can play an important role in the development of I4.0, since they provide a rich environment where researchers and companies can collaborate and test (in multiple scenarios) the application of cutting-edge technologies (e.g. the internet of things, big data, collaborative robots, additive manufacturing, simulation modeling). The concept of a learning factory emerged in 1994 in the US but has evolved over the years [6]. There are different morphologies and typologies of learning factories in the literature. The multidimensional description model proposed by the International Academy

for Production Engineering Collaborative Working Group (CIRP CWG) on Learning Factories involves 59 characteristics, grouped in 7 categories (i.e. operating model, purpose/target, process, setting, product, didactics, and metrics) [7]. Overall, a learning factory aims to provide a close-to-industry real environment for education and training as well as supporting collaboration among different stakeholders, research, development, technological transference, and innovation [6].

Learning factories are mainly present in universities, industries, consulting companies, and vocational schools [8]. Similar to I4.0, a learning factory can be considered as a socio-technical system [2], [8]. Concerning the technological infrastructure, a learning factory can assume different levels of configuration (i.e., station, cell, system, segment, factory, network) and adopt different products (i.e. real products, didactically prepared products, fantasy products, self-developed products) [8]. However, it must be as close as possible to reality and allow experiential learning approaches [6]. Learning factories may have different purposes, such as production process improvement, energy and resource efficiency, sustainability, logistics optimization, business administration, emergency processes, demonstrations, and more [6][7]. There are also different learning factory environments, i.e. physical, digital, virtual, or hybrid environment, where the latest is more significant in the context of I4.0 [6]. Regarding the scope of this research, it is limited to I4.0 learning factories with a focus on research, technology transfer, and innovation.

According to Abel et al. [6, p. 809], “learning factories are more and more used as test areas for research,” specially I4.0 learning factories. However, existing literature reviews on I4.0 learning factories focus on theoretical studies or descriptive cases of underdevelopment learning factories rather than how I4.0 learning factories is applied to conducting applied research [6], [8]. Hence, the purpose of this paper is twofold: first, based on a literature review, identify and describe testbeds and proof-of-concept experiments, mainly related to simulation modeling, developed in learning factories to support I4.0 deployment; second, to present the lab shared by *Productique Québec* and its Center of Excellence in Innovative Manufacturing Enterprise Management (CEGEMI) in Sherbrooke, Canada, identifying its potential to conduct simulation modeling research and to promote the digitalization of manufacturing companies. For the literature review, the systematic guide to literature review described in Okoli and Schabram [9] was adopted. The data were collected through electronic data sources (Web of Science Core Collection and Scopus) using two search strings (see Figure 1 and Table 1) to analyze the development of I4.0 learning factories and to identify existing I4.0 testbeds and proof-of-concept experiments documented in the scientific literature. As for the case presentation (or lab description), we conducted site visits and semi-structured interviews with lab coordinators to understand how it can support applied research and companies’ transition to I4.0.

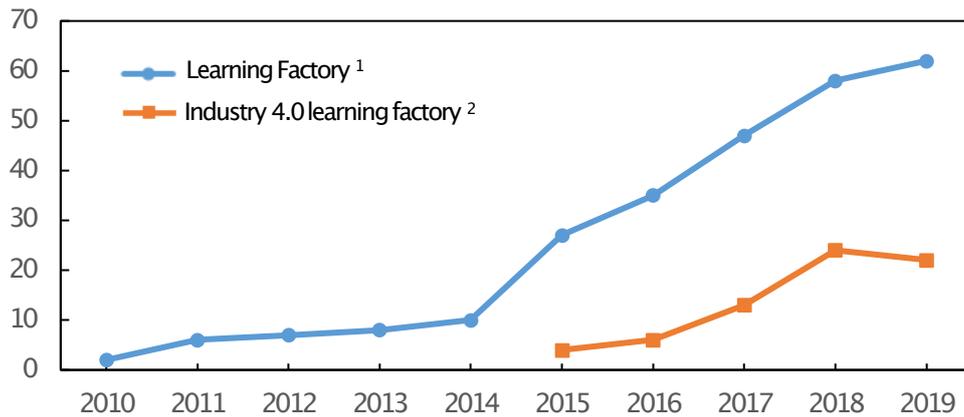
The remainder of the paper is organized as follows: Section 2 introduces Industry 4.0 learning factories and describes key Industry 4.0 testbeds and proof-of-concept experiments. Section 3 presents the lab description. Section 4 discusses the potential use of the lab as a research setting and drawn the conclusions.

2. Literature Review

2.1. Industry 4.0 learning factories

There are over 12 design principles and 14 enabling technologies within the context of I4.0 [2], [10], covering different socio-technical dimensions (i.e., technology, organization, and personnel) [11]. However, conforming Elbestawi et al [12], only few learning factories cover a wide range of I4.0 components. Although, along with I4.0 [2], [13], the number of publications on I4.0 learning factories is growing over time (see Figure 1). Similar to companies, most existing learning factories are not yet Industry 4.0-ready [6], [14]. Hence, there is a branch in the scientific literature seeking to support the transition of existing learning factories to I4.0. In Karre et al [14], the authors describe a detailed roadmap to transform an existing Lean Manufacturing learning factory into an I4.0 learning factory. A transformation model based on three pillars (e.i., didactic, integration, and organization) is also proposed in Baena et al [15].

The primary purpose of a learning factory is to provide a close-to-industry environment to improve knowledge transfer [8]. However, existing I4.0 learning factories are mainly directed to research and technological transfer [6], [16]–[18]. In Elbestawi et al [12], the authors describe an I4.0 learning factory at McMaster University, Canada. A modular and reconfigurable learning factory at Winston University, Canada, is reported in [19]. Other examples of I4.0 learning factories include the AutoFab at the Darmstadt University of Applied Science, Germany; the Smart Production Laboratory at Aalborg University, Denmark [16]; and the Industry 4.0 Pilot Factory in Vienna University of Technology, Austria [20].



Search strings: 1 – TOPIC (“Learning Factory”);

2 – TOPIC (“Industry 4.0” OR “Industrie 4.0”) AND (“Learning Factory”)

Figure 1: Learning Factories’ publications over the last 10 years

2.2. Industry 4.0 testbeds and proof-of-concepts

According to Tisch and Metternich [17, p. 92], “learning factories environments are often used as validation settings.” There is an increasing number of scientific articles in the field of I4.0, including a testbed or a proof-of-concept experiment, mostly developed in learning factories (see Table 1). Testbeds are experimental platforms that provide means for testing different artifacts (e.g. models, methods) and new technologies. They are “composite abstraction of systems used to study system components and interactions to gain further insight into the essence of the real system” [21, p. 33]. While proof-of-concept “is framed in terms of a particular kind of research that provides justification in practice of the potential transportability of knowledge acquired through the experimental test case” [22, p. 737]. Further analysis of the term can be found in [23]. As summarized in Table 1, a list of key research papers on I4.0 applying or describing the development of a testbed or proof-of-concept experiments is analyzed in the next paragraphs.

In Li et al [24], the authors proposed a smart manufacturing framework of I4.0, modeling the shop-floor-entities as a multi-agent system (MAS). They also proposed an evaluation and control algorithm to reduce the load unbalance in manufacturing scheduling with big data feedback assistance. Their model consists mainly of four agent types, i.e. task agent (TA), smart product agents (PA), machining agents (MA), and conveyor agents (CA) that compete and cooperate in the self-organized manufacturing system. To validate their framework, the authors conducted a proof-of-concept experiment in a learning factory setting with a process of candy-picking located at the South China University of Technology, assuming that nine types of mixed candies need to be packed. The candy-picking process is mainly composed of five servers (for private cloud assistance), five robots (representing the MAs), and five conveyors controlled through PLCs (representing the CAs). Their findings suggest that their control method can improve both load balance and efficiency. This candy-picking process is also used as a validation setting in other similar studies [25]–[29].

I4.0 systems must be flexible and reconfigurable to allow highly customized products [1]. In [30], the authors describe in detail the development of a modular factory that serves as a testbed to analyze reconfigurable manufacturing systems. The main aspects investigated to speed factory configuration are self-layout recognition, fast workstation and robot programming, interlayer information sharing, and configurable software for shop-floor monitoring. Composed of ten workstations and multiple components (e.g. robotic arm, pallet transfer system, NFC tags, infrared communication modules), the testbed adopts a three-layer MAS architecture with three agent types (i.e., coordinator, workstation agent, workstation executor) for all shop floor decisions. Another modular learning factory used as a testbed for research, to analyze the introduction of a new product family in reconfigurable systems, is reported in [31]. According to the authors, the modular and changeable learning factory (iFactory), located at the University of Windsor, Canada, is equipped with robotic and manual assembly stations, a computer vision inspection station, an automated storage and retrieval system, an RFID system, and several material handling modules.

In Zarte et al [32], the authors used an educational manufacturing system at the University of Applied Sciences Emden / Leer, in Germany, as a testbed to evaluate their predictive maintenance simulation model to improve production planning. Their simulation framework is based on a MAS and was implemented using the software AnyLogic[®]. The physical structure of the laboratory, also described in Zarte et al [33], includes an input/output module to feed raw material and deliver finished products, a camera, a high-rack warehouse, a main conveyor belt line, three industrial robots, two work places, and multiple buffer positions for the carriers to assemble three products, all made of LEGO Duplo bricks equipped RFID tags.

In Saez et al [34], the authors present a hybrid simulation framework for shop-floor real-time performance monitoring by combining discrete event simulation (DES) with continuous dynamics (CD) in a sole simulation environment. The manufacturing testbed at the University of Michigan, USA, mainly composed of two Fanuc robots, four CNC milling machines, and a conveyor loop, was used to validate their framework. The testbed was modeled in MATLAB/Simulink, and real data (both discrete and continuous signals) were gathered from the PLC using an IIoT agent, i.e. a Rockwell Automation Industrial Internet of Things (IIoT) adapter. The novelty of their framework is allowing the comparison of real-time shop-floor data with real-time simulation data to analyze system and machine performance. Another example for real time monitoring with predictive functionalities can be found in [35]. In [36], the authors used the open source platform Ptolemy II to model and simulate a heterogeneous system. Their main goal was to model and simulate the I4.0 demonstration production line located at Shenyang Institute of Automation, in China (that serves as a testbed for smart and intelligent manufacturing) to provide a reference model for its upgrading. The production cell counts with different workstations, conveyors, pallets with RFID tags, robots, and AGVs. Their model applies mainly a DES approach [37].

Digital Twin is another key simulation technology in I4.0 [13], used to converge manufacturing physical and digital spaces. In [38], the authors discuss the concept of experimentable digital twins (EDTs) and their interconnection. According to the authors, EDTs combines digital twins with model-based systems engineering and simulation technology. They developed a full digital representation of a reconfigurable assembly work cell (named ReconCell), equipped with two UR10 robots (cobots). They also employed the concept of a virtual testbed to allow the network of interacting EDTs. The ReconCell also appears as an environmental setting in other scientific studies [39], [40]. In [41], the authors proposed a general framework for knowledge-drive digital twin manufacturing cell (KDTMC) for intelligent manufacturing (characterized by autonomy and self-optimization). The KDTMC is based on three main technologies (i.e. digital twin, dynamic knowledge bases, knowledge-based intelligent skills) operating in four spaces (i.e. physical, digital, knowledge, social), endowed with the capacity of self-thinking, self-decision-making, self-execution, and self-improving. To show KDTMC feasibility and provide practical insights, the authors built a testbed using Xi'an Jiaotong University' lab and presented three application examples concerning intelligent process planning, scheduling, analysis, and dynamic regulation. The physical system consists of two robotic arms, three machine tools, two buffers, one AGV, a warehouse, and a Kanban system.

There are other I4.0 research testbeds documented in the literature. In [42], the authors introduce the concept of cyber-physical manufacturing cloud (CPMC) to allow direct operation and monitoring of machines remotely in a manufacturing cloud. They also present a scalable service-oriented layered architecture of CPMC to allow manufacturing web services and cross-platform applications. Moreover, the authors describe the development of a testbed based on CPMC architecture, which links two geographically distributed manufacturing sites over the Internet. One site is located at the University of Arkansas, in the USA, equipped with one CNC, two 3D printers, two robotic arms, three controllers, and one local server. The other site is located at the Missouri Institute of Science and Technology, also in the USA, equipped with one 3D printer, one robotic arm, two controllers, and one local server. In [43], the authors describe a real-scale IoT-based warehouse testbed (PhyNetLab), used to evaluate logistic solutions in material handling and warehouse applications. The PhyNetLab includes 50 cellular transport system (mobile robots for materials handling), operating as CPS nodes, intelligent bins, and intelligent containers. In [44], the authors used simulations and a smart factory testbed to evaluate the practicality of their proposed RFID-enabled positioning approach in AGV system for smart factories. In [45], the authors describe the development of a cyber-physical system of I4.0 testbed (CPSI4.0), a small serial line equipped with several sensors, a conveyor belt, an RFID system, and an IoT Gateway to make data available at the local webserver. The testbed is mainly directed to research labs as well as for education and training purposes, with a concentration on sensor technology and measurement data acquisition. Similarly, in [46], the authors developed a small IoT testbed and performed experiments, including OPC UA and database on the cloud. Other papers adopt virtual environments to develop a testbed [47] or proof-of-concept [48], [49].

Table 1: Industry 4.0 testbeds and proof-of-concept experiments

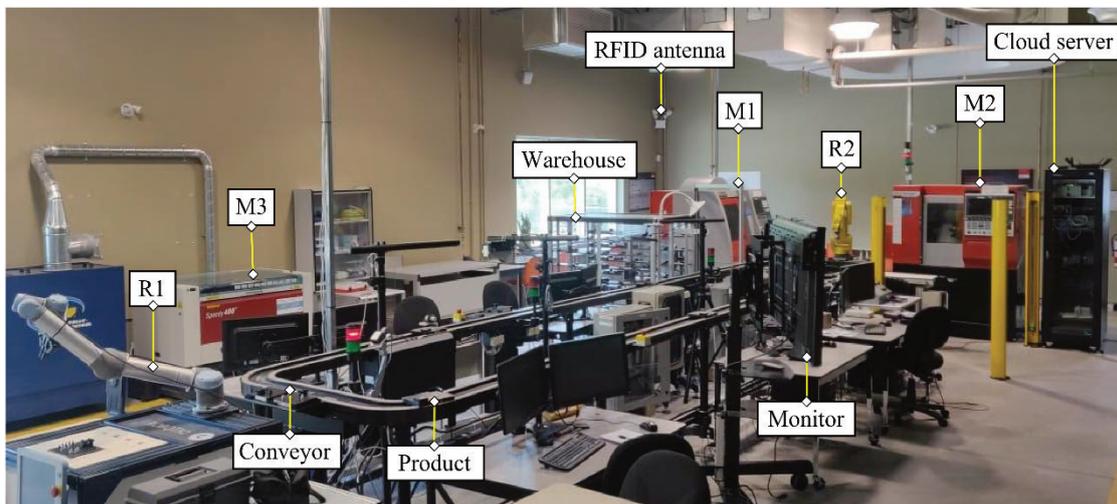
Reference	Year	Approach	Main technologies	Focus /Application
Zhou et al. [41]	2019	Testbed	Simulation	Intelligent Manufacturing. A general framework for knowledge-drive digital twin of a manufacturing cell.
Delbrügger et al. [47]	2019	Virtual testbed	Simulation	Combine different simulation models to interdisciplinary multi-level (process, factory, and human interaction) analysis and optimization of production systems
Tzimas et al. [48]	2019	Proof-of-concept	Augmented reality	Machine tool setup instructions
Kim et al. [30]	2019	Testbed	Simulation	Reconfigurable manufacturing systems
Priggemeyer and Rossmann [39]	2018	Testbed	Simulation	Simulation-based control of reconfigurable robotic workcells (Reconcell):
ElMoaqet [45]	2018	Testbed	IoT and CPS	Development of a testbed for I4.0
Saez et al. [34]	2018	Testbed	Simulation	Hybrid simulation for real-time performance monitoring
Tang et al. [25]	2018	Proof-of-concept	Smart Factory, Simulation and Big Data	A cloud-assisted self-organized architecture for distributed manufacturing scheduling.
Wang et al. [27]	2018	Proof-of-concept	IoT, Simulation, Cloud computing.	Cloud-based smart manufacturing for personalized consumption demands
Chen et al. [26]	2017	Testbed	IoT, Big Data, Cloud Computing	Hierarchical architecture of smart factory
Schluse et al. [38]	2017	Testbed	Simulation and Industrial Robots	Experientable Digital Twin of an autonomous robotic workcell (ReconCell)
ElMaraghy et al. [31]	2017	Testbed	Simulation	Reconfigurable manufacturing systems. Introduction of new product family.
Nie et al. [36]	2017	Testbed	Simulation	Reference model of an I4.0 demonstration production line using Ptolemy II
Masoudinejad et al. [43]	2017	Testbed	IoT, CPS, and AGV	Cellular transport systems in material handling and warehouse applications.
Atorf et al. [40]	2017	Testbed	Simulation	Formalism and modular framework for model configuration and simulation-based optimization. Testbed: ReconCell.
Liu et al. [42]	2017	Testbed	CPS and Cloud computing	Development of the Cyber-Physical Manufacturing Cloud architecture
Li et al. [24]	2017	Proof-of-concept	Smart Factory, Simulation and Big Data	Distributed manufacturing scheduling.
Zarte et al. [32]	2017	Testbed	Simulation	Predictive maintenance using AnyLogic®.
Lu et al. [44]	2017	Testbed	RFID, CPS, and AGV	RFID-enabled positioning approach in AGV for smart factories
Giorgio et al. [49]	2017	Proof-of-concept	Virtual Reality	Human-robot collaboration
Okuda et al. [46]	2017	Testbed	IoT, Cloud computing	Development of an IoT testbed. Controlled experiment using OPC UA protocol.
Wan et al. [28]	2016	Testbed	IoT, CPS, Big Data	Software-defined IIoT architecture to operate physical devices and provide an interface for data exchange
Wan et al. [29]	2016	Proof-of-concept	IoT, Mobile service and Cloud computing	Mobile services for customization of intelligent manufacturing systems

Search string: TOPIC: ("Industry 4.0" OR "Industrie 4.0") AND TOPIC: ("testbed" OR "test bed" OR "proof-of-concept")

3. Lab description

The learning factory of *Productique Québec*¹, located at Sherbrooke, in the Canadian province of Quebec, was inaugurated in 2009 to support education, training, and applied research in mechatronics and industrial informatics. At that time, the lab also counted with one of the most advanced 3D printers in the province of Quebec, as additive manufacturing was emerging as a key technology. The I4.0 became a major topic in the manufacturing world after 2011, along with its primary enabling technologies, i.e. IoT, CPS, and Smart Factory [1]. Hence, the focus of the learning factory shifted towards I4.0 concepts. In 2018 *Productique Québec* joined forces with the Cégep de Sherbrooke, Université de Sherbrooke, and other partners to create the CEGEMI², gradually transforming the learning factory into a living lab. They aim to support education, training, research, and innovation as well as to assist manufacturing SMEs in their digital transformation by offering various services, including managerial and technical assistance. Even though, similar to SMEs [5] and other I4.0 learning factories [14], [15], its transition to I4.0 will be incremental, by incorporating key I4.0 enabling technologies, such as IoT, Cyber-Physical Production System (CPPS), the Internet of Services (IoS), and simulation modeling.

Figure 2 shows an overview of the lab's current structure. The process has multiple stations and counts mainly with a UR5 collaborative robotic arm (cobot), an LR Mate robotic arm, a CNC turning centre, and a CNC milling centre to produce didactically prepared products. Concerning education and training, the Cégep de Sherbrooke and the Université de Sherbrooke have done multiple projects to assist their academics, including the lab as a part of their curricula. Programming robots to perform specific tasks and the automation of the assembly line are some of the didactic topics used to develop specific teaching-learning situations. In the last academic term, around 50 students worked with projects to learn how to program robotic arms. Starting from the next academic term, Masters students from the Université de Sherbrooke will use the lab study the application of new management principles considering the cobot in the production line. It also served to demonstrate the use of some I4.0 technologies to SME (e.g. IIoT, cobots). Current research in the lab includes a project to calculate Overall Equipment Effectiveness (OEE) in real time using a Fanuc robotic arm through the advanced internet data gateway EWon Flexy205; a project to develop a social media platform for collaborative data sharing; a project about achieving the ISA 95 standard to enable the integration of enterprise and control systems; among others. Currently, there are 3 Ph.D., 1 M.Sc. student and several research professionals using the lab to develop their research.



Legend: R1- Robot UR5 (Universal Robot); R2 - Fanuc LR Mate iC 5L Robotic Arm; M1 - EMCO Concept Mill 155 Vertical Machining Centre; M2 - EMCO Concept Turn 250 Turning Center; M3 - Laser Cutting Machine.

Figure 2: Lab infrastructure overview

¹ <http://productique.quebec/>

² <https://cegemi.org/>

4. Discussion and Conclusions

Numerous research papers adopting a learning factory to develop an I4.0 testbed or proof-of-concept were identified and analyzed in section 2.2, demonstrating the relevance of learning factories in supporting I4.0 applied research. These articles also reveal research opportunities areas to *Productique Québec* and CEGEMI lab, such as predictive maintenance, distributed production planning and control, and different simulation modeling methods in I4.0 (e.g. agent-based, discrete-event, hybrid simulation, digital twins, virtual reality, augmented reality). They also provide different examples of I4.0 applications, methods, and technologies, which are extendable to the lab. Moreover, *Productique Québec* and CEGEMI lab present a similar physical infrastructure to that of other learning factories documented in the scientific literature, such as in [32], [34], [41]. Therefore, its roadmap towards I4.0 can be more easily defined. Furthermore, it reinforces the potential of the lab for the development of applied research in different areas of I4.0.

This study reveals an increasing number of publications on I4.0 learning factories. It also describes how learning factories can support applied research in I4.0. To this end, studies with a testbed or a proof-of-concept experiment developed in learning factories were identified and analyzed. These studies cover different I4.0 design principles (e.g. real-time capability, decentralization, modularity, interoperability) and enabling technologies (e.g., IoT, CPS, big data, cloud computing, simulation modeling). The practical examples described here may help the further development of *Productique Québec* and CEGEMI lab as well as of other learning factories. This research also suggests that learning factories may support technological transfer to SME, which also tend to move incrementally towards digitalization by showing how to incorporate and testing a wide range of I4.0 methods and technologies.

Future research may consider *Productique Québec* and CEGEMI lab to develop an I4.0 testbed or proof-of-concept experiment using a simulation modeling technology. Another research avenue is the integration of the lab with other learning factories to create a distributed supply chain.

Acknowledgments

This research is supported by the Federal Institute of Education, Science and Technology of Sao Paulo (IFSP) in Brazil, by Mitacs Globalink, by Quebec's Ministry of Economy and Innovation, and by the Natural Sciences and Engineering Research Council (NSERC) of Canada.

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Thematic Session
Humans and Environment
(Chair: Prof. Elias Ribeiro da Silva)

Theoretical framework of the Industry 4.0 risks from sustainability perspective

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Abstract: Industry 4.0 is a rising theme that has brought a lot of discussion in the literature, especially in relation to its benefits for the industrial sector. However, one area of study that is little discussed is in relation to the possible negative risks that the concepts and technologies of Industry 4.0 can generate. In this way, this work aims to raise and discuss the risks of the Fourth Industrial Revolution currently found in the literature from a sustainability perspective and develop a theoretical framework to represent them. For this, a methodology of systematic analysis of the literature was used to relate the relevant works to the theme and thus to discuss them. Two data bases (Scopus and Web of Science) were used in which 7772 articles were evaluated, of which 66 were used for the discussion. The 28 risks found were grouped into four dimensions (Economic Risks, Social Risks, Environmental Risks and Technological Risks) where their relationships were studied and represent in the theoretical framework constructed. Moreover, regulatory issues have been found and discussed where the lack of standards can affect all the four dimensions. In this way, in addition to contributing with the academy building more theoretical contribution to the theme, the risks raised can help managers and companies to check points of attention before implanting technologies and concepts of industry 4.0, where errors can be circumvented and losses avoided.

Keywords: “industry 4.0”, “risk management”, “sustainability”

1. Introduction

The so-called “industrial revolutions” are characterized by technological leaps capable of changing the productive form [1]. The First Industrial Revolution initiated in the late eighteen century introduced mechanical manufacturing systems using water and steam. Begun in the late nineteenth century, the Second Industrial Revolution was characterized by the use of electricity in mass production. In the mid-twentieth century, the Third Industrial Revolution made possible use of automation and microelectronic technology [2]. In recent years, a change in manufacturing logic with an increasingly decentralized and self-regulating value creation approach through advanced technologies (Internet of Things, Cyber Physical Systems, Autonomous Systems, etc.) that, according to [3], has reduced the boundaries between the physical a virtual world. These changes have been called “Fourth Industrial Revolution” or “Industry 4.0”.

The term “Industry 4.0” arose in Germany from a technology development plan launched in 2011 [1]. A few years later, this theme was deepened from a report released in 2013 by Kargerman, Wahlster and Helbig further discussing the benefits of the new industrial age. [4] In Davos in 2016, this term became even more influential at the World Economic Meeting (WEF) with the theme “Mastering the Fourth Industrial Revolution” [5]. In a short time Industry 4.0 began to spread and be discussed by companies, research centers and universities globally [6].

In any case, Industry 4.0 has been describing a trend towards the increasing use of information technologies and production environment automation [4] from a multitude of technologies and concepts [7] building a digital and interconnected value chain [1].

The use of emerging concepts and technologies from discussions promoted by Industry 4.0 can lead great benefits to companies. However, conceptualizations of the negative impacts of the Fourth Industrial Revolution on sustainability approach still have little theoretical support. According to [8], Industry 4.0 deployment requires that opportunities outweigh the challenges and risks to be assessed. Thus, studying the possible risks posed by Industry 4.0 technologies and concepts to a whole industrial value chain from a sustainability perspective can help companies be more successful and assertive in adopting these concepts, and governments can be aware of issues that may involve an entire society.

2. Methods

The *Methodi Ordinatio* developed by [9] was applied to survey the articles which were used to discuss the Industry 4.0 risks. This methodology ranks articles based on criteria such as the impact factor of the journals where the articles were published, year of publication and number of citations. For this, nine steps are followed as shown in Figure 1.

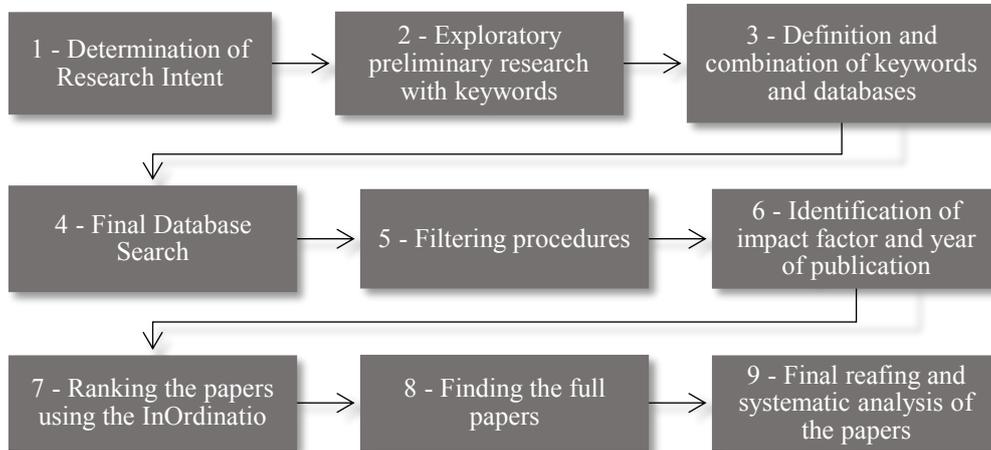


Figure 1 – Steps of *Methodi Ordinatio* [9]

From these steps, two keywords axes (“Industry 4.0” and “risks”) were used where each axis was varied in synonyms enabling 72 different combinations as shown in Figure 2. Each combination was verified in two databases (Web of Science and Scopus) from which the articles were extracted.

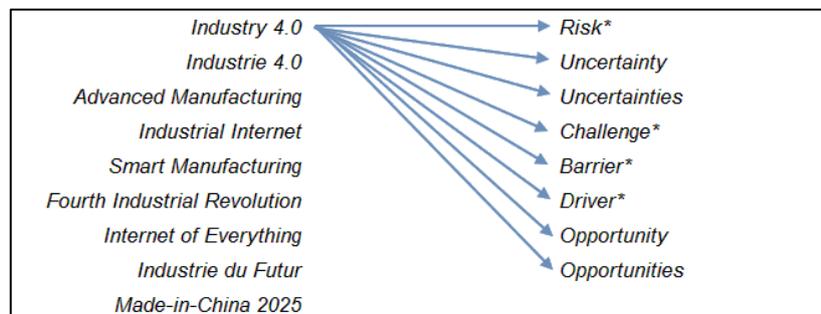


Figure 2 – Keyword Combination Demonstration

Thus, 7772 articles were surveyed and subsequently filtered to compose only works within the scope suited. The used filters can be seen in the table below.

Table 1: Filtering Steps

Step	Number of Excluded Articles	Number of Remaining Articles
Gross number of articles	-	7772
Exclusion of duplicates	4582	3190
Book and book chapters exclusion	102	3088
Filter by Reading titles	1842	1246
Filter by Reading abstracts	1134	112
Filter by Reading the full articles	46	66
Total		66

The articles rank step was not performed due to the study had used all 66 articles in the final portfolio. This rank is better used when there is a need for a criterion of choice among the most relevant works in final the portfolio.

Thus, by reading the 66 final articles, 28 risks were found which are distributed in four dimensions: Economic Risks, Social Risks, Environmental Risks and Technological Risks. The first three dimensions are based on the concept of sustainability of Elkington's Triple Bottom Line. The fourth dimension is proposed on the technological issues. In addition, 11 subdimensions are built to better group the mapped risks. Briefly, this distribution can be seen in the Table 2.

In the next topic, the risks are discussed according to the authors used for their construction.

3. Industry 4.0 Risks

3.1.1. Economic Risks

Financial Risks

Economic risks may have an effect on the economic sustainability of companies. Within this context, the first challenge encountered is the cost of deploying Industry 4.0. The high degree of complexity in developing a suitable infrastructure for Industry 4.0 implementation can require heavy investment costs [10, 11, 12, 13] in IT systems, machine parks [14] and skilled labor [12]. Moreover, according to [15], for efficient transformation, companies will need to invest not only in current and fixed problems, but also for future developments.

There are also uncertainties about the cost-benefit of technologies, where financial returns may not be the expected [10]. In the survey by [14], respondents comment that investing in Industry 4.0 is costly in the short term and returns may only be visible in the long run. The authors also comment that customers' willingness to pay for new solutions may not be commensurate with the costs generated.

Planning Risks

Although overall industry 4.0 opportunities are already well-documented [16], there is a lack of deployment standards [10]. A strategic policy towards Industry 4.0 is important for its successful implementation [11] and wrong solutions can be avoided.

When we address the issue of company size, technology trends have stronger positive relationships in large companies than in SMEs [8]. The research of [17], reveals that the smaller a company, the greater its chances of becoming victims rather than beneficiaries. Thus, within a fully connected supply chain through the Industry 4.0 End-to-End integration concept, widening the gap between SMEs and large corporations is uninteresting [17], as smaller companies may feel pressured and not catch up with the new trends, affecting partners in the top of the chain. Furthermore, in this context of companies' relationships, some of them fears becoming dependent on services offered by suppliers who have expertise in key technologies of the Fourth Industrial Revolution [8, 16].

Market Risks

When we look at market issues, competition between companies can increase rapidly as industrial boundaries begin to shift in the technological context. New market players from different industries and geographic regions may emerge, facilitated by business boundaries that may disappear due to virtualization [2, 12]. In addition, new service-related business models can increase their value creation capacity [18]. Increasingly sought-after customer, personalization is beginning to convert the value chain from the production side to the service side [15], where offering functionality and accessibility beyond tangible product can be a market-leading concept [19]. Any resource, such as production lines, assembly lines, storage, computing, labor, know-how, etc., can be offered through a network [20], both internally and externally to enterprises boundaries [21], where other companies may pay for these services [20].

Table 2: Risks from implementation Industry 4.0 concepts and technologies

Dimension	Subdimension	Risk	Description	Author
Economic Risks	Financial Risks	<i>High deployment costs</i>	Large amounts of investment for technology adoption and infrastructure building for industry 4.0	[10], [11], [12], [13], [15], [65]
		<i>Uncertain financial return</i>	Possibility of financial returns not reaching expectations	[10], [12], [14], [38], [71]
	Planning Risks	<i>Implementation inaccuracy</i>	Adoption of Industry 4.0 technologies and solutions in the wrong way	[8], [10], [11], [12], [14], [16], [18], [70]
		<i>Self-sabotage over a value chain</i>	Partners may not catch up on new technologies and industry 4.0 concepts affecting the companies in the top of the chain	[8], [10], [13], [14], [17]
		<i>Partners Dependency</i>	Companies can become dependent on suppliers with the knowledge and technologies needed for technology development.	[12], [104], [16]
	Market Risks	<i>Increased competition</i>	Increased competition due to easier entry of new players by the disappearance of industrial boundaries and new business models where companies from different branches and geographic regions can join the market.	[12], [15], [18], [66]
		<i>Negative customer interventions</i>	Customers can adversely affect the production process due to new business models, where clients can intervene and adjust specifications throughout a product cycle	[14], [15], [22], [23], [66], [68]
<i>Customer acceptance difficulty</i>		Customers may not adhere to new industry 4.0 features and solutions	[12], [16], [23]	
Social Risks	Human Capital	<i>Lack of skilled labor</i>	Shortage of skilled labor to handle new technologies	[10], [11], [12], [15], [18], [24], [25], [38], [74]
		<i>Reluctance to changes</i>	Partners and employees may be reluctant to technology changes	[13], [16], [26]
		<i>Risk to the physical integrity of employees</i>	Accidents due to work approach between employees and machines	[27], [28], [29], [50], [51]
		<i>Psychosocial issues</i>	Employees may develop psychosocial problems due to changes caused by digital transformation	[29], [30], [74]
	Society	<i>Increasing inequalities and social tensions</i>	Fewer people benefit from improvements caused by industry 4.0	[15], [18], [31], [32], [33], [34], [35]
		<i>Job losses</i>	Unemployment caused by the replacement of labor by machines	[15], [18], [30], [32], [33], [73]

Dimension	Subdimension	Risk	Description	Author
Social Risks	Ethic and legality	<i>Artificial Intelligence ethical issues</i>	Artificial intelligence may not be able to identify ethical issues in making autonomous decisions	[36], [37]
		<i>Privacy invasion</i>	Customers and employees may get privacy intrusion due to private data access by companies	[38], [39], [40], [41], [42], [43], [46]
Environment Risks	Consumption	<i>Increased consumption of natural resources</i>	High consumption of natural resources in the manufacture of new machinery and equipment to meet the demands of Industry 4.0	[35], [44]
		<i>High energy consumption</i>	High energy consumption for the new technologies' operation	[11], [22], [39], [45]
	Pollution	<i>Electronic Waste</i>	Increased o electronic waste due to machinery replacement	[35], [44]
		<i>Emission risk</i>	Increased fuel consumption for new equipment manufacturing, transportation of obsolete equipment and use of primary energy for technologies operation may generate carbon emissions	[11], [35], [44]
Technological Risks	Technical Risks	<i>Signal Interference</i>	The large number of devices connected simultaneously can interfere with the signals between them. In addition to the difficulties caused by adverse conditions from the industrial environment	[22], [45], [46], [69]
		<i>Network technical inability</i>	The industrial internet may not be able to meet the demands of the vast amount of information generated.	[11], [13], [22], [46], [47], [48], [58], [69]
		<i>Lack of interoperability</i>	Machines, systems and software may not be able to communicate with each other due to the large heterogeneity of data formats	[2], [10], [12], [22], [35], [46], [48], [49], [50], [60], [61]
		<i>Technological chaos</i>	A failure in a highly connected system can cause widespread clutter	[19], [31], [38], [43], [67]
	Data Security	<i>Cyber attacks</i>	Systems and equipment can be hacked	[10], [12], [22], [25], [31], [38], [39], [41], [43], [50], [51], [52], [53], [54], [55], [56], [57], [58], [59], [75]
		<i>Disclosure of private data</i>	Private customer, partner or company data may be disclosed	[2], [14], [18], [40]
	Data Handling	<i>Ineffective Data Analysis</i>	Inefficient data analytics may arise due to Big Data management difficulties	[45], [48], [58], [59], [60], [67], [72]
		<i>Low data quality</i>	Data generated by equipment, people, and systems may have information quality issues	[2], [13], [45], [47], [60], [62], [63]

When it comes to customer relations, companies also need to be aware of the level of client's participation in product customization. In a context where companies use technologies that enable interventions, the customer will be actively involved in the value creation process of a product. Customers will be able to intervene and adjust specifications not only before ordering, but also during design, manufacture, assembly and testing [15], incorporating last-minute changes also [22]. Thus, it is important to note to what extent this freedom of intervention can be beneficial to companies. In addition, companies may also face challenges related to convincing customers about the beneficial nature of new technology solutions [23], where they will need to better understand which services customers are willing to pay for [16].

3.1.2. Social Risks

Human Capital

The high demand for skilled labor to handle and work with the new concepts and technologies can lead managers to face critical situations due to the possible shortage of professionals with necessary technical skills [15, 11]. Thus, finding human talents for the demands of industry 4.0 can be a potential challenge [24, 25]. Moreover, employees may be reluctant to the changes from the Fourth Industrial Revolution [26]. The diffusion of the Industry 4.0 concept should be analyzed to understand how employees depending on hierarchical level perceive it or to find what fears may arise due to digital changes [16].

As for employee safety, in an industrial environment proposed by the Fourth Industrial Revolution, humans and machines can interact in difficult and dangerous tasks. As the separation of spaces between humans and robots is removed, established safety procedures can be breached making space for risks of impact between humans and machines [27, 28]. In this context, close human-machine interactions present a wide range of risks that are difficult to predict. Therefore, collaborative robots should be safety conscious and should recognize actions that could cause injury or threaten safety of employees [29].

Moreover, within a psychological setting, people's ability to adapt to technological change is becoming increasingly important, where developing the notion of career adaptability can help in understanding, which psychosocial resources need to handle to be succeed in challenges from the increasingly digitized and automated working model [30]. Changes and interactions in the form and organization of work can be viewed in a negative form and generate psychosocial risks that must be considered [29].

Society

As with all previous industrial revolutions, there is a risk that the Fourth Industrial Revolution increase social inequality, raise geopolitical tensions, and diminish the well-being of large numbers of people [31]. It is not unlikely that digitalization reproduces the most serious contradictions due to income accumulation: declining employment and rising inequalities [32]. Digitalization can increase the pressure on less skilled workers who will have their jobs threatened. Thus, a smaller portion of the society with higher qualifications can benefit [33], increasing social [34] and wage [18] inequality.

Moreover, there is concern that machines and robots can replace human work, not only in repetitive and low-skilled tasks, but also in highly complex occupations [18]. However, there are still uncertainties regarding the negative impacts on employability, because while occupations are at risk of disappearing, new occupations may arise [33, 30, 32].

More broadly, inequalities can also happen between countries. In this case, if the spread of Industry 4.0 does not happen geographically homogeneously, there will be niches of economically and socially favored countries, widening the gap between developed and underdeveloped countries [35].

Ethic and legality

The use of intelligent and autonomous systems generates important and necessary ethical discussions [36]. A challenge related to Artificial Intelligence, for example, is the accountability of ethical consequences arising from decisions made by machines. In this case, it is discussed to whom the error should be attributed [36, 37]. In addition, technologies can quietly enter our environment and influence our decisions [37]. Therefore, developing machines that are aware of their actions and the possible harmful consequences is a problem that deserves attention [36]. Nevertheless, ethical issues are difficult to attribute to artificial intelligences because related principles vary according to domains of analysis and cultural contexts [37] further hampering this issue.

As for data ownership, high equipment connectivity through IoT (Internet of Things) can endanger sensitive user data. Private information may be leaked improperly or without consent [38, 39]. Privacy and personal security concerns start to emerge from the appropriation of information [40], where, according to [39], legal issues may be involved. Thus, there is a need for regulations for this scenario [41]. Moreover, data appropriation can lead to legal and ethical problems regarding misuse of information [42]. For example, companies may use personal data to predict the health of an employee in order to base a promotion or contract termination [38], or a person in total control of knowledge networks in science and society may create social and political power structures in the form of authoritarian governance [43].

Environment Risks

Consumption

As there will be a need to build a support infrastructure for digital transformation, new machines, sensors, software systems, etc. will be demanded. This massive adoption of technologies will depend on the use of natural or man-made resources for their manufacture, such as water, raw materials and fuels [35]. Scarce resources on the planet such as lithium and rare earths, which are difficult to extract, manipulate and purify, may have their demands increased [35]. In addition, there may be an increase in the use of materials and natural resources that are difficult to reuse, where recycling practices are not yet in place or the costs involved may be high. Moreover, the miniaturization of technologies has enabled the use of small quantities of technology metals in their compositions, which makes their recovery difficult and may be lost forever if they are not returned in closed-loop material cycles [44].

From an operational perspective, the use of new technologies may require a large amount of energy, becoming a potential challenge [35, 44]. Industrial wireless networks that require low latency [45, 22], cryptographic data security system [39], and processing large amounts of information (Big Data) in data centers [44] may require heavy consumption of this resource [45, 22].

Pollution

An increase in electronic waste can be expected in the context of Industry 4.0. Machines or equipment may be replaced because they cannot be integrated into new digital systems and environments [35]. Thus, recycling and reuse of obsolete equipment can become a recurring issue.

In the high-consumption scenario, the increase in primary energy use can trigger a growth in CO₂ and greenhouse gas emissions [44, 11]. These emissions may also occur in the consumption of fuels to manufacture new equipment and technologies, or even, in distribution logistics and transportation of obsolete materials for disposal or recycling [35].

3.1.3. Technological Risks

Technical Risks

Industrial Internet of Things (IIoT) will enable the integration of a large number of devices and coexisting in close proximity. This dense layer of devices can lead to an unprecedented number of interferences between them [46]. Industrial Wireless Network, for example, can face major challenges due to the multiple signals in connected environments. In addition, the industrial environment is characterized by challenging signal transfer conditions, such as dust, vibration, critical temperatures, humidity, motor presence, metal obstacles, etc. [45].

The internet network may also face overload challenges [47]. Real-time control and access, a major issue within the context of Industry 4.0, requires bandwidth to be fast and unloaded. A delay in data transfer, for example, can create problems for connected physical devices [48].

Another problem regarding high connectivity is the lack of interoperability. Industrial networks based on industry 4.0 concepts will be highly heterogeneous, as they will feature several interconnected technologies [49] such as machines, sensors, Cyber Physical Systems (CPS), IoT devices, etc. [48]. Thus, a barrier to the adoption of IoT solutions and the creation of a CPS ecosystem is the establishment of integration and continuous interoperability between these different technologies and systems [10]. Many installations may contain machines and equipment, where each one has a different format for communicating with other machines [50]. The lack of interoperability between devices will significantly increase the complexity and cost of deploying technologies [46].

Hyperconnectivity can also lead to systems becoming fragile in interruptions events, where an error in one part of the system may cause general disorder [38] as in a domino effect [43].

Data Security

One of the most commented risks in the literature is related to data security. IT integrations and production digitization can create a potential danger [25], both in vertical and internal business connections as well as horizontal connections across entire value chains [12]. As connectivity increases due to technologies, industrial systems are becoming increasingly susceptible and vulnerable to cyberattacks [51, 10, 38, 31, 43, 41, 52, 39, 53, 54]. The large amount of heterogeneous data and its transfer to the cloud increases the security risk [48] because wireless networks can be easily intercepted [22] as well as the open connection between participants in a value chain [12]. The most diverse damage may be caused: machine scrapping, defective products [55], service interruptions [56], operator safety can be threatened [50], etc.

Data vulnerability may also lead to the disclosure of private data. Companies should be aware that sensitive data may be disclosed [57]. In the absence of appropriate security mechanisms, private information leakage is inevitable [39]. Not only internal business data, but also information from connected partners may be in danger [14].

Data Handling

The big amount of data (Big Data) in different formats are also a challenge for information acquisition, transformation [48], storage and analysis [58]. Knowing which data should be collected, how this data should be collected and how to formulate it are important points to study [59]. In this context, the processing and analysis of heterogeneous information may be hampered by the lack of unified format solutions [60] such as standardized IoT architectures [61].

In addition, data quality may also become a challenge [45, 62]. The large amount of data generated can make it difficult to obtain useful information [45]. The vast majority of data from intelligent manufacturing is unstructured [47], which must be transformed into structured data so that barriers due to source, shape, size and other factors are eliminated and useful information can be extracted [63]. Thus, in the context of Industry 4.0 it is easy to obtain incomplete and deficient data due to transport failure, data limitations and errors or packet loss, especially in large scale industrial networks [45].

4. Regulation Aspects

Besides all economic, social, ecological and technological aspects, regulatory and legal issues involved in business digitalization should be discussed as they may support the benefits. According to [32], national and supranational institutions are expected to adjust economic regulation to provide a facilitating framework for new digital trends.

When it comes to cybersecurity, there are no specific standards in manufacturing, let alone to intelligent manufacturing [57]. There is a need for regulations due to potential cyber risks and implications for the privacy of individuals [41], where the absence of effective standards and regulations coupled with weak governance limit the functioning of IoT [64].

From a social perspective, worker safety, health and physical integrity regulations may be set late due to laws, regulations and standards arising in a reactive manner. In addition, standards must suit changes driven by technological innovations where old rules do not apply [29]. Moreover, the regulation involved in the use of artificial intelligence is still a necessary task [37].

Regarding the environment, within the portfolio studied, there are few studies on the negative environmental impact of Industry 4.0, which may lead to unexpected problems for this field of knowledge, in which regulations may be involved.

Thus, inaccurate regulations can affect all of the risk dimensions discussed in this paper, thereby increasing the need for standards to help manage and mitigate uncertainties in Industry 4.0 implementation. According to [57], although standards are not regulations, regulators can dictate compliances from a standard in such a way that it becomes part of a regulation.

5. Theoretical Framework

From the discussions of risks arising from the implementation of Industry 4.0 concepts and technologies, it is possible to perceive certain relationships between the dimensions due to some risks may have effects between them. For example, the lack of interoperability between machines, despite being characterized as technological risk, can also have an effect on the economic sustainability of companies, increasing the cost of implementing new technologies. Another example is the question that the successful implementation of Industry 4.0 depends on skilled professionals [11], where investments in skilled labor will be required. In addition, employee resistance to change may affect the technology transition to Industry 4.0 [26]. We can also see a relationship between environmental and economic issues, where the environmental risk related to the consumption of natural resources may entail the use of materials that are difficult to reuse and the recycling costs may be high [44].

In general, technological risks are closely related to economic issues, as misused technologies or technological difficulties may lead to reduced productivity or require correction costs. For example, some technologies may increase exposure to external risks, where a non-localized disruption in a supply chain may affect the performance of the entire chain in a ripple effect [67].

Therefore, a framework is built to represent the relationships between the risk dimensions described in this paper. For this, based on the Triple Bottom Line theory, Elkington's three dimensions (economic, social and environmental) receive a dimensional addition where four ellipses are intertwined (Figure 3). In addition, as it has been found that there is a need for precise regulations for the 4.0 industry context, the regulatory issue will be illustrated as a support base for all dimensions.

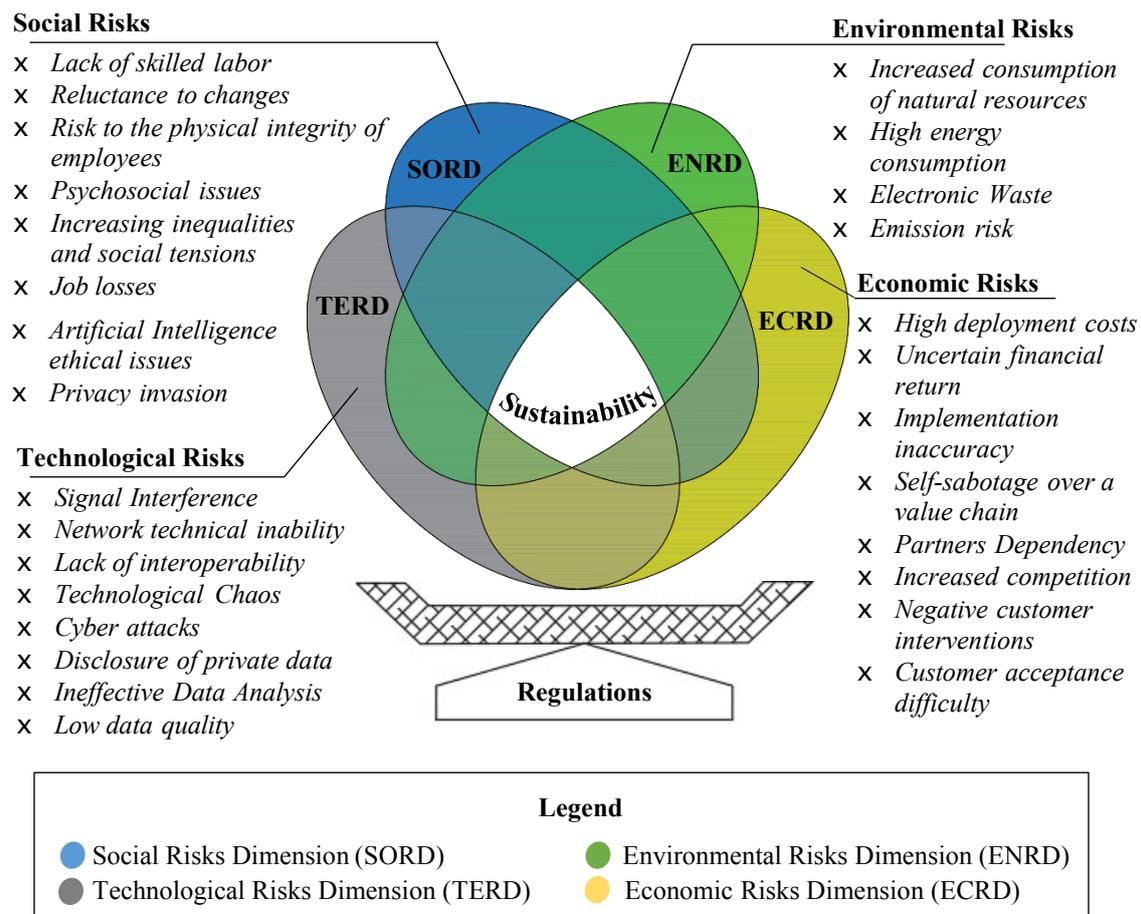


Figure 3 - Theoretical framework for the effects of industry risks 4.0

6. Conclusion

The presented study discusses the main risks identified in the literature regarding the implementation of Industry 4.0 concepts and technologies from a sustainability perspective. Elkington's three dimensions (economic, social and environmental) together with a proposed fourth dimension are used to group the risks encountered. More economic, social and technological risks were verified and environmental risks are still little discussed in the literature. In addition, regulatory and standardization issues are presented as important points for this rising theme.

The built theoretical framework, demonstrates the risks found in a general way and the relationships between the proposed dimensions. In addition, this framework can be used for future risk analysis and categorization that may still arise, as the theme is recent and many challenges have not yet been mapped. This work, besides contributing to academia in the development of theoretical constructions for the theme, can also help managers and companies to check important points before starting their journey in the Fourth Industrial Revolution. Furthermore, public agencies can be alerted to issues of inequality, unemployment and regulations.

The limitations of the study refer to the use of only two databases and only the literature for risk assessment. Thus, practical studies focused on interviews with experts can be performed. Moreover, more relationships between the mapped rich can be made in the form of quantitative analyzes.

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Historical perspective of the industrial revolutions: how we got here Industry 4.0

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Abstract: This study focus on conceptual analysis of conjoint strategy related to industrial revolutions and what were the factors - social, technological, etc., that characterized them and which brought us to the 4th Industrial Revolution. In order to better understand “Industry 4.0”, analysis and guidelines for future research perspectives, we carried out a literature review. This chapter has synthesized and categorized the industrial revolutions in order to identify the definition of evolution, development and the degree of involvement to the term “Industry 4.0” in other production areas. We observed that the term "Industry 4.0" is much broader concept than originally thought. These trends (Industry 4.0) are not to be compared simply with a greater level of production automation, a process that has, since the last decade, been driven by developments in electronics and information technology. The widespread adoption by manufacturing industry around the world of information and communications technology is now paving the way for disruptive approaches to development, production, logistics chain and enterprise, and all kind of communication, as machine to machine (m2m), machine to human (m2h), human to human (h2h), and new business opportunities.

Keywords: Industrial Revolution; Industry 4.0; Historical perspective

1 Introduction

Industrial capital was preceded and became possible from the European commercial capital that circulated among the countries. It assumes fundamental importance for the beginning of capitalism, which structured itself from the first industrial revolution. Thus, in order to understand the industrial revolution and its mode of production, we began to study about the European commercial capital that laid its foundation during the sixteenth and eighteenth centuries, essentially in European soil. This study will be of crucial relevance to understand the 1st Industrial Revolution.

The world capitalist economy was developed in Europe, in those centers where there were coal reserves and population concentration. Certainly, there were such elements in other parts of the world, although did not pave the way to such developed forms of industrial economics. The industrial boom of capitalism in Europe, and later on in the United States, is explained by the magnitude of accumulation of commercial capital, the penetration rate of the market economy in agriculture, transformations in agricultural relations and other elements that did not happen in the same intensity and extension elsewhere (HOBBSAWM, 2013).

In this way, it will be analyzed the economic scenario that preceded the first industrial revolution and brought together the elements for it to occur. It will also go through each of the revolutions (1st to 4th Industrial Revolution), highlighting their main characteristics and particularities.

2. Industrial Revolution

Definition of “Industrial Revolution”

Never before in the history of humanity there have been as many extreme social transformations as in the past three centuries. Developed countries used to adopt free-market economy, but in the last years of this century, labor, labor force, society and government are different in a qualitative and quantitative way: different in configuration, processes, problems and structures (DRUKER, 2001).

According to Stearns (2018), the industrial revolution was the most important single development in human history over the past three centuries. It is not, however, a historical episode alone. It continues to shape the contemporary world. Even the oldest industrial societies are still adapting to its impact, for example, on family relations and the environment.

The phenomenon began about two and a half centuries ago. It has changed the world. Focused on new methods and organizations, industrialization has altered where people live, how they play, how they define political issues – even, many historians would argue (STEARNS, 2018).

In this way, the definition of Dombrowski and Wagner (2014) is: “The term “industrial revolution” refers to the change of the technological, economic and social systems in the industry. Especially, the circumstances of work, the changes of living conditions and the economic wealth are in focus”. The classic, traditional view of the industrial revolution in general focuses on two aspects: unprecedented change of techniques accompanied by rising income per capital without any upper limit (FREMDLING, 1996). Based on the previous definitions, in this work, we defined as: **"Industrial Revolution is changes in the mode of production with strong technological influence, which impacts the economy and society."**

In order to occur an industrial revolution, it arises an economic, social and mainly technological environment that enables a new condition. In the following chapter will be discussed the aspects that lead to the 1st Industrial Revolution.

Pre-Industrial Revolution – environment conditions

According to Hobsbawn (2013), the problem of the Industrial Revolution origin is not just the economic growth acceleration, but the growth acceleration related to the economic and social transformation. The British revolution was the first in history. This does not mean that it has begun from scratch. It was preceded by at least 200 years of continuous economic development. In order to better understand it, some aspects that preceded the 1st Industrial Revolution will be shown below.

The “first” world economy was based in the trading between Europe and the East. Europe bought certain products from the East, China and paid them with gold and precious metal. The dominant capital was commercial and based in certain European countries. Europe was an importer of goods. There were routes which European merchants sought some products- especially luxury goods – the European consumer of the feudal elite was used to those products (DANTAS, 2017).

To meet this demand, Europe brought from Asia goods manufactured (fabrics, jewelry, carpets etc.) and spices. Clearly, these trades confirm that Asia and the Arabs had more developed economies than the Europeans, which sought outside for manufactures more advanced than theirs. Historians have agreed that Modern Age began when the Turks dominate Constantinople in 1453, a strategic city, and block the European trade with Asia. When the commercial route was closed, the demand and the merchandise prices increased (DANTAS, 2017).

As a result of this dearth, the commercial capital accumulated in certain European cities sought for new routes and, associated with the State, financed the so-called great navigations. It was the start of the search for alternative ways to continue that trade. Already in the sixteenth century the circuit was completed to the five continents, via the alternative sea route. In this same process, Europeans were creating colonies around the world, that is, specialized enclaves in production for their market.

During the sixteenth and eighteenth centuries, the colonial dynamic of the “first” world economy was based in a kind of triangulation: European bourgeoisie – mainly Spanish and Portuguese – brought gold, silver and sugar (Brazil) and tobacco (Antilles) from the Americas to Europe and took slaves captured in Africa to their colonial enclaves in the Americas. In the end, the European commercial bourgeoisie accumulates the surplus wealth, an essential base of capital that financed the English industry soon after (mid-eighteenth century). In other words, the enrichment of Western Europe and the capital accumulation in that region had everything to do with the looting and predatory relationship that the European capitalists established with

each region 'discovered' and colonized. It is by this way that the network of relations was constructed, which, in the end, built a certain type of international economy (DANTAS, 2017).

The European commercial capital, that circulated among countries and preceded industrial capital, assumed fundamental importance in the beginning of capitalism. During the sixteenth and the eighteenth centuries, the mode of production laid its foundations essentially on European soil. Until then, the mode of production (before the Industrial Revolution) was well defined. Handicraft was the industrial form of the Late Middle Age (urban and commercial Renaissance). It was a family production, where the worker (artisan) had the production resources (owned the workshop and the tools) and worked with his family in his own house. He performed all the stages from the preparation of the raw material to the final finishing. There was no division of labor or specialization for the making of any product. In some situations, the artisan had a helper, but not a salaried worker, and the helper even needed to pay a "fee" for the use of the tools. It is important to remember that during this period artisan production was under the control of craftsmen's guilds, just as commerce was also under the control of associations, which limited the production development (CARVALHO, 2018).

The following topic will present the characteristics of the environment that gave support to the 1st Industrial Revolution.

1st Industrial Revolution – animal force to steam engines (1750)

Until then, the power generation system was limited to nature elements as wind (wind mill) and water wheel, as well as animal or even human power. It is easy to understand that production capacity was low, what limited the product offer.

In the middle of the 18th century, the first industry movement started in England. Following by USA and European countries like Germany that began to change an agricultural society to industrial one (DOMBROWSKI, WAGNER, 2014). In this context, Thomas Newcomen invented the first important technology known as steam engine in 1712. James Watt fundamentally improved the steam engine later on (COLEMAN, 992). It brought the transition from manual work to the first manufacturing processes; mostly in textile industry (ROJKO, 2017).

This advancement transferred most of work from the land to factories. Therefore, bigger factories and many manufacturing machines were built particular in the industry of weaving. Those machines needed a connection with the transmission grid or had to be implemented near the central steam engine, where the power was provided. The resulting mass production is characterized by a standardization of products and processes. It provided new jobs for the growing population. People started moving to bigger cities to find work in the factories even though the wages were low and they did not have any possibilities and rights to improve their work circumstances. The situation was degrading and unhealthy, even children had to work in factories. Additional problems appeared and the industrial cities had excessive demands. Especially the health of citizens was harmed. Until 1815 the wages had risen and the living standard became higher. At that time, the design of factories was energy flow driven. This flow was restricted to architecture of the steam engine and the transmission technology (DOMBROWSKI, WAGNER, 2014).

With the improvement of the steam engine, new applications have emerged, such as railways and steamships, which have enabled a better flow of products, in especial of food, to meet the growing demand of the population.

According to Yin et al. (2018), Industry 1.0 (I 1.0) brought human activities from focusing on agriculture to the industrial society. The demand for industrial products in I 1.0 had only one dimension – product volume. We can call this demand environment as the *Simple Market*. In I 1.0, supplies were smaller than

demands. Outputs of industrial products could not satisfy the demands of society. A central idea in I 1.0 came from the economist Adam Smith in *Wealth of Nations*, in which price was described as an automatic tool to adjust mismatch between supply and demand. If supplies are smaller than demands, prices rise. If supplies are larger than demands, prices fall. Product variety was very low and most commodities were agricultural products, so price adjustment was a good tool for balancing the supply–demand mismatch at that time. Adam Smith is considered the ‘Father of Economics’ and *Wealth of Nations* was the first publication on modern economy.

Summarizing the main impacts of the 1st Industrial Revolution:

Technological: Invention and development of steam engine;

Development of new Technologies: The development of steam locomotive and steamship created new economic segments;

Social: Displacement of people from the countryside to the city, which transformed the work form from agricultural to industrial. The new technologies created new jobs, thus the working class, which is all the social levels that live from the sale of their workforce. This has led to an improvement in the living standard of society;

Production: Creation of mass production with high level of standardization, the design of factories was energy flow driven;

Economical: Emergence of more dynamic economic system, due to the increase of product supply (as consequence of mass production), and the increase of population purchase power (salary and workers’ income).

2nd Industrial Revolution – electric motor to automation (1870)

Industry 2.0 (I 2.0) (from the end of the nineteenth century to the 1890s) was the period when industrial products burgeoned both in volume and variety. Major technological innovations included electricity, electronic and mechanical devices, and cars (YIN, 2018). This technology allowed decentralized engines and motion (DOMBROWSKI, 2014).

Moreover, the iron - and steel - production raised worldwide and provided material for bridges, railroads and skyscrapers. These advances demonstrate the scope of the second industrial revolution (DOMBROWSKI, 2014). Products of I 2.0 are still widely used today. A milestone of I 2.0 was Frederick Taylor’s *The Principle of Scientific Management*, which was the first publication on modern management theory. Taylor is considered the ‘Father of Management’. The demand during I 2.0 had two dimensions – volume and variety. We can call this demand environment as *Stable Market* (YIN, 2018).

Gottlieb Daimler and Karl Benz worked on the first car in 1885, which represented a new form of transportation. The innovations in this period went along with higher life quality (McNEESE, 2000). To meet the growing demand, new technologies in production were developed, for example the assembly line. In this way, Henry Ford was able to increase the productivity, increase wages, while lowering the price of the T-model significantly (FORD, 2012).

Two innovators, Henry Ford and Taiichi Ohno, practiced and extended Taylor’s theory. (i) Ford addressed the shortage of supply in product volumes using mass production assembly lines; (ii) Ohno addressed various customer interests in product varieties by developing the Toyota production system (TPS), the precursor to lean (YIN, 2018).

Summarizing the main impacts of the 2nd Industrial Revolution:

Technological: Invention of electric motor;

Development of new Technologies: Use of electric motors as a power unit of machines and equipment, what enabled more equipment flexibility. Ford invented the assembly line. There was the development of chemistry and petrochemical industry. Rudolf Diesel (1858-1913), German Engineer, invented and developed the internal combustion engines;

Social: The increase of industrial development, low-cost production of automobiles on a large scale, allowed the generation of more jobs, better wages and higher income. In the same way as in the previous revolution, the new technology created more jobs (Figure 01). All these new opportunities led to an improvement in the living standard of society;

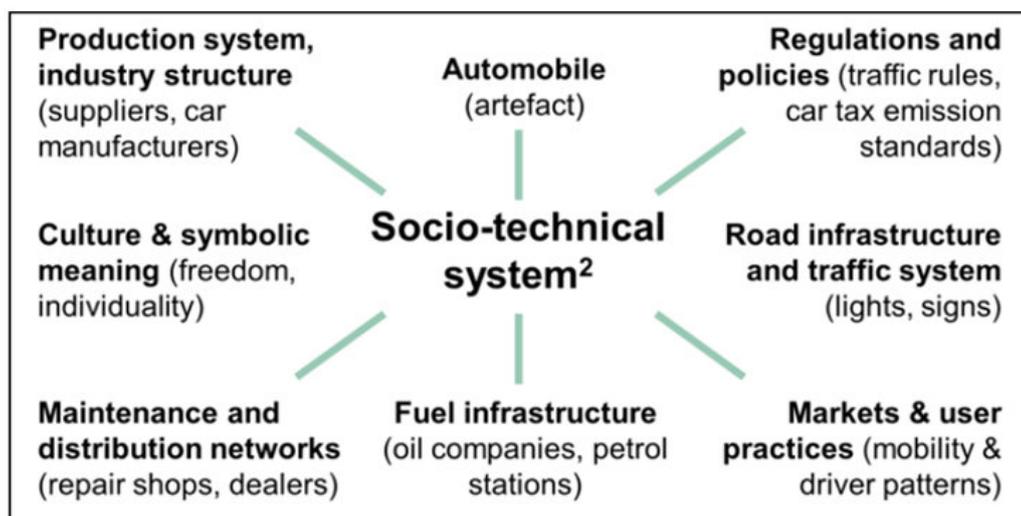


Figure 1: Automobile (artifact) Socio-technical System
Source: Mazur (2016)

Production: The electric motor enabled the creation of Ford’s assembly line, as well as new production techniques, which led to the production of approximately 1000 cars per year in 1820, and 2 million similar vehicles in the beginning of 1920 (WOMACK, et al, 2004). That consolidates the mass production with a high level of standardization. A quote of Henry Ford is often mentioned, who said about the Ford T-Model car: “You can have any color as long as it is black”. The quote captures well the introduction of mass production, but without the possibility of products’ customization (ROJKO, 2017).

Economical: Introduction of new production techniques by Ford, such as: (i) reduction of work cycle from 514 minutes to 2.3 minutes; (b) cut of costs by more than 2/3 for the consumer, thus, the unit cost fell in relation to the competitors. The price drop was constant: in 1908, the launch year of T-model, each model cost US\$ 850; in 1927, the last year of its manufacture, the price had slumped to US\$ 290 (WOMACK, et al, 2004). This enabled car sales on a large scale, where the employees themselves could pay for the product.

The dissemination of car ownership led to a big impact on society (Figure 01). According to Davis et al. (2014), the interaction of technological and social aspects in workplaces is called socio-technical system. Thus, automobile integrates tightly this relationship, which is necessary techniques, social, economic information and others to integrate the company internal work design to the external environment analyses (MAZUR, 2016).

The main product of the 2nd Industrial Revolution was the automobile (Figure 01). There are many new business opportunities that emerged from it and even created new professions, employment and income, which improved living standard and the well-being of society.

3rd Industrial Revolution – automation to virtualization (1971)

The new industrial production pace created a bigger necessity for more automation and monitoring. The productive system evolved to the 3rd Industrial Revolution, which integrated the application of electronic systems and information technology with manufacturing automation.

The invention of the microchip in 1971 was considered as the start point of this revolution. Personal computers increased considerably the productivity of factories and decreased the labour costs. Therefore, factories had to focus on problems such as overcapacity. In addition, the work environment changed because of the different communication forms and technology management (JENSEN, 1993). Furthermore, the workplace changed through different ways of communication and the management of technologies came to the fore. The organization of a company needed to adapt to networking organizations that worked more efficiently and exploited the faster information technology (JENSEN, 1999).

Industry 3.0 (I 3.0) is characterized by technological innovations such as change from analogue to digital, which had big impact, especially on the electronics industry. The product architecture of most electronic products changed from integral to modular, accompanied by a dramatic reduction in the average of product life cycles. The demand for products during I 3.0 increased to three dimensions – volume, variety and delivery time (YIN, 2018). In manufacturing, this facilitates flexible production, where a variety of products is manufactured on flexible production lines with programmable machines. Although, such production systems still do not have flexibility concerning production quantity (ROJKO, 2017).

Summarizing the main impacts of the 3rd Industrial Revolution:

Technological: Invention of microchip;

Development of new Technologies: Growing use of computing resources in industrial production processes, which the main example is the Robotics. The use of technologies in the production processes aims to reduce costs and production time. Biotechnology development increased the medical industry and improved the quality and efficiency. Mass production of technological products, linked to the media and the Internet, such as: cell phones, personal computers, notebooks, tablets and smartphones;

Social: Decrease in employment (mainly manual tasks), because people were replaced by machines, automated systems, computers and industrial robots. On the other hand, the demand for skilled labor increased to work and to develop products with new technologies.

Production: Robotics and genetic engineering advances were incorporated in the productive process, which depends less on labor and more on high technology. The basic principle is: production must combine new technologies with machines more and more sophisticated, aiming to produce more with fewer resources and fewer people.

Economical: The impact of new technologies of the 3rd Industrial Revolution did not happen just on the industries, but affects commercial enterprises, service providers and even ordinary people. Which means that was a much more comprehensive revolution. In terms of magnitude and scope, the revolution spread worldwide, what allowed the emergence of new industrial and economic powers, such as Germany and Japan, and China begins to appear. Since the 1980s, environmental awareness increased in the big industries, which started to look for productive processes with less or no environmental impact.

4th Industrial Revolution – virtualization to decentralization (2012)

The basic concept was first presented at the Hannover fair in 2011. Industry 4.0 (I 4.0) is a “strategic initiative” of the German government that was adopted as part of the High-Tech Strategy 2020 (KAGERMANN et al, 2013).

It is not surprising that the I 4.0 concepts come from Germany, since Germany has one of the most competitive manufacturing industries in the world and is even a global leader in the sector of manufacturing equipment. I 4.0 is a strategic initiative of the German government that traditionally supports heavily the development of the industrial sector. In this sense, I 4.0 can be seen also as an action towards sustaining Germany’s position as one of the most influential countries in machinery and automotive manufacturing (ROJKO, 2017).

The vision of the impending industrial revolution includes technological concepts and solutions to enable a combination of the economy of scale with the economy of scope. The 4th industrial revolution is characterized by a high level of complexity and uses a total network integration of product and production processes. Therefore, it is necessary to find a way of customization in mass production, this field of research is known as mass customization (KAGERMANN et al, 2013).

I 4.0 should therefore not be approached in isolation but should be seen as one of a number of key areas where action is needed. Consequently, I 4.0 should be implemented in an interdisciplinary manner and in close cooperation with the other key areas, Figure 02.

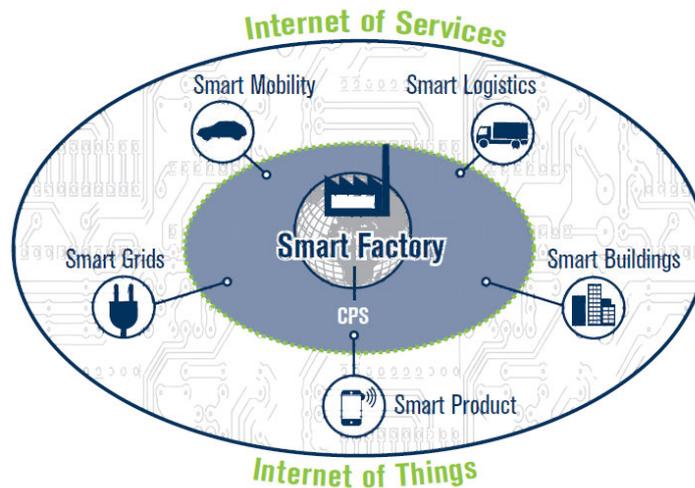


Figure 2: Industry 4.0 and smart factories as part of the Internet of Things and Services
Source: Kargeramm et al, (2013).

The Figure 02 shows that the principles, techniques and tools of I 4.0 went beyond the factory boundaries (Smart Factory) and they are increasingly part of other economic segments, such as Logistics, Buildings, Mobility, Product, Healthcare, etc.

I 4.0 does not only concern systems and intelligent connected machines. Its scope is much broader. Waves of new discoveries occur simultaneously in areas ranging from genetic sequencing to nanotechnology, from renewable energies to quantum computing. What makes I 4.0 fundamentally different from the previous ones is the fusion of these technologies and the interaction between the physical, digital and biological domains (SCHWAB, 2016).

the aim of I4.0 is to focus humans in the working system. Thereby, it leads to the combination of automated processes and manual tasks in hybrid systems. Automation can result in positive scale effects from standard sequences of high volume processes (DOMBROWSKI, WAGNER, 2014). The core process is digital to physical conversion in a reconfigurable manufacturing system. Reconfigurable manufacturing systems are the latest advance in the development of a manufacturing system (ROJKO, 2017). The results of the latest development are reconfigurable manufacturing systems able to adapt their hardware and software components to follow ever-changing market requirements of type and quantity of the products (KORENA, SHPITALNIB, 2010; NAYAK et al., 2015). Figure 4 depicts the I 4.0 smart factory.

Economical: With capacity to explore new technologies and their concepts, such as: availability and use of IoT, IoS, and IoD; integration of technical processes and business processes in the companies; digital mapping and virtualization of the real world; development of “Smart Process” (Factory including “Smart” means industrial production and “Smart” products (ROJKO, 2017)), the possibilities of new products, processes and businesses are limitless. According to Kagemann (2013), the I 4.0 initiative has huge potential: meeting individual customer requirements, flexibility, optimized decision-making, resource productivity and efficiency, creating value opportunities through new services, responding to demographic change in the workplace, work-life-balance, high-wage economy that is still competitive. Bauernhanst et al. (2016), indicates that I 4.0 factory could result in decrease of: production costs by 10-30%, logistic costs by 10-30%, and quality management costs by 10-20%.

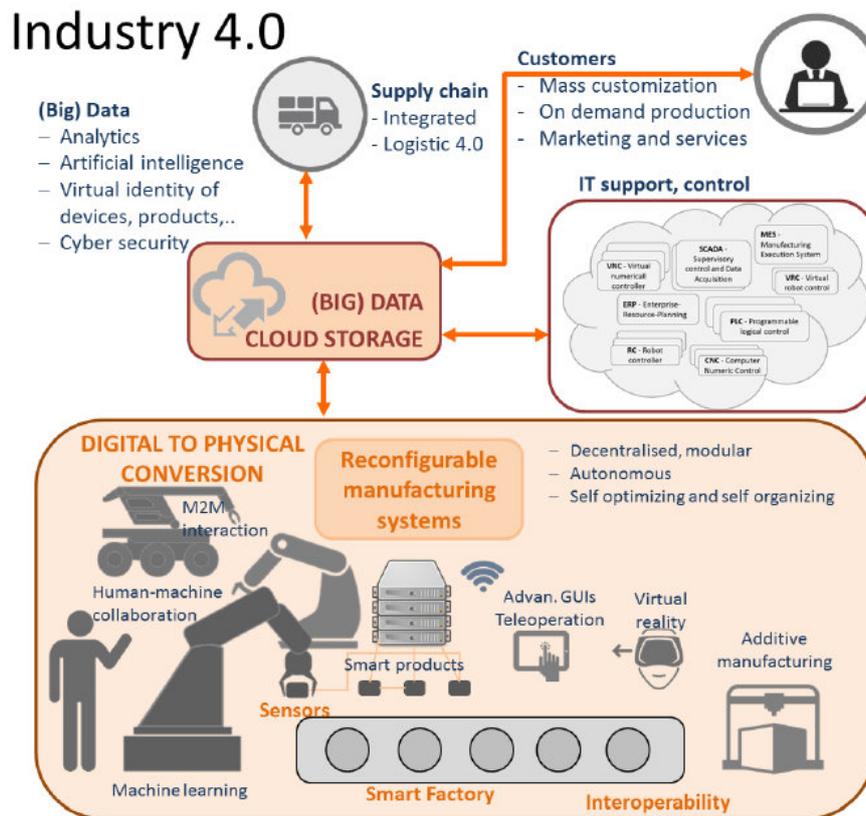


Figure 4: Industry 4.0 smart factory
Source: Rojko (2017)

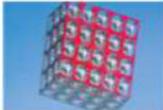
3. Research analysis

Each of Industrial Revolutions has its own characteristics, but all of them caused a big change in employment. This change does not mean unemployment, but the creating of different kinds of jobs, which required more qualification of the employees. The result of Industrial Revolution's impact on society allowed a better living standard, due to the generation of better qualified jobs, better wages and income.

According to Bleicher (2014), Table 01 shows in a more detailed and comparative form the main paradigms of Industrial Revolution manufacturing.

According to Bleicher (2014), the production structure goes from "factory system" to "virtualization", indicating that the production structure goes from craftsman centralization to customer centralization. The same way, the products structure goes from individual parts made by craftsman to adaptive variability requested by customer. On Table 01, Bleicher analyses the evolution of worker, markets, and resource efficiency.

Table 1: The paradigm change in manufacturing due to Industry Revolution

	Mechanisation	High volume prod.	Automation	Intelligence
Chronology	18. century	19. century	20. century	21. century
Production system	Manufactory	Taylorism	Toyota System	Learning Factory
Production structure	Factory system	Focussing	Modularisation	Virtualisation
Product structure	Individual parts	Standardisation	Complexity	Adaptive variability
Flexibility vs. Productivity	Ratio ≈ 1	Ratio $\ll 1$	Ratio < 1	Ratio ≈ 1 (adaptable)
Worker	All-rounder	Specialist	Flexible	Self organizing
Markets	Regional product	Globalization	Regionalization	Localization
Resource efficiency	Extensive use	Intensive use	Careful use of res.	Recycling
				

Source: Bleicher (2014)

In the other hand, Table 02 analyses the evolution of Industrial Revolutions by addressing the technologies resulting from the main technology, working conditions and the social impact, as well as the evolution of the production system, market and some publications that had big influence on this period.

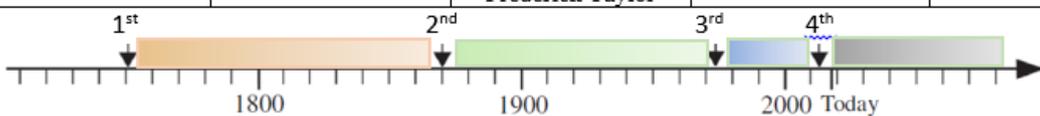
This analysis aims to have a better understanding of the various dimensions of the Industrial Revolutions' scope.

4. Final considerations

Throughout this study was possible to verify that none of Industrial Revolution started from scratch. Since the 1st Industrial Revolution, there was an environment that enabled the technological leap that preceded each of Industrial Revolutions. One very important aspect to be highlighted is that the 4th Industrial Revolution is the only one that has been studied at the same time as it is happening.

Table 02: The time line of Industrial Revolution (1st to 4th) and paradigms changes

Industrial Revolution and main developed technology.	 1st Mechanization, Water Power, Steam Power	 2nd Mass Production, Assembly Line, Electricity	 3rd Computer and Automation	 4th Cyber Physical System
Main Impacts				
Resulting Technologies	<ul style="list-style-type: none"> ◦ Railways ◦ Steamships 	<ul style="list-style-type: none"> ◦ <u>Electronic</u> ◦ <u>Mechanich</u> devices ◦ Cars 	<ul style="list-style-type: none"> ◦ Robotics ◦ Cell phone ◦ Notebooks ◦ Tablets ◦ Smartphones ◦ Etc... 	<ul style="list-style-type: none"> ◦ <u>IoT, IoS, IoD</u> ◦ RFID ◦ VR, AR, AI ◦ 3D Printer ◦ “Smart” means ◦ Etc...
Working Condition	<ul style="list-style-type: none"> ◦ Degrading and unhealthy; ◦ Children had to work in factories; 	<ul style="list-style-type: none"> ◦ Division of labor ◦ Application of times and methods 	<ul style="list-style-type: none"> ◦ Depends less and less on manpower and increasingly high-tech 	<ul style="list-style-type: none"> ◦ Humans and machines can be complementary in a socio-technical system
Negative Social Impacts	<ul style="list-style-type: none"> ◦ Excessive demands of the industrial cities 	<ul style="list-style-type: none"> ◦ The worker works repetitively and intensively 	<ul style="list-style-type: none"> ◦ Workers being replaced by machines, automated systems, computers and industrial robots. 	<ul style="list-style-type: none"> ◦ Educated employees are necessary to execute complex manual tasks
Positive Social Impacts	<ul style="list-style-type: none"> ◦ Working class ◦ Salary ◦ Income ◦ Improving the standard of living 	<ul style="list-style-type: none"> ◦ Increase the salary ◦ New jobs opportunities 	<ul style="list-style-type: none"> ◦ Increase the salary ◦ New jobs opportunities ◦ Increasing demand for skilled labor 	<ul style="list-style-type: none"> ◦ Increase the salary ◦ New jobs opportunities ◦ The aim is to focus the human in the working system
Production system	<ul style="list-style-type: none"> ◦ Craft Production 	<ul style="list-style-type: none"> ◦ Mass Production 	<ul style="list-style-type: none"> ◦ Lean Production 	<ul style="list-style-type: none"> ◦ Mass Customization ◦ Agile Manufacturing
Market	Simple: <ul style="list-style-type: none"> ◦ Production volume 	Stable: <ul style="list-style-type: none"> ◦ Production volume and product variety 	Volatile: <ul style="list-style-type: none"> ◦ Production volume, product variety, delivery time 	Smart: <ul style="list-style-type: none"> ◦ Customer participate individual customization
Publication	<i>Wealth of Nations</i> Adam Smith	<i>The Principle of Scientific Management</i> Frederick Taylor		



In this article, the background and concept development from the 1st to the 4th Industry Revolution are presented. All the concepts are very comprehensive and complex. Some points are identified about I 4.0:

- The I 4.0 concept is not just the direct manufacturing and its automation, but also includes a complete value chain from provider to customers and all enterprise’s business functions and services;
- The I 4.0 concept is not just the resource transformation in smart product. The smart products are “smart” not only in the manufacturing process, but in all part of their lifetime. During the manufacturing process, they need to inform their finds in each stage of value aggregation. During

their lifetime, besides performing the functions that they were designed and constructed, they need to provide data to be used for preventive maintenance, useful information about lifetime and reliability of their products for the manufacturer. In addition, provide in real-time the status of their interaction with the environment;

- I 4.0 is not only the specialization of Iot, IoS, and IoD, applied to the manufacturing / industrial / customer environment. It also assumes a real-time data collection leading to the issue of handling and analyzing huge data in complex systems as: Bid Data, Data Analytics, and so on. All this data need to be analyzed in real-time by cyber security systems with the purpose to provide security and privacy for the user.
- I 4.0 does not only improves the processes, products and the actual business, but also allows the creation of new business, within its own value chain. For example, greater approach to the client, making him participate in the updating and product development; identify new market needs in real-time and change the processes in order to respond the new demands. I 4.0 does not only improves the processes of company's relationship with the market, but a plethora of new business opportunities based on new technologies that are yet to come.

Many aspects of these areas (I 4.0) are unknown, and uncertain. Because of the interdisciplinary characteristics of the three areas of business, engineering and information technology, studies have been performed from different perspectives (YIN, 2017). The incorporation and integration of these three areas are recommended for future research.

Other point need to be explore: (a) big data collection as IoT, IoS, and IoD, and the interaction with Bid Data, Data Analytics, and so on, in all part of enterprise's business functions and services; (b) Artificial intelligence or deep learning need to be developed and approached the same way; (c) customer demand dimensions in this new environment (I 4.0), using new technologies in order to respond to customer more quickly and efficiently; (d) conduct case studies with the purpose of understanding and monitoring the application of new technologies and how they are helping organizations.

The 4th Industrial Revolution has disruptive technologies, which will enable the emergence of a new industry generation, services and business completely different from the current ones. In this way, many other research opportunities will emerge in the near future.

Finally, there are limitations to our study. Our analysis was based on a literature review. The literature search was limited to our university databases. This research did not have as an objective to deepen in the social aspects, what already has vast literature available. But it had as objective a general research about the aspect of the evolution of manufacture and the impacts that it had throughout the 4th Industrial Revolution. When exploring I 4.0, this study had not as objective to exhaust the subject, what would be much pretentiousness, and because of the 4th Industrial Revolution is only beginning. Moreover it would be impossible to imagine the possible innovations and their respective applications that will soon appear. Thus, it is important to continue researching in this area.

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Marketing 4.0 and Social Responsibility: A Bibliometric Contribution

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Abstract: With the arising of new technologies and industry 4.0 principles that forges company's behavior with products, consumers and market, brand's methods of market insertion and consumers behavior become the focus of this study. The connection between marketing and the Industry 4.0, here denominated as Marketing 4.0, evidences how the relationship between consumers and companies are built on personal and feeling's bases. Choices are made based on one brand's principles, making it fundamental on the buying decision process, listing those principles and transmitting this image towards society. In this context, note the crescent interest of companies to have a social, environmental and economically ethical posture to the consumer's requirement be supplied in such a way that the companies get competitive advantage and build a strong relationship with its consumers. In Industry 4.0's context, companies have obligations towards society and are pressed to reduce the impact of their activities. For those reasons, the objective of this study is to analyse the academic literature about Social Responsibility connected with Marketing 4.0, with the purpose of establishing the principal authors associated with the theme, to detect and prospect principal contents and trends. This is a field which has barely been explored on the academic literature, so the methodological analysis used for this search is a systematic literature review, with techniques of bibliometric analysis by the PRISMA method and content analysis through the NVivo software. The research was made in scientific databases *ISI, Web of Knowledge, Scopus* and *Science Direct*. The databases were selected because was detected the most important and significant studies related with the purpose of this research in this databases. Therefore, this research, besides reach objectives, identifies the gaps related to the theme. The results of the study complement the short literature in an objective way and promote the understanding on the level of interaction of the consumers regarding the actions of Social Responsibility of the companies.

Keywords: "Social Responsibility", "Marketing", "Industry 4.0", "Bibliometric Analysis".

1. Introduction

Social Responsibility is an important concept and deserves attention, as it addresses and addresses and considers central concerns of different audiences when it comes to the relationship between companies and society. In Marketing, the concept of exchange is fundamental, because it is only through exchange that it is possible to configure a Marketing activity and Stanton [1] states that the process called marketing "consists of activities that are developed to generate and facilitate exchanges that want to satisfy human needs and desires". The definition of Marketing has evolved since 1935, so this study will objectively present its evolution, so it becomes interesting to integrate the concepts of Social Responsibility with the Marketing concepts, since it is found that a growing number of organizations in everyone is embracing socially responsible causes and implementing various initiatives to make sense of social causes [2]. In this context, it is noted that with the new technologies that fit the concept of Industry 4.0, the relationship of consumers with companies is personal and sentimental, which see the brand of which they identify as a fundamental component, revealing its principles and conveying its image to society [3]. The integration of these concepts is of great importance, some authors allude to the leadership role that marketing must play acting essentially with Social Responsibility and new technologies.

This article contributes not only to the areas of marketing and social responsibility, but also involves engineering-oriented management areas. Therefore, the searches were performed in the scientific databases, since they obtain the most relevant and significant studies related to the purpose of this research and provide a set of essential data that allow a deep and tangible analysis of the subject.

1.1. Methodology

Data collection involved a systematic search of journal articles in major academic databases until May 2019, with no restrictions on academic subjects or journals. The databases *ISI Web of Knowledge, Scopus*

and *Science Direct* were selected for this research process because they include indexed impact factor journals in the Journal Citation Report (JCR), and provide essential data for bibliometric analysis, including abstracts, references, number of citations, list of authors, institutions, and countries and others.

The keywords used for the search were: Social Responsibility; Marketing; Industry 4.0; Bibliometric Analysis. This first scan aimed to detect all the material produced focusing on Marketing and Social Responsibility, to gain a panoramic view on how subject has been treated in the academic field. The searches resulted in a total of 103 articles. The removal by duplicate articles was performed, articles whose title does not show the theme addressed, and then excluded articles whose abstract did not coincide with the present study, after these filters, we reached the number of 34 articles, and then, their texts were analyzed and used for this work of 13 final articles.

The developed study adopted as technical procedures the bibliographic research, which is traditionally done through the analysis of documentation, making use of magazines, books, newspapers, theses, dissertations and annals of scientific events, searching for authors and checking the production of previous studies on the theme in focus can also classify the research method used as its objectives as exploratory, as it is based on the investigation of a particular subject, seeking greater knowledge through reading reviews [4]. Exploratory research aims to: a) raise a problem and / or define it more precisely; b) investigate alternative actions; c) raise hypotheses; d) examine relationships and variables in isolated ways; e) to gather information that helps in the development to address the problem [5].

The approach to the research problem of this study is characterized as qualitative, because it applies its analysis through descriptive methodology, relating information with other factors and seeking associations that can contribute to explain what is researched, and its main characteristics are: subjectivity, multiplicity, interpretation, narration, data collection and data analysis [4]. Figure 1 represents a four-step flowchart of the PRISMA methodology (Principal Items for Reporting Systematic Reviews and Meta-Analysis).

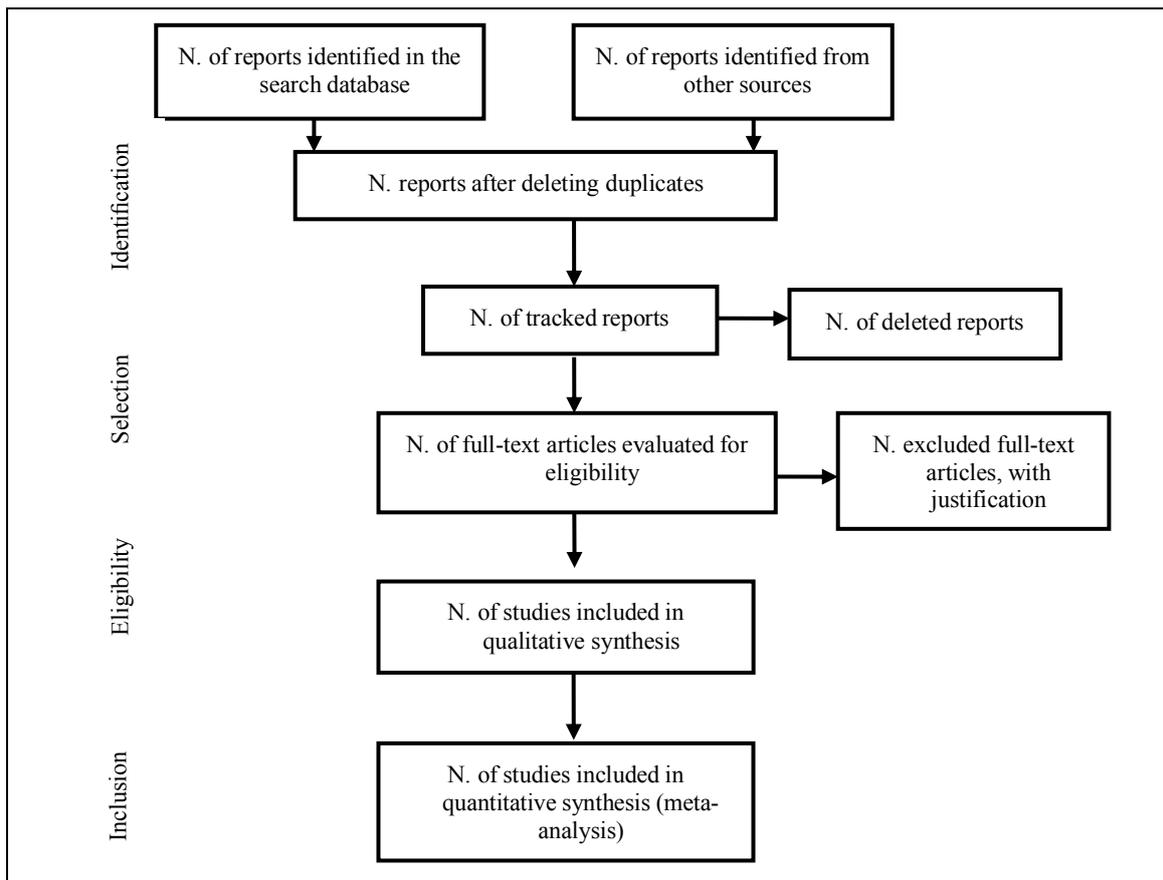


Figure 1 - information flowchart with the different phases of a systematic review [6]

The PRISMA methodology was used in this work to bring clarity and coherence to the systematic literature review research, this methodology helps authors to improve the reporting of systematic reviews and meta-analyses [6].

1.2. Industry 4.0 e Marketing 4.0

The so-called Industry 4.0, has promoted the integration of cyber physical systems by merging the real with the virtual and connecting digital, physical and biological systems, enabling personalized mass production. One of its great assets that contribute to the differentiation of companies in the business world is the management of their knowledge and the qualification of their workers for this new phase of production processes, since such production processes are constantly challenged with the demands of consumers. With each industrial revolution the profile of consumers changes, as well as the profile of workers, evolving from manufacturing to technology, from manual to intellectual work [7].

The first industrial revolution took place in the second half of the eighteenth century until the mid-nineteenth century and was characterized by the introduction of the steam engine to mechanize the production that was previously essentially manual. The second industrial revolution took place from the mid-nineteenth century until the first half of the twentieth century, was characterized by the advent of electric power facilitating production lines and mass production. The third industrial revolution took place in the second half of the twentieth century and was characterized by the implementation of electronic components and technologies that allowed the automation of production processes. The fourth industrial revolution began in the first decade of the 21st century and was characterized by the digitization of production, which enabled the personalization of mass production characterized by the internet of things, artificial intelligence, interconnected cyber physical systems, among others. I4.0 brings profound changes in the form of production and consumption, triggering the development of new business models and especially new forms of consumption [8].

The new forms of consumption shape companies' positioning towards society, the internet has been transforming the world exponentially and has leveraged the development of collective intelligence, stimulating collaboration between people. Companies need to keep up with these transformations of generations, as it will represent the workforce in a few years, which has a profile concerned with generating less waste, with different concepts of success than traditional, considering the spirit of global collaboration. The Internet has broken the barriers of space and time by creating countless digital tools and expanding the reach of the web through IoT - Internet of Things, becoming increasingly popular and accessible to people. Prior to the emergence of the Internet, radio and television marketing communication, for example, used a model based on program interruption and advertiser-sponsored programs. Over the years, this invasive system has become destabilized, initially by the proliferation of channels itself, and then by competition from the internet [9].

Although the traditional model, considered by many as invasive, has not disappeared, it has had to invest in the seduction of consumers by other means, stimulating the so-called consumption of experiences, composed by the interaction of social and corporate entertainment logics, in which it has been shared. content in a volume never seen and progressively. The digital age is characterized as a worldwide trend towards internet connectivity and the decline of traditional media corroborates these major changes and investments in digital media are booming and the key to success lies in the humanization of brands and the engagement generated in the media. consumers to share their content [10].

The rapid transmission of information between consumer and business increases their interaction and user demands must be met with much greater urgency. Globalization has changed the concept of community, has broken the barriers of time and distance, generating increasingly heterogeneous communities with specific demands [11]. Along with the industry, marketing has evolved over the years into various phases, being named as: Marketing 1.0 - focusing on the product and the mass market; Marketing 2.0 - focusing on consumers and market segmentation; Marketing 3.0 - focusing on the human being and his yearnings for a better world; and Marketing 4.0 - focusing on brand identification with the target audience [3]. Table 1 objectively describes the phases of industry developments along with marketing developments, and thus it can be seen that both continue together in their market-related revolutions.

Table 1- Industrial Revolution and Marketing Evolution

1st Industrial Revolution x Marketing 1.0	2ª Revolução Industrial x Marketing 2.0	3rd Industrial Revolution x Marketing 3.0	4th Industrial Revolution x Marketing 4.0
<p>Industry advances with steam engines;</p> <p>Advances in the textile and iron industry;</p> <p>Bulk buyers with physical needs;</p> <p>Rational consumer;</p> <p>Mass production and development of new products;</p>	<p>Advances in the chemical, electrical, petroleum and steel industries;</p> <p>New information technologies;</p> <p>Rational and emotional consumer;</p> <p>Seek differentiation to build customer loyalty;</p>	<p>Speed and development of new technologies, such as the internet;</p> <p>Companies needed to make the world a better place because of the new wave of technologies;</p> <p>Products and services designed for human beings gifted with emotion;</p> <p>Consumers set trends and move the market;</p>	<p>Production Digitization;</p> <p>Utilization of Artificial Intelligence, physical cyber systems, IoT, among others;</p> <p>Consumers create, that is, they participate in the development of products and services;</p> <p>Humanization of brands; Identification with what they consume;</p> <p>Consumers seek brand content and empathy;</p>

It can be interpreted that organizations gradually turned from product to people and environment, enhancing the relationship with their customers, highlighting its principles and values. Kotler, Kartajaya and Setiawan argue that the evolution of marketing will be continuous considering "changes in the business environment - recession, environmental concerns, new social media, consumer empowerment, new technology wave and globalization" [3].

1.3. The Social Responsibility

With the simultaneous variety of offerings, consumers have the opportunity to choose from companies that operate sustainably, so organizations need to know how to engage their customers with social causes [12]. The concept of CSR has become an association between social responsibility and business strategy for the purpose of competitive differentiation [13].

Researchers are seeking greater awareness of consumers and employees about CSR initiatives, there is still a significant gap regarding the study of the results generated by their performance, so companies are competing to become continuity, connection and direction, that is, being socially responsible, since Social Responsibility is the term used to describe a company's obligations to society [14]. People yearn for responsible brands that strive to make the world a better place, that show concern for well-being and quality of life. As a result, the need for future growth and the call for differentiation oblige them to maintain. In connection with social causes, companies that want to "do good" are able to do so through initiatives [15]. Research conducted in 2010 by Cone Communication [16], a foundation that acts as a public relations agency related to social responsibility, showed that 90% of consumers want companies to tell them how they are working on social causes, or over 278 million. People want to know what the company does to benefit social causes. The study also points out that 85% of consumers have positive images of companies that support social challenges even in times of crisis, more than half of consumers expect companies to support social challenges.

For Martinelli [17], when the practice of social responsibility is effective, it can increase the company's performance and sustainability, adding value to the corporate image, motivation of internal employees, competitive advantage, ease of financing, recognition as business leaders, among others. Socially responsible corporations that are able to innovate in this segment are highly likely to succeed, they can improve social well-being, strategically position themselves in the market, create secure and firm consumer ties, improve the company's public image, boost morale. increase the company's market value [18]. The number of consumers who use CSR as a buying factor is growing day by day, which makes companies socially responsible and the current goal is to encourage such companies to reconcile economic effectiveness with social, environmental and environmental concerns. ethics, generating value and customer satisfaction [19].

2. Conclusion

Considering also the influence of marketing on the perception and loyalty of consumers, the work acts holistically, together with the developed stages and investigates the literature in depth and, besides realizing the influence of CSR actions, strategically develops the improvement of integrated marketing management of companies within the context of industry 4.0, that is, in the context of new technology-driven business models. With easy access to information on social, economic and environmental issues, it is inevitable that human beings will seek actions to solve these problems effectively and immediately. Since we live in one of the societies that move through consumption, the solution is to equalize consumption with the beliefs and values of consumers. The tendency is for social awareness to expand due to the ease of obtaining information, quick access to data that explain and explain the vulnerability of society in the face of so many adversities.

Understanding that companies have a duty to help people lead a decent life without having their basic rights hurt (education, health, infrastructure, safety) leads us to conclude that there must be a balance between the actions of company to the community so that neither party is harmed and harmed. The practices of Corporate Social Responsibility actions are proving increasingly strong as a form of competitive differentiation, consumers' perception becomes clear and impartial when it comes to the damage caused to society by both production, and the excessive acquisition of products and / or services.

For many years business activities acted in an individualistic manner, disregarding the consequences and damage caused to society and the environment. Capitalism has increasingly turned desires into needs, industry and commerce generally encourage rampant consumption, releasing products and / or services every minute without considering the consequences for the environment and society. This negative line of reasoning has become evident to consumers, and so, especially companies, should consider their attitudes toward winning the market and improving their relationship with suppliers, employees and consumers. Thus, this research concludes that investments in technology and innovation help society as a whole, shape marketing, bring comfort and ease in countless areas, transform industries and connect businesses with their consumers.

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**Thematic Session
Emerging Technologies
(Chair: Prof. Fabiano Armellini)**

The influence of blockchain in business ecosystems

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Abstract: Business ecosystems have risen as a new way of organizing multi-company economic activities in a comprehensive and dynamic way, which is needed in the Industry 4.0 environment. Although trust cannot be demanded from the ecosystem members, it plays an important role in defining the structure of a business ecosystems and the behaviour of its actors [1,2]. As the technology emerge, blockchain have been shown to contribute significantly to increased level of trust between actors due its intrinsic characteristics, allowing all stakeholders to maintain an immutable ledger whose data is consistent among all participants, providing transparency and traceability to interactions [3–5]. In this way, blockchain redefines the value that actors provide in an ecosystem as well as their influence on it. However, it remains unclear they add value using the technology and how to position their organizations accordantly. Thus, this study explores how each actor absorb value from blockchain-based business ecosystem. Given the dynamics and roles within a typical ecosystem, we have studied the value of blockchain adoption from the perspective of different actors in their business ecosystems. By analysing the different roles that each actor plays in a business ecosystem we correlate these aspects with blockchain characteristics and their related value drivers. The four main groups that constitute a business ecosystem are analysed, namely orchestrators, aggregators, innovators, and complementors. Analysing the main four groups of actors found in an ecosystem, we identified the value each of them may gain by using blockchain differs depending their level of dominance and trust, as well as the use of blockchain redefines the value those actors provide to an ecosystem and their influence on it. We also identified that blockchain use also changes barriers to entry, so that actors in the same group should act differently depending on how consolidate they are in their business. While being valuable to orchestrators, it provides negative value for complementors or aggregators whose competence is primarily based on trust. Thus blockchain-based business ecosystems may have a different dynamic than traditional ones. Conceptually the study explores the actor specific implications of using blockchain technologies in the business ecosystem, and area largely unexplored. Practically, a framework is presented to assist managers in determining strategies related to the adoption of blockchain in their business ecosystems.

Keywords: Blockchain, distributed ledger, business ecosystems, value, Industry 4.0.

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Assessment of potentially attractive tasks to collaborative robotics application: A case study based on electronics industry

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Abstract: The use of robotics in the electronics industry has been of great importance to raise productivity and quality levels. When compared to the classic industrial robots, the collaborative ones present themselves as a trend, bringing greater flexibility, improving ergonomics, shortening implementation time and degree of configurability. However, the correct definition of their use, when compared to industrial robots, still needs more understanding and discussion so as not to become an intuitive process. The objective of this work is to present a case study based on a time and motion analysis to evaluate the assessment of the easiest tasks, which have the greatest potential to be automated and implemented by collaborative robots. To validate this assessment, two consecutive stations of a packaging assembly line of smartphones were considered. The obtained results show feasibility and applicability in the tested solution, allowing it to be applied in other situations.

Keywords: Robotics, Collaborative robotics, Automation, Electronics industry

1. Introduction

The adoption of automated systems by industries constitutes as one of the main strategies to increase their productivity. In the case of electronics manufacturing, traditionally marked by intensive use of labor, two main factors are considered: high complexity of activities and low life cycle between the development and its obsolescence in the productive process [1].

Traditionally, the classic automated manufacturing systems are rigid and require large batches production to be economically justifiable. Consequently, in situations where the demand is fragmented, that is, smaller batches where the exchanges are more frequent, in most cases it precludes the implementation of automation [2,3]. In these systems, robots are traditionally used with safety cages - cloistered- in rigid operations of simple and repetitive tasks, presenting limitations in new uses (reconfigurations) [4].

Unlike industrial robots, the collaborative robots or cobots aims to operate in more dynamic environments through interaction with operators, varieties of tasks and more frequent changes. The introduction of collaborative robots can create a number of benefits for industrial operations by allowing the robot to work in the open environment without physical protection, and it is possible to combine elements of manual operations with the robot activities, eliminating from the operator tasks which are heavy and do not aggregate value [5].

Supported by computer vision systems and equipped with sensitive sensors, this new treatment allows the work of the robot in collaboration with the human being [6]. In this context, it is possible to eliminate ergonomically critical tasks at workplaces, which was not previously possible, and also to implement faster and more appropriately reach the return of investment.

The collaboration between the robots and the human being has been announced as promising to face the challenges in the present scenario, allowing the use of cognitive capacities of the human being, their versatility and flexibility. While robots demonstrate their excellence in performing repetitive tasks with a high degree of repetitiveness and replacing heavy and ergonomically inadequate tasks [7]. As a

consequence of this hybrid system, it is possible to achieve more reconfigurable systems which allow more agile adaptations in environments of permanent changes, as well as in the manufacture of customized products [8].

However, because it is still a recent technology, companies still need more knowledge about the applications and the potential of implementation, promoting initiatives based solely on the experience and intuition of the staff involved [9]. The objective of this work is to evaluate solutions involving the use of collaborative robots through appropriate methodology. This will be done through a case study at a smartphone manufacturing company located in Jaguariúna - SP, Brazil.

A brief overview of traditional industrial robots and collaborative robots will be presented in the second section. In the third section, a methodology will be proposed to define the potential activities for automation that will be validated through the case study present in the fourth section. Finally, the conclusions will be addressed in the fifth section.

2. Overview - Industrial Robots versus Collaborative Robots

A convergence of factors has contributed to the increased use of robots in the industrial environment. Prices for hardware and software are expected to fall more than 20 percent in the next decade. At the same time, as the robot will become more accessible and easier to program, a large number of smaller companies will be able to deploy and integrate automated systems using robots in their manufacturing. Advances in vision systems, sensors, robotic grippers systems, and information technology will enable these systems to become smarter, more networked, and immensely more useful for a wide variety of applications. As a consequence of this scenario, an exponential growth of the installed base of the robots from the current approximate 2 million units to 4 million by 2025 is expected [10].

The speed at which it will occur will depend on the industrial segments as well as the economic / social conditions of the countries. Taking into consideration the industrial segments, the automotive sector, electrical and electronic equipment and machinery in general will account for about 75%. Table 1 gives a summary of this growth observed during the period between 2014 and 2016, with emphasis on the electronics industry [11].

Table 1 – Number of robots sold by industry segments

Segmento	Year			Growth(%)
	2014	2015	2016	
Automotive	94000	98000	103000	9,57
Electronics	43000	65000	91000	111,63
Machinery	21000	29000	29000	38,10
Chemical -Plastic	17000	20000	20000	17,65

Source: IFR International Federation of Robotics. (2017)

Countries that adopt more aggressive policies with the more intensive use of robots will realize the significant increase in productivity relative to the costs of dedicated labor as shown in Figure 1. For South Korea, for example, a productivity increase is projected of about 6% in relation to the cost of labor based on the American market, while countries such as Brazil will have a reduction in labor productivity estimated at around 3% with a projection of 2025 [10].

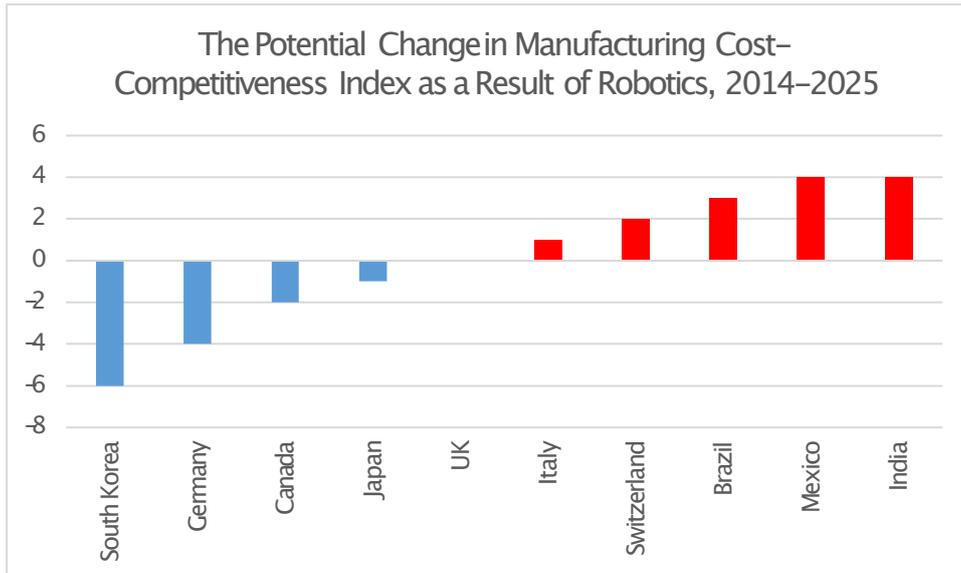


Figure 1: Gains or losses in productivity relative to the projected US market to 2025
Source: Boston Consulting Group (2015)

Finally, the production and sales forecasts for the collaborative robots are very promising before this scenario as detailed in Figure 2. According to surveys conducted, in the last year there were approximately 20,000 units produced with an average price around \$ 28,000 dollars. The forecasts indicate annual reduction from 3 to 5% reaching the value of \$ 17,000 dollars in 2025 and an exponential increase estimated at 700,000 units [12].



Figure 2: Perspective of the exponential increase of production of collaborative robots
Source: Bouchard, S. and Mathieu Bélanger-Barrette, R. (2017)

3. Methodology

Many studies have been conducted in the field of industrial assemblies. Most of the work is based on fully manual or automatic processes [13]. However, it will be necessary to consider hybrid models combining manual operation with those performed by robots. The methodology adopted in this work will be specific to the process in which it will be applied and validated through the case study and has as reference the

studies conducted by BALOGH et al. (2015) and ARGYROU et al. (2016). The suggested sequence includes: mapping the current process, determining the human capacity indicators in relation to the robot and determining the degree of complexity required by the automation. The following is a brief explanation of this model.

Mapping of the current process:

The labor time for the application to be validated will be obtained through a traditional time and motion study and methods detected in practice. Subsequently, to validate the robot cycle times, practical simulations will be done in the laboratory using boundary conditions close to the manufacturing environment. For this study, activities in a packaging assembly line will be considered.

Determination of the human performance indicators in relation to the robot:

Based on the work of BICK (1991), MICHALOS et al. (2016), BEUMELBURG (2005) and D. Schrötera et al. (2016) [16,17,18] and [19], the specially developed criteria will be presented for the application to be validated. This way, for each of the activities considered in the time and motion study, the performance of the human being in relation to the robot will be evaluated. Table 2 exemplifies the criteria which will be used to evaluate the performance of the operator in relation to the robot for each of the tasks. Note, for example, that for criterion (C1) the specification (E1) recommends that activities with short and repetitive cycles (≤ 8 sec) are more appropriate to the robot and, therefore, the performance level of the human being would be 0. Likewise, criterion (C3) demonstrates that cellulosic materials typical of packaging processes (boxes, trays, cushions, etc.) are usually supplied in a flat shape and need to be molded. This shaping process requires skill and force control, being more suitable for the human being and would receive performance grade 1 for the specification (E7).

Table 2: Criteria and specifications for measuring the degree of performance of activities

Criterion		Specification	Weight	
C1	Cycle Time	E1	Better (≤ 8 sec.)	0
		E2	Equal (9 e 15 sec.)	0,5
		E3	Worse (> 15 sec.)	1
C2	Product weight	E4	Less than 1kg	1
		E5	Between 1 to 8kg	0,5
		E6	Greater than 8Kg	0
C3	Shaping of cellulosic material	E7	Yes	1
		E8	No	0
C4	Quality of the process	E9	Better	1
		E10	Equal	0,5
		E11	Worse	0
C5	*Posture (ErgonomicEvaluation)	E12	Lower than 13	1
		E13	Equal to 13	0,5
		E14	Greater than 13	0

Note - * This ergonomic evaluation was proposed by the studied company, using its own methodology ,taking into account aspects such as lateral movements, top-down or bottom-up movements and using the hand as a tool. It is also considered the frequency in which these movements occur in each of the activities / cycle times.

Once the criteria have been fulfilled and their respective weights have been qualified by the responsible technical team, the operator performance indexes will be calculated for each of the criteria according to equation (1). When the performance index of the human being and the robot, respectively, are,

It would not matter which activity is used (manual or automatic). In this case, it should not be included for the calculation of the global capacity index to avoid having the result diluted.

The global capacity index for the human being, for each of their activities (i), would be an average of all the criteria (k) with their respective weights according to equation (2). For the robot the global index will be calculated according to equation (3)

$$I_{i,h} = \frac{\sum_{k=1}^n W_k \cdot C_{k,i,h}}{\sum_{k=1}^n W_k} \quad \{0; \dots; 1\} \quad (1)$$

$$I_{i,r} = \frac{\sum_{k=1}^n W_k \cdot C_{k,i,r}}{\sum_{k=1}^n W_k} \quad \{0; \dots; 1\} \quad (2)$$

$$I_{i,r} = \frac{\sum_{k=1}^n W_k \cdot C_{k,i,r}}{\sum_{k=1}^n W_k} = 1 - I_{i,h} \quad \{0; \dots; 1\} \quad (3)$$

Source: Schrötera et al.. (2016)

Determination of the degree of complexity required by automation:

Likewise, for each of the activities, criteria and specifications will be created in order to assess the degree of complexity for the introduction of automation adapted through reference [20] as suggested in table 3.

Table 3 - Evaluation of the degree of complexity for task automation

Criterion		Specification			Weight
CA1	Do activities require strength control (torque) and manual dexterity?	EA1	no	easy	0
		EA2	yes	hard	1
CA2	Do the pieces come in different shapes?	EA3	no	easy	0
		EA4	yes	hard	1
CA3	Are the parts mechanically indexed?	EA5	yes	easy	0
		EA6	no	hard	1
CA4	Are the tasks always executed in the same sequence and time, making programming easier?	EA7	yes	easy	0
		EA8	no	hard	1
CA5	Do the tasks require integration with other systems?	EA9	no	easy	0
		EA10	yes	hard	1

In an analogous way, the equations (1), (2) and (3) will have the capacity indexes computed for simple tasks to be automated $I_{i,h}$ and the complex $I_{i,r}$ according to equations (4), (5) and (6).

$$I_{i,h} = \frac{\sum_{k=1}^n W_k \cdot C_{k,i,h}}{\sum_{k=1}^n W_k} \quad \{0; \dots; 1\} \quad (4)$$

$$I_{i,r} = \frac{\sum_{k=1}^n W_k \cdot C_{k,i,r}}{\sum_{k=1}^n W_k} \quad \{0; \dots; 1\} \quad (5)$$

$$I_{i,r} = \frac{\sum_{k=1}^n W_k \cdot C_{k,i,r}}{\sum_{k=1}^n W_k} = 1 - I_{i,h} \quad \{0; \dots; 1\} \quad (6)$$

Source: Schrötera et al.. (2016)

Once the calculations of the indicators are finalized, a summary table will allow to select the activities with the highest potentials to be automated, lower values of $I_{i,h}$ at the same time correlating with simpler activities to be automated, smaller values of $I_{i,r}$ (ideal scenario).

4. Case Study– Validation

To exercise the proposed methodology two stations in sequence of a packaging assembly line will be considered. The individual activities within the stations are sequential, dependent and performed by a single operator. Table 4 below summarizes the activities and respective cycle times obtained in the manufacturing process.

Table 4: Summary table of the activities in the assembly stations

#	Activities	CT (sec)	Station	Total Time (s)
A1	Unload a full box and load an empty one	9,83	1	E = 37.87
A2	Stick traceability tag on the box	6,10		
A3	Visual inspections of unit boxes	7,80		
A4	Send the full box to the next station	2,12		
A5	Assemble the empty box	12,01		
A6	Scan the box label and individual units	20,63	2	E = 47.93
A7	Close the box and dispose it to the sealer	5,95		
A8	Remove from the sealer and dispense to the conveyor	7,00		
A9	Fold and insert the cellulosic cushion 1 into the carton	7,18		
A10	Fold and insert the cellulosic cushion 2 into the carton	7,18		

* It is necessary to work less than 55 seconds in order to meet the takt time

Once the mapping of the activities was accomplished, the next step was to attribute to each of the activities the weight of each of the criteria defined specifically for the packaging process according to table 1. Then, the performance indexes were calculated to the human being and the robot according to equations (2) and (3). Similarly, the complexity indexes for automation were calculated taking into account table 2 and equations (5) and (6). The summarized results are shown in Table 5.

Table 5 - Performance indicators versus automation complexity.

Activities	$g_{1,9}$	$g_{2,9}$	$g_{7,9}$	$g_{7A,9}$
A1	1,00	0,00	0,2	0,8
A2	0,40	0,60	0,6	0,4
A3	0,50	0,50	0,4	0,6
A4	0,67	0,33	0,0	1,0
A5	0,60	0,40	0,2	0,8
A6	0,25	0,75	0,4	0,6
A7	0,50	0,50	0,4	0,6
A8	0,00	1,00	0,0	1,0
A9	0,60	0,40	0,6	0,4
A10	0,60	0,40	0,6	0,4

To better understand the activities with higher potential for automation, it is necessary to draw a correlation graph CO_i versus CAS_i . This scenario will be ideal when both tend to zero. As can be seen in the graph of figure 3, the activities A₆ and A₈ represent the highest potential to be automated. A₂, A₃, A₅, A₇, A₉ and A₁₀ show some balance suggesting that they can be hybrid, ie manual or automatic. Finally, A₁ and A₄ are activities which tend to remain as manual.

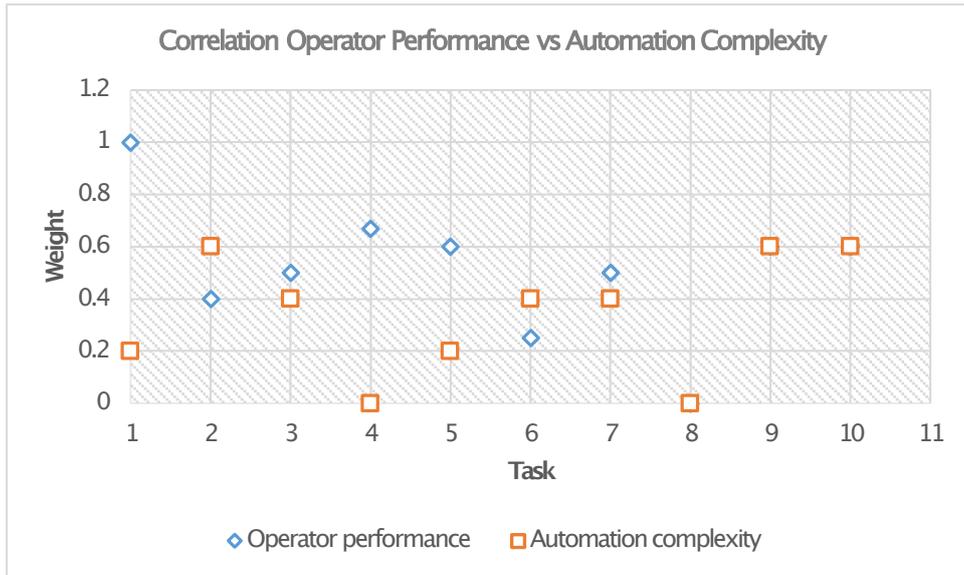


Figure 3: Performance versus automation correlation graph

Considering the potential of the activities, the sequence of the process with its precedence relations and the balance of the activities, it was possible to consider activities A₆, A₇ and A₈ for the robot station. Figure 4 shows details of the robotic gripper designed to perform these operations. The gripper consists of a vacuum-driven scanning system and suction cups necessary to carry out the movement, loading and unloading the boxes. This project considered the universal type, that is, capable of attending any type of product without the need of a setup.

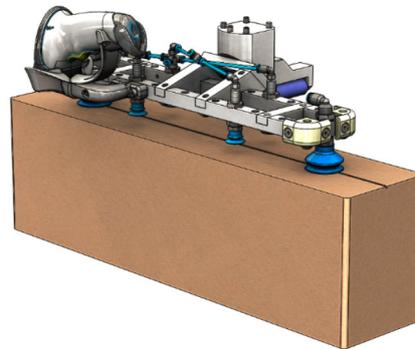


Figure 4: Representation of the robotic gripper

In order to have the three activities transferred to the robot, a readjustment of the production arrangement was necessary. First, the robot capacity in terms of reach was analyzed, load in (kg) and precision to perform the three activities proposed in figure 3. Then, a virtual robotic simulation was performed to guarantee the attendance to the time for meeting the demand of the process. Finally, station 1 (manual) was balanced again with the inclusion of new activities and revision of some elements of time elapsed from the readjustment of the layout. Table 6 shows in detail the new configuration of the proposed activities followed by the respective time elements which were properly validated.

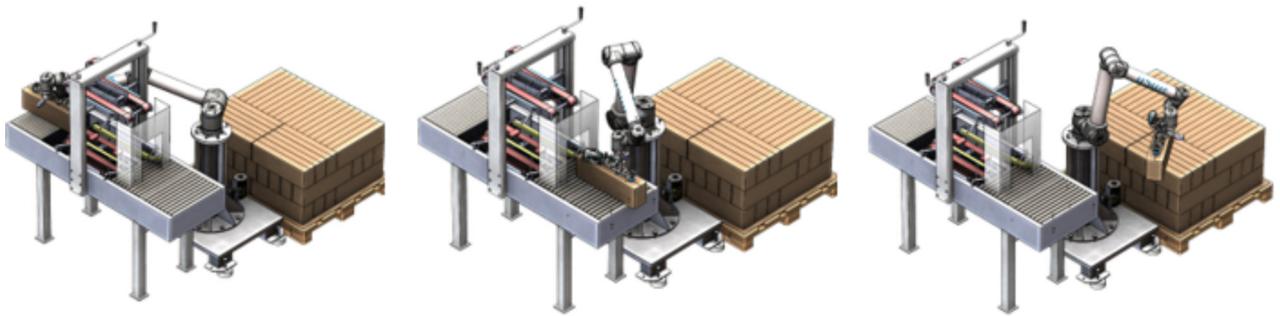


Figure 4: Sequence of robot activities: scan, dispose in the sealing machine, remove and stack

Table 6: Balancing of stations after automation

#	Activities	T (seg)	Station	Total Time(s)
A1	Unload a full box and load an empty one	8,50	Manual	LMI' E = 44.91 IM(
A2	Stick traceability tag on the box	6,10		
A3	Visual inspections of unit boxes	7,80		
A4	Send the full box to the next station	1,50		
A5	Assemble the empty box	9,00		
A9	Fold and insert the cellulosic cushion 1 into the carton	6,00	Robot	N E = 44.91 K
A10	Fold and insert the cellulosic cushion 2 into the carton	6,00		
A6	Scan the box label and individual units	15,00		
A7	Close the box and dispose it to the sealer	5,95		
A8	Remove from the sealer and dispense to the conveyor	20,00		

* It is necessary to work less than 55 seconds in order to meet the takt time

As can be seen in Table 6, the proposed new balancing met the need for the process provided in 55 seconds.

5 Final Considerations

The electronics industry still uses a large part of its labor-intensive processes and represents great potential for the use of automation despite the challenging scenario (very rapid changes and complex operations).

The prospects of the production volumes of robots are very promising, which will allow the reduction of costs and more intense use in the industrial sector. This speed will depend on the type of industry, trade barriers and the cost of labor in different countries. However, productivity gains in the adoption of advanced robotics are undeniable.

The methodology presented, when considering two sequential stations of manual activities, allows greater freedom to choose the activities which will be automated, taking into account the human performance potential and the complexity degree of automation.

As a practical result of this methodology it is possible to raise the level of productivity and quality, transferring to the robot activities which are non-ergonomic and requires a greater degree of repetitiveness. At the same time, the activities transferred to the robot are not specific and complex, which translates into shorter development and implementation times and future opportunities in its reconfiguration for new products and processes.

In this study, it was restricted to evaluate only one study of the packaging process. Therefore, the criteria defined for the assessment of both the operator performance and the automation complexity were defined and evaluated for this specific process.

As proposals for future work it is suggested:

- applying this methodology to other processes and establishing a comparative study;
- Considering also automation of complex tasks;
- Establishing a study of safety standards involving collaborative robotics;
- Evaluating situations where there is possibility of time elements that involve the displacement of the robot in autonomous vehicles.

Acknowledgements

The authors are grateful to all FIT researchers responsible for the projects, to the Lenovo / Moto partner for funding R & D initiatives with funding from the "Computing Law" and to the Flex company for supporting the initiatives in their manufacturing line. Finally, to Marcos Bregantin, for his great encouragement, and FCA-UNICAMP for the partnership in the research.

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Blockchain in sustainable supply chains: a literature review about benefits and applications

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Abstract: Recently the features and functionalities of blockchain technology have been discussed well beyond applications in financial markets. By providing new ways of trust and decentralization, it has been proved a disruptive technology with potential in different management areas. The purpose of this study is to present what is being discussed in the emerging literature about the benefits and applications of blockchain in sustainable supply chain, from the perspective of the triple bottom line. For this, a systematic literature review method called FastSLR is used to build the data set on studies addressing blockchain applications in sustainable supply chains. The results show the main implications in this field are related to guarantee information reliability, traceability and authenticity, providing transparency in sustainable practices. The use of smart contracts eliminates the need of a trusted central organization, enabling real-time updating of transactions between partners, and allowing customers to track product/service information. Concerning the limitations of the research, due to blockchain technology still be in initial stages of development and application, few cases were found. In this sense, the study consolidates the need to explore new applications for blockchain in supply chain regarding the three interrelated elements of triple-bottom-line.

Keywords: Supply chain, sustainability, blockchain, distributed ledger, sustainable operations

1. Introduction

In the context of industry 4.0, emergent technologies have implications in sustainability of organizations, especially in supply chain. Technological advances are supporting decision making in supply chains, contributing to improved performance. Considering strategic and competitive sustainability issues regarding supply chains, cooperation among the various chain members and significant challenges can prevent sustainable results from being achieved, as well as confirmation and verification of what processes, products, and activities within the supply chain meet certain sustainability criteria and certifications [1-5]. Supply chains rely on centralized information management systems, which can lead to failures, inefficient transactions, fraud, vulnerability, poor performance, leading to greater lack of trust and therefore better sharing and verification of information and data transparency. In this sense, blockchain technology, which is moving from the broad and rapid trial phase to critical business adoption helps to address such concerns about transparency, security, durability and integrity of the supply chain process [3, 6].

In general, a blockchain is a data structure, which combines blocks of information that are chronologically chained and recorded in encrypted form, such as a distributed ledger, using distributed node consensus algorithms to generate and update data, ensuring secure data transmission, as transactions on the network cannot be tampered [7, 8].

For sustainable supply chain, blockchain increases visibility and transparency, as well as mitigate trust issues, include broad stakeholder participation, lower transaction costs, and reduce lead times, resulting in greater efficiency. However, as blockchain is in the early stages of development and application, the implications of its use in supply chains remain limited and it has several obstacles, such as organizational, behavioural, technological and infrastructure difficulties, and such issues still need to be addressed in a comprehensive and effective manner [2, 3, 9].

In this sense, this article aims to present what the state-of-art in the emerging literature about the benefits and applications of blockchain in sustainable supply chain, from the perspective of the triple bottom line. Therefore, a systematic literature review was performed using the FastSLR method.

This article is organized as follows: next section addresses the sustainability background, sustainable supply chain, and blockchain and sustainable supply chain; methodology section describes the FastSLR method and its characteristics; results and discussions are presented based on the TBL perspective, followed by final considerations.

2. Background

2.1. Sustainability

Sustainability and sustainable development are terms that, according to [10] entered the political and business agenda from the 1980s with the launch of the Brundtland report in 1987, which defined sustainable development as “one that meets the needs of the present without compromising the ability of future generations to meet their own needs” [11]. Corroborating this, [12] proposed the Triple Bottom Line (TBL), known as the three pillars of sustainability, consisting of economic, social and environmental dimensions. [13] suggested transposing the idea of sustainability at the business level so that organizations broaden their economic, social and environmental base to contribute to sustainability at the political level, with corporate sustainability being defined as “meeting the needs of a company's direct and indirect stakeholders without compromising its ability to meet the needs of future stakeholders as well” ([13] p. 131).

In light of growing concerns and heavy pressure on this, companies have begun to adopt the triple bottom line in their reporting to measure environmental and socio-economic impacts, making operations management increasingly connected to sustainable issues. It means that organizations are currently focusing not only on their commitment to environmental, safety and health factors, but also on how to develop them more economically [14].

2.2. Sustainable supply chain

Organizations are increasingly being required to take responsibility for their entire products life cycle, considering that green supply chains are important to companies that are responsible for reclaiming packaging and other reusable materials by managing waste systems and disposal practices. Reverse supply chains include reverse logistics, procurement of used products, inspection and disposal of replacement or recycling parts, remanufacturing and remarketing. In this way, closed supply chains promote sustainability, as product recovery and reuse mitigate the environmentally harmful effects of waste disposal, transport and distribution [14, 15].

The concept of sustainable supply chain management has been defined by [16] as “the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements”. [17] extend the idea by providing an overview of key functional activities and relationships in a green supply chain, as shown in Figure 1:

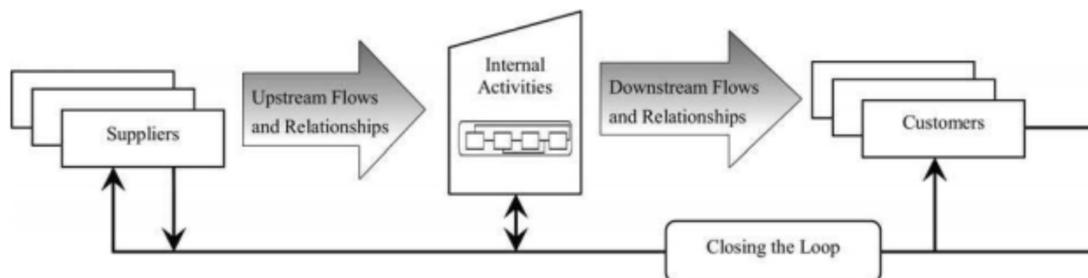


Figure 1: A green supply chain diagram with stages and relationships
Source: [17] p. 204

For [17], upstream activities and relationships involve procurement functions, including sourcing, auditing, supplier management and selection, collaboration and supplier development, highlighting concerns with material handling and transportation activities. Internal activities may include: research and design, quality, inventory, materials and technology management, and may influence the environmental characteristics of internal organizational processes. Outbound flows and downstream relationships may include external logistics and transportation, marketing, distribution, packaging and storage. Considering the closing of the supply chain loop, activities can be extended to include reverse supply chains [17].

In order to be sustainable, a supply chain must consider the entire life cycle of its flow - products, materials, resources, energy and information - from suppliers to the end user, considering the reverse flows and length of life of materials for their efficient use in closing the supply chain cycle and involving environmental, social, technological and economic issues in sustainable supply chain management [18].

2.3. Blockchain and sustainable supply chain

Blockchain technology was first introduced by Satoshi Nakamoto in 2008 while developing the cryptocurrency Bitcoin, which consists of a system for electronic transactions characterized by a peer-to-peer distributed server without the need for surveillance of a central authority [19]. Even its main use is still related to financial markets, blockchain use has been expanded to different areas such as supply chain, healthcare, real estate, government, and others [1, 19].

In short, a blockchain is a distributed database of records - or a ledger - of all digital transactions that have been performed and shared among users, where each transaction is verified by the consensus of network participants and information can never be deleted [20].

The main characteristics of blockchain are defined as follows [8]: (i) *decentralization*, according to peer-to-peer data distribution, information is shared and distributed between nodes without third party intervention, where the participants are the active actors in the transactions; (ii) *trust*, as it is a decentralized system, the transfer of information between nodes on the network does not require mutual trust between the participants, as it stores all data in each block, making the transaction reliable; (iii) *transparency*, users can examine and share information transparently as transaction data is open to participants; (iv) *traceability*, the data are recorded, and the timestamp allows transactions to be kept in order, ensuring traceability; (v) *immutability*, the transaction once validated can no longer be changed, which makes it difficult to invade and modify the records in the system; (vi) *anonymity*, data is encrypted through asymmetric encryption, which ensures transaction security and reduces the risk of data forgery, while digital signatures ensure transaction identification; and (vii) *credibility* can be considered one of the characteristics of blockchain, once transactions depends on each network node, so there is protection against external attacks, protecting the privacy of all users.

Blockchain technology can highlight some key product dimensions: nature, quality, quantity, location, and ownership, eliminating the need of a reliable central organization that operates and maintains this system, which allows customers to inspect uninterrupted chain of custody and transactions from raw materials to final sale. For better understanding it and the intrinsic characteristics addressed above, Figure 2 contrasts a traditional supply chain with a blockchain-based supply chain.

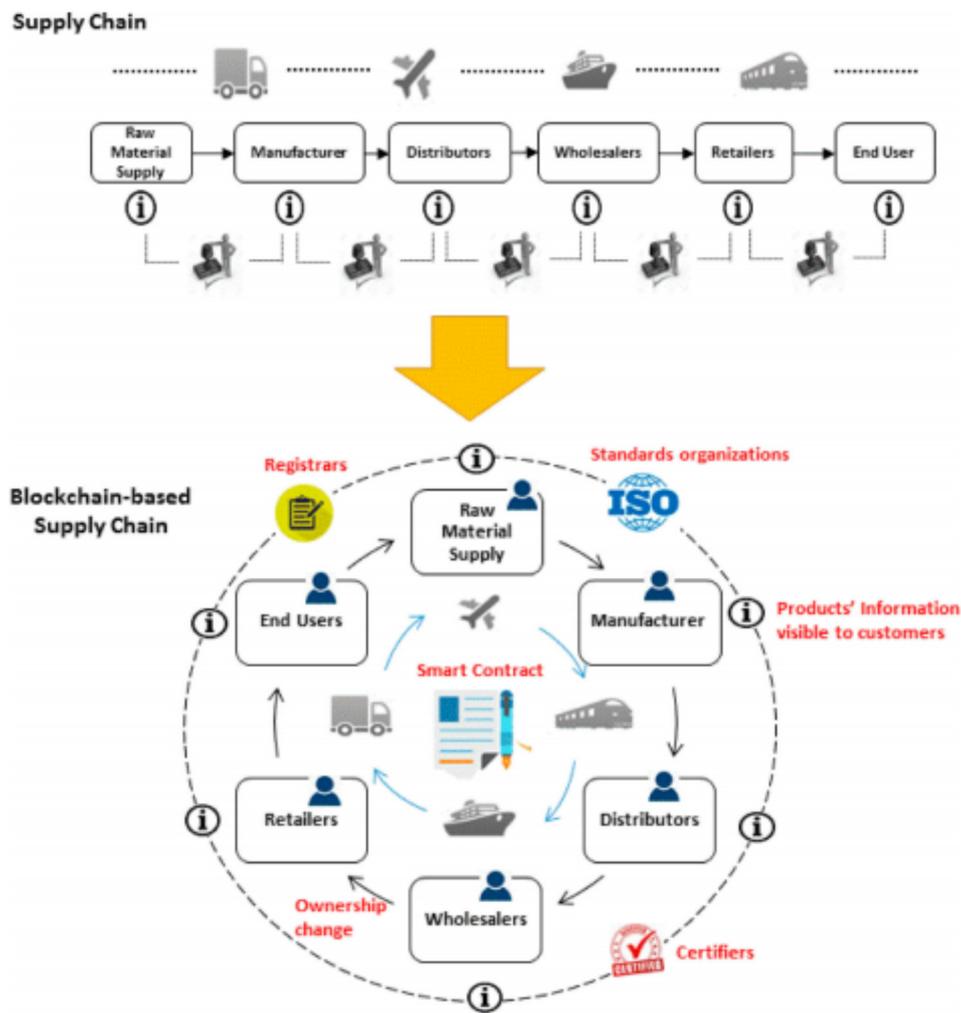


Figure 2: Blockchain based Supply Chain
Font: [3] p. 2121

Blockchain influences sustainable supply chain by creating trust among network participants, as well as cooperation, information and knowledge exchange, due to its properties as a distributed, immutable, transparent and reliable database, and considering the economic, social and environmental dimensions, the blockchain has the potential to benefit different business and economic performance, make social information stable and immutable, and ensure product and process information that is environmentally friendly, among many other environmental factors [3, 21].

3. Method

The systematic literature review (SLR) refers to a research methodology developed to gather and evaluate the available evidence on a specific theme [22]. In the study, the SLR method used was the Fast Systematic Literature Review (FastSLR). This method aims to minimise errors in systematic reviews, reduce the process execution time and supports diagnosis, validation and evaluation of research content. The process is designed according to an inductive approach based on the accumulated knowledge during the execution of several systematic literature reviews in the field of industrial and systems engineering, consisting of three phases [23]: *Step 1*: Define criteria for search terms according to the study objectives; *Step 2*: save the data set into a reference manager and a sample calculation technique statistically defines the representative subgroup of this article sample, and then keyword, abstract, and title are analyzed to test adherence to the theme. It is analyzed to identify trends in the field. Therefore, filters are created and applied to the dataset,

refining such articles and thus generating a new dataset. A new cycle of analysis is performed to make the data set size and adherence to the theme in accordance with the study objectives and, finally, a content analysis is performed in this final data set. *Step 3*: Selected articles are imported into MC3R software for quantitative calculation and analysis and bibliometric reporting.

In this study, the research themes chosen were: “blockchain”, “supply chain” and “sustainability”. Each theme was inserted into a search axis, accompanied by the research terms selected for each theme, as shown in table 1:

Table 1: Selection and combination of research terms

Axis: Sustainability	Boolean Operator	Axis: Supply chain	Boolean Operator	Axis: Blockchain
"sustainability"				"blockchain"
OR				
"triple bottom line"	AND	"supply chain"	AND	OR
OR				
"green operations"				"distributed ledger"

The database chosen was Scopus and the search was restricted by article title, abstract and keywords. This search resulted in 14 articles, and it was possible to access only 12 of them. This first data set was exported to Mendeley reference manager for keywords, abstract and title analysis, thus 9 articles were selected as adherent to the research field.

4. Results and discussions

This section will address the results according to the articles obtained by the systematic literature review and the benefits and applications of blockchain in sustainable supply chain from the perspective of the triple bottom line will be discussed.

4.1. Economic dimension

From the economic dimension of sustainability, blockchain has the potential to economically benefits the supply chain, as Maersk-IBM partnership for maritime container management already saved billions of dollars having a more accurate and reliable landing accounts [3, 24]. Blockchain enables the management of information technology outsourcing chains by monitoring the movement of assets and transactions from one node to another in an outsourcing network [25]. Reduced transaction costs and time savings are achieved due to supply chain disintermediation, where blockchain-based distributed records, such as IBM Fabric, R3 Corda, and Digital Asset Holding, increase transaction confidence as they enable visualization of real-time transaction status for all network members, which saves on verification costs and faster transactions [3, 26]. In addition, real-time transparency ensures data security and authenticity, lowering surveillance costs and supply chain risks. In this sense, information transparency can be perceived as a competitive advantage, as it results in increased customer confidence [3, 26].

4.2. Social dimension

Regarding the social dimension of sustainability, risks related to human rights and fair work are mitigated through the traceability mechanism that blockchain provides, as a product history can be recorded allowing consumers to consult to get confidence for purchasing an ethically sourced product [3, 24]. For instance, in Philippines, a blockchain was developed for the detection of counterfeit pharmaceutical products through a distributed application and smart contracts. In a similar case, as a decentralized system, blockchain

enabled small farmers to get organized by eliminating the need for intermediaries. Blockchain stores supplier's data, as well as location, installation type, and logistics design, which contributes improving supplier development programs. In addition, blockchain platform are useful for certification and recertification in organizations to simultaneously make documents and updates available, providing accurate and timely data to management [1, 2, 28].

Blockchain technology contributes in detecting unethical suppliers, as well as assisting in the supplier selection process, as information is shared on the network and recorded by authorized users. By making it immutable, it is possible to identify falsified information in a supply chain, as may occur with counterfeit products, as well as transportation and logistics processes in which information is shared, avoiding data manipulation, and cases of document verification in third-party chains [1, 3, 5, 25].

4.3. Environmental dimension

Regarding the environmental dimension of sustainability, blockchain technology contributes in different ways for reducing gas emissions and manage carbon assets more efficiently. For instance, two clear examples are: (i) by using the supply chain environmental analysis tool - SCEnAT 4.0, companies integrate several technologies such as blockchain, IoT, artificial intelligence, and machine learning to effectively manage and link organizations to reduce carbon emissions; (ii) the development of blockchain platforms for organizations to track and measure their carbon footprint helps to determine how much carbon tax a company should be charged, and enable, through real-time transparency and smart contracts, efficiently trading carbon assets in the market [1, 3].

Through product traceability and the application of smart contracts, it is possible to optimize the reverse logistics process as well as the remanufacturing processes, which reduces rework and, consequently, also reduce resource consumption and waste in supply chain. Blockchain-based energy platforms such as Echchain, ElectricChain, and Suncontract reduce long distance transmission and energy storage [1, 3, 27]. Blockchain technology tracks and verifies environmentally friendly products as recorded information can be available for verification, such as the sourcing of some 740 million acres of certified forests worldwide under the program of Forest Certification; the use of information-transparent packaging contributes to green marketing [1, 3].

In agricultural supply chains, blockchain are providing traceability by collecting authentic real-time data from food agriculture, processing, storage, distribution and retail, as well as information related to the purchase and use of pesticides and other harmful agents to soil quality and climate for agriculture [2, 5].

Recycling can be enhanced through blockchain programs such as the Social Plastic and RecycleToCoin projects, which seek to reduce plastic waste by motivating people to trade plastic for financial reward in the form of cryptocurrency [3].

Blockchain also contributes with packaging traceability through effective monitoring for later reuse, such as the "smart pack" launched by Walmart. Through smart contracts and data transparency, it may be possible to verify and measure supplier environmental performance in a supply chain. In addition, blockchain can be used to improve eco-design to disseminate information, control the environmental quality of materials and project management for product development [1].

5. Conclusions

This study aimed to present the current state of art discussion in emerging literature about blockchain applications in sustainable supply chains from the perspective of the triple bottom line. From the results, it can be seen the main implications of using this blockchain in sustainable supply chains are related to ensuring reliability, traceability and authenticity of information, providing transparency in sustainable practices. The use of smart contracts eliminates the need for a reliable central organization, allowing real-time updating of transactions between partners, allowing customers to track product/service information.

Regarding the limitations of the research, due to the choice of the systematic literature review method that restricts the search to one database, few articles adherent to the theme were found. Moreover, since blockchain technology is still in the early stages of development, few applications are currently been developed in this field.

In this sense, this study consolidates the need to explore how the use of blockchain, through its promising characteristics, provides benefits in supply chains as well as operations management in order to improve

sustainable performance. In addition, further study is needed regarding the barriers and difficulties regarding the application of this technology in supply chains, as well as the potential threats and risks of its use in this context.

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Big Data with Data Lake: A Case of a Paper Industry

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Abstract: The pillars of Industria 4.0 present a diversity of technologies that promote the journey of digital transformation in the company. Klabin is a company that strives to find innovation through technologies such as IIoT (Industrial Internet of things), Systems Integration, cloud computing and Big Data. This work presents a proposal for the development of a structural data layer concentrating the different data in a data lake, integrating different systems such as Information Management System of the Plant and combining data from sources like process, maintenance and quality data. These correlations will allow Klabin to establish conditions through the different data sources with the purpose of making better predictions in the process, and reestablishing the process more efficiently, while at the same time increasing stability. This could consequently reduce the reclassification of products. Maintenance prediction analysis extends asset life, process reliability, and productivity. The proposed standardization of the Data Lake model makes the industrial environment scalable with greater security through the elaboration of high-performance predictive analysis, management reports and indicators.

Keywords: Industry 4.0, Data Lake, IIOT, Intelligent Manufacturing, Big Data, Supply Chain.

*3rd International Symposium on Supply Chain 4.0: Challenges and Opportunities of Digital Transformation,
Intelligent Manufacturing and Supply Chain Management 4.0,
ISSC4 - 2019, October 24-28th, Indianapolis, USA.*

Collaborative Research Network on Supply Chain 4.0

ISSC4²⁰¹⁹

Joint-organized by
SC4 (Collaborative Research Network on Supply Chain 4.0),
Conexus Indiana www.conexusindiana.com, and
Butler University, Lacy School of Business www.butler.edu/lacyschool