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A Decade of Research on Industry 4.0: A Bibliometric Study of Key Research Areas with Life Cycle Analysis of Publication Dynamics

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Abstract:

Purpose: *The aim of the research is to investigate the dynamics of scientific publications on Industry 4.0 and to present the idea of Industry 4.0 on the basis of publications using the life cycle of research areas.*
Approach/Methodology/Design: *Over the last few years, the fourth industrial revolution has attracted more and more attentions all around the world. A decade has passed since the concept of Industry 4.0 was initiated. In 2011, for the first time a German business and government group presented a new technical strategy called: "Industrie 4.0". Since that year, the concept of Industry 4.0 has been popularised around the world, especially in highly developed countries whose industries have implemented the technological innovations of the third industrial revolution. Today, after a decade since the initiation of the Industry 4.0 concept, it is worth taking stock of the global development of science on the basis of the Industry 4.0 idea. In this paper a bibliometric analysis of world scientific works in the area of the Industry 4.0 concept was carried out. Scientific publications placed in the Web of Science (WoS) database were analysed. The time scope of the analysis covered the period from 2011 to 2021. The analysis is a reconstruction of development trends of the Industry 4.0 concept on the basis of scientific works of researchers from all over the world.*
Findings: *The results of the performed analysis created an interesting picture of knowledge about Industry 4.0 focused around the idea of this concept of industrial development, and presented chronologically and historically using the method of life cycle of the analysed research subject.*
Practical Implications: *The utilitarian aspect of the work is the methodology of the publication life cycle used, based on the dynamics of the number of publications in the WoS scientific database.*
Originality/Value: *The added value of the research is the use of the product life cycle to perform a bibliometric analysis on the topic of Industry 4.0, where the product life cycle is replaced by a life cycle developed from the dynamics of publications on Industry 4.0.*

Keywords: *Industry 4.0, bibliometric analysis, life cycle analysis.*
JEL classification: *D25, L61, O33.*
Paper Type: *Literature review.*

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1. Introduction

Since 2011, when the German government presented the concept of Industry 4.0, industries strongly influenced by the idea of Industry 4.0 started to create Industry 4.0. Regardless of the type of activity, the influence of new technologies of the fourth industrial revolution is visible everywhere. The pace and scale of changes enforces the necessity of conducting analyses and scientific research whose aim is to build knowledge about Industry 4.0. In 2011, scientists and practitioners started to create knowledge and provide information about the ongoing industrial revolution. Publications of significant scientific importance are placed in global scientific databases.

The collection of publications gathered, in scientific databases, can be analysed by different areas and subjects, as well as by time and by scientific indexes. The basic method of analysing the collection of scientific publications is bibliometric analysis as a method of assessing the research results of the scientific world. Bibliometric analysis is a measure of scientific achievements based on quantification of quantitative data about scientific publications and their authors (Norton, 2001). The aim of this paper was to analyse the dynamics of publications on Industry 4.0. The paper is based on the analysis of bibliometric data collected in the WoS database from 2011 to 2021 for the subject (Industry 4.0).

2. About the Concept of Industry 4.0

Since the concept of Industry 4.0 was initiated, there have been difficulties in defining it. It is difficult to search in literature for a universal definition of Industry 4.0, which has been copied by other authors. Industry 4.0 is both a paradigm and a philosophy of the development of industry in the fourth revolution, as well as a set of key technologies of that revolution which, when introduced (implemented) in enterprises, will create cyber-physical production systems in place of old manufacturing systems, and factories will transform into smart factories. Industry 4.0 is a popular term to describe the trend towards digitisation and automation of the manufacturing environment (Oesterreich and Teuteberg, 2016). Background for Industry 4.0 is an increasing use of automation, data processing and exchange, cyber-physical systems, Internet of things and cloud technology in industry. Industry 4.0 is a modern concept of development and global challenge for the existence of manufacturing sectors. The Industry 4.0 concept represents a paradigm shift where physical objects are seamlessly integrated into information networks (Cattaneo *et al.,* 2017).

Industry 4.0 is a megatrend and a strongly popularised change in the fourth revolution. This megatrend focuses on the establishment of intelligent products and production processes as future manufacturing factories have to cope with the need of rapid product development and flexible production, as well as complex environments (Erro-Garcés, 2020 based on Vyatkin *et al.,* 2007).

Companies creating Industry 4.0, aim to make their production intelligent, which requires the construction of cyber-physical production systems. The architecture of cyber-physical production systems (CPPS), was proposed by Lee *et al.* (2015): 1. Connection level, 2. Conversion level, 3. Cyber level, 4. Cognition level, 5. Configuration level. Cyber-physical systems are engineering systems to monitor, control and integrate operations in physical and computer (digital) systems (structures) (Flores *et al.*, 2020 based on Monostori *et al.*, 2016). Roblek *et al.*, 2016 based on: Almada-Lobo, 2016; Schlechtendahl, Keinert, Kretschmer, Lechler and Verl, 2015) listed three basic technological components that form the framework of Industry 4.0, they are: 1. Digitization of production –information systems for management and production planning, 2. Automation – systems for data acquisition from the production lines and using machines, 3. Linking manufacturing sites in a comprehensive supply chain-Automatic Data Interchange.

Industry 4.0 is defined by smart, efficiency, effectiveness, optimisation, dynamism, personalisation and castomisation of production at reasonable (acceptable) costs (Kumar and Kumar, 2020). In this Industry 4.0, the Internet of Things (IoT) has an important place, without which the CPS in smart factories does not function. IoT, and in particular the Industrial Internet of Things (IIoT) as a huge collection of industrial computers, sensors, installations, networked systems. IIoT enables communication, data exchange and analysis between installations and products (Boyes *et al.*, 2018).

Internet allows a continuous interaction and exchange of information between humans (C2C) and human and machine (C2M) and between the machines themselves (M2M) (Cooper and James, 2009). Greengard, 2015 proposed four components of Industry 4.0, cyber-physical systems (connections between the real and virtual worlds), the Internet of Things (IoT) which increases the data available as different products can be connected to the Internet, the Internet of Services and the smart factory. There is no universal path to building a smart factory, each company sets its own path towards Industry 4.0 (Gajdzik *et al.*, 2021).

In the popularised concept of Industry 4.0 there is also a place for Human - Operator 4.0. Romero and his team (2016) proposed to extend CPS with Human and the acronym H- CPS was created from the full name: Human Cyber-Physical Systems. Romero *et al.* (2016) defined the figure of the "Operator 4.0" as a smart and skilled operator who performs "work aided" by machines if and when needed.

Over time, the concept of Industry 4.0 exposes sustainability (Gajdzik *et al.*, 2020). Companies want to save resources and diversify energy sources (Wolniak *et al.*, 2021; Gajdzik *et al.*, 2021). Industry 4.0 is based on interoperability among smart factories, products and services embedded in the Industrial Internet of Things (IIoT), which provides huge opportunities for sustainable manufacturing using ubiquitous information and ICT infrastructure (Garrido-Hidalgo *et al.*, 2016).

Characteristic of Industry 4.0 is increased competitiveness through smart equipment, making use of information about high-wage locations, demographic changes, resources, energetic efficiency, and urban production (Heck and Rogers, 2014). To conclude, the introduction draws the conclusion that the concept of Industry 4.0 can be framed narrowly or broadly, and that the scope of research into the components that make up Industry 4.0 appears to be limitless in the ongoing fourth industrial revolution, from enterprises along with supply chains to ecosystems. Industry 4.0 projects implemented in companies start from simple changes in workstations to complex projects in entire supply chains as the collaboration between suppliers, manufacturers and customers (Tjahjono *et al.,* 2017).

It can be assumed that the vast research opportunities have not been exhausted and the concept will be the subject of many publications in the next decade.

3. Research Approach and Method

In the research procedure, bibliometric analysis of scientific publications on Industry 4.0 was applied. The term bibliometrics was first introduced to the scientific community by Alain Pritchard in 1969 and was quickly used to assess the number of publications by individual authors or scientific centres. Many authors have undertaken the task of defining bibliometric analysis and its essence, among them were Norton (2001), Polanco (1995), Stefaniak (2008), Nowak (2006). Norton (2001) states that a bibliometric study is a measurement of literature used for specific, by the user (researcher), purposes. Studies are most often reportable.

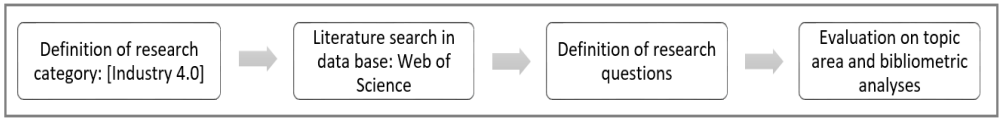
Stefaniak (2008) emphasizes that bibliometrics is the application of quantitative methods to study the state and developmental tendencies of the literature on the basis of various criteria of evaluation of scientific publication databases. According to Palanco (1995) the bibliometric method is a description of the evolution of research in a given topic using quantitative criteria (indicators). According to Nowak (2006), bibliometric studies find application in describing and explaining scientific phenomena. The application of bibliometrics allows the user to trace the interest of other users in a particular research topic.

The bibliometric analysis identifies the author(s) of the publication, the affiliation of the authors, the extent of the authors' collaboration (bibliographic links, citations), the publisher of the publication, the country or region of origin of the publication, the year of publication, the number of citations, the IF of the publication, the form of access to the publication, and the research areas and keywords.

Many researchers (Hart, 1998; Cook *et al.,* 1997; Mulrow, 1994; Czakon, 2011; Bocken *et al.,* 2014; Tranfield *et al.,* 2003) identify and discuss three stages of bibliometric analysis, research planning, research implementation, reporting. In the present study according to the mentioned research stages the research area for Industry 4.0 was established and the data source was selected from the scientific

database of Web of Science (WoS) publications. The analysis time was limited; the analysis period is from 2011 to 2021 (from 2011-12-31 to 2021-12.31). Key bibliographic criteria were applied in the analysis number, type, country, language, research areas. The records (data sets) created were analysed using Excel and VOSviewer. The obtained results of the bibliometric analysis were described in the publication. The scheme of the research procedure was presented in Figure 1.

Figure 1*. Research approach*



Source: *Own elaboration.*

Purpose: The aim of the research is to investigate the dynamics of scientific publications on Industry 4.0 and to present the idea of Industry 4.0 on the basis of publications using the life cycle of research areas.

The research questions were set as follows:

Research Question 1: What is the dynamics of publication about Industry 4.0 and the development of the publications based on the life cycle of the research area?
Research Question 2: What is the essence of the concept of Industry 4.0 and the content of research records?

Argumentation for choosing the WoS database: the Web of Science database is a consistent database of scientific publications used by scientific institutions around the world. The database collects many biometric indicators and contains literature from many disciplines. The WoS database thematically covers the sciences, technology, social sciences, humanities, medicine and the arts. The database indexes articles from over 12,000 titles of scientific journals and conference proceedings. The WoS database has a high position in the scientific ranking of the number of citations of publications. The use of more databases could duplicate data and even cause problems as the databases are not fully integrated.

4. Results of Bibliometric Analysis

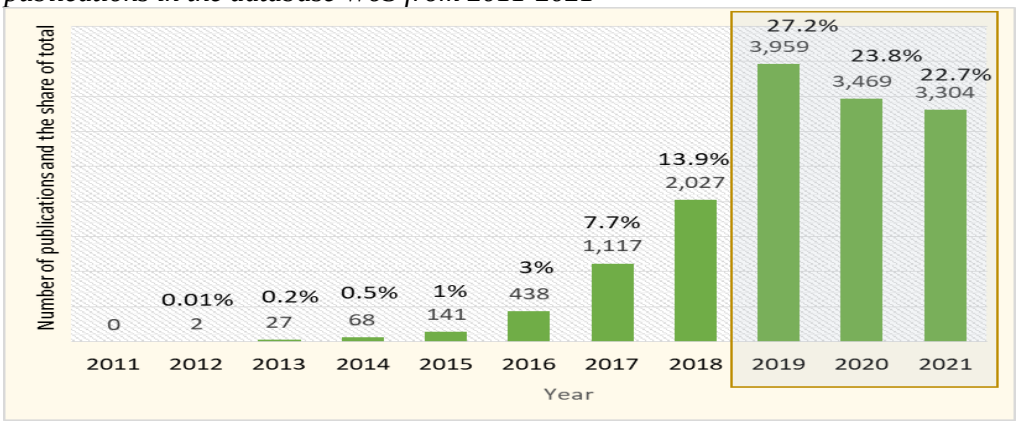
Based on the analysis of scientific publications in the WoS database, the size of the collection was determined 14,627 publications, including 75 publications published in the period from 2011 to 2021, which were published in the last days and concerned the year 2022 (the database search was completed on 23 January 2022). In the set of all publications, 6201 publications (42.4%) had full access mode (open access). On the basis of bibliometric data, it was determined that the subject of Industry 4.0 was initiated in scientific publications of 2012. In the first year of analysis, 2011, no publication on Industry 4.0 was registered in the WoS database.

The first two scientific publications appeared, in the WoS database, only in 2012, and they were:

- Smartphone Green Vision at Dawn of Industry 4.0: Hofmann D., Margull R., (...), Duntsch, E., in: 7th International Conference on MEMS, NANO and Smart Systems (ICMENS 2011); 2012, MEMS, NANO AND SMART SYSTEMS, PTS 1-6 403-408, pp. 4079;
- Industry 4.0: GMA wants to develop current ICT Trends specifically for the Automation: Bettenhausen K.D., 2012, ATP EDITION (6), pp. 8-8.

In the following years, the number of publications increased rapidly. At the end of 2021, the number of publications (excluding publications dated 2022) was 14552. The trend in the number of publications is shown in Figure 2. The share of publications by year in the total set of publications, which was highest in 2019 and was over 27%. In the following two years, the share of publications in total publications was above 20%.

Figure 2*. Number of publications in the field: „Industry 4.0" and the share in total publications in the database WoS from 2011-2021*



Source: *Own elaboration based on records obtained from WoS database.*

Conclusions:

based on the analysis of the number of publications on Industry 4.0 in the studied period, it was found that:

- the most publications were in 2019 then the number of publications in the database was 3,957 (share in the total number of publications was 27.2%),
- the least number of publications was in 2012, only 2 publications included in the database (share 0.01%),
- in the last two years there was a decrease in the number of publications compared to the number of publications in 2019, this could be due to the emergence of another important area of research, the Covid-19 pandemic,

- the dynamics of publications on Industry 4.0 were high throughout the period under review,
- researchers' interest in the Industry 4.0 concept significantly (strongly) increased after 2015 from 141 publications to 3,304 publications in 2021,
- in the first years after the concept of Industry 4.0 was created, there was no significant increase in the number of publications despite the fact that the beginning of the concept was dated 2011, the first two publications were registered in the database in 2012,
  the period of emergence of the scientific research area about Industry 4.0 was from 2012 to 2015, after 2015 the dynamics of publications was high and in 2019 the highest number of publications was recorded, while in 2020 and the following year there was a decrease in the number of publications compared to 2019.

At this stage of the research, the dynamics of publications on Industry 4.0 have been structured according to life cycle phases. Four phases of development were adopted:

Phase I of cycle: emergence (beginnings) of a new research area - at this stage the first scientific publications about Industry 4.0 appeared in the database but the number of publications was small,
Phase II: the growth of scientists' interest in the research area of Industry 4.0 during this phase the number of publications registered in the scientific database, in the adopted research subject, was growing from year to year the dynamics of publication was high, a significant increase of scientific publications on Industry 4.0 in the database was noted,
Phase III: publication maturity - scientific maturity in a given research area reached its maximum, after which the number of publications decreased, the highest number of publications in the analysed time period was noted,
Phase IV: continuation of research in this phase there may be a decrease in the number of publications in comparison to the maximum achieved in phase III, caused by the emergence of new areas of research, which turned out to be more interesting for researchers (scientists) than the previous area of research.

The results of the analysis based on the research area; Industry 4.0 were included in Table 1.

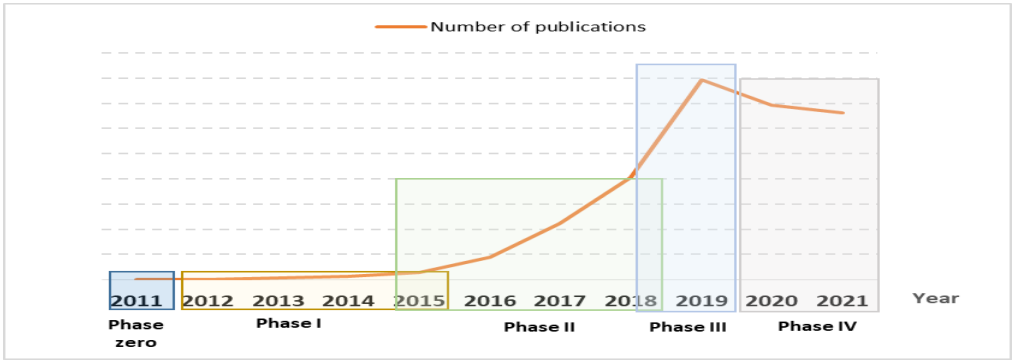
Table 1. *Number of publications on "Industry 4.0" by phases of the research area life cycle*

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of publications	0	2	27	68	141	438	1,117	2,027	3,959	3,469	3,304
Share in total (%)		0.01	0.2	0.5	1.0	3.0	7.7	13.9	27.2	23.8	22.7
Phase of life cycle	Zero	I	I	I	I/II	II	II	II/III	III	IV	IV

Source: *Own elaboration based on records obtained from WoS database.*

Graphically, the life cycle analysis of the research area on Industry 4.0 was shown in Figure 3.

***Figure 3**. Presentation of phases of life cycle for publications about Industry 4.0 based on WoS*



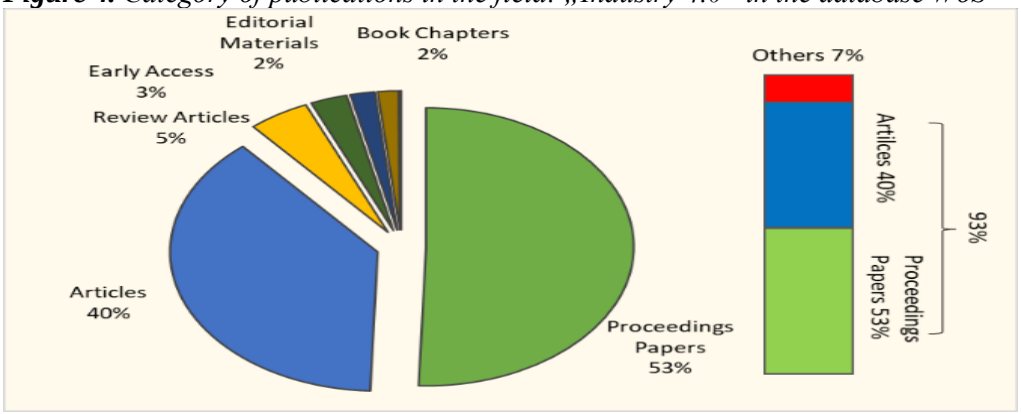
***Source:** Own elaboration based on records obtained from WoS database.*

Conclusions based on the life cycle analysis of the research area on Industry 4.0:

- in the analysed research area: "Industry 4.0" initial phase started in 2012 (2 publications in the WoS database) and continued in the following years, in 2013 there were 27 publications in the database and in 2014 the number of publications increased to 68 but the high level in the phase was recorded only in 2015 - 141 publications; based on the performed analysis it can be considered that 2015 was a breakthrough year for the dynamics of publication in the research area: "Industry 4.0" in the first phase (Phase I) of the cycle,
- in 2016-2019 the research area: "Industry 4.0" was on the rise (phase II), researchers' interest in this topic increased sharply,
- phase III started in 2018 and the most publications were in 2019 (3,959),
- in 2020, for the first time, a decrease in the number of scientific publications on Industry 4.0 was noted, the noted downward trend, however, does not entitle the author to formulate a conclusion about the decline phase due to the short period of analysis, it is rather a phase of continuing research,
- phase IV of the cycle was implemented in 2020-2021 and will be continued in the following years as the research topic - Industry 4.0 is a current scientific area in the ongoing fourth revolution.

Among the found records of publications on Industry 4.0, proceedings papers and scientific articles dominated (Figure 4). The share of proceedings papers in the total number of publications was 53%, and articles was 40%. These two categories together accounted for 93% of all publications.

Figure 4. *Category of publications in the field: „Industry 4.0" in the database WoS*



Source: *Own elaboration based on records obtained from WoS database.*

Among the titles (top 5 list) were Procedia Computer Science; IOP Conference Series Materials Science and Engineering; IFAC Papersonline, Sustainability, 2nd International Conference on Informatics Engineering Science and Technology INCITEST 2019. In the category: publisher, IEEE dominated (23%), the second position was held by Elsevier (20%), in third place was Springer Nature (11%), fourth belonged to MDPI (8%) and fifth to IOP Publishing Ltd (4%). Just behind the top 5 list was Taylor & Francis (3.3%). In the next step, a ranking of Industry 4.0 researchers was extracted (top 5 list) and the results were presented in (Table 2).

Table 2. *List top 5 of publication authors about Industry 4.0*

Position	Name	Share in total	Record count
1.	Bogoviz A.V.	0.321	47
2.	Popkova E.G.	0.294	43
3.	Martinek R.	0.287	42
4.	Romero D.	0.260	38
4.	Xu X.	0.260	38
5.	Rauch E.	0.246	36
5.	Zharinov I.O.	0.246	36

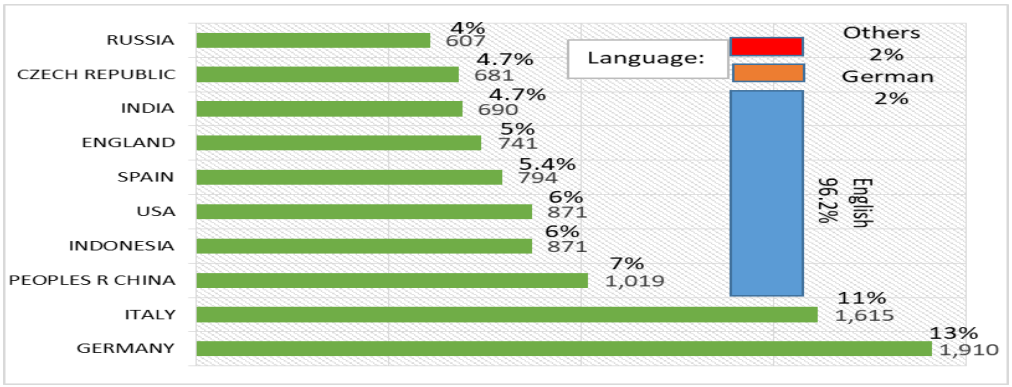
Source: *Own elaboration based on records obtained from WoS database.*

The leading academic institutions (affiliation) were IV Computer Indonesia (number of publications: (239), Polytechnic University of Milan (230), Centre National De La Recherche Scientifique CNRS (156), Ministry of Education Science of Ukraine (149), Fraunhofer Gesellschaft (145).

As the concept of Industry 4.0 started in Germany, the country's share of the total number of publications was the highest at 13%. Italy was second with 11% and China third with 7%. The ranking of the top 10 countries in the database is shown in Figure 5 along with the number of publications. More than 96% of publications

were in English and 2% in German. Other languages of communication amounted to 2%.

Figure 5. *Publication countries and language in the field: „Industry 4.0" in the database WoS*



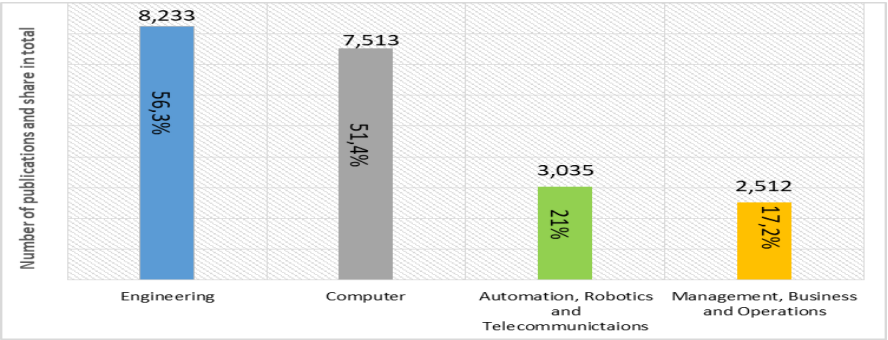
Source: *Own elaboration based on records obtained from WoS database.*

The key scientific areas d were Engineering Electrical Electronic (number of publications 2,297, share 15.7%), Engineering Industrial (2,264, 15.5%), Computer Science Theory Methods (2,225, 15.2%) Engineering Manufacturing (2004, 13,7%), Computer Science Information Systems (1,851, 12.6%), Automation Control Systems (1,492, 10.2%).

The remaining categories were less than 10% and did not belong to the top 5 list. Analysing the wide range of WoS categories, one may draw a conclusion that Industry 4.0 is a multidisciplinary research area. Industry 4.0, as a research area, falls into technical sciences and engineering, into specific areas of management, economics, business and many other fields, e.g., medicine, telecommunications, education, mathematics, art, etc. Based on the list of the top 25, the analysed WoS categories were grouped and two basic segments were obtained.

The first research segment is engineering and the second is computer science. Since each publication was classified into a clique of areas, the proportion of the number of categories assigned to individual publications was more than 50% in these two segments (Figure 6). Explanation: engineering was included in the categories: Engineering Electrical Electronic, Engineering Industrial, Engineering Manufacturing, Engineering Multidisciplinary, Engineering Mechanical, to the category: Computer was added: Computer Science Information Systems, Computer Science Theory Methods, Computer Science Interdisciplinary Applications, Computer Science Artificial Intelligence, Computer Science Hardware Architecture, Computer Science Software Engineering, the third segment included: Robotics, Automation Control Systems and Telecommunication, management included: publications in the area of management and business and Operations Research Management Science.

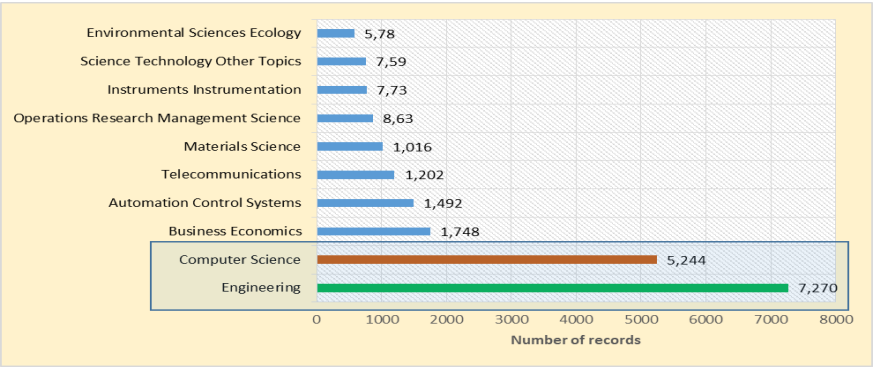
***Figure 6**. Key categories Web of Science in the field: „Industry 4.0" in the database WoS*



***Source:** Own elaboration based on records obtained from WoS database.*

The analysed Web of Science categories coincide with the categories of research areas - the top 10 list is shown in Figure 7. The previous conclusion that engineering and computers are among the key research areas of Industry 4.0 was confirmed.

***Figure 7.** Key categories research areas in the field: „Industry 4.0" in the database WoS*

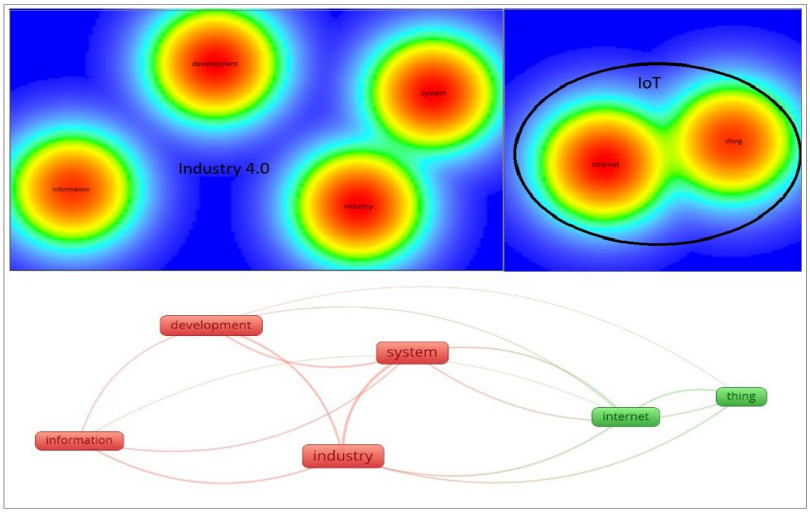


***Source:** Own elaboration based on records obtained from WoS database.*

In the next stage of analysis, a more detailed analysis of the study areas was carried out using the VOSviewer programme, based on the keyword associations used by the authors of the individual publications. Using the Export from WoS database and category: keywords functions, data tables were created for analysis using the VOSviewer computer program. The analysis started from the narrowest range, a few basic keywords, and the density map was then formed by two key segments.

The first segment was directly related to the essence of the Industry 4.0 concept, which is the development of industries based on Cyber-Physical systems in which information is important. The second segment concerned the key technology (pillar) of Industry 4.0, which is IoT. The segments were shown in Figure 8.

Figure 8. *Key areas in the field: „Industry 4.0" – two key segments of analyses*



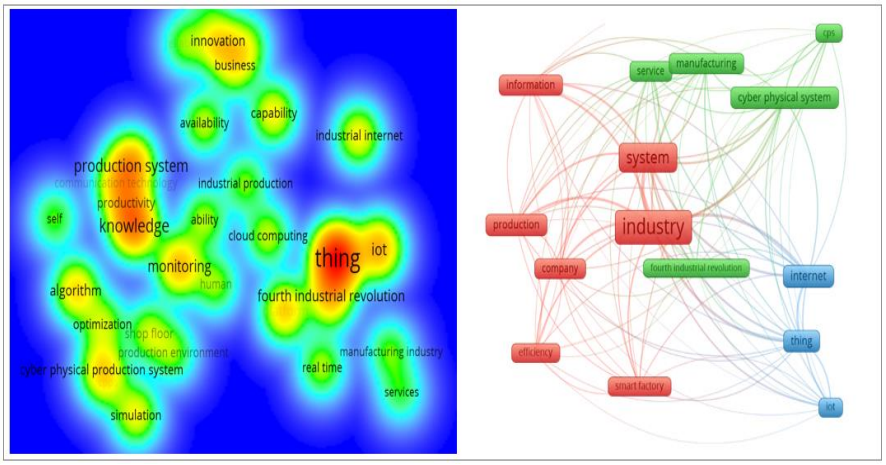
Source: *Own elaboration based on records obtained from WoS database by VOSviewer.*

Gerenral conclusion: Industry 4.0 does not exist without the Internet of Things. IoT connects the individual technologies of Industry 4.0 and enables companies to build smart factories.

In Figure 9, using a limited scope of analysis - keywords - the smallest record that can be retrieved from the WoS database and its analysis using VOSviewer, confirmation was obtained that Industry 4.0 is centred around CPS, IoT, information and efficiency. The aim of Industry 4.0 is to achieve higher efficiency than before. At this stage of the analysis, three segments were obtained, including two legacy segments (shown in Figure 8) and a key segment - CPS. A detailed analysis of the evolution of CPS based on the literature review was performed by the team of Klotzer *et al.* (2017). The team of researchers analysed the CPS, among others, in the arrangement of links with the Internet of Things (IoT), Industry 4.0 or the Industrial Internet. The analysis of the evolution of Cyber-Physical Systems (CPS) within the meta-context of digitalization was realized.

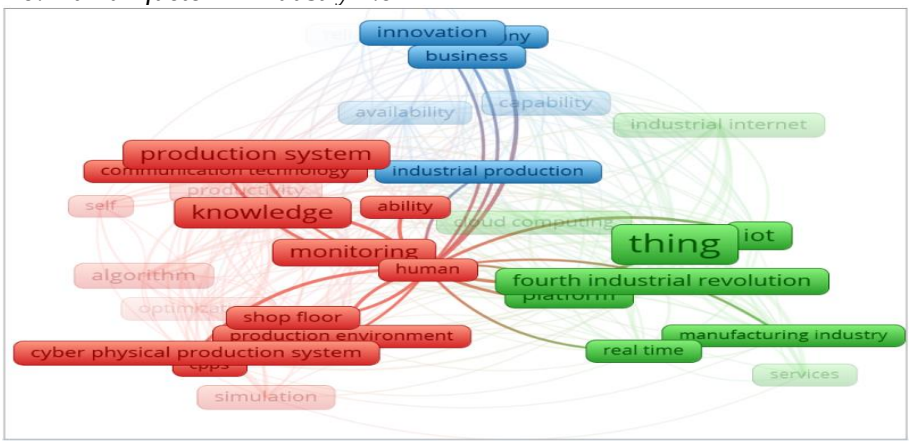
An important segment of research is the human factors in Industry 4.0 focused on CPS. HCPS has become popular thanks to the publications of D. Romero. The vision of Operator 4.0 was presented in the paper (2016) in the context of human cyber-physical systems and adaptive automation towards human automation symbiosis work systems for a socially sustainable manufacturing workforce. Discussions included base concepts and enabling technologies for the development of human-automation symbiosis work systems in Industry 4.0. The human factor is directly related to the following research areas (red segment on Figure 10): production system, knowledge, capability, workshop, monitoring, communication technology, production environment, CPS.

Figure 9. *Key areas in the field: „Industry 4.0" – three key segments of analyses.*



Source: *Own elaboration based on records obtained from WoS database by VOSviewer.*

Figure 10*. Human factor in Industry 4.0*

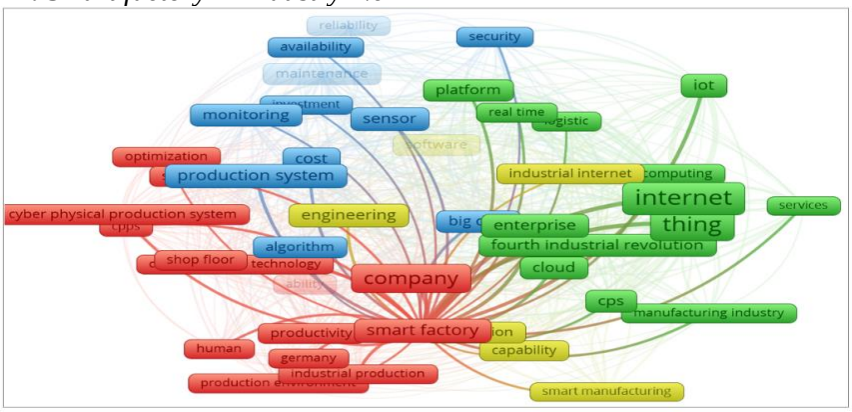


Source: *Own elaboration based on records obtained from WoS database by VOSviewer.*

Companies that are making changes that bring them closer to Industry 4.0 want to create a smart factory. The arrangement of keyword links to the research area: Smart factory is very extensive. The analysis of records from the WoS database using VOSviewer created four key research segments for smart factory (Figure 11).

The first segment (red colour on Figure 11) concerns research areas related to changes in the company. The second segment (blue) concerns changes in production systems. The third segment (green) is the technologies of the fourth industrial revolution that companies are adapting to create Industry 4.0, among these technologies IoT comes to the fore. The fourth segment (yellow colour on Figure 11) includes solutions categorised as: engineering and smart manufacturing.

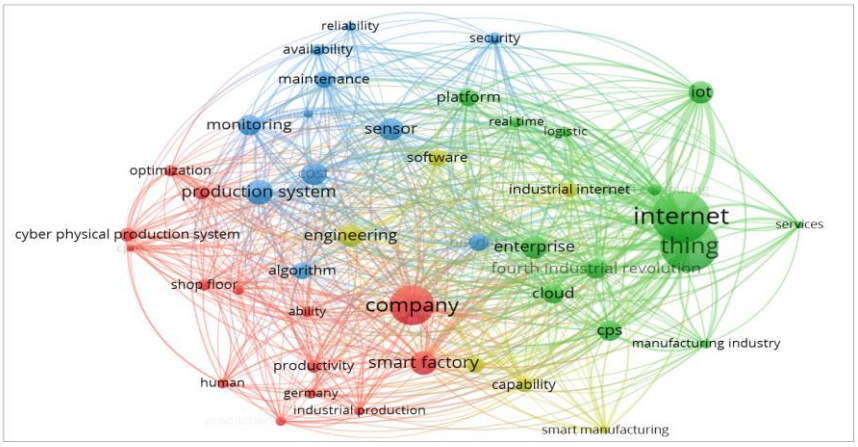
Figure 11. *Smart factory in Industry 4.0*



Source: *Own elaboration based on records obtained from WoS database by VOSviewer.*

Increasing the analysis records with a large number of keywords used by the authors of publications to describe Industry 4.0 leads to the final conclusion that the concept of Industry 4.0 is a multidisciplinary research area. It all started with the fourth industrial revolution and Germany, and changes are being implemented in production, enterprises (factories, organisations) and all industries. The illustrative Figure 12 shows the many relationships between the different research areas (keywords) used to describe Industry 4.0. This is the end of the research at this stage, as the aim of the paper was to address the essence of Industry 4.0, which, over the course of a decade, is still about the development of industry under the conditions of the fourth industrial revolution and is focused around the key technologies of this revolution, among which the Internet and IoT (IIoT) occupy an important (significant) place. By implementing the changes, enterprises aim to create CPS, and in time also smart factories, in which productivity will be much higher than before, and the implemented solutions will optimise manufacturing processes in enterprises.

Figure 12. *Key words of Industry 4.0 (limited on 50 interactions)*



Source: *Own elaboration based on records obtained from WoS database by VOSviewer.*

5. Conclusions

The analysis is the part of research about Industry 4.0 based on a systematic literature review. Such analyses were carried out by Liao *et al.* (2017), Erro-Garcés, (2021), Roblek *et al.* (2016). Our own analysis allowed to answer the research questions formulated.

Research Question 1: What is the dynamics of publication about Industry 4.0 and the development of the publications based on the life cycle of the research area?

Answer: In the decade analysis (from 2011 to 2021), there was a rapid growth dynamic of scientific publications about Industry 4.0, from 2 publications in 2012 to nearly 4,000 publications in 2019. Phase zero of the life cycle of the research area on Industry 4.0 was in 2011, the first year after the concept was initiated by scientists and researchers in German.
Phase I - the beginning of research on Industry 4.0 was between 2012 and 2015.
Phase II - the growth of research on Industry 4.0 was between 2015/2016 and 2018.
Phase III - maturity was reached in the studied decade in 2019 - number of publications: 3,959.
Phase IV - continuation of research was in the past decade in 2020-2021.

Research Question 2: What is the essence of the concept of Industry 4.0 and the content of research records?

Answer: The term 'Industry 4.0' was used to describe the fourth industrial revolution. The name – Industrie 4.0 – was used by in German environment. Industry 4.0 is a new paradigm enabled by the introduction of the Internet of Things (IoT) into the production and manufacturing environment. The vision of Industry 4.0 emphasizes the global networks of cooperative systems (machine, objects) setting capable of autonomously exchanging information and controlling each other. The key component of Industry 4.0 is cyber-physical systems allow the smart factories to operate autonomously and more productively then up to now.

6. Research Limitations

The paper is illustrative, the paper does not include all publications on Industry 4.0 but only focuses on generating key research areas from them and attempts to situate the dynamics of Industry 4.0 publications in the life cycle.

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