DUMLUPINAR ÜNİVERSİTESİ SOSYAL BİLİMLER DERGİSİ
DUMLUPINAR UNIVERSITY JOURNAL OF SOCIAL SCIENCES
E-ISSN: 2587-005X http://dergipark.gov.tr/dpusbe
Dumlupınar Üniversitesi Sosyal Bilimler Dergisi, 67, 159-175; 2021
DOI : 10.512901/dpusbe.789178

Araştırma Makalesi / Research Article

REVIEW AND BIBLIOMETRIC ANALYSIS OF INDUSTRY 4.0 IN SOCIAL SCIENCES

Gencay TEPE[1]*
Burcu MUCAN ÖZCAN[2]

Abstract
The increased rate of technological advancements with Globalization changed, and still changing the industry structures, corporates, the way of working. In recent years Industry 4.0 became one of the prominent subjects. Therefore various corporations and research companies have contributed greatly to the literature of Industry 4.0. In order to find out the fields, countries and authors' contribution to the subject in terms of conducting studies and their influence on other studies, published studies for the last two decades are reviewed with the bibliometric analysis method. The types, key research subjects, the cross-subject relations and collaborations for 1084 document reviewed by the analysis are revealed. With a systematic map that will be created for Industry 4.0, the aim is to indicate the progress of published papers in graphics, to determine the current fields of interest regarding the subject and in turn to guide the potential future researches. Among these results, it is seen that Business and Management fields, and Engineering are the most prominent disciplines in terms of working on Industry 4.0. Germany has most publications and BRIC countries, such as China at the forefront, Brazil and Russia follow Germany closely.
Keywords: Social Sciences, Scopus, Bibliometric Analysis, Industry 4.0.
JEL Codes: M1, O3

SOSYAL BİLİMLERDE ENDÜSTRİ 4.0'IN İNCELENMESİ VE BİBLİYOMETRİK ANALİZİ

Öz
Küreselleşmeyle birlikte teknolojik gelişmelerde yaşanan hızlı değişim, endüstri yapılarını, şirketleri, iş yapış biçimlerini etkilemiş ve halen de etkilemeye devam etmektedir. Son yıllarda Dördüncü Sanayi Devrimi diğer bir adıyla ise Endüstri 4.0 oldukça dikkat çeken konulardan biri olmuştur. Bu nedenle son yıllarda çeşitli kurumların ve araştırma şirketlerinin Endüstri 4.0 literatürüne olan katkıları giderek büyümektedir. Konuyla ilgili yapılan çalışmalara hangi alanların, ülkelerin ve yazarların daha çok katkı sağladığı ve bu çalışmaların diğer araştırmaları nasıl etkilediği sorusunun araştırılması amacıyla, çalışmada bibliyometrik analiz teknikleri kullanılarak son yirmi yılda yayınlanan çalışmalar incelenmiştir. Analiz sonucunda incelenen 1084 dokümanın türleri, anahtar araştırma konuları, konular arası karşılıklı ilişkiler ve iş birlikleri ortaya çıkarılmıştır. Endüstri 4.0 alanında yapılacak olan bu sistematik haritalama ile yayınların zaman içindeki gelişimi grafiksel olarak gösterilerek, konuya dair mevcut ilgi alanlarının belirlenmesi ve gelecekteki potansiyel araştırmalara yön göstermesi amaçlanmaktadır. Sonuçlar incelendiğinde İşletme ve Yönetim ile Mühendislik alanlarının Endüstri 4.0 çalışmalarına en fazla katkı sağlayan disiplinler olduğu görülmektedir. En çok çalışmanın Almanya ve BRIC ülkeleri tarafından yapıldığı, Çin, Brezilya ve Rusya'nın literatüre katkı bakımından Almanya'yı yakından takip ettiği belirlenmiştir.
Anahtar Kelimeler: Sosyal Bilimler, Scopus, Bibliyometrik Analiz, Endüstri 4.0
JEL Kodları: M1, O3

[1] Araş. Gör., Manisa Celal Bayar Üniversitesi İşletme Fakültesi, ORCID: 0000-0001-7752-7167,
* **Sorumlu Yazar** (Corresponding Author): gencay.tepe@cbu.edu.tr
[2] Dr. Öğr. Üyesi, Manisa Celal Bayar Üniversitesi İşletme Fakültesi, ORCID: 0000-0002-6499-4660.
Başvuru Tarihi (Received): 01.09.2020 **Kabul Tarihi** (Accepted): 27.01.2021

Introduction

The purpose of Industry 4.0 is to create a highly flexible manufacturing model of the digital products and services that are personalized with real time interacting between humans, products and devices (Zhou and Zhou. 2015: 2147). Introduced by an article published by the Government of Germany, the term Industry 4.0 in short indicates the fourth industrial revolution. It is understood as the Cyber Physical Systems (CPS) to be applied in industrial manufacturing systems (cyber physical manufacturing systems) (Drath and Horch, 2014:56). Industry 4.0 was needed due to the requirement of transforming the standard machinery to increase their interaction with the environment, to enhance their general performance and maintenance method where they could recognize the other machinery autonomously and become machinery that can learn (Vaidya et. al. 2018:234).

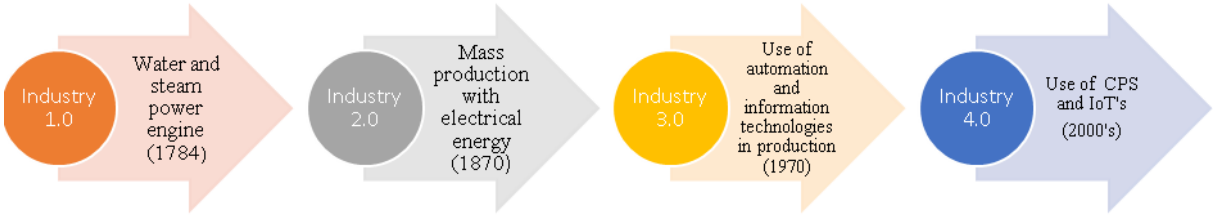
There is a need to identify trends in the Industry 4.0 field as a guideline for further research. In the literature review, no research has been found on how Industry 4.0 is examined in the field of social sciences and what the specific research method should be. Bibliometric analysis is a method that enables the identification of trends specific to a specific research topic and guides future research. It creates scientific outputs for potential researchers to map the research area and what resources they should use.

The results of this research are expected to identify the most common keywords, the most contributing authors, the journals that include the most publications in Industry 4.0 studies. Also, the countries and institutes where this topic was most researched and the most popular years of the subject are expected to identify in this study.

1. Literature Review

In order to comprehend Industry 4.0, it is necessary to review the progress in the field of manufacturing, starting from the First Industrial Revolution. The scientific and technological advancements in the field of manufacturing supported the progress of industrialization on a global scale (Belvedere et. Al., 2013) and triggered the occurrence of various revolutions. Following the start of these revolutions, starting from the last quarter of the twentieth century, the technological inventions became more frequent, and the advancements such as the Internet and wireless networks, sensors, embedded systems, software, automation, advancements in mechatronics and robotics lead the terms such as Industry 4.0 to become more prominent in our daily lives (Banger, 2018:165). The manufacturing phases are increased and became more complex, however on the other hand they became automated and sustainable, and lead the manufacturing employees to utilize the machinery with more ease and efficiency (Wahlster, 2012). The changing nature of the products disrupted the value chains and forced the businesses to rethink almost every aspect of their work, such as how they designed, manufactured and offered services, how they built the information technologies infrastructure required and how to secure all these aspects (Porter, 2014:5). Simultaneously, the business world today require the corporations to make a decision rapidly in order to increase their efficiency. Although this left the businesses with major data issues, many manufacturing systems are not ready to manage big data due to lacking the smart analytic instruments. In Figure 1, it is seen that the transformation initiated with Industry 1.0 progressed with Industry 4.0.

Figure 1*: Industrial Revolutions*



Source: Gülseren and Sağbaş (2019)

Industry 1.0 first was surfaced in England in 18th century (Industry 1.0) and is accepted as the initiation of Industrialization, and influenced the entire world (Alçın, 2016). As stated by Lukaˇc (2015) the manufacturing facilities that have mechanized thanks to water and steam power initiated the First Industrial Revolution. Especially mechanization in textile industry and then disseminated to other fields in terms of manufacturing with mechanization changed the way products are manufactured and also the number of products manufactured is increased (Ashton, 1948). In 1978 the first mechanic weaving loom was used in manufacturing. Manufacturing was mechanized with water and steam power (Fırat and Fırat, 2017). As a result of the First Industrial Revolution, the large industrial cities were founded. The small sized farmers sold their land and migrated to these large industrial cities to look for a job. With increased urbanization, many issues surfaced such as infrastructure, epidemics, highly increased working hours and child labor (Günay, 2002).

In the beginning of the Twentieth century, the Second Industrial Revolution (Industry 2.0) signified by the serialized labor manufacturing based on electrical energy is initiated (Lukaˇc, 2015). The mass production adopted widely in Second Industrial Revolution was first applied in Henry Ford's vehicle factories, and utilization of mass production was accepted as the initiation of the Second Industrial Revolution. However at the end of 1960's this mass production system that is based on a single type of product could not adopt to the changed and diversified consumer needs and increased competition, collapsed following the oil crisis in 1973 (Alçın, 2016). The results of the first two industrial revolutions showed that earth's resources were depleting, natural environment was negatively affected by these developments and the sustainability of the world itself was at risk (Banger, 2018:14).

Following the Second Industrial Revolution, the Third Industrial Revolution (Industry 3.0) based on digitization was initiated and witnessed the inventions of various devices, which the enhanced models are in use today. Invention of the first programmable logical systems in 1969 elevated the use of automation in manufacturing with increased use of electronics and information technologies (Fırat and Fırat, 2017). The manufacturing sites are moved from the central countries to neighboring countries (Günaydın, 2018). The invention of the first micro computer Altair 8800 in 1971 and then the invention of Apple I by Steve Jobs and Steve Wozniak in 1976, are among the most prominent inventions of the Third Industrial Revolution (Fırat and Fırat, 2017).

Prior to Industry 4.0, to summarize the preceding industrial revolutions, "mechanization" due to invention of steam machines was the center of Industry 1.0, "serial manufacturing" with the utilization of electricity in Industry 2.0, "digitization" was at the forefront in Industry 3.0 with the utilization of electronics and information technologies. Lastly the cyber physical systems, the utilization of Internet of things and services dawned the age of Industry 4.0 (Jazdi, 2014).

Today we live in the Fourth Industrial Revolution (Industry 4.0) where the cyber physical manufacturing systems rely on heterogeneous data and information integration (Lukaˇc, 2015). As the preceding industrial revolutions are studies, it is seen that all revolutions were borne of

technological advancements. However Industry 4.0 may be viewed differently in terms of enabling the inter-machinery communication and a process that does not require manual physical labor.

The main aspects of Industry 4.0, among others are cyber physical systems (CPS), Internet of things, cloud computing systems and smart factories. Rüßmann et. al. (2015) added big data, robotics, simulation, cyber security, augmented reality, additive manufacturing, horizontal and vertical system integration to these technological advancements.

It may also be indicated that the studies regarding Industry 4.0 was increased in the last decade. Some of these studies include, reviewing Industry 4.0 in terms of manufacturing systems, (Lobo;2015, Mrugalska and Wyrwicka; 2017; Kang, et. al. 2016), meanwhile others reviewed subjects such as Industry 4.0 and logistics (Hoffman, Rüsch; 2017), global value chains (Stange and Zucchella; 2017, Bogers, et. al. 2015), human resources (Sivathanu, Pillai,2018), smart products and services (Frank, et al. 2019, Schmidt, et. al; 2015, Belvedere, et. al. 2013), Internet of things and smart factories (Roblec, et. al. 2016, Nolin and Olson, 2016, Vaidja, et. al. 2018). Some of these studies aimed to review Industry 4.0 in general (Lasi, 2014; Liao, et. al. 2014; Lu, 2017; Muhuri, et. al. 2019). In these studies the authors conducted a systematic literature review, analyses such as meta analysis or bibliometric analysis.

Bibliometric or Scientometric analysis facilitates certain current subjects regarding certain trends to be analyzed, and guides the future research studies. Essentially it indicates the general template and the general structure of the field of research (Muhuri, et. al, 2019; 218). There are numerous studies that utilize bibliometric analysis from past to present (Baumeister and Leary, 1997; Bornmann and Mutz, 2015; Fahimnia, et.al. 2015; Oesterreich and Teuteberg, 2016). There are various studies that utilize the bibliometric analysis in Turkey (Hotamışlı and Erem, 2014; Bozkurt and Çetin, 2016; Tayfun, et.al. 2018; Tayfun et. al. 2016). The targeted contributions with this study can be summarized as below;

Conducting detailed bibliometric analysis of Industry 4.0 through one of the most commonly utilized database Scopus, taking note of the studies conducted in the last two decades (1998 - 2018);

- On Scopus, determining the number of studies based on years, the most researched institutions, authors, countries, research documentation types, the most cited resources and the research fields regarding Industry 4.0;
- Visualizing the most common keywords and resources regarding Industry 4.0;
- In addition to bibliometric analysis, with the results of the most cited articles in Scopus and the further progress in Industry 4.0, a guide is aimed to be prepared to future researchers.

2. Data Collection and Methodology

In this study the research data regarding Industry 4.0 in the last two decades in one of the most commonly used databases, Scopus, are collected and analyzed. "Industry 4.0" was queried as as keyword and the results on Scopus database were found via searching in all types of publications. As a result of queries with "Industry 4.0" as the keyword in Scopus database, publications in "Social Sciences, Business, Business Management, Marketing, Accounting, Finance and Economy" research fields were searched on May 20th, 2019.

As a result, a total of 1084 data were found. In Scopus, the studies regarding Industry 4.0 in Social Sciences field were 540 in total with 49.81% of the total number of studies. Another major category, conference sciences held 33.11% (359) of the total studies. Other categories were articles in press (16), books (8), book chapters (70), conference reviews (15), editorials (1), errata (1), notes (21), reviews (34) and short surveys (6) respectively. The breakdown of all documentation in Scopus is shown in Table 1.

Table 1: *Distribution of document types in Scopus between 1998-2018.*

Document Type	Total Numbers	Contribution (%)
Articles	540	49.81
Articles in Press	16	1.47
Book	8	0.73
Book Chapters	70	6.45
Conference Papers	359	33.11
Conference Reviews	15	1.38
Editorials	14	1.29
Errata	1	0.09
Notes	21	1.93
Reviews	34	3.13
Short Surveys	6	0.55
Total	**1084**	**100**

For Bibliometric analysis certain performance indicators were calculated. Formulation of the methods utilized in the analysis is coded by the authors as R based coding via R studio 1.2 software. The data processed by the software is also processed with Gephi 0.8.2 and VosViewer 1.6.11 software for mapping and the final version of the output is created. Gephi is a tool for data analysts and scientists keen to explore and understand graphs. Like Photoshop™ but for graph data, the user interacts with the representation, manipulate the structures, shapes and colors to reveal hidden patterns. The goal is to help data analysts to make hypothesis, intuitively discover patterns, isolate structure singularities or faults during data sourcing (https://gephi.org/features/, Access date 11.09.2019). VOSviewer is a software tool for constructing and visualizing bibliometric networks. These networks may for instance include journals, researchers, or individual publications, and they can be constructed based on citation, bibliographic coupling, co-citation, or co-authorship relations. VOSviewer also offers text mining functionality that can be used to construct and visualize co-occurrence networks of important terms extracted from a body of scientific literature (https://www.vosviewer.com/, Access date 11.09.2019).

The performance indicators in the study; Total Publication (TP) show the total publication regarding the subject. Total Citation (TC), indicate the total number of citations regarding the publications about the subject. Citation per Publication show the number of citations per publication, it is calculated by dividing the total citation (TC) to total publication (TP). Lastly, the H-index (Hirsch, 2005) is a performance indicator that is utilized to evaluate the scientific publication of the researcher, developed by Hirsch.

3. Bibliometric Analysis

Bibliometric analysis is used to guide and inspire future researchers by identifying trends related to a research topic. This research method enables to see the popular years of a particular research topic, the countries, the most published journals, research fields, institutes and contributing authors and researchers to discover trends in the research subject at a glance. Bibliometric methods have benefited from technological advances in data processing and are statistically reliable. In this

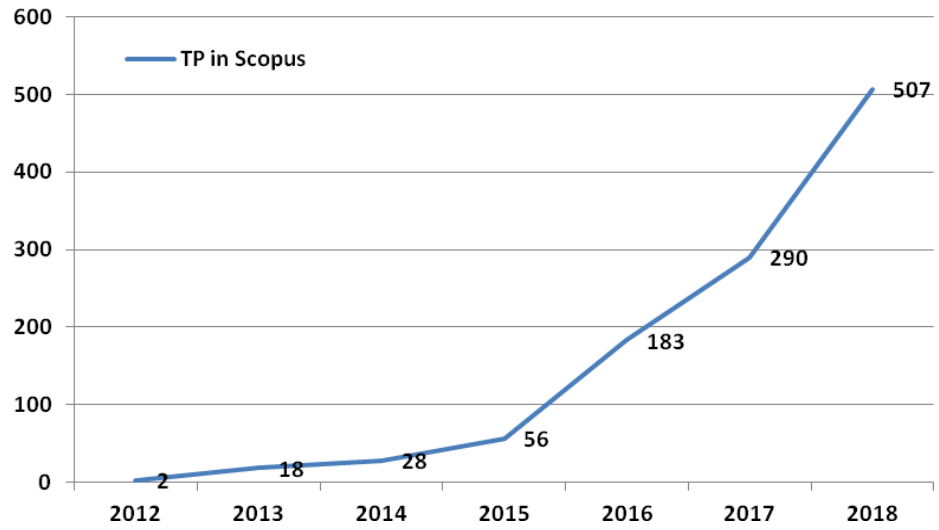
study, the outputs were obtained by statistical analysis of mostly academic articles indexed in the main databases.

In this section of the analysis, the bibliometric analysis results are provided. These results were reviewed under various headlines in Scopus such as research development, most productive and most cited authors, most published areas based on disciplines, journals with most publications, discipline-wise analysis, country-wise analysis, top-source journal, top 10 highly influential papers and top most keywords.

3.1. Research Development

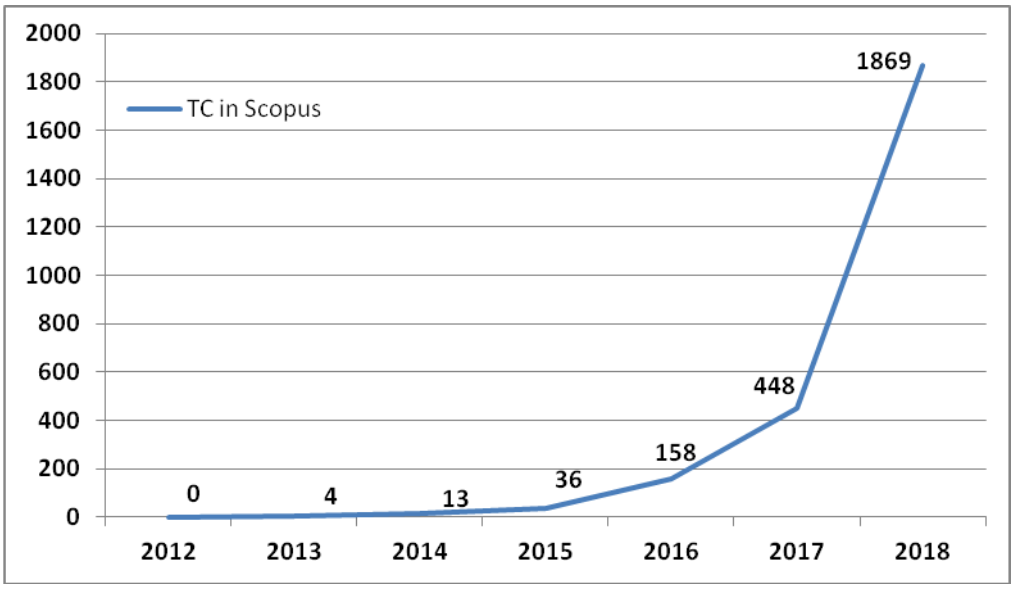
There is an increase in studies about Industry 4.0 in recent years. Figure 2 shows the total publications in Scopus based on years. In Social Sciences field the first studies regarding "Industry 4.0" are first seen in 2012 (TP=2). The highest number of publications is in 2018 with 507 studies. The total number of citations of publications in Scopus is shown in Figure 3.

Figure 2: *Total number of publications in Scopus*



The studies in 2012 did not contain any citations; since these were the first publications regarding the subject, this is to be expected. The total number of citations in 2017 is 448, meanwhile this number increased to 1869 in 2018. Due to the fact that these publications are fairly new, the number of citations is expected to increase with the passage of time. As the publications and citation analyses are reviewed, it is seen that the first publication regarding Industry 4.0 in Scopus database was in 2012, therefore it can be concluded that this is a fairly fresh field of research. Within 6 years, a total of 1084 publications are available in the Scopus database. Furthermore, the number of citations are drastically increased compared to the number of publications.

Figure 3: *Total number of citations in Scopus*



3.2. Most productive and highly cited authors

The most productive authors are listed in Scopus database based on total publications (TP). The authors with the same number of total publications are listed among themselves based on total citations (TP). Based on this method the top 10 most productive authors are listed in Table 2. Voigt, K.I., is the most contributing author in Social Sciences about Industry 4.0 with 8 publications and 168 citations in literature. Voigt, K.I. is followed by Rauch, E. and Telukdarie, A. with the same number of total publications (TP=8). The fourth, fifth and sixth productive authors are Dallasega, P., Kletti, J., and Basl, J. respectively. Basl, J. is on seventh spot with 6 publications. Deschamps, F., Metternich, J. and Theuer H. (TP=5) are in through 8th to 10th spots respectively. Although Theuer, H. has 5 publications, on the date of the analysis the number of total citations (TC) were 0.

Table 2: *Top 10 most productive authors in Scopus*

Authors	TP	TC	CPP
1. Voigt, K.I.	8	168	21
2. Rauch, E.	8	14	1.75
3. Telukdarie, A.	8	3	0.38
4. Matt, D.T.	7	16	2.29
5. Dallasega, P.	7	13	1.85
6. Kletti, J.	7	1	0.14
7. Basl, J.	6	13	2.17
8. Deschamps, F.	5	159	31.8
9. Metternich, J.	5	24	4.8
10. Theuer, H.	5	0	0

The most influential authors are listed in Scopus database based on total citations (TC). The top 10 most influential authors list is shown in Table 3. Kim, H. is the most influential author in Social Sciences regarding Industry 4.0 with a total of 232 citations and 2 publications. The citations for first 8 authors in the list originate from the same article. Furthermore, with a total of 231 citations, including the other published article, Choi, S. takes the second spot as the most influential author. The top 8 authors are Kang, H.S. , Kim, B.H. , Lee, J.Y. , Noh, S.D. , Park, J.H. and Son, J.Y. The 9th and 10th most influential authors, with their joint published article and a total of 210 citation are Shrouf, F. and Miragliotta, G. On the other hand, when the most productive and influential authors list in Scopus database and the lists shown in this paper are compared, the same authors do not feature in Scopus database list. This indicates that the Scopus database index various international conferences and journals and therefore allow a wider group of researchers and readers.

Table 3: *Top 10 most influential authors in Scopus*

Authors	TP	TC	CPP
1. Kim, H.	2	232	116
2. Choi, S.	2	231	115.5
3. Kang, H.S.	1	230	230
4. Kim, B.H.	1	230	230
5. Lee, J.Y.	1	230	230
6. Noh, S.D.	1	230	230
7. Park, J.H.	1	230	230
8. Son, J.Y.	1	230	230
9. Shrouf, F.	1	210	210
10. Miragliotta, G.	1	210	210

3.3. Discipline wise analysis

As a result of queries with "Industry 4.0" as the keyword in Scopus database, publications in "Social Sciences, Business, Business Management, Marketing, Accounting, Finance and Economy" research fields were searched. The breakdown of these studies to the top 10 most published disciplines is shown in Table 4. In addition, the total of the percentages being not equal to 100% in the analysis indicate that the interdisciplinary studies are available. Business and Management (TP=777) is on the top of the list. With the contribution that our subject of research is Industry 4.0 in Social Sciences, 71.67% of the studies in Business and Management discipline shows that Business and Management is a dominant discipline. The most published disciplines are Engineering (TP=584), Decision Sciences (TP=451), Social Sciences (TP=328), Computer Sciences (TP=304), Economy and Finance (TP=139), Mathematics (TP=133), Energy (TP=59), Environmental Sciences (TP=58), Arts and Humanities (TP=31) respectively. Another conclusion that can be drawn from Table 4 is that although the subject of research is limited to Social Sciences, Industry 4.0 is an enormous field of study. Furthermore featuring disciplines such as business, engineering, mathematics, environmental sciences, arts and humanities which are regarded independent in the list indicate the breadth of the integration in interdisciplinary studies.

Table 4: *Top 10 subject areas related to social sciences covered by Industry 4.0*

Discipline		TP	%
1.	Business and Management	777	71.67
2.	Engineering	584	53.87
3.	Decision Sciences	451	41.61
4.	Social Sciences	328	30.25
5.	Computer Science	304	28.04
6.	Economics and Finance	139	12.82
7.	Mathematics	133	12.26
8.	Energy	59	5.44
9.	Environmental Sciences	58	5.35
10.	Arts and Humanities	31	2.85

3.4. Top source journal

In this section of the study, the journals or sources that had the highest number of publications regarding Industry 4.0. The total publications (TP) and total citations (TC) of the journals or the sources are specified in Table 5. The listing of journals and sources are based on the number of publications. Zeitschrift fuer wirtschaftlichen Fabrikbetrieb is the journal with highest number of total publications with 120 publications and 189 citations. The journal is followed by Cogent Business and Management (TP=56,TC=74), Productivity Management (TP=42, TC=26), Advances in Transdisciplinary Engineering (TP=39, TC=34), Lecture Notes in Business Information Processing (TP=33, TC=156), Proceedings of the International Conference on Industrial Engineering and Operations Management (TP=31, TC=13) respectively. International Journal of Production Research holds the seventh spot (TP=26, TC=696) is among the top 10 sources with highest number of total publications and has the highest number of total citations. This journal is followed by 2017 IEEE 15th International Conference on Industrial Informatics with 24 publications and 86 citations. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences (TP=18, TC=41) and 2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC 2018) (TP=17, TC=11) hold the ninth and tenth spot respectively. As the journals, conferences and sources published by studies regarding Industry 4.0, publications in high quality and refereed journals and in different conferences indicate that Industry 4.0 has a large scope in terms of contribution to literature.

Table 5: *Top 10 journals publishing works on Industry 4.0*

Journal	TP	TC
1. Zeitschrift fuer wirtschaftlichen fabrikbetrieb	120	189
2. Cogent Business and Management	56	74
3. Productivity Management	42	26
4. Advances in Transdisciplinery Engineering	39	34
5. Lecture notes in Business Information Processing	33	156
6. Proceedings of the International Conference on Industrial Engineering and Operations Management	31	13
7. International Journal of Production Research	26	696
8. Proceedings -2017 IEEE 15th International Conference on Industrial Informatics Indin 2017	24	86
9. International Archives of the Photogrammetry Remote Sensing and Spatial Information Sciences- ISPRS Archives	18	41
10. 2018 IEEE International Conference on Engineering Technology and Innovation ICE/ITMC 2018- Proceedings	17	11

3.5. Country-Wise Analysis

In this section of the study, the output from the data, the total citation in countries (TC), citation per publication (CPP) and h indexes are specified and listed based on the total publication (TC). This evaluation is shown in Table 6. In Scopus database Germany holds the top spot with 311 publications and a total of 1469 citations. Regarding Industry 4.0, the Scopus database index show at least 17 publications in Germany holds at least 17 citations (h-index=17). Italy, USA and United Kingdom follow Germany with 78, 74 and 62 publications respectively. In addition, the citation per publication (CPP) the top three countries are USA (CPP=10.44), Spain (CPP=10.2) and Brazil (CPP=9.38). Lastly, Czech Republic (CPP=2.51) and Austria (CPP=3.91) have the lowest citation per publication rate although the mentioned countries are in the top 10 in the countries publishing work list. The works published internationally in Scopus database by Germany regarding Industry 4.0 is higher in quantity when compared against other countries.

Table 6: *Top 10 countries publishing work on Industry 4.0 in Scopus*

Authors	TP	TC	CPP	h-index
1. Germany	311	1460	4.69	17
2. Italy	78	537	6.88	10
3. United States	74	773	10.44	12
4. United Kingdom	62	398	6.41	12
5. China	48	227	4.72	9
6. Russian Federation	39	193	4.95	5
7. Brazil	36	338	9.38	7
8. Austria	32	125	3.91	6
9. Czech Republic	31	78	2.51	4
10. Spain	30	360	10.2	6

3.6. Institutions wise analysis

The total publications (TC), total citations (TC), citations per publication (CPP) and h indexes of the institutions that had publications regarding Industry 4.0 in Scopus database are specified and they are categorized as top 10 based on their total publications (TP). For institutions with the same number of total publications (TP), their number of citations (TC) are taken into consideration in classification. In publications regarding Industry 4.0 indexed in Scopus, Rheinisch-Westfälische Technische Hochschule Aachen Institution and University of Johannesburg have the top two spots with 16 publications. Friedrich-Alexander-Universität Erlangen-Nürnberg (TP=14, TC=217) holds the third spot in the list, however it's the only institution with an h-index of 6. Furthermore, it is the second most cited institution (TC=217) and most cited per publication (CPP=15.5) in the top 10 list. The most accomplished institution in terms of citing is Institution of Politecnico di Milano (TP=10, TC=253). The most prominent technical institution of Italy, Politecnico di Milano, with a citing per publication (CPP) of 25.3 is extremely accomplished compared to other publishing institutions.

Table 7: *Top 10 leading institutions publishing on Industry 4.0*

Institutions	TP	TC	CPP	h-index
1. Rheinisch-Westfälische Technische Hochschule Aachen	16	40	2.5	3
2. University of Johannesburg	16	5	0.31	1
3. Friedrich-Alexander-Universität Erlangen-Nürnberg	14	217	15.5	6
4. TU Dortmund University	13	73	5.61	5
5. Technical University of Munich	13	36	2.76	4
6. Politecnico di Milano	10	253	25.3	3
7. Vysoká škola ekonomická v Praze	10	19	1.9	2
8. Gottfried Wilhelm Leibniz Universität	9	31	3.44	3
9. Universität Stuttgart	9	29	3.22	3
10. Technische Universität Dresden	9	21	2.33	3

In this section of the study, the most cited 10 articles in Scopus are reviewed. The names of the

studies, their citations based on years are specified in Table 8; also the publications are cited in References. Publication with the highest number of citations (Kang, et. al. 2016), has a total of 230 citations. The second place in highest number of citations is (Shrouf, Ordieres ve Miragliotta; 2014) with 210 citations. Other publications exceeding 100 citations are; (Liao, et. al. 2017) TC=176, (Ivanov, et. al. 2016) TC=131, (Kagermann, 2015) TC=125, (Schmidt, et. al. 2015) TC=116, (Xu, Xu and Li; 2018) TC=114 and (Roblek, Meško and Krapež; 2016) TC=103. Furthermore, publications in top 10 with less than 100 citations are (Sanders, Elangeswaran and Wulfsberg; 2016) TC=76 and (Theorin , et. al. 2017) TC=70, respectively. As the articles that are most frequently searched in Scopus and the most cited articles are reviewed, it is seen that articles published prior to 2014 have no citations. As the citations for the last two years are reviewed, the increase in studies conducted regarding Industry 4.0 reflect on the number of citations and continue to increase.

Table 8: *Breakdown of number of citations of the most cited articles based on years*

Publications/ Year	2012	13	14	15	16	17	2018	2019	Total
Smart manufacturing: Past research, present findings and future directions (2016)	0	0	0	0	9	40	93	88	230
Smart factories in Industry 4.0: A review of the concept and of energy management approached in production based on the Internet of Things paradigm (2014)	0	0	0	1	21	37	75	76	210
Past, present and future of Industry 4.0-a systematic literature review and research agenda proposal (2017)	0	0	0	0	0	2	83	91	176
A dynamic model and an algorithm for short-term supply chain scheduling (2016)	0	0	0	0	8	18	50	55	131
Change through digitization- value creation in the age of industry 4.0 (2015)	0	0	0	0	12	15	57	41	125
Industry 4.0 - potentials for creating smart products: Empirical research results (2015)	0	0	0	0	10	21	49	36	116
Industry 4.0 - State of the art and future trends (2018)	0	0	0	0	0	0	33	81	114
A complex view of Industry 4.0 (2016)	0	0	0	0	0	15	44	44	103
Industry 4.0 implies lean manufacturing: Research activities in industry 4.0 function as enablers for lean manufacturing (2016)	0	0	0	0	1	8	37	30	76
An event driven manufacturing information system architecture for Industry 4.0 (2017)	0	0	0	0	0	9	35	26	70

3.7. Topmost keywords in Scopus

In this section of the study, the most searched keywords in publications regarding Industry 4.0 indexed in Scopus database are reviewed. The keywords specified by the authors in their respective works are analyzed and visualized via VOS viewer. As seen in Figure 4, as expected, the most utilize keyword is "Industry 4.0". Other keywords accumulated around the center and utilized in connection with "Industry 4.0" are "Internet of Things", "Smart Manufacturing", "Digitalization", "Big Data". In addition, the keywords, author names, references, headers and abstracts are removed from the articles and the most frequently utilized words are analyzed, and visualized in Figure 5 via R Studio and Gephi software. As seen in Figure 5 the most utilized words are placed from largest to smallest and placed based on center location. As result of the analyze, it is seen that the publications contained 105 "manufacture", 77 "management", 72 "engineering", 56 "decision making", 50 "Industry 4.0".

Figure 4: *Most popular keywords in Scopus (VOSviewer)*

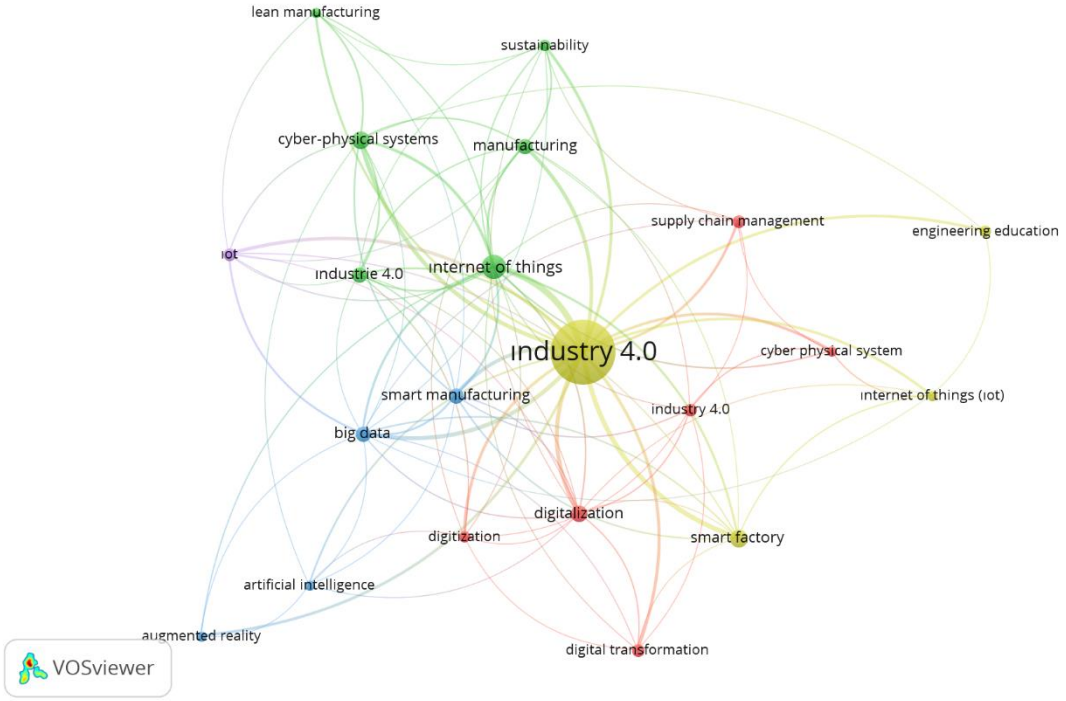


Figure 5: *Most popular keywords in Scopus*

4. Conclusion and Discussions for Future Researches

Continuing to progress further even today, Industry 4.0 provides a technologically, organizational and managerial new perspective for manufacturers, managers and scientists. Therefore the academic literature works regarding Industry 4.0 have increased drastically in recent years. Finding out the fields, countries and authors' contribution to the subject in terms of conducting studies and their influence on other studies, published studies regarding Industry 4.0 in social sciences is the subject of this study. For this purpose, bibliometric analysis method is utilized and the works published in Scopus under Social Sciences are reviewed.

As a result of queries with "Industry 4.0" as the keyword in Scopus database, publications in "Social Sciences, Business, Business Management, Marketing, Accounting, Finance and Economy" research fields were searched and a total of 1084 data were found. Various sets of results were obtained via VOSviewer and Gephi software. Based on these results, the first work regarding Industry 4.0 was published in 2012 and a total of 1084 works were published in Scopus database until 2018; furthermore the number of citations drastically increased throughout the years. Furthermore the most productive and most influential authors' list were created. As the disciplines that study Industry 4.0 are reviewed, it is seen that Business and Management fields, and Engineering are the most prominent disciplines in terms of working on Industry 4.0. It is seen that among other results. Germany has most publications, and a German journal is the most cited journal. In parallel, for publications that feature Industry 4.0 and indexed in Scopus, Rheinisch-Westfälische Technische Hochschule Aachen Institution and University of Johannesburg share the top two spots with 16 publications. Lastly the keywords specified in the authors' articles in Scopus database are visualized. Based on this, it is seen that the most prominent keywords are "Industry 4.0, Internet of Things, Smart Manufacturing, Manufacturing, Digitalization, Big Data, and Cyber Physical Systems" among others, which shape the main subject of Industry 4.0. These results are similar in works of Muhuri et. al (2019), Liao et. al (2017) and Trotta, Grengo (2018). In the aforementioned works, the concepts such as Industry 4.0, Cyber Physical Systems, Manufacturing, Smart Factories and Internet of Things are used as keywords. Despite the differences in labels adopted by different countries in terms of Industry 4.0, it is indicated by the results of this study and Trotta, Grengo (2018) that the fundamental concepts covered by the researchers are the same.

Pioneered by Germany, it is seen that the concept of Industry 4.0 still pioneered by Germany in terms of publishing journals and institutions based in Germany. However from BRIC countries, with China at the forefront, Brazil and Russia follow Germany closely and it would not be wrong to assume that researchers from these countries will be known in the literature in the near future. This conclusion is consistent with the study conducted by Liao et.al (2017). Similarly, Muhuri et. al (2019) indicated that Germany and China are two countries that pioneer Industry 4.0 in both Web of Science and Scopus databases. China aims to further enhance Industry 4.0 in 2025 manufacturing plans and use the concept as a means to restructure its manufacturing technologies (Lu, 2017:8). This also indicates that China is positioned well to adopt Industry 4.0.

As the field of Industry 4.0 expands, it is possible to foresee that since new authors are contributing to the literature, this concept may create new sub disciplines in the future. The most prominent feature that differentiates this study from other studies is that this study reviewed the literature in Social Sciences in the database. This study, reviewing the change the number of publications and citations regarding Industry 4.0 throughout the years is seen as a limitation by the authors since it is only focusing on the numbers and not featuring a review regarding the quality of the studies mentioned. Furthermore, analyzing solely the studies available in Scopus database is another limitation. The researchers' browsing other databases such as Web of Science or Google Scholar with different analysis tools will provide a guidance to future studies.

Yazarlık Katkıları (Authorship Contributions): Gencay Tepe, Burcu Mucan Özcan.

References

Alçin, S. (2016). Üretim için yeni bir izlek: Sanayi 4.0. *Journal of Life Economics, 3*(2), 19-30.

Ashton, T. S. (1997). *The industrial revolution 1760-1830.* Oxford: Oxford University Press.

Banger, G. (2018). *Endüstri 4.0 ve akıllı işletme*. Eskişehir: Dorlion Press

Baumeister, R. F., & Leary, M. R. (1997). Writing narrative literature reviews. *Review Of General Psychology, 1*(3), 311-320.

Belvedere, V., Grando, A., & Bielli, P. (2013). A quantitative investigation of the role of information and communication technologies in the implementation of a product-service system. *International Journal of Production Research, 51*(2), 410-426.

Bogers, M., Hadar, R., & Bilberg, A. (2016). Additive manufacturing for consumer-centric business models: Implications for supply chains in consumer goods manufacturing. *Technological Forecasting And Social Change,* 102, 225-239.

Bornmann, L., & Mutz, R. (2015). Growth rates of modern science: A bibliometric analysis based on the number of publications and cited references. *Journal of the Association for Information Science and Technology, 66*(11), 2215-2222.

Bozkurt, Ç.Ö., & Çetin, A. (2016). Girişimcilik ve kalkınma dergisi'nin bibliyometrik analizi. *Girişimcilik ve Kalkınma Dergisi, 11(2),* 229-263.

Drath, R., & Horch, A. (2014). Industrie 4.0: hit or hype?. *IEEE Industrial Electronics Magazine, 8*(2), 56-58.

Fahimnia, B., Sarkis, J., & Davarzani, H. (2015). Green supply chain management: A review and bibliometric analysis. *International Journal of Production Economics,* 162, 101-114.

Fırat, S. Ü., & Fırat, O. Z. (2017). Sanayi 4.0 devrimi üzerine karşılaştırmalı bir inceleme: kavramlar, küresel gelişmeler ve Türkiye. *Toprak İşveren Dergisi, 114*(2017), 10-23.

Frank, A. G., Mendes, G. H., Ayala, N. F., & Ghezzi, A. (2019). Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. *Technological Forecasting and Social Change,* 141, 341-351.

Gülseren, A., & Sağbaş, A. (2019). Endüstri 4.0 perspektifinde sanayide dijital dönüşüm ve dijital olgunluk seviyesinin değerlendirilmesi. *European Journal of Engineering and Applied Sciences, 2*(2), 1-6.

Günay, D. (2002). Sanayi ve sanayi tarihi. *Mimar ve Mühendis Dergisi, 31*(2002), 8-14.

Günaydın, D. (2018). Türkiye'de dördüncü sanayi devrimini beklerken: çerkezköy organize sanayi bölgesi'nde bir araştırma. *Institute of Business Administration-Management Journal, 29*(85), 73-106.

Hirsch, J. E. (2005). An index to quantify an individual's scientific research output. *Proceedings of the National academy of Sciences, 102*(46), 16569-16572.

Hoffman, E., & Rüsch, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry,* 89, 23–34.

Hotamışlı, M., & Erem, I. (2014). Muhasebe ve Finansman Dergisi'nde yayınlanan makalelerin bibliyometrik analizi. *Muhasebe ve Finansman Dergisi,* 63, 1-20.

Kagermann, H. (2015). Change through digitization—Value creation in the age of Industry 4.0. In *Management of permanent change* (pp. 23-45). Wiesbaden: Springer Gabler

Ivanov, D., Dolgui, A., Sokolov, B., Werner, F., & Ivanova, M. (2016). A dynamic model and an algorithm for short-term supply chain scheduling in the smart factory industry 4.0. *International Journal of Production Research*, *54*(2), 386-402.

Jazdi, N. (2014, May). *Cyber physical systems in the context of Industry 4.0.* Paper presented at Automation, Quality and Testing, Robotics, 2014 IEEE International Conference, Cluj-Napoca, Romania. Retrieved from https://ieeexplore.ieee.org/abstract/document/6857843

Kagermann, H. (2015). Change through digitization—Value creation in the age of Industry 4.0. In Management of permanent change (pp. 23-45). Wiesbaden: Springer Gabler

Kang, H. S., Lee, J. Y., Choi, S., Kim, H., Park, J. H., Son, J. Y., & Do Noh, S. (2016). Smart manufacturing: Past research, present findings, and future directions. *International Journal Of Precision Engineering and Manufacturing-Green Technology*, *3*(1), 111-128.

Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering*, *6*(4), 239-242.

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

Lobo-Almada, F. (2015). Industry 4.0 revolution and the future of the manufacturing execution systems (MES*). Journal of Innovation Management*, *JIM 3, 4* (2015), 16-21.

Lu, Y. (2017). Industry 4.0: A survey on technologies, applications and open research issues. *Journal of Industrial Information Integration*, *6*, 1–10.

Lukaˇc, D. (2015, November). *The fourth ICT-based industrial revolution Industry 4.0? HMI and the case of CAE/CAD innovation with EPLAN P8*. Paper presented at *23rd* Telecomunications Forum (TELFOR*)*, Belgrade, Serbia. Retrieved from https://ieeexplore.ieee.org/document/7377595

Mrugalska, B., & Wyrwicka, K.M. (2017). Towards lean production in industry 4.0. *Procedia Engineering*, 182, 466 – 473.

Muhuri, K.P., Shukla, K.A., & Abraham, A.(2019). Industry 4.0: A bibliometric analysis and detailed overview. *Engineering Applications of Artificial Intelligence*, *78*(2019), 218–235.

Nolin, J. & Olson, N. (2016). The internet of things and convenience. *Internet Research*, *26*(2), 360-376.

Oesterreich, D.T., & Teuteberg, F. (2016). Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. *Computers in Industry, 83*(2016), 121–139.

Porter, M. E., & Heppelmann, J. E. (2014). How smart, connected products are transforming competition. *Harvard Business Review*, *92*(11), 64-88.

Roblek, V., Meško, M., & Krapež, A. (2016). A complex view of industry 4.0. *Sage Open*, *6*(2), 1-11.

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). Industry 4.0: The future of productivity and growth in manufacturing industries. *Boston Consulting Group*, *9*(1), 54-89.

Sanders, A., Elangeswaran, C., & Wulfsberg, J. P. (2016). Industry 4.0 implies lean manufacturing: Research activities in industry 4.0 function as enablers for lean

manufacturing. *Journal of Industrial Engineering and Management (JIEM*), *9*(3), 811-833.

Schmidt, R., Möhring, M., Härting, R. C., Reichstein, C., Neumaier, P., & Jozinović, P. (2015). Industry 4.0-potentials for creating smart products: empirical research results. In Abramowicz W. (Ed.), *Business Information Systems BIS 2015 Lecture Notes in Business Information Processing* (pp. 16–27). Cham:Springer.

Shrouf, F., Ordieres, J., & Miragliotta, G. (2014, December). *Smart factories in Industry 4.0: A review of the concept and of energy management approached in production based on the Internet of Things paradigm*. Paper presented at 2014 IEEE International Conference On Industrial Engineering And Engineering Management, Bandar Sunway, Malaysia. Retrieved from https://ieeexplore.ieee.org/document/7058728

Sivathanu, B. & Pillai, R. (2018), Smart HR 4.0 – how industry 4.0 is disrupting HR. *Human Resource Management International Digest, 26*(4), 7-11.

Stange,R. & Zucchella, A. (2017). Industry 4.0, global value chains and international business, *Multinational Business Review, 25*(3), 174-184.

Tayfun, A., Ülker, A., Gökçe, Y., Tengilimoğlu, E., Sürücü, Ç., & Durmaz, M. (2018). Turizm alanında yiyecek ve içecek ile ilgili lisansüstü tezlerin bibliyometrik analizi. *Journal of Tourism and Gastronomy Studies, 6/2*(2018), 523-547.

Tayfun, A., Küçükergin, G.F., Aysen, E., Eren, A., & Özekici, K.Y. (2016). Turizm alanında yazılan lisansüstü tezlere yönelik bibliyometrik bir analiz. *Gazi Üniversitesi Turizm Fakültesi Dergisi, 1*(2016), 50-69.

Theorin, A., Bengtsson, K., Provost, J., Lieder, M., Johnsson, C., Lundholm, T., Lennartson, B. (2017). An event-driven manufacturing information system architecture for Industry 4.0. *International Journal of Production Research, 55*(5), 1297-1311.

Trotta, D., & Garengo, P. (2018, March). *Industry 4.0 key research topics: A bibliometric review.* Paper presented at 7th International Conference On Industrial Technology And Management (ICITM), Oxford, United Kingdom. Retrieved from https://ieeexplore.ieee.org/document/8333930

Vaidya, S., Ambad, P. & Bhosle, S. (2018). Industry 4.0: A glimpse. *Procedia Manufacturing, 20*(2018), 233–238.

Wahlster, W. (2012, May). *From industry 1.0 to industry 4.0: Towards the 4th industrial revolution.* Paper presented at Forum Business Meets Research, Luxembourg.

Xu, L. D., Xu, E. L., & Li, L. (2018). Industry 4.0: state of the art and future trends. *International Journal of Production Research, 56*(8), 2941-2962.

Zhou, K., Liu, T., & Zhou, L. (2015, August). *Industry 4.0: Towards future industrial opportunities and challenges.* Paper presented at 2015 12th International conference on fuzzy systems and knowledge discovery (FSKD), Zhangjiajie, China. Retrieved from https://ieeexplore.ieee.org/abstract/document/7382284

https://gephi.org/features/, Access Date 11.09.2019.

https://www.vosviewer.com/, Access Date 11.09.2019.