A BIBLIOMETRIC RESEARCH OF INDUSTRY 4.0 OPPORTUNITIES IN INDUSTRIAL ENGINEERING

UMA PESQUISA BIBLIOMÉTRICA DE OPORTUNIDADES DA INDÚSTRIA 4.0 EM ENGENHARIA INDUSTRIAL

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Abstract. Transformations from the traditional industry model to the Industry 4.0 model presents great challenges for Industrial Engineering professionals and students. Consequently, it becomes necessary to adapt already consolidated concepts in the academic and professional environment to meet the peculiarities and needs of this new business model. To understand these challenges of the fourth industrial revolution for those professionals, it was performed a bibliometric research to comprehend the publication's profile involving the main concepts of Industry 4.0 and Industrial Engineering topics. This research consists of the analysis and interpretation of Scopus and Web of Science databases from January 2012 to November 2019. The results found indicate significant growth of scientific articles covering Industry 4.0 concepts applied in Industrial Engineering fields, as well as the distribution of publications by branch. The main contribution of this research article is to present the applicability of Industry 4.0 concepts in Industrial Engineering branches, plus the trends and opportunities for future research.

Keywords: industry 4.0; industrial engineering; bibliometric; research; education.

Resumo. As transformações do modelo tradicional da indústria para o modelo da Indústria 4.0 apresentam grandes desafios para profissionais e estudantes de Engenharia Industrial. Consequentemente, torna-se necessária a adaptação de conceitos já consolidados no meio acadêmico e profissional para atender às peculiaridades e necessidades desse novo modelo de negócios. Para entender esses desafios da quarta revolução industrial para esses profissionais, foi realizada uma pesquisa bibliométrica para compreender o perfil da publicação envolvendo os principais conceitos dos tópicos da Indústria 4.0 e Engenharia Industrial. Esta pesquisa consiste na análise e interpretação das bases de dados Scopus e Web of Science de janeiro de 2012 a novembro de 2019. Os resultados encontrados indicam um crescimento significativo de artigos científicos abrangendo conceitos da Indústria 4.0 aplicados nas áreas de Engenharia Industrial, bem como a distribuição de publicações por ramo. A principal contribuição deste artigo de pesquisa é apresentar a aplicabilidade dos conceitos da Indústria 4.0 nos ramos da Engenharia Industrial, além das tendências e oportunidades para pesquisas futuras.

Palavras-chave: Indústria 4.0; Engenharia Industrial; bibliométrica; pesquisa; Educação.

INTRODUCTION

Technological advances in recent years have significantly transformed governments, universities, companies, professionals, and society. As a result, in 2011 a new industry concept emerged, known as Industry 4.0 or forth industrial revolution (Kargemann et al., 2013). Industry 4.0 has been remodeling manufacturing concepts into a new business model, in which physical and virtual systems are linked to networks and digital platforms are connected to data cloud storage. The main components of the Industry4.0 consist of Cyber-physical Systems (CPS), Internet of Things (Iot) and the Internet of Services (Ios), that when applied to turn traditional factories into smart ones (Vogel-Heuser & Hess, 2016). Transformations provided by the fourth industrial revolution impact all levels of industry and education, demanding adaptations of educational institutions, companies and professionals to new development processes and business management (Xie & Reider, 2014; Belarmino, 2017). The implementation of new technologies in diverse sectors of society and chiefly in corporate environments starts with the rupture of traditional models (Kolberg & Zuhlke, 2017). The training of engineering students is impacted by current changes and educational institutions have sought to those students learn significant curricular content (Ramaswamy et al., 2001; Xie & Reider, 2014; Chang & Chen, 2020).

Recent research shows applications of Industry 4.0 concepts in the scope of Industrial Engineering. Applying these concepts creates a new ambient of manufacturing, which directly alters the future of Industrial Engineering. The growing number of academic studies and papers covering consolidated Industrial Engineering concepts side by side with tools from Industry 4.0, reveals tendencies for scientific research to transform today industries model into the new 4.0 model.

In order to understand the challenges that guide the new phase of the global industry and the consequences of those changes for an Industrial Engineering professional, this article was produced using a bibliometric analysis and examination of publications from the last years. This research seeks to identify the profile of those publications on the subject, the main authors, the countries with most publications and the profile of projects involving Industrial Engineering topics. Thus, to reach the goal of this paper, Scopus and Web of Science's (Wos) databases were analyzed and pieces of information about the main ideas of this work were extracted. The keywords' combinations allowed to detect the pertinency of Industry 4.0 concepts in Industrial Engineering and the evolution of projects over the years. In addition, it was possible to spot opportunities for future research considering relevant Industrial Engineering topics.

With the purpose of comprehending the research, this article was initially structured with an introductory approach, a brief theoretical framework, followed by a methodology and presentation of results from Scopus and Web of Science's databases

THEORETICAL FRAMEWORK

Industry 4.0

The term Industry 4.0 or Industrie 4.0 was born in Germany in 2011 from entrepreneurs and government efforts that saw opportunities to establish Germany as a leader in the technology market. In 2006, the German government launched a strategic plan that aimed to increase the productivity and competitiveness of German products by 2020. Known as the High-Tech Strategy – 2020, it emphasizes the deployment of Industry 4.0 as a leverage for the German industrial process (Hermann et al., 2015).

Industry 4.0 also called fourth industrial revolution has been changing the current denomination of industry, providing new business models and new ways of creating values for products and services (Kargemann et al., 2013). If the first industrial revolution was well- known by steam machines, the second one is noted by electricity and the assembly line, the third appeared with robotics and automation integrated with information and communication technologies (ICT), the fourth industrial highlights will be the use of cyber-physical systems (CPS), integrated data and information and also the use of digital systems in the entire assembly line (Lu, 2017).

The fourth industrial revolution trends to automate the traditional industry, using cybernetic systems, information and communication, and the Internet thus, forming the so-called smart factories (Kotynkova, 2017). This new phase of the global industry will be distinguished by greater flexibility, quality and well-developed manufacturing, logistics, production planning and controls and consequently, engineering. The new industrial revolution will enable real-time responses to better resources optimization based on pre-established decision-making criteria (Kargemann et al., 2013).

Industry 4.0 is also known as value chain integration. This integration consists of the transformation of traditional factories into intelligent factories, using cyber-physical systems (CPS) for process control and monitoring. The bond between cyber-physical systems and humans will be possible using the Internet of things (Iot). These processes services can be offered by the Internet of Services (Ios) (Hermann et al., 2015).

Industry 4.0 is a strategic approach that involves communication among high-tech systems using the Internet and complex processes integration in large networks (Anderl, 2014).

The importance of Industry 4.0 concepts is inserted in the integration of intelligent networks products and processes that optimize efficiently the resources of an organization. This new industry concept will allow creating products and services with high added value for customers (Santana et al., 2017).

Strategically, Industry 4.0 aims to boost the performance of value chains products and services over the entire life cycle whence to increase the economic value of products with a high level of innovation in a sustainable way, developing intelligent products and processes (Kargemann et al., 2013).

Aiming to remodel the current industry model, Industry 4.0 offers the computerization and interconnection of processes, products, and services, providing a large scale of tailored products, supply chain flexibilization, shortened delivery times, elevated productivity and reduced costs (Lu, 2017).

The main components of Industry 4.0 are cyber-physical systems (CPS), Internet of things (Iot), Internet of services (Ios) and Smart factories. CPS consists of physical systems integrated into computational and communication systems. The interaction between a physical and virtual world in cyber-physical systems occurs using sensors, actuators, processing units, and communication devices (Lee et al., 2015). Internet of things involves an exchange of information among computational systems via wireless sensors, creating a global network. IoT also allows interactions between physical objects and machines that share network information and store databases available to users (Wikowski 2017). Internet of Services consists of the use of the Internet to offer high-added value to users and customers. Services are available via the use of platforms that communicate all services available for users in an effective, dynamic, and quick way (Buxmann et al., 2009). Smart factories integrate people, machines, processes, and systems using the Internet, presenting the physical world in a virtual model to support decision-making. The combination of information technology with factory operations and systems allow the creation of a new business model, shaping expressively different manufacturing processes (Li, 2015).

Industry 4.0 has six principles that thrive from its pillars. Interoperability is the capacity of communication between people, systems, and CPS using Iot and Ios. Virtualization consists of obtaining a sample of the real world into the virtual world, allowing to supervise processes of smart factories with actions that grant decision-making. Decentralization permits cyber-physical systems to make their own decisions, only requiring human action in the event of a failure. Real-time capability of operations consists of collecting and analyzing data instantly. Service Orientation consists of Ios services oriented to software architecture. The final one, Modularity is related to modular systems which can easily adapt to requirements changes by only replacing or expanding its individual modules (Hermann et al., 2015).

Industrial Engineering

Industrial Engineering plays a fundamental role in Brazil industrial development. Industrial Engineering is responsible for several aspects of the production chain, unifying processes, systems, people, information and energy to produce goods and services. The elements of the study of this area of engineering are essential to increase competitiveness and diminish the costs of companies worldwide. This set of knowledge becomes primal for any operation and productive system (ABEPRO, 2015).

ABEPRO (from Portuguese, Brazilian Association of Production Engineering) presents several branches for Industrial Engineering, highlighting thirteen topics: Product Engineering, Factory Project, Production Processes, Methods and Processes Engineering, Production Planning and Control, Production Costs, Quality, Maintenance Planning and Scheduling, Reliability Engineering, Ergonomics, Occupational Health and Safety, Logistics and Supply Chain and Operations Research.

The transformations in the last few years have challenged professionals and academics of Industrial Engineering to seek new knowledge and to adapt quickly to the consumer market and government demands, mainly regarding subjects related to environment and security (Xavier et al., 2015). The changes also impact the training of engineering students. There are new paradigms regarding the training of engineers in the twenty-first century (Seah & Magana, 2019; Ramaswamy et al., 2001).

RESEARCH METHODOLOGY

This article analyzes bibliometric publications about Industry 4.0 following all thirteen topics of Industrial Engineering. The period considered for the research in the bases was from January 2012 to November 2019, representing the moment of the first publications of this theme to the final period of research by the authors. Bibliometric analysis is classified as quantitative research because it seeks quantitative aspects of scientific production and indicates possible gaps and opportunities for a theme through mathematical models (Filser et al., 2017; Ellegaard, 2018). The bibliometric study aims to apply statistical methods and techniques to gather analytical pieces of information about publications from an area of interest (Hood & Wilson, 2001).

Therefore, the bibliometric approach is justified for the understanding of study opportunities focused on the proposed theme (Assis et al., 2018). LsciFigure 1 shows this paper approach, interrelating Industrial Engineering topics with Industry 4.0.

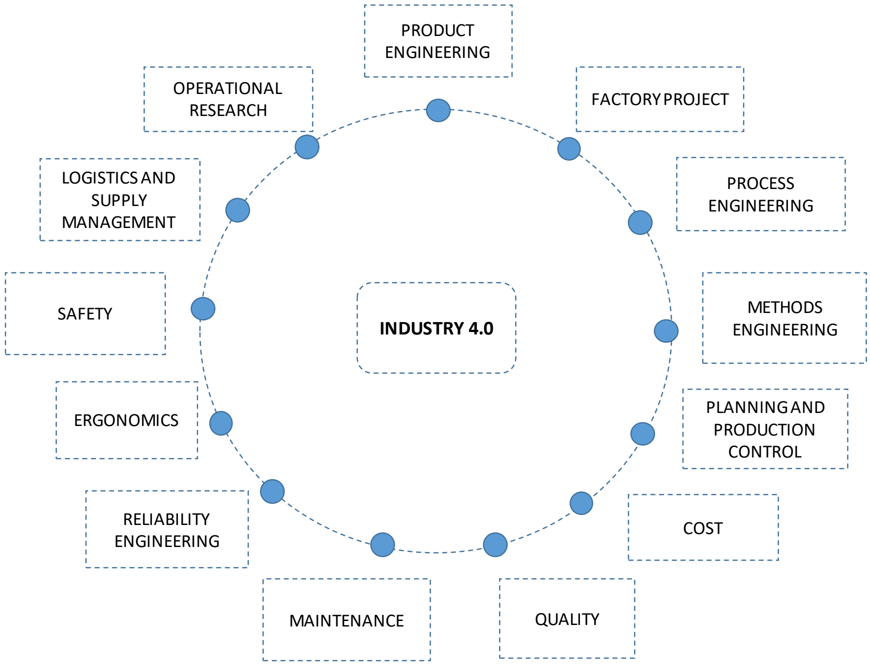


Figure 1. Interrelation between Industrial Engineering and Industry 4.0. Source: Authors, 2021

The bibliometric study has started defining the research objectives. Scopus and Web of Science (WoS) databases were subsequently selected, as they are the main information sources of citations and are widely used for scientific research. Using both databases provides greater assertiveness regarding published work by extending study coverage. The research in the databases was carried out in English due to its universalization in the academic and professional environment, thus searches and publications on other languages were excluded.

After the database definition, 42 keywords pertinent to the subject of study were selected. The research considered the main documents for analysis, e.g., articles, abstracts, and reviews.

The search on Scopus' database was performed considering the same keywords from the Industrial Engineering branches, combined with the keyword Industry 4.0, thereby allowing to check the publications profile and the number of citations within this approach. The combination of these keywords was executed applying the Boolean operator AND. To analyze bibliometrically the data collected from Scopus, the results were imported to Microsoft® Excel 2013, thereafter, all duplicates were eliminated from the data obtained. The information generated from the Scopus enables the development of numerical data to perform a statistical analysis.

The examination on Web of Science was performed considering the same search period and keywords as the Scopus examination. The search strategy regarded the basic research of the main collection on Web of Science, limited to Industry 4.0, jointly with the words referring to the 13 branches of Industrial Engineering, and the Boolean operator AND to associate the keywords. The type of all documents surveyed was encompassed by topic items. The data was listed through the citation index and imported to Microsoft Excel 2013. Figure 2 presents all steps associated with the research development.

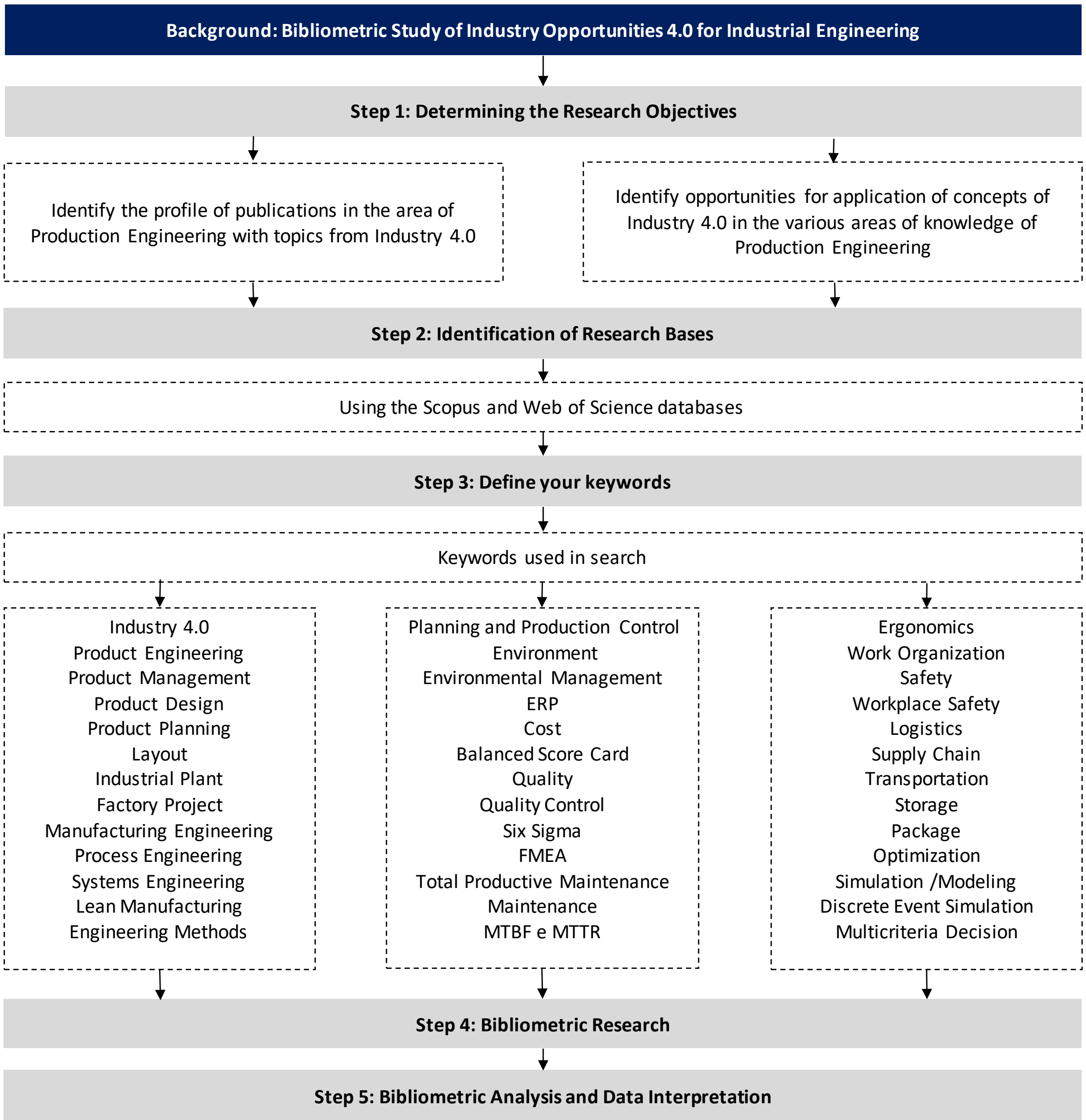


Figure 2. Schematic view of the research method. Souce: Authors, 2021

BIBLIOMETRIC ANALYSIS

With the purpose of analyzing the publications in Industrial Engineering and Industry's 4.0 point of view, searches on Scopus and Web of Science databases were executed initially only having the theme Industry 4.0. The initial numbers of documents containing the keyword Industry 4.0 on Scopus and Web of Science were 6.516 and 5.327, respectively. Then the collected data were refined eliminating all the documents unrelated to the proposed theme. Lists have been consolidated into a single database, enabling to eliminate duplications. In the end, the data processing has generated a final number of 3613 documents about Industry 4.0. Table 1 illustrates the results obtained. In summary, Scopus has a greater number of documents involving Industry 4.0 than Web of Science.

Table 1. Scopus and Web of Science (Wos) research results about industry 4.0

Database	Scopus	Web of Science (Wos)
Initial number of documents	6516	5327
Number of refined documents	6468	5305
Number of duplicates	4630	
Final number of documents	7143	

Souce: Authors, 2021

The results' consolidation on a single basis allowed to determine the distribution of publications over the years. The research results accounted for 3613 documents published between January 2012 and November 2019 and it is noticeable growth in the number of publications in the last few years. Figure 3 graphics the distribution of annual publications addressing Industry 4.0 concepts.

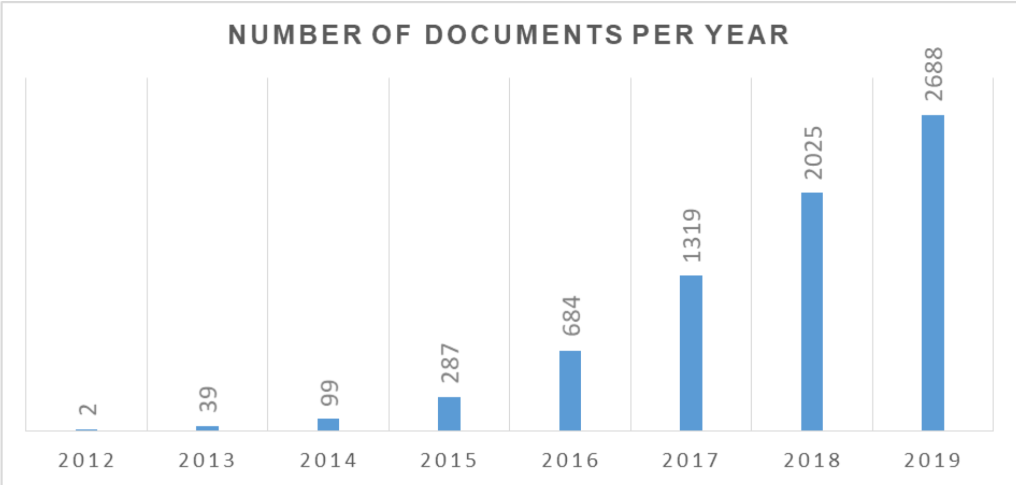


Figure 3. Number of publications about Industry 4.0. Souce: Authors, 2021

The expansion and evolution of this theme over time demonstrate the interest of professionals and academics in studies involving Industry 4.0. Analyzing Figure 3, it is possible to conclude that the number of publications doubled between 2016 and 2017. This shows a trend to significant growth of publications for the following years.

In addition, the research also sought to identify the fifteen countries with the highest number of publications. Table 2 describes the distribution of published articles by country.

Table 2. Articles distribution by country.

Country	Number of publications	Percentual
1 Germany	1256	17%
2 Italy	715	10%
3 United States	434	6%
4 China	381	5%
5 United Kingdom	351	5%
6 Spain	308	4%
7 Russian Federation	251	4%
8 Austria	222	3%
9 Portugal	219	3%
10 Brazil	214	3%
11 France	207	3%
12 India	196	3%
13 Poland	187	3%
14 Indonesia	173	2%
15 Czech Repuclic	162	2%

Souce: Authors, 2021

Germany has the biggest number of publications, 1256 papers are registered on Scopus and Web of Science database, representing 18% of the total of publications about Industry 4.0. This large number of publications from Germany is justified mainly by being the creator of the term Industry 4.0. Italy comes in second representing 10% off publications with a greater advantage over developed countries such as the United States and the United Kingdom. Brazil is the tenth with 214 publications about Industry 4.0, the country represents 3% of publications and stands out as the only South America country in the top fifteen which has published articles referring to Industry 4.0. The research has also identified the authors who published the most about the theme, Table 3 ranks these authors.

Table 3. Numbers of publication by author

Author	Number of publications	Percentual
1 Zakoldaev, D.A.	26	20%
2 Zharinov, I.O.	26	20%
3 Shukarov, A.V.	25	19%
4 Gurjanov A.V	12	9%
5 Zharinov, O.O	10	8%
6 Raunch, E.	10	8%
7 Macchi M	12	9%
8 Nurhasanah N.	4	3%
9 Aribowo B.	4	3%
10 Devana M.	3	2%

Souce: Authors, 2021

To assess the relationship between the authors, the co-citation criterion is considered, in which authors who have more than one text referenced in the research base are analyzed, and they are grouped in the map composition presented through the VOSviewer software (Figure 4). The analysis of co-citation allows to approach the author or group of authors whose texts appear cited together in different works.

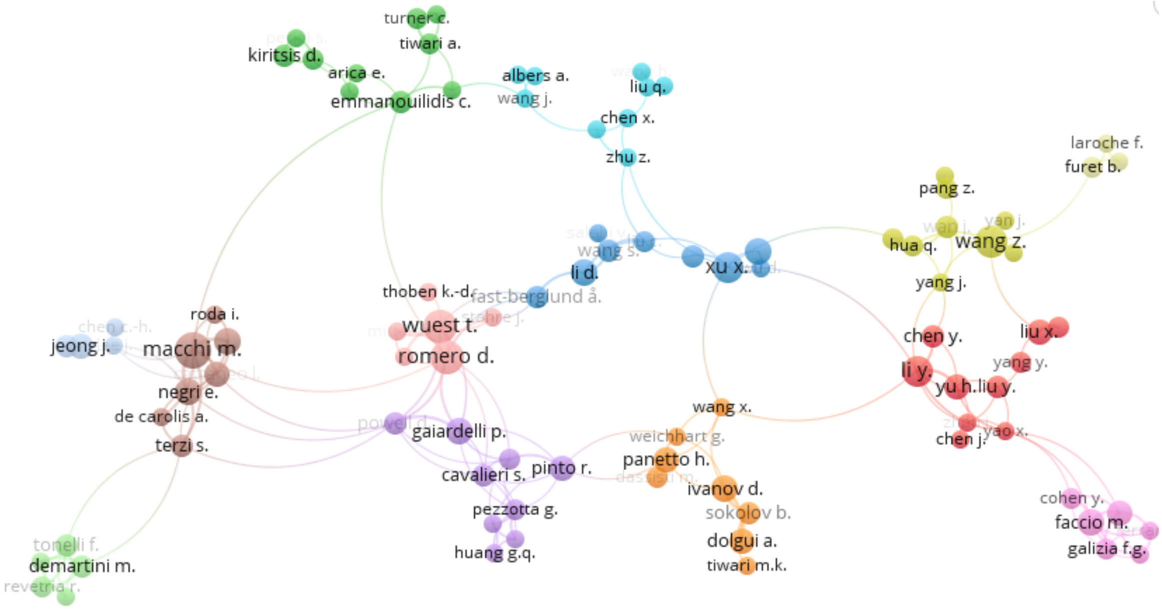
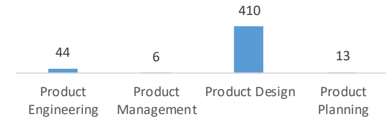
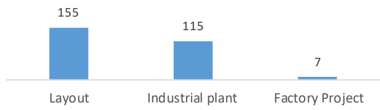
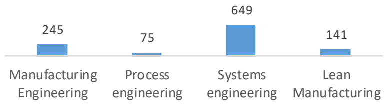
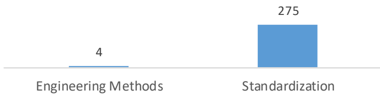
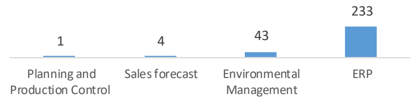
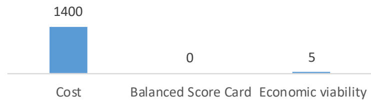
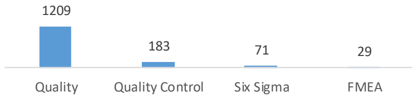
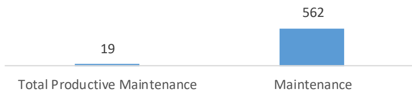
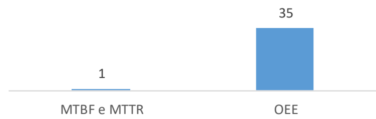
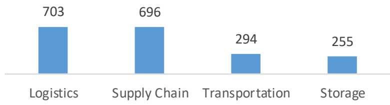
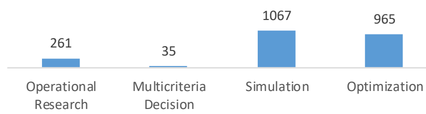


Figure 4. Grouping by co-citation of the authors. Souce: Authors, 2021

To verify the profile of publications related to Industrial Engineering, searches on the databases were carried out using a combination of 42 keywords. The research enabled to analyze the profile of Industry 4.0 within the topics of Industrial Engineering. Table 4 illustrates the distribution of publications using Industry 4.0 and the topics as keywords based on Scopus and Web of Science databases. Duplicates of the same topic were eliminated yet documents cited in another topic were considered. Table 4 also demonstrates the results of the bibliometric search on Scopus and Web of Science, presenting the main topics covered in the thirteen topics of Industrial Engineering linked to Industry 4.0. The extracted data does not have duplications from the same topic since the goal is to ascertain opportunities in the related area.

The results found, indicate a keen interest in publications involving topics such as Logistics and Supply Management, Operations Research, Quality, and Costs. The investigation has shown that these four branches account for 64% of publications about Industry 4.0 employed in Industrial Engineering. Data analysis shows a small number of publications citing themes like Factory Project, Methods Engineering, Ergonomics, Planning and Production Control, those represent 10% of all publications. The analysis of articles distribution on the databases states that Reliability Engineering has zero percent of documents therefore, there are still branches slightly explored containing Industry 4.0 concepts.

Table 4. Publications' distribution per Industrial Engineering topic

	Topics	Keywords	Publications	Percentual	Graphic
1	Product Engineering x Industry 4.0	Product Engineering	44	4%	
		Product Management	6		
		Product Design	410		
		Product Planning	13		
2	Factory Project x Industry 4.0	Layout	155	2%	
		Industrial plant	115		
		Factory Project	7		
3	Process Engineering x Industry 4.0	Manufacturing Engineering	245	10%	
		Process engineering	75		
		Systems engineering	649		
		Lean Manufacturing	141		
4	Methods Engineering x Industry 4.0	Methods Engineering	4	3%	
		Standardization	275		
5	Planning and Production Control x Industry 4.0	Planning and Production Co	1	3%	
		Sales forecast	4		
		Environmental Management	43		
		ERP	233		
6	Cost x Industry 4.0	Cost	1400	13%	
		Balanced Score Card	0		
		Economic viability	5		
7	Quality x Industry 4.0	Quality	1209	13%	
		Quality Control	183		
		Six Sigma	71		
		FMEA	29		
8	Maintenance x Industry 4.0	Total Productive Maintenanc	19	5%	
		Maintenance	562		
9	Reliability Engineering x Industry 4.0	MTBF e MTTR	1	0%	
		OEE	35		
10	Ergonomics x Industry 4.0	Ergonomics	261	3%	
		Protective equipment	5		
		Work Organization	21		
11	Safety x Industry 4.0	Safety	612	6%	
		Workplace Safety	5		
		occupational health	32		
12	Logistics and Supply Chain x Industry 4.0	Logistics	703	17%	
		Supply Chain	696		
		Transportation	294		
		Storage	255		
13	Operational Research x Industry 4.0	Optimization	965	21%	
		Simulation	1067		
		Multicriteria Decision	35		
		Operational Research	261		

Souce: Authors, 2021

RESULTS AND DISCUSSION

The research with a thematic approach has revealed a quantitative and qualitative profile of the papers. The first topic surveyed was Industrial Engineering, which according to Júnior et al. (2012), is fundamental for the definition of new products pointing to competitive and marketing advantages. Industrial Engineering mostly deals with issues related to development and innovation aimed at introducing new products on the market on demand and opportunities (Júnior et al., 2012). Industry 4.0 concepts are tied to Industrial Engineering demands. As reported by Nunes et al. (2017), today´s industry transformation will have a direct impact on products and processes already established through the introduction of intelligent products with highly complex features, functionality, and interaction with various technologies. The use of CPS augmented reality, internet of things, among others will provide new opportunities for the launching of new products and services on the market. The results of the bibliometric research show that 5% of the papers involving Industry 4.0 topics refers to Industrial Engineering, most of them are related to new products' development on the market, but there are research opportunities involving other topics such as 3D printing and augmented reality that are promising technologies for Industrial Engineering, particularly as regards of costs and benefits on prototypes development.

New concepts of the fourth industrial revolution directly impact new factory projects, layouts, and physical arrangement of objects in space. Smart factories empower greater connectivity among machines and equipment, better optimization of resources, more flexibility, autonomy for decision-making and shorter response time when compared to the current industry model) (Wang et al., 2016). The bibliometric analysis revealed that 3% of publications covering Industry 4.0 refer directly to factory projects with the application of simulation techniques, augmented reality, and cyber-physical systems.

Production processes is a branch with great importance for Industrial Engineers, by this, it is possible to notice this statement over the years several publications which cover topics like Lean Manufacturing and Systems Engineering. Opportunities for Industry 4.0 concepts applied on lean manufacturing, eliminate gaps and create opportunities through integrated information and communication systems, increasing productivity and reducing costs, therefore the statements described is a Lean Manufacturing's goal (Sanders et. al., 2016).

Inside the pillars of Industrial Engineering, a branch called Methods Engineering is presented which it was born along at the time of the first industrial revolution and now has been transformed by the last industrial revolution, Industry 4.0. The current industry is being transformed by the real-time combination of processes and information resulting in the maximization of operational capacity, processes standardization, and productivity increase. The use of augmented reality, cloud computing, cyber-physical systems, and the internet of things, impact directly a transformation in the present model (Vaidya et al. 2018)

Sustainability of processes and products are also benefited by Industry 4.0. These benefits are presented in products' designs with lower usage of raw materials and more recycled products through control and monitoring of processes and products (Man & Strandhagen, 2017).

Moreover, Industry 4.0 presents the evolution of methodologies related to quality and continuous improvement. For Arcidiano and Pieroni (2018), the application of Industry 4.0 concepts such as Iot and additive manufacturing allows for greater integrity of information which is the basis for any continual improvement process.

Furthermore, Maintenance Planning and Scheduling is modified by Industry 4.0 concepts. As stated in Scurati et al. (2018), there are functionalities and benefits of augmented reality for the scanning of maintenance manuals and standards. The applications of augmented reality concepts demonstrate many opportunities for the maintenance branch, resulting in better confidence and fewer risks in the execution of activities.

Gašová et al. (2017) discuss the application of Industry 4.0 as an opportunity of change for modern ergonomics. The use of apps on mobile devices, internet of things and real-time information, consent the creation of healthier and safer work environments leading to a real-time risk evaluation.

Safety at work is also benefited by Industry 4.0 since that in high-risk activities it can replace humans by robots using cyber-physical systems. Industry 4.0 provides better monitoring of production processes as well as workers activities.

Scientific studies show great applicability of Industry 4.0 in Logistics and Supply Management. The progress of studies regarding Industry 4.0 are justified by the fact that time and innovation are major competitive advantages in today´s world. Witkowski (2016) states that Industry 4.0 concepts can help in logistics monitoring and tracking of cargo and vehicles. This monitoring assists to identify delivery delays, freight cost, and tolls. Transport management is improved by applications in route control, maximization of fuel use and control of pickup and delivery service, increasing the safety and transport predictions. Smart concepts can also be applied in cargo storage locations, enabling automated CPS controlled stocks with real-time responses. Besides, there is an increase in inventory management performance via the use of pallets and smart shelves. Witkowski (2016) alleges on his paper that 90% of the companies that work with Logistics and Supply Management already use Iot concepts in their processes. Hence, the application of those concepts in supply chain implies the reduction of logistics cost and lower response time for decision-making. It was observed on the analyzed articles the use of internet of things, internet services, cloud computing and big data concepts for improvement of logistics processes.

Supplying materials to their destination is fundamental in logistics processes. It was noted an increase of technologies like Automated Guided Vehicles (AGVs) that allows sequencing of items to the production lines using general concepts of CPS. AGVs can transport materials via already known or easy to predict ways, with maximum efficiency, reducing risks of failures in product availability. Thus, there is a reduction of large stocks and lack of materials beyond a decrease of process resources (Neradilova & Fedorlo 2017; Bloch & Schneider 2016).

Several scientific studies apply optimization methods on processes through Industry's 4.0 tools. Vaidya et al. (2018), presents the changes that have occurred from the use of these tools, identifying improvements on operational capacity optimization and efficiency.

Furthermore, Tuner et al. (2016), describes the use of simulations along with augmented reality, proofing the benefits that come from Industry 4.0 concepts when inserted on Industrial Engineering.

CONCLUSION

This article presented the main results of papers involving themes related to Industry 4.0 and Industrial Engineering. The growing number of publications involving both subjects show a new job profile for professionals and academics in this area whose adaptation to the fourth industrial revolution concepts indicates opportunities for the current industry progress. The research indicated that Industry 4.0 publications have doubled over the past year, with a significant increase at upcoming years. Countries like Germany, China, Italy, the United States of America, United Kingdom and Spain stand out as the countries that published most articles, representing together 51% of all publications on the subject.

The profile analysis of Industrial Engineering branches publications shows great interest in topics like Logistics and Supply Management, Operations Research Production Processes and Costs, representing 64% of all publications covering Industry 4.0. On the other hand, the research revealed a lack of studies on these branches: Factory Project, Reliability Engineering, Ergonomics, Maintenance Planning, and Scheduling and Production Planning and Control. This low number of papers indicates a great opportunity for research and the combination of themes related to these branches, thus presenting an opening for future scientific studies.

This research made it possible to identify potential advantages with the applications of Industry 4.0 concepts and tools in Industrial Engineering topics. The mix of the topics addressed in this study will allow the development of several industrial sectors, increasing competitiveness and the integration of supply chain in real-time. Publications showed an extension on the use of technology in various Industrial Engineering topics, featured by augmented reality, internet of things, cyber-physical systems and cloud computing. So, applying these technologies permits optimization of processes, greater security to the employees and a bigger costs reduction. Hence, the new industrial revolution creates a need to adapt professionals and academics from the Industrial Engineering environment to new the market´s demands.

IDENTIFYING SCIENTIFIC GAPS

Due to the opportunities found in the research, it is recommended for future works to gather information covering Industry 4.0 and Industrial Engineering topics. This recommendation consists of the analysis of the applicability of tools like augmented reality, virtualization, cloud computing and big data applied in branches such as Ergonomics, Workplace Safety, and Maintenance Planning and Scheduling.Besides that, it is promising to research opportunities involving not yet applied in Industrial Engineering, analyzing their potential gains in productivity, competitiveness, and cost reduction.

This scientific study did not address the application of Industry's 4.0 pillars in all Industrial Engineering thirteen topics. It is highly advisable a careful analysis combining words related to Industrial Engineering and Industry 4.0. This merge of keywords will allow the evaluation of the applicability of Industry 4.0 concepts as well as the study needs by professionals from the area associated. The research will also collaborate in the identification concepts evolution and tools which are already consolidated in the Industrial Engineering environment, resulting in the modeling of forthcoming engineers' profile.

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