INTERNATIONAL HELLENIC UNIVERSITY

SCHOOL OF ENGINEERING

DEPARTMENT OF INFORMATION AND ELECTRONIC ENGINEERING

MASTER IN WEB INTELLIGENCE

BIBLIOMETRIC ANALYSIS AND SYSTEMATIC LITERATURE REVIEW OF INDUSTRY 5.0: A RESILIENT, SUSTAINABLE, AND HUMAN-CENTRIC APPROACH

MASTER THESIS

by

KONSTANTINOS MOURATIDIS

Thesis supervisor: Prof. Periklis Chatzimisios

Thessaloniki, September 2023

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It was approved by the three-member examination committee on 30/09/2023

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Thessaloniki, September 2023

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Konstantinos Mouratidis

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Abstract

The current M.Sc. thesis determines research trends and scopes for Industry 5.0 through an exploratory analysis of the emerging literature upon Industry 5.0. As Industry 5.0 is a novel concept, this study first attempts to understand the landscape, scope and agenda of Industry 5.0 literature. Secondly, identifies the progress and development trends of Industry 5.0. Furthermore, it investigates if human-centricity, sustainability, and resiliency are stressed in Industry 5.0 literature or if it is only seen as an extension of the Industry 4.0 paradigm with no mention of societal objectives. Lastly, considering that Industry 5.0 is a concept that the European Commission introduced, determines if there is a larger emphasis on human-centricity, sustainability, and resilience in the EU region than there is in the rest of the world. The scientific databases Scopus and Web of Science were utilized together with and the bibliometric tools Bibliometrix/Biblioshiny, VOSviewer, and ATLAS.ti. The result of the performed study concluded that Industry 5.0 mainly emerged due to limitations in the implementation of Industry 4.0 that is technology oriented. Small and Medium Enterprises (SMEs), which are significant factors in the development of the global economy and the creation of jobs, could not participate in Industry 4.0 due to their well-known resource limitations in terms of personnel, technology, and budget. Major Political, Social and Environmental crises emphasized the importance of workers and generated attention for the environmental and social impact of Industry. Furthermore, young generation of workers, Millennials and Zoomers, are among the most passionate supporters of worker welfare and stress the importance of human aspects in the working environment of the coming years. The bibliometric analysis demonstrates the shift towards a societally focused industry, a more resilient and sustainable industry that is enhancing humanization and protecting the environment.

Keywords: Industry 5.0; Industry 4.0; bibliometrics; Scopus; Web of Science, Bibliometrix; Biblioshiny; VOSviewer; ATLAS.ti; trajectory; human-centricity, sustainability, resiliency

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Acronyms

5G/6G	5^{th} and 6^{th} Generation of Communication Technologies
AHCI	Arts and Humanities Citation Index
AI	Artificial Intelligence
AR	Augmented Reality
Cobots	Collaborative Robots
CPS	Cyber Physical System
EC	European Commission
EU	European Union
FA	Factorial Analysis
HMI	Human Machine Interaction/Interface
HRC	Human-Robot Collaboration
HRI	Human-Robot Interaction
I4.0	Industry 4.0
I5.0	Industry 5.0
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
IIoT	Industrial Internet of Things
IoT	Internet of Things
ISI	Institute for Scientific Information
LC	Local Citations
MCA	Multiple Correspondence Analysis
MCP	Multiple Countries Publication
NCS	Normalized Citation Score
NLP	Natural Language Processing
NP	Number of Publications
OECD	Organization for Economic Co-operation and Development
PICOTS	Populations, Interventions, Comparators, Outcomes, Timing, and Setting
PRISMA	Preferred Reporting Items Around Systematic Reviews and Meta-Analyzes

PY	Publication Year Start
QDA	Qualitative Data Analysis
QoS	Quality of Service
RQ	Research Question
SDGs	Sustainable Development Goals
SCI	Science Citation Index
SCP	Single Country Publication
SLR	Systematic Literature Review
SMEs	Small and Medium-Sized Enterprises
SSCI	Social Sciences Citation Index
TC	Total Citations - Global Citations
UN	United Nations
VOS	Visualization of Similarities
VR	Virtual Reality
WoS	Web Of Science

1

Introduction

Over the past years, profound changes have occurred in production systems, largely driven by the wave of digitalization. This integration of Information and Communication Technologies (ICT) into all phases of production has brought about intricate challenges in technological, logistical, organizational, and environmental domains. The effective management of this transformative process is of paramount importance. The influence of novel technologies extends beyond operations to impact the workforce and daily life. Both employees and customers play pivotal roles in acclimating to emerging circumstances and embracing continuous learning. This era witnesses the prominence of decentralization within contemporary organizational structures, utilizing technology and data to expedite decision-making processes.

In Britannica dictionary, industry is defined as “a group of productive enterprises or organizations that produce or supply goods, services, or sources of income” [1]. The term Industry 5.0 (I5.0), also known as the Fifth Industrial Revolution, is a new industrial paradigm, which emphasizes the human factor, develops as a complementary paradigm to Industry 4.0. Actually, Industry 5.0 that advocates a holistic strategy that takes into account both the human factor and technological improvements for sustainable and effective manufacturing processes, marks a significant change in industrial practices.

Different authors have varied perspectives on the definition of Industry 5.0 and what it involves. While Industry 4.0 was still developing, the idea of Industry 5.0 was slowly formed, especially after the drawbacks of Industry 4.0 were pointed during COVID-19 pandemic.

1.1 Industry transformation

Industry 4.0 (Industrie 4.0 – I4.0), started in 2011 as a German government initiative. It promotes digital manufacturing by expanding digitization and the connectivity of products, value chains, and business models. It also makes an effort to advance research, networking among industry collaborators, and standards. The usage of digital technologies in the workplace results in numerous novel production techniques, business models, and products. Industry 4.0 mixes modern ICT with traditional industrial techniques [2].

Industry 4.0 marked a significant advancement in human-machine interaction; however, it necessitates a thoughtful consideration of the central role humans play. This paradigm hinges on the concept of smart factories, where intelligent products, machines, storage systems, and data converge within the realm of cyber-physical production systems [3].

Industry 4.0 does have some limitations, though. For example, it prioritizes encouraging industry innovation and productivity over sustainable development and employee welfare. As these limitations were pointed out, the concept of Industry 5.0 emerged.

Major Political, Social and Environmental crises have occurred in recent years, such as the COVID-19 pandemic, climate change, Brexit and the Russia Ukraine war, that had led to change the value focus from economic to societal value and the goal is to build a sustainable, inclusive economy that benefits everyone in society [4].

The COVID-19 pandemic emphasized the value of employees and caused the Industry 4.0 paradigm to be reexamined. Thus, Industry 4.0 had to be extended to include social and environmental aspects and as a result Industry 5.0 emerged. Industry 5.0 emphasizes workers' capacity to effectively collaborate with machines and robots by focusing on their skills, knowledge, and collaboration abilities. Additionally, it emphasizes production process flexibility and takes the environment's effects into account [3].

Industry 5.0 was based on ideas such as the Sustainable Development Goals (SDGs), established by the United Nations in 2015 as a historic global endeavor to address a wide range of social, economic, and environmental concerns confronting the world [5]. Additionally, the vision of Japan for society, the Society 5.0 in 2016, which is a focused-on humans’ society that balances economic advancement with the eradication of societal issues [6]. Furthermore, the Economy of Well-being, by the Organization for Economic Co-operation and Development in 2019, that reflects a change in the economic paradigm toward a more thorough and human-centered approach to development, acknowledging that economic success does not ensure a good standard of living for everyone [7].

The above actually led EC in 2021 to define Industry 5.0, as an industry that builds on and complements Industry 4.0. It emphasizes elements that determine variables for the position of industry in the future European society, not merely economic or technological ones. These elements also have aspects related to the environment and society [8].

According to the European Commission stated in 2021: "It moves focus from shareholder to stakeholder value, with benefits for all concerned. Industry 5.0 attempts to capture the value of new technologies, providing prosperity beyond jobs and growth, while respecting planetary boundaries, and placing the wellbeing of the industry worker at the center of the production process" [8].

Industry 5.0, also refers to the use of technologies like Artificial Intelligence (AI) and robotics to improve the overall customer experience. Eliminating the gap between humans and technology to enable seamless integration and interaction between the two, is one of the guiding principles of Industry 5.0 [9].

While Industry 4.0 is essentially about connecting devices together and is based on the concept of typical centrally managed manufacturing processes, Industry 5.0 is about collaboration between workers and machines on the factory floors having decentralized control of processes and giving a central role to skilled workers [10]. Industry 5.0 implies a creative human touch on the production instead of a standard robotic production. Workers' skill development is a priority of Industry 5.0. New skill sets and even professions are emerging. Skilled workers will assume better roles on the factory floor. Industry 5.0 is the return of the human touch on the factory floors [11] [12].

Thus, Industry 5.0 marks the transition from Industry 4.0's technology-centric philosophy to a more human-centric one. It acknowledges the value of resilience, sustainability, and the role of humans in the context of industry. Industry 5.0, as it began to be recognized, has broadened the scope of research beyond technology-driven developments to concentrate on supporting a smart and prosperous socio-economic transition that combines both humans and technology. The significance of how people influence technical advancement is emphasized [3].

While the existing literature extensively addresses resilience, sustainability, and human-centricity in isolation or pairs, Industry 5.0 introduces a distinctive framework that harmonizes these dimensions in a novel context.

This study examines Industry 5.0 concepts, approaches, and challenges using bibliometric analysis and Systematic Literature Review (SLR). Through an analysis of authorship, publication venues, research locations, and keywords, the study seeks to comprehend the widespread adoption and advancement of Industry 5.0 [13].

Figure 1 - The 3 pillars of Industry 5.0 according to the EC – human-centric, resilient and sustainable [14]

1.2 Scope of Thesis

This study seeks to explore the research trends and scopes for Industry 5.0 through an exploratory analysis of the emerging literature upon Industry 5.0. There are several reviews that performed systematic literature reviews on Industry 5.0 that formulated a basis to start this research. Among those the closest to this work are [15], [16] yet they were based on a small number of articles. Moreover, they were based only on Scopus articles and used only VOSviewer to comment their research. In [17], both Scopus and Web Of Science articles were used although not clearly stated if and how they used them altogether through Bibliometrix to output results. All these three works luck from volume of data that their based on, even [15] that is published in 2023 has articles published until July 2022.

As our review was under development, an article was published on 22 March 2023 [18], which had a similar scope with this work and follow a similar methodology and analysis stage. The difference is that their work is based only on Scopus articles for the period 2019-2022, although they use both VOSviewer and Bibliometrix/Biblioshiny, besides MS Excel software; our work also uses the aforementioned tools, but there are certain differences. The first difference is that the utilized keywords in [18] are not only oriented to Industry 5.0 as in our work. The aim of our work is to gather as much as possible, but documents relevant to this research area and, therefore, any document in the collection of this study contains the term Industry 5.0. The reasoning for this, is that an article about Industry 5.0 certainly uses this term in order to get the attention. Other than that, this work analyses documents from both databases, Scopus and Web of Science, and through R-Studio merges the two datasets. Although the merged dataset has several drawbacks (that will be analyzed later), it provides certain useful information based upon a relatively big dataset.

Moreover, our work focuses on the Human-Centric, Sustainable and Resilient dimensions of Industry 5.0 based on the definition that European Commission gave for Industry 5.0 and extends [19] and examines (not only human-centricity) all 3 pillars. Furthermore, it is also inspired from [20] where the 3 dimensions of Industry 5.0 are explored from the perspectives only of operations and supply chain management. Our work provides a broader view. Additionally, our work uses ATLAS.ti as proposed for Industry 4.0 in [21] that gives extra features such as conceptualization and Natural Language Processing (NLP) features in this work.

Figure 2 - Scope of Thesis [22]

1.2.1 Contributions of the thesis

A total of four Research Questions (RQ) were formulated in the present study as follows:

1. What is the landscape, scope and agenda of Industry 5.0 literature?
2. What is the progress of Industry 5.0 and what are Industry 5.0's development trends?
3. Is human-centricity, sustainability and resiliency a priority in Industry 5.0 literature or is Industry 5.0 regarded just as an evolution of the Industry 4.0 paradigm with no societal goals promoted?
4. Is there a greater emphasis on human-centricity, sustainability, and resilience of Industry 5.0 in the EU region compared to the rest of the world, given that Industry 5.0 is a concept that the European Commission introduced?

1.3 Structure of the Thesis

The current Thesis is comprised of seven chapters, with the first chapter serving as an introduction to the main aspects of the research presented throughout the Thesis. This introductory chapter helps readers to better understand the subject matter of the Thesis. The remaining chapters are structured in the following manner:

Chapter 2 presents the Methodology of the bibliometric analysis carried out.

Chapter 3 presents an overview of Industry 5.0's literature.

Chapter 4 explores literature findings on Industry 5.0. Furthermore, its distinguishing features in relation to past industrial revolutions by drawing on sources from the literature.

The direction of the literature related to Industry 5.0 is examined in Chapter 5. Moreover, the Thesis studies if the literature is human-centered and not just a technological evolution of Industry 4.0.

In Chapter 6 the interest in the EU region compared to the rest of the world is studied.

Finally, Chapter 7 concludes the Thesis by summarizing the main points. Extended research related bibliography is included in the current Thesis.

2

Methodology

Bibliometrics is a method based on quantitative analysis of scientific literature [23]. Scientific research is increasingly being visualized using cutting-edge scientometric methods called "science mapping". Making maps based on thorough research on a subject gives one a comprehensive view of the subject that enables one to connect various fields of knowledge. Science maps can help scholars from a variety of fields cross disciplinary barriers and collaborate to increase knowledge while creating value [24].

The enormous multidisciplinary database Scopus contains references and abstracts from peer-reviewed journal articles, business publications, books, patent records, and conference proceedings. It offers resources for monitoring, evaluating, and displaying search results. Launched in November 2004, Scopus. The most thorough summary of scientific findings in the humanities, social sciences, science and technology is provided by Scopus.

It is common practice to employ bibliometric techniques to track the evolution of management notions and theories [16]. On the other hand, in order to address an issue or collection of questions, systematic reviews use scientific procedures that specifically try to reduce unintentional mistakes or bias by locating, evaluating, and combining all pertinent research.

Using cutting-edge scientific mapping software, which makes use of co-citation analysis to visualize the relationships amongst scientometric indicators, the mapping and cutting-edge reviews are carried out. Information such as the author, the document, the organization, the keywords, the sources, and the countries of publication might all be identified by combining sophisticated thematic analysis techniques were possible by the extraction of frequently occurring noun phrases. This technique clusters all of the collected data's content literature on Industry 5.0 [24].

For evaluating intellectual output in certain fields, bibliometric techniques have grown in popularity as a research methodology in business and management studies. Bibliometric techniques offer insights on the trajectories and development of management theories and concepts by using statistical analysis of scholarly publications. By counting and classifying publications on a particular topic, researchers frequently use bibliometric studies to chart the evolution of interest in management concepts [25].

Despite some detractors' claims to the contrary, bibliometric methods, through statistical analysis of scientific literature, do offer useful information regarding the macro-level evolution of these concepts. They do not, however, provide profound insights into the practical application of management principles in organizations. In the context of the current study, which seeks to gain an extensive understanding about the conception as well as the rise of the Industry 5.0 paradigm as a field of study using bibliometric methods rather than examining its adoption in specific organizations or even industries, is thought as a reasonable approach [26].

The Scientific bibliography databases used were the Scopus (www.scopus.com, last accessed 1st of July 2023) and the Web of Science (WoS - www.webofscience.com, last accessed 1st of July 2023), in order to gather the bibliometric data for the current study. Both databases offer benefits and drawbacks. Scopus has a number of benefits, including greater source coverage than Web of Science. On the other hand, Web of Science contains two fields - Keywords Plus and Subject Category - that can aid in the development of this study. An issue that in other cases may exist is the older coverage, however, since Industry 5.0 only recently began, it should be highlighted that current analysis does not need to take this into account. Furthermore, since early articles about a new concept often appear outside of a discipline's primary or leading publications, wide coverage is essential in the context of Industry 5.0. According to [27], "broader coverage is useful for mapping smaller research areas" [16]. Despite heterogeneity difficulties between these two databases - which are later explained - data from each of Scopus and the Web of Science databases were gathered with a merging procedure in order to provide the study a broader scope.

The 397 documents that were identified as duplicates, they have been removed from the merged dataset. The analysis was performed on the merged database, but whenever the data were inadequate the analysis was performed separately for each database.

The bibliometric study identifies Industry 5.0's inception and development as a research area. The search keyword has a major effect on the research's findings. The reason for this is that, as stated in [28], some important questions that define the review's parameters and provide details regarding the Populations, Interventions, Comparators, Outcomes, Timing, and Setting (known as PICOTS), as well as sporadically the study designs or other interesting examine features, are prone to bias and inconsistencies.

That is why the analysis conducted for the present research focuses on how the term "Industry 5.0" is used, using double quotations in order to get an accurate match when using phrase search, in titles, abstracts and keywords. Furthermore, it covers publications published from 2018 to June 2023. In order to avoid missing any possibly relevant works, we chose to look for anything having "Industry 5.0" within their title/abstract/keywords fields. It is crucial to take this into account since Industry 5.0 is an emerging concept so there is not much literature on it.

Although past Industry 4.0 reviews, enhanced the variety of keyword searches they used, by having related to Industry 4.0 terms, like "smart manufacturing" or "smart factories", it could have led to a significant number of articles that did not specifically address Industry 5.0. It is also unknown what other words or synonyms have been used, because Industry 5.0 is yet a new and developing concept [16]. Therefore, in regard to this, it was assumed that it is probably used in every document that refers to it, excluding for instance in the search string an abbreviation such as “I5.0” or a similar concept “Society 5.0” (with the Boolean operator OR). Although Society 5.0 has similar objectives with Industry 5.0, it has dissimilarities that distinguish it from Industry 5.0. As pointed by [30], for the forthcoming industrial and societal landscape, these coexisting conceptions (Industry 5.0 and Society 5.0) can be seen as two parallel ideas. This can also be seen illustrated in Figure 1, the fundamental shares and the differences between them. Instead of focusing on production, the goal of Society 5.0 is to cope with societal issues [31]. Moreover, Industry 5.0 can be seen as a subset of Society 5.0 [30].

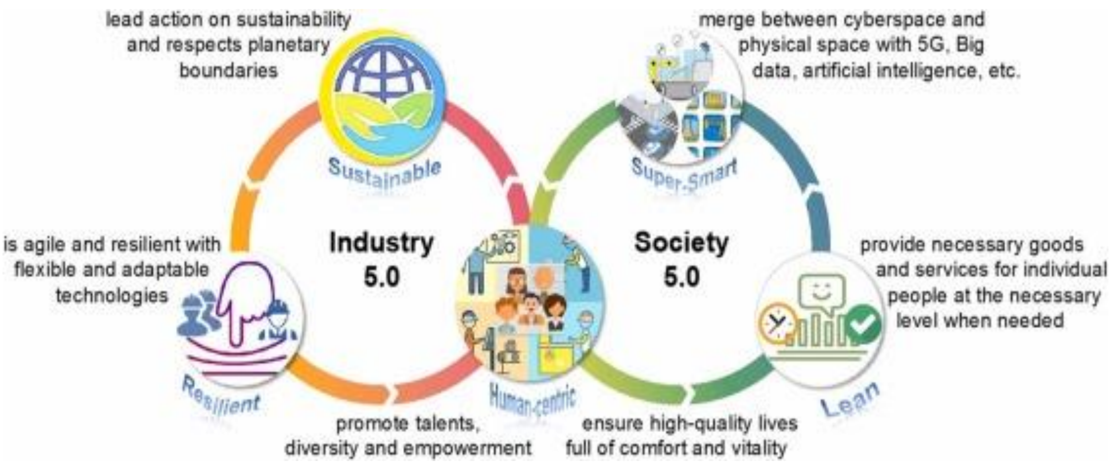


Figure 3 - Pillars of Industry 5.0 and Society 5.0 [29]

The Systematic Literature Review (SLR) approach adopted for the current study serves to provide a thorough and intelligible summary of the analysis of literature, as opposed to a descriptive literature review. According to [10], finding fresh research opportunities in a subject of study can be done effectively using systematic literature, by evaluating and synthesizing previously published papers. The SLR performed for this study intends to collect, verify, evaluate, and describe scientific evidence on the principles, frameworks, difficulties, and constraints of Industry 5.0. A five-step process is used as suggested in [18], [32], [33], [34]. The five stages of the suggested science mapping workflow are outlined as follows:

(1) developing the research questions,

(2) finding relevant studies,

(3) choosing and assessing the research findings,

(4) investigating and combining findings, and

(5) summarizing and applying what was found.

The systematic review methodology provides a comprehensive overview and framework for future investigations [19].

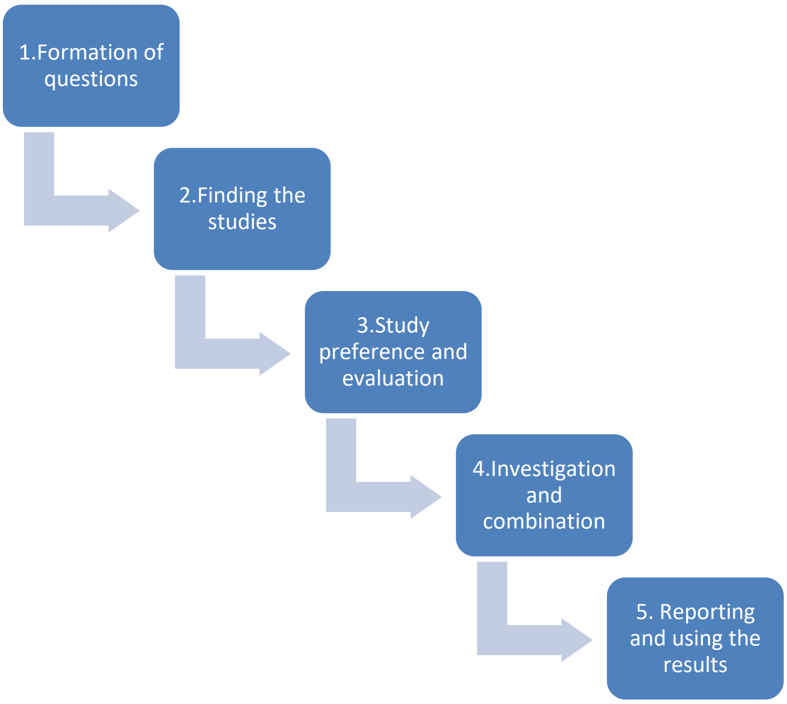


Figure 4 - SLR Five-step process

By utilizing the meta-analysis, which occurs after the qualitative assessment of the chosen articles, qualitative as well as quantitative methods can be advantageous for an SLR and neutralize the effects of selection bias with regard to a traditional (narrative) literature review [35]. Thus, after collecting the articles from the databases and in order to avoid a risk of bias, before using the studies in the review, a four-phase flow diagram and the PRISMA (preferred reporting items around systematic reviews and meta-analyzes) framework's principles were applied. Through PRISMA established guidelines for inclusion and exclusion is utilized and the worth of chosen publications is rigorously evaluated before they are either included or excluded [36].

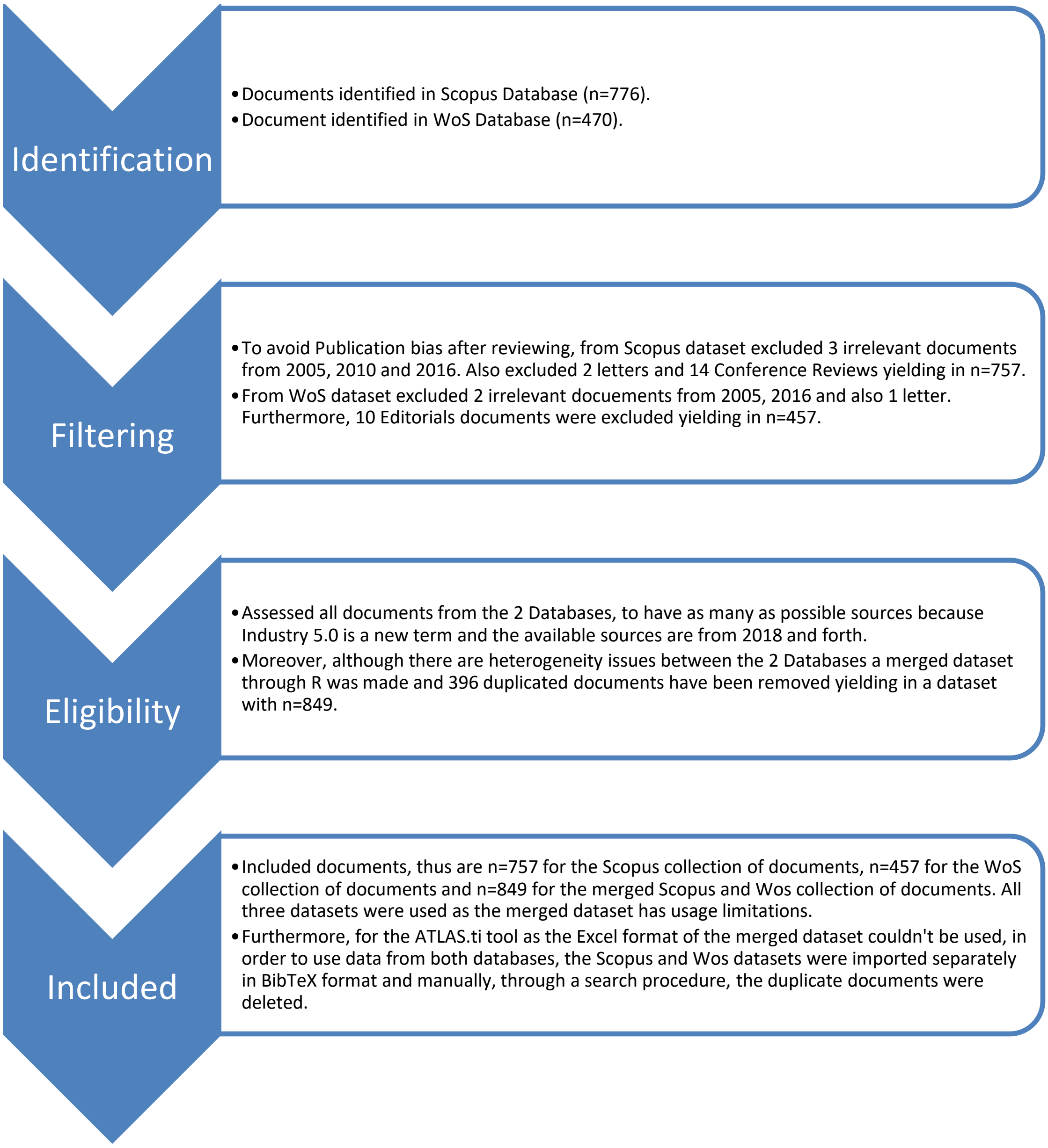


Figure 5 - The PRISMA Flow Diagram – Presenting findings derived from the systematic research.

Evaluation regarding the authors, the publication venues, the research locations, the publication year and the keywords are all included in the descriptive analysis of the gathered papers. This analysis explains how Industry 5.0 has become more widely accepted and how its trends have evolved over time. To get insights into the topic's evolution and trends, areas like journals, authorship distribution across time, geography, and keyword analysis are investigated [37].

(1) Formation of the Research questions (RQs)

- What is the landscape, scope and agenda of Industry 5.0 literature?
- What is the progress of Industry 5.0 and what are Industry 5.0's development trends?
- Is human-centricity, sustainability and resiliency a priority in Industry 5.0 literature or is Industry 5.0 regarded just as an evolution of the Industry 4.0 paradigm with no societal goals promoted?
- Is there a greater emphasis on human-centricity, sustainability, and resilience of Industry 5.0 in the EU region compared to the rest of the world, given that Industry 5.0 is a concept that the European Commission introduced?

(2) Finding the studies using the Scopus and Wos Databases

- The TITLE-ABS-KEY keyword that was applied was "Industry 5.0" but also searches made through Boolean operators for specific keyword searches to answer RQs as: ("Industry 5.0" and "Human*"), ("Industry 5.0" and "Sustain*"), ("Industry 5.0" and "Resilien*"), ("Industry 5.0" and ("Human*" or "Sustain*" or "Resilien*")), ("Industry 5.0" and not ("Human*" or "Sustain*" or "Resilien*")).

(3) Study preference and evaluation

- To select only appropriate studies to include in the review - studies that truly address the study questions - filtering criteria were provided using the PRISMA framework in this stage.
- To avoid Publication bias after a review, documents prior to 2018 were excluded as they were irrelevant. In addition, letters and conference reviews (no abstract present) were excluded from the Scopus database and for the WoS database, after reviewing the sources the Editorial documents (no abstract present) and one letter were also excluded.
- Seeking to expand the research's focus and not exclude potentially essential data, the exclusion criteria were minimized. After reviewing the retrieved Scopus documents, the books and editorial documents were included, to get a broader view of the field studied. Thus, in order to avoid missing any minor collection of publications that are possibly less mentioned but yet significant, as many documents as possible were kept.
- Moreover, no language restrictions were applied as the TITLE-ABS-KEY fields are in English.

(4) Investigation and combination

- Each paper's content was examined to determine the major concerns and then data synthesis was applied through the use of bibliometric software tools (VOSViewer, Biblometrix/Biblioshiny and ATLAS.ti) and Excel.

(5) Reporting and using the results

- This step involves the Interpretation of the findings. Therefore, the data in the papers was condensed, then the results were produced with related categories, such as study methodology and other main discoveries.

Figure 6 - Constructing the SLR

A thorough knowledge of Industry 5.0 as a human-center paradigm is provided utilizing bibliometric analysis in conjunction with rigorous literature study. The study examines the concepts and techniques of Industry 5.0, as well as the difficulties that come with putting them into practice. The results add to our understanding of Industry 5.0 and offer a framework for further study and investigation in this field of study.

2.1 Utilized software tools

The extra benefit of using software tools to conduct a SLR using quantitative analysis of a considerably larger body of literature than is often included in traditional systematic reviews, allows researchers draw conclusions while offering policy and procedure suggestions [38].

Data and graphical information, in this study, were obtained from the Scopus and the WoS databases, but to further analyze the bibliometric data the software tools that were used are: Microsoft Excel, for tables and graphs, Microsoft Word, for Shapes and SmartArt, R studio, for the merging process and to run Biblimetrix/Biblioshiny and three bibliometric software tools, Bibliometrix/Biblioshiny, VOSviewer and ATLAS.ti.

Regarding the bibliometric software tools, we have used the following ones:

1) For in-depth science mapping study, the open-source R-package bibliometrix is useful. Bibliometrix, designed and developed by Massimo Aria and Corrado Cuccurullo, comprises an entire package for Science Mapping Workflow, i.e., provides the resources needed for carrying out a comprehensive bibliometric analysis while adhering to the Science Mapping Workflow. There is a wide range of tools available, through the R-package bibliometrix (www.bibliometrix.org), for conducting quantitative bibliometric and scientometric analysis. It is written in the open-source, ecosystem-rich R language. The availability of reliable, effective statistical algorithms, the availability of exceptional numerical routines, along with integrated data visualization capabilities are perhaps the major factors that make R superior over other programming languages for scientific computation. A web-interface for bibliometrix is provided by the Shiny application biblioshiny, that provides an interactive web-based environment from which it is easy to use the bibliometrix functions.

   Data collected by the six major bibliographic databases can be used by Bibliometrix: Scopus (in 'BibTeX' and 'CSV export' format), Web of Science (in BibTeX', 'plaintext' and 'EndNote Desktop' format), Dimensions (in 'Bibliometric mapping' and 'Excel' format), The Lens (in 'CSV export file' format) PubMed (in 'PubMed export file' format) and Cochrane Library (in 'plaintext' format).

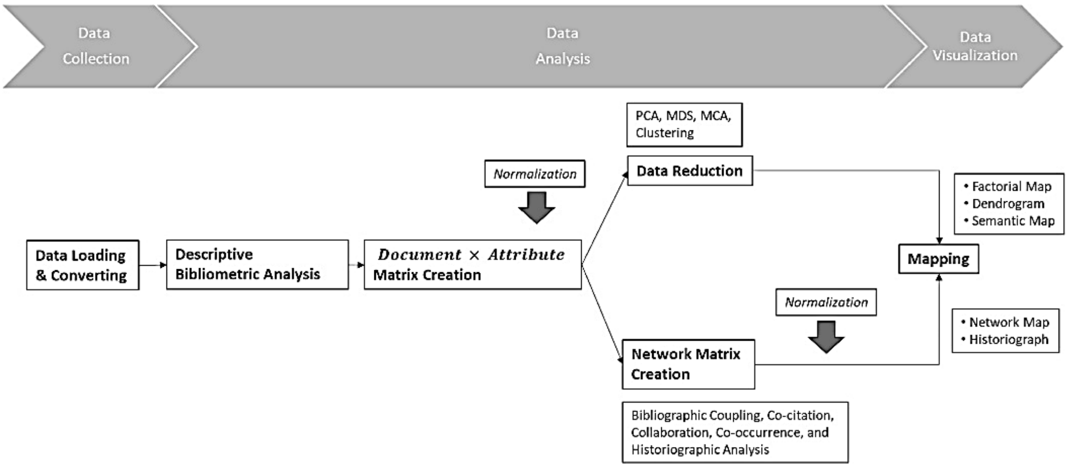


Figure 7 - Implementing the recommended science mapping workflow through Bibliometrix [34]

For Data Acquisition the Web of Science (WoS) or the Scopus databases can be queried to retrieve bibliographic information using a variety of search criteria, including topic, author, journal, time period, and more.

Figure 7, shows how the Bibliometrix workflow supports the second through the fourth of the 5 steps of the suggested scientific mapping workflow.

The discovery of pertinent studies is the second step and Bibliometrix supports the following sub-stage for the data gathering stage:

- Data import and R data frame conversion.

For the third step, that is the choosing and assessing of the research findings, the Data Analysis in short, it is broken down into three sub-stages:

- Examining a Bibliographic Data Frame Descriptively;
- Network synthesis of Bibliographic Coupling, Co-Citation, Collaboration, and Co-Occurrence analysis; and
- Normalization.

For the fourth step, that is investigating and combining findings, the Data visualization stage in short:

- Conceptual structure mapping;
- Network mapping [39].

2) Another software application for creating and visualizing bibliometric networks is VOSviewer. It was released in 2010 by Nees Jan van Eck and Ludo Waltman from the Leiden University in the Netherlands. Such networks may include journals, researchers, or papers and can be created by citation, bibliographic coupling, co-citation, or co-authorship links. Data can be used from Web of Science, Scopus, Dimensions, Lens, and PubMed, but also from Crossref, Europe PMC, and OpenAlex and moreover from Semantic Scholar, OpenCitations, and WikiData. VOSviewer also

has text mining capabilities that enable the creation and visualization of co-occurrence networks of relevant phrases extracted from a body of academic literature. The visual depiction of bibliometric maps is a focus of VOSviewer. When presenting extensive bibliometric maps, VOSviewer's features make it easy to comprehend.

The tool is accessible to bibliometric researchers for free at www.VOSviewer.com. In particular, maps of authors, journals, or keywords can be created with VOSviewer using input from co-citations and co-occurrences. A viewer provided by the application enables in-depth examination of bibliometric maps. Using VOSviewer, a map can be displayed in several of methods, all stressing a different aspect of the map. It contains functions for scrolling and zooming, but also provides searching features, that make it simpler to view a map in depth. For maps with at least a reasonably significant number of items (such at least 100 items), VOSviewer's viewing features are extremely helpful. The majority of bibliometric mapping software does not display such maps in an acceptable manner.

VOSviewer use the Visualization Of Similarity (VOS) mapping technique introduced in [40], to create maps. It may display maps which were created via any suitable mapping method. As such, in addition to the VOS mapping approach, the program can also be used to display maps made using other methodologies, such as multidimensional scaling. VOSviewer supports a variety of hardware and operating system platforms and may even be started via the web (@ https://app.VOSviewer.com/).

Using any appropriate mapping approach, VOSviewer may display maps that have been created. As a result, the program can be used to display maps created using other approaches as well, including multidimensional scaling, in addition to the VOS mapping methodology. VOSviewer may be launched immediately from the internet and is compatible with a wide range of hardware and operating system platforms [41].

3) ATLAS.ti, is Qualitative Data Analysis (QDA) software tool with a full range of innovative features and tools helping to organize data and discover valuable insights. It can be used as a literature review tool to empower researchers to perform powerful and collaborative analysis and to help them make sense of the most important insights in their research field.

   Data analysis was promoted by the usage of coding software in a cyclical and iterative manner that would not have been possible with note cards, word processing, or spreadsheet programs. Instead of encouraging a linear progression of activities, ATLAS' design and functionality, as proposed in [42], encourages a flowing and developing method for qualitative research. The coding method used by ATLAS.ti is inductive rather than hierarchical. The software follows the suggestions of [42] and allows for the expression of techniques to design relationships between codes, concepts, and themes that are frequently unable to be described in a hierarchical list. ATLAS.ti leverages spaCy, a free open-source Python library written in Cython, as its natural language processing engine for Sentiment Analysis with AI [43].

2.2 Data collection process

Three separate stages make up the data collection process. Data retrieval comes first. Many online bibliographic databases are potential resources for bibliographical data, such as Clarivate Analytics Web of Science (WoS formerly known as Web of Knowledge @ www.webofscience.com), owned by Clarivate Analytics, which was established by Eugene Garfield, one of the bibliometrics founders, and Elsevier's Scopus a database of abstracts and citations, released in 2004 (@ www.scopus.com), which will be both used in this study. These databases store metadata about scientific works. There are certain consistency difficulties to take into account later in the subsequent stage, which is loading of data and conversion to suitable for the bibliometric tools format, because they do not provide the same coverage of scientific subjects and journals in the same way.

WoS and Scopus, are the most well-known academic literature databases, that are frequently used for literature searches, on various scientific subjects [44]. For many years, WoS was the only publication and citation database that included all study fields. Nevertheless, Scopus was launched in 2004 by Elsevier Science, and has already made a name for itself as a good competitor [45]. The introduction of Scopus presented a challenge to WoS, and resulting competition has improved the services they both provide [46].

New techniques for indexing and sharing the world's scientific and academic research material were invented by Eugene Garfield and by the Institute for Scientific Information (ISI) that Garfield was its founder. The idea of citation indexing for the sciences was initially proposed by Garfield in 1955, and the first Science Citation Index (SCI) was created by ISI in 1964. Information retrieval has been transformed via citation indexing. The SCI served as an index of associations of ideas, by indexing and linking together the references that authors mentioned in their publications.

In 1973, the Social Sciences Citation Index (SSCI) and in 1978, the Arts and Humanities Citation Index (AHCI), respectively were found. Several items, including Index Chemicus, the ISI's debut release in 1960, were devoted to the chemical sciences. The Journal Citation Reports, which were first published in 1976, compiled journal-to-journal citations to assist publishers and libraries in understanding the communication structure of the literature in the social sciences and sciences, as well as the standing and influence of certain works. The Journal Impact Factor was most well-liked among the product's other indicators.

Quantitative studies in science's sociology and history were also built on SCI data, which eventually gave rise to the area of scientometrics. In 1997, The Web of Science makes its online debut.

While the Thomson Corporation obtained ISI in 1992, Thomson and Reuters joined to establish Thomson Reuters in 2008. In 2016, Clarivate purchased Thomson Reuters' scientific and academic information division [47].

Scopus is a large multidisciplinary database, which is regularly updated and enlarged. It contains references and abstracts from peer-reviewed journal articles, business publications, books, patent records, and conference proceedings. It offers resources for monitoring, evaluating, and displaying search results. It is regarded as having the largest citation and abstract database. [48]. The Scopus Cited References Expansion project, launched in March 2014, added content from before 1996 (extending back to even 1823). The results of the expansion have impact on the metrics of the documents published as the total citation count increases and the widely used metric h-index is impacted [49]. Scopus database, provides the most thorough summary of the world's studies in the humanities, social sciences, technology, and science [46] [50] [51].

The assumption made for the current study is that merging these data sources may improve the quality of the bibliometric study as it can produce outcomes that are broader in terms of the literature fields [52].

The documents collected should have had Industry 5.0 in the central theme or Industry 5.0 was one of the several topics addressed within the articles. Thus, to collect related to Industry 5.0 documents, initially the keyword used for searching the database was “Industry 5.0” for TITLE, ABS and KEY fields. That made a search of academic papers having the term “Industry 5.0” either within the title, abstract, or keywords by the author fields and no any constriction.

The search in Scopus returned 776 documents.

To avoid Publication bias after reviewing the Scopus dataset 3 papers from 2005, 2010 and 2016 were excluded as they were irrelevant. In addition, the 2 letters and the 14 conference reviews retrieved founded with little significance, thus were excluded. In order to avoid missing any minor collection of publications that are possibly less mentioned but yet significant, as many documents as possible were kept. Therefore, after examination, the books and editorials documents were included, to get a broader view of the field studied.

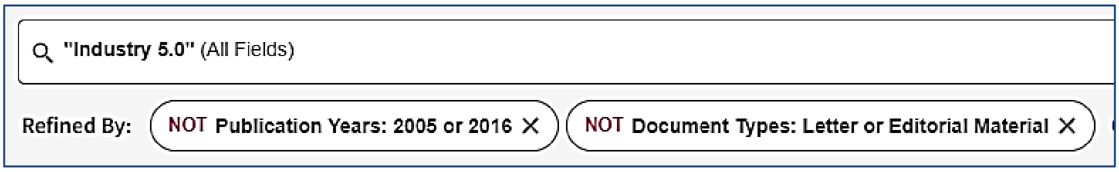


Figure 8 - Search String used for WoS

Thus, the keyword search term posed was:

TITLE-ABS-KEY ("Industry 5.0") AND (EXCLUDE (PUBYEAR, 2010)) AND (EXCLUDE (PUBYEAR, 2005)) AND (EXCLUDE (PUBYEAR, 2016)) AND (EXCLUDE (DOCTYPE, "cr")) AND (EXCLUDE (DOCTYPE, "le"))

Giving 757 document results, which were exported in a csv format file to be used for bibliometric analysis.

For the WoS dataset the search string and the exclusion criteria was made similarly (Figure 3).

And after reviewing the retrieved documents, 2 documents were excluded from 2005 and 2016, one letter and 10 Editorial Material (of minor significance) yielding in a dataset of 457 documents, which were exported in a text format file for bibliometric analysis.

The two datasets exported from Scopus and WoS bibliographic Databases hereafter in this review will be named as the Scopus dataset and the WoS dataset respectively.

The integrity of the Scopus data when inserted in the Bibliometrix/Biblioshiny tool, is shown in the below table (Table 1).

Table 1 - Completeness of Scopus's bibliographic metadata

Metadata	Description	Missing Counts	Missing %	Status
AB	Abstract	0	0,00	Excellent
AU	Author	0	0,00	Excellent
DT	Document Type	0	0,00	Excellent
SO	Journal	0	0,00	Excellent
LA	Language	0	0,00	Excellent
PY	Publication Year	0	0,00	Excellent
TI	Title	0	0,00	Excellent
TC	Total Citation	0	0,00	Excellent
C1	Affiliation	1	0,13	Good
CR	Cited References	23	3,04	Good
DI	DOI	39	5,15	Good
DE	Keywords	72	9,51	Good
RP	Corresponding Author	154	20,34	Poor
ID	Keywords Plus	272	35,93	Poor
WC	Science Categories	757	100,00	Completely missing

Table 2 - Completeness of WoS's bibliographic metadata

Metadata	Description	Missing Counts	Missing %	Status
C1	Affiliation	0	0,00	Excellent
AU	Author	0	0,00	Excellent
DT	Document Type	0	0,00	Excellent
SO	Journal	0	0,00	Excellent
LA	Language	0	0,00	Excellent
PY	Publication Year	0	0,00	Excellent
WC	Science Categories	0	0,00	Excellent
TI	Title	0	0,00	Excellent
TC	Total Citation	0	0,00	Excellent
CR	Cited References	1	0,22	Good
RP	Corresponding Author	1	0,22	Good
AB	Abstract	3	0,66	Good
DI	DOI	18	3,94	Good
DE	Keywords	23	5,03	Good
ID	Keywords Plus	123	26,91	Poor

Respectively for the WoS data the integrity of the data when inserted in the Bibliometrix/Biblioschiny tool is shown in the above table (Table 2). The integrity of the data in WoS is better than Scopus data.

The overview of the bibliometric analyses via Bibliometrix/Biblioshiny for the Scopus and WoS datasets respectively are shown in Figure 9 and in Figure 10.

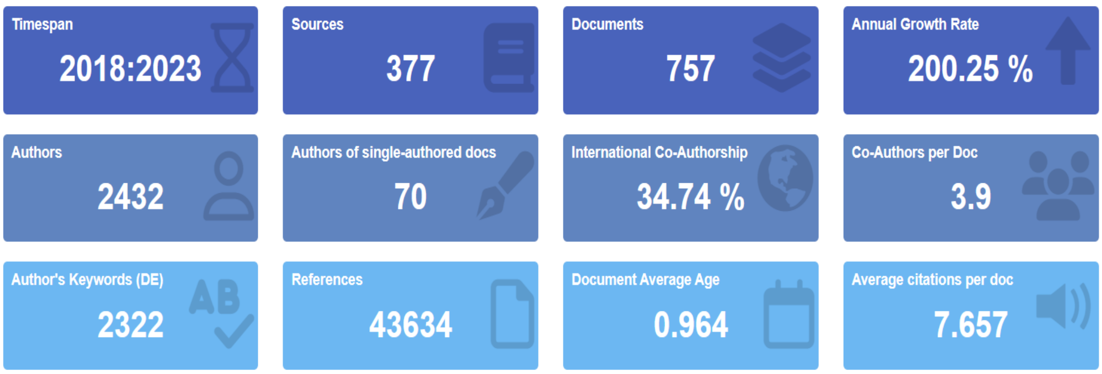


Figure 9 - Overview of Scopus dataset by Bibliometrix/Biblioshiny

Figure 10 - Overview of WoS dataset by Bibliometrix/Biblioshiny

Following the initial examination of the datasets, the merging of the two datasets through the Bibliometrix library in R-Studio was attempted. The procedure of the merging through R-Studio was:

1) Loading Bibliometrix/Biblioshiny
   > *library(bibliometrix)*
2) Scopus dataset to a bibliographic dataframe conversion
   > *S = convert2df("R/biblioanalysis/scopus.bib", dbsource = "scopus", format = "bibtex")*
3) WoS dataset to a bibliographic dataframe conversion (the conversion from the text format dataset worked better than the BibTeX format for WoS)
   > *W = convert2df("R/biblioanalysis/ Wos1stJuly.txt", dbsource = "wos", format = "plaintext")*
4) Merging the two dataframes
   > *Merged_df = mergeDbSources(S, W, remove.duplicated = TRUE)*

   Yielding in 388 duplicated documents removed

5) Export the merged dataframe
   > library(openxlsx)
   > write.xlsx(*Merged_df*, file = "R/biblioanalysis/Database.xlsx") [53]

Thus, the merging was done but had some issues that will be discussed later on. The Venn diagram in Figure 11, presents the number of documents contained in each collection.

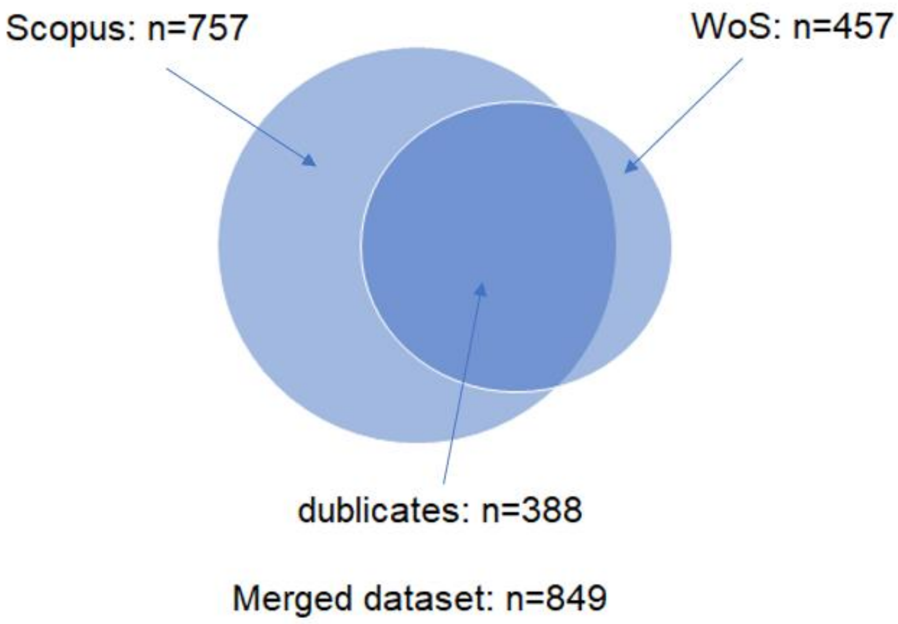


Figure 11 - The 3 datasets: Scopus, WoS and the merged

Table 3 - Completeness of the merged dataset Bibliographic metadata

Metadata	Description	Missing Counts	Missing %	Status
AU	Author	0	0,00	Excellent
DT	Document Type	0	0,00	Excellent
SO	Journal	0	0,00	Excellent
LA	Language	0	0,00	Excellent
PY	Publication Year	0	0,00	Excellent
TI	Title	0	0,00	Excellent
TC	Total Citation	0	0,00	Excellent
C1	Affiliation	5	0,59	Good
AB	Abstract	14	1,65	Good
CR	Cited References	26	3,06	Good
DI	DOI	45	5,30	Good
DE	Keywords	91	10,72	Acceptable
RP	Corresponding Author	158	18,61	Acceptable
ID	Keywords Plus	314	36,98	Poor

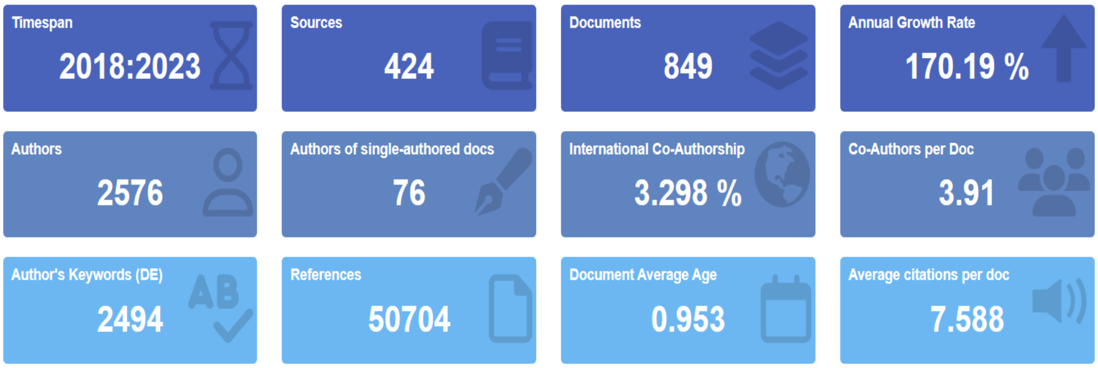


Figure 12 - Overview of the merged dataset by Bibliometrix/Biblioshiny

Some of the issues derived from the merging process will be described. WoS has a field named Science Categories, not found in the Scopus database, that in the merging procedure was neglected and thus it is empty.

Also, there are two types of keywords as viewed within Bibliometrix/Biblioshiny. The Author's keywords named as Keywords, that are chosen by the author to best reflect the content of the document and the Keywords Plus, as referenced in Bibliometrix/Biblioshiny that is different in the two databases. The Scopus keyword field that fills the Keywords Plus field in Bibliometrix/Biblioshiny are the indexed keywords by Scopus. The Indexed keywords are chosen by Scopus, a team of professional indexers assigns them, and are standardized to thesauri-derived vocabulary that Elsevier owns. For instance, the Ei Thesaurus is used in engineering, technology and physical sciences. The Indexed keywords, as opposed to Author keywords, takes into consideration synonyms, alternative spellings, and plurals. The Index keyword field for some recently added articles, as it is not done automatically, may take a period to appear. Thus, there are documents that this field is empty in our selected dataset from Scopus and consequently in the merged dataset.

The WoS discovered KeyWords Plus field in WoS contains the data for Keyword Plus in Bibliometrix/Biblioshiny. These are phrases or terms that are frequently used in references yet not in the title of an article. By searching across disciplines for all the publications that have cited references in common, KeyWords Plus expands the functionality of cited-reference searching. The foundation of KeyWords Plus is a proprietary algorithm unique to Clarivate datasets. KeyWords Plus are extracted from cited titles and cannot be altered. KeyWords Plus are phrases that are formed from the names of publications mentioned by the author of the piece being indexed, therefore papers without references or papers whose references are not linked to source items will not have them. KeyWords Plus can additionally be included in publications that don't have any author keywords or with publications that merely contain significant terms not included in the author keywords [54] [55].

When comparing WoS Keywords Plus terms and the Author's Keywords terms, Garfield, that as previously noted, introduced the concept of citation indexing for the sciences in 1955, suggested that Keywords Plus terms can more effectively and diversely capture an article's substance [56]. In terms of bibliometric analysis, which looks at the knowledge structure of scientific subjects, the Keywords Plus field is just as useful as the Author Keywords field, although it is less thorough in describing the content of an article [57].

All types of keywords mentioned above, was used in this research, but the keyword plus field in the merged dataset, although filled in during the merging procedure, cannot be used due to its data inconsistency, as it is derived from either index keywords in Scopus or the keyword plus in WoS and these two fields are different. Therefore, the keyword plus field is only used separately either on Scopus or WoS datasets.

Moreover, from the merging process, besides the keyword plus and the subject category fields issues mentioned already, there are also other issues to report. The Corresponding Author field has incomplete data which is an issue that the merging report did not initially indicate. But, while reviewing the overview of the merged dataset and trying to produce graphs by the Bibliometrix/Biblioshiny tool, it came out that the International Co-Authorship percentage is false and thus the Corresponding Author's plot cannot be derived from the merged dataset.

Furthermore, another issue is due to the variation in citation counts between each of these databases. That happens because each database stores independently the citation information and any information regarding Total Citations and metrics derived from it cannot be used when merging records from them. Finally, minor metadata used in the analysis was missing by the merging process not affecting though the analysis procedure.

Some general information derived from the data, either, when possible, from the merged dataset or from the Scopus or the Wos datasets. Besides the heterogeneity issues mentioned for the two databases the merged dataset can be used only from the Biblimetrix/Biblioshiny tool as the format of the data is not recognized both from the VOSviewer and ATLAS.ti tools. Thus, it cannot be used by the VOSviewer tool, so the two datasets have to be analyzed separately by the VOSviewer tool. For the ATLAS.ti tool, the merging of the datasets is done differently, and the merged dataset, after being transformed to pdf format, was used to produce Word Clouds and Concept Clouds. In order to use ATLAS.ti for Opinion Mining, a Sentiment mining method, after importing separately, the Scopus and WoS datasets in BibTeX format, the duplicate records were deleted manually. Hereafter, if not mentioned, the data used in a Bibliometrix/Biblioshiny graph are from the merged dataset, otherwise it is noted from which dataset the information (either some kind of graph or table) is derived.

3

Overview of Industry 5.0's literature

The First Industrial Revolution, which emerged in the 18th century, driven from the development of mechanical power, included textiles, steam power, iron, cement, chemicals, gas, lighting, transportation and other things, and it promoted growth in industries like agriculture, transportation, and employment; however, it also brought about problems like pollution and slow implementation, while using mathematical tools like linear programming.

The Second Industrial Revolution, which emerged in the 19th century, electrical energy prevails, a focus was placed also on steel, machine tools, petroleum, chemical, trains, cars, engines, turbines, telecommunications and contemporary business management, which helped to advance telephone systems, electrical grids, and internal combustion engines, but was hampered by high power prices and a reliance on differential equations.

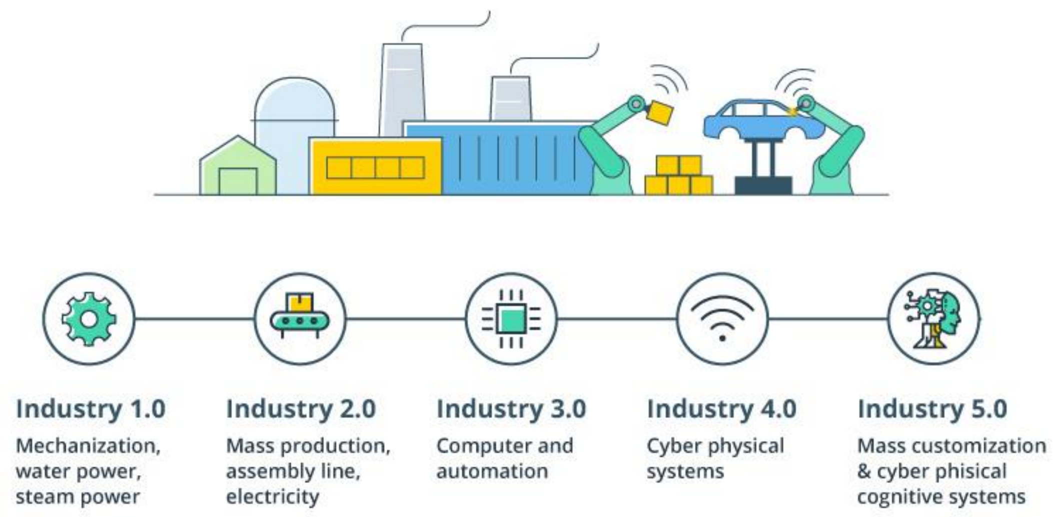


Figure 13 - The five industrial revolutions - The advances in technology that drove them were agents of changes and emerged as revolutions in business, economy and manufacturing [58]

The Third Industrial Revolution, which emerged in the 20th century, was using electronics and information technologies. Industry 3.0 was centered on semiconductors, digital circuits, programmable integrated circuits, automation, and renewable energy, ushering in the telecommunication, robots and automated industries but encountering complexity issues in the implementation of its Flexible Manufacturing Systems, utilizing differential equations and logical controllers.

Industry 4.0, which emerged in the 21st century, uses technologies such as IoT and Cloud Computing. The fourth Industrial Revolution involves intelligent systems across industries, introduces full automation, AI and machine learning, but there are also problems introduced such as cloud data security concerns. Industry 4.0 employs network theory and optimization approaches as mathematical tools [26] [10].

The European Commission (EC) outlined its vision of Industry 5.0 in 2021, which aims to promote inclusive workplaces, strong supply networks that are resilient to disruptions, and the use of sustainable production techniques. Industry 5.0 provides a unique paradigm that harmonizes resilience, sustainability, and human-centricity in a novel context, whereas the existing literature extensively discusses these topics in isolation or pairs [20].

In order to answer the first RQ to get an overview of Industry 5.0 and understand the spread of the topic and its acceptance globally, the following features through the analysis will be obtained:

1. Research volume and growth trend for Industry 5.0
2. Types of publications
3. Languages of publications
4. Distribution across different Subject Areas
5. Top cited Publications
6. Most relevant and most influential Authors
7. Most relevant and most influential Affiliations
8. Most relevant ana most influential Sources
9. Major Sponsors
10. Most relevant and most influential Countries

3.1 Annual Scientific Production

The first feature to observe is the annual number of Industry 5.0 documents published in either of the two bibliographic databases until 1st of July 2023. More documents are published every year and in 2023 it seems that the number of documents will continue to rise.

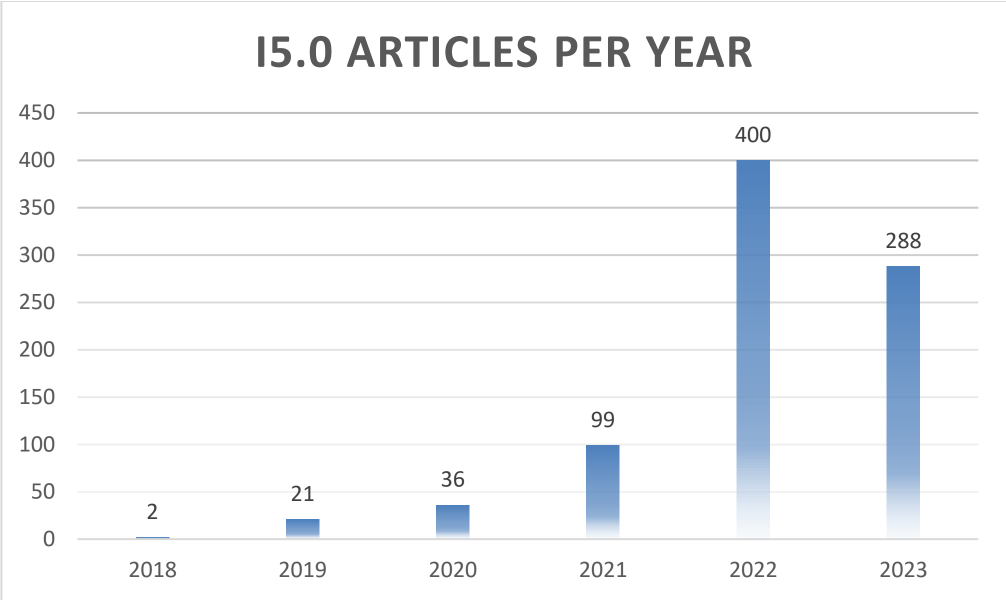


Figure 14 - Industry 5.0's Annual Scientific Production

3.2 Types of Publications

As already noted, the search in Scopus returned 776 documents. Before applying any filter, the document types are presented below.

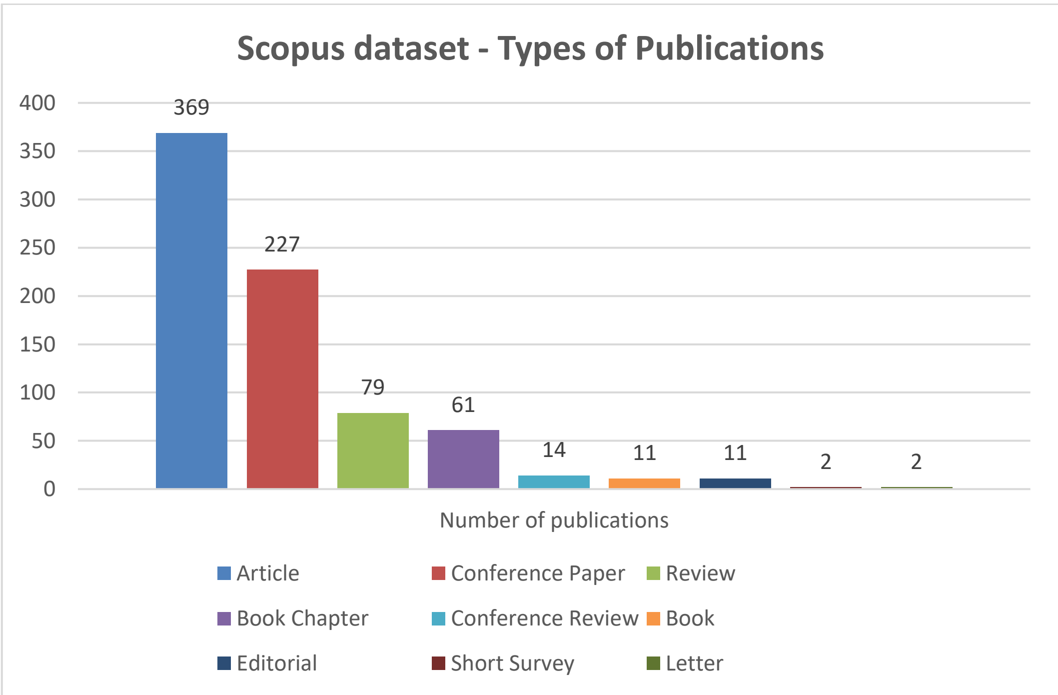


Figure 15 - I5.0's Types of Publications in Scopus

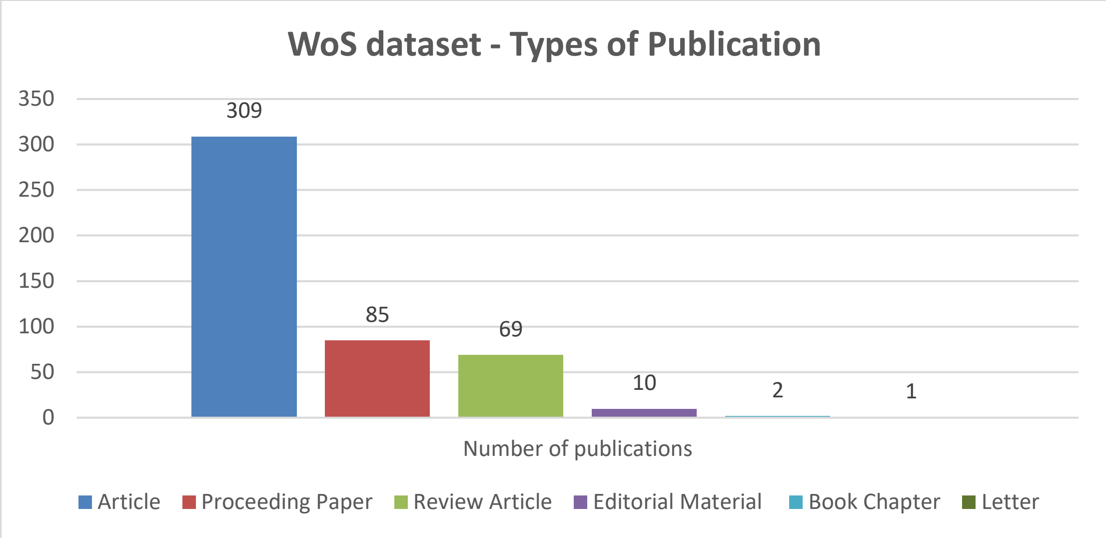


Figure 16 - I5.0's Types of Publications in WoS

Similarly, the search in WoS returned 470 documents, of which their document types can be seen in Figure 16.

3.3 *Languages of Publications*

Industry 5.0 has an international interest from all over the world, therefore English, as expected, is the dominant language in both databases, Scopus and WoS, as only 11 out of 776 and 1 out of 470 respectively, were non-English documents. Moreover, it is found that the documents referring to this research field in a language other than English are very few. Although there could be excluded, however, after reviewing them, it was found that those documents not in English but written in another language, have the Title/Abstract/Keywords fields written in English, thus these documents can be used for the current research and were included in the datasets used.

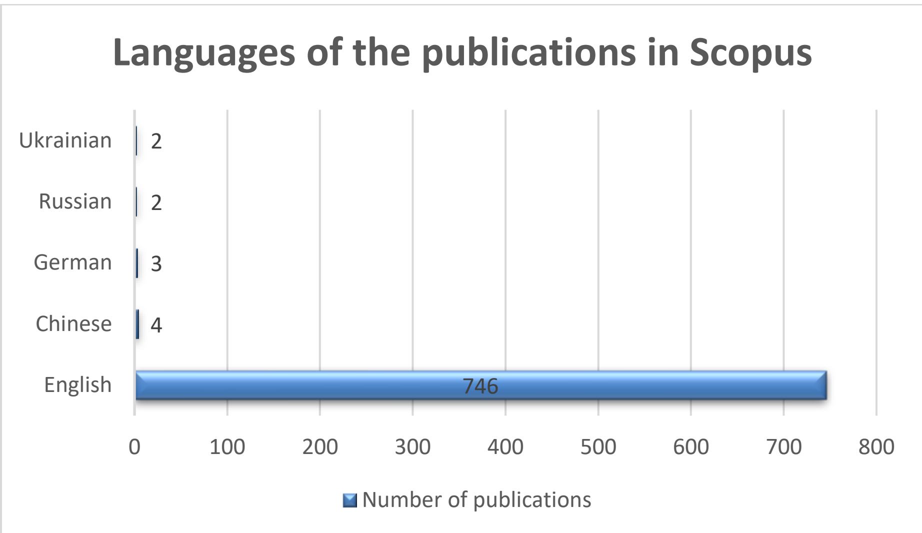


Figure 17 - Languages of Industry 5.0 documents in Scopus

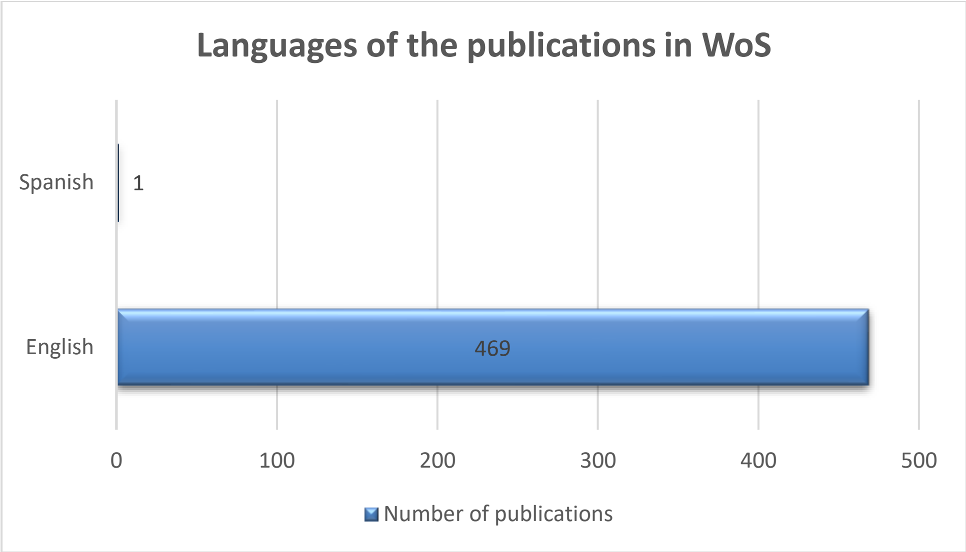


Figure 18 - Languages of Industry 5.0 documents in WoS

3.4 Area of Knowledge

As Scopus dataset does not contain the field provided by WoS named "Subject Category", the Subject Areas information has to be retrieved separately from the two datasets. From the Scopus dataset, it can be obtained by the number of documents categorized by the subject area that they are published. The heterogeneity of the classification by the two scientific databases results in non-unified results.

A wide distribution can be seen from the below pie chart, across different areas. Half of the documents (one quarter each) belong to Engineering and Computer Science, and the other half, belongs to many different subject areas.

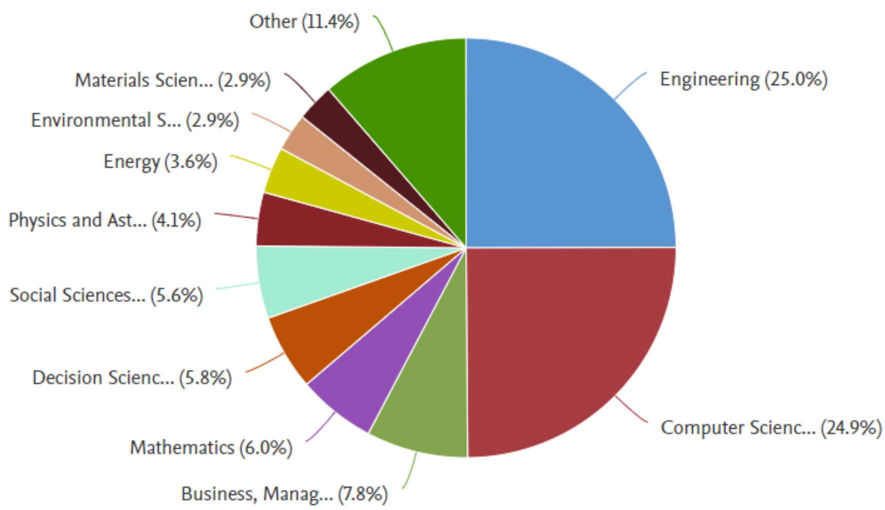


Figure 19 - I5.0's Scopus Documents by subject area (graph provided by Scopus)

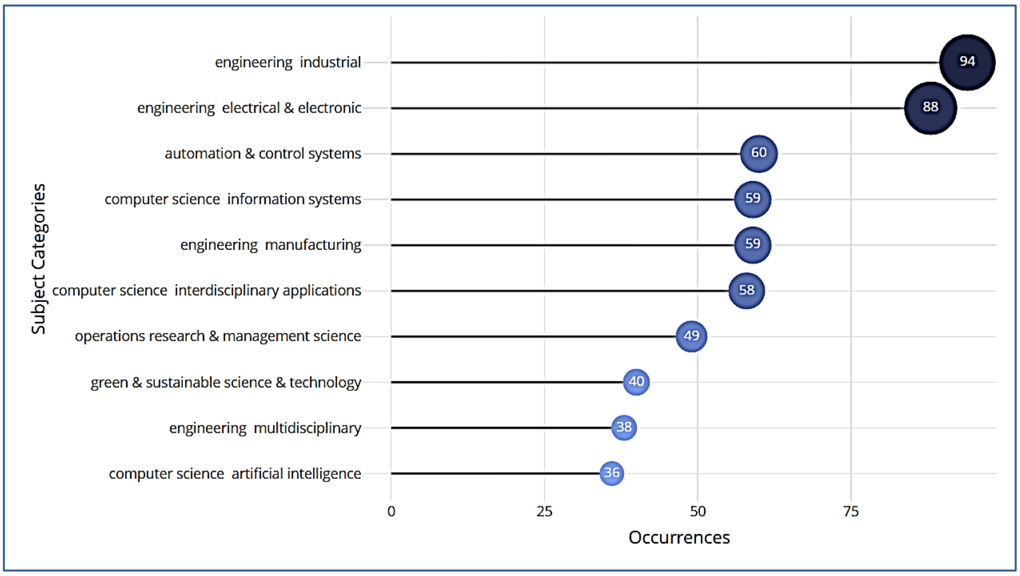


Figure 20 - I5.0's WoS Documents by Subject Category (through Bibliometrix/Biblioshiny)

As WoS offers a field called Subject Category that was used to get the Subject Area information. Thus, from the WoS dataset based on the Web of Science Subject category through Bibliometrix/Biblioshiny derives the above scatter graph. The Subject Categories reported are mostly various engineering and computer science categories.

3.5 Top cited publications

The most Globally and most Locally cited documents are investigated. Global Citations (TC - Total Citations) is used to describe the overall quantity of references from sources contained in a bibliographic database (such as WoS, Scopus, etc.) that a document found within a collection has received, whereas, Local Citations (LC) quantify the number of times an author (or a document) in a collection has been cited by other authors who are authors in the collection themselves. Thus, from the nature of the TC field, the merging dataset cannot be used for anything that involves the TC field. Instead, the analysis must be done separately with the two datasets from Scopus and WoS.

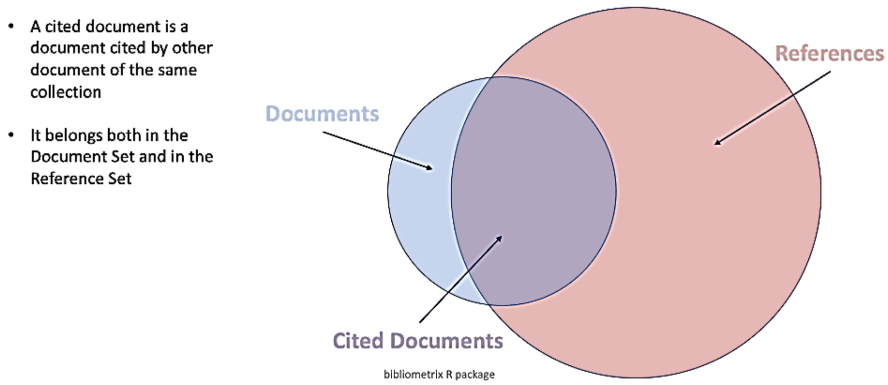


Figure 21 - Bibliometrix figure for Documents, References and Cited Documents of a collection [59]

Table 4 - Industry 5.0 10 Most Global Cited Documents in Scopus

Paper	Total Citations	TC per Year	Normalized TC
NAHAVANDI S, 2019, SUSTAINABILITY	372	74.40	7.91
MADDIKUNTA PKR, 2022, J IND INFOR INTEGR	298	149.00	45.38
XU X, 2021, J MANUF SYST	286	95.33	21.33
ÖZDEMIR V, 2018, OMICS J INTEGR BIOL	228	38.00	1.00
DEMIR KA, 2019, PROCEDIA COMPUT SCI	199	39.80	4.23
LONGO F, 2020, APPL SCI	146	36.50	6.12
ABDEL-BASSET M, 2020, IEEE INTERNET THINGS J	109	27.25	4.57
PILLAI SG, 2021, INT J HOSP MANAGE	108	36.00	8.05
BEDNAR PM, 2020, INF SYST FRONT	103	25.75	4.32
CHOI T-M, 2022, PROD OPER MANAGE	96	48.00	14.62

To determine the normalized citation score for documents, authors, and sources considering both global and local citations, bibliometrics uses the normalized TC measure. It is possible to calculate a document's Normalized Citation Score (NCS) by dividing the actual number of citing items by the anticipated citation rate for works published in the same year.

The Most Globally Cited Documents are shown in Table 4 and Figure 22.

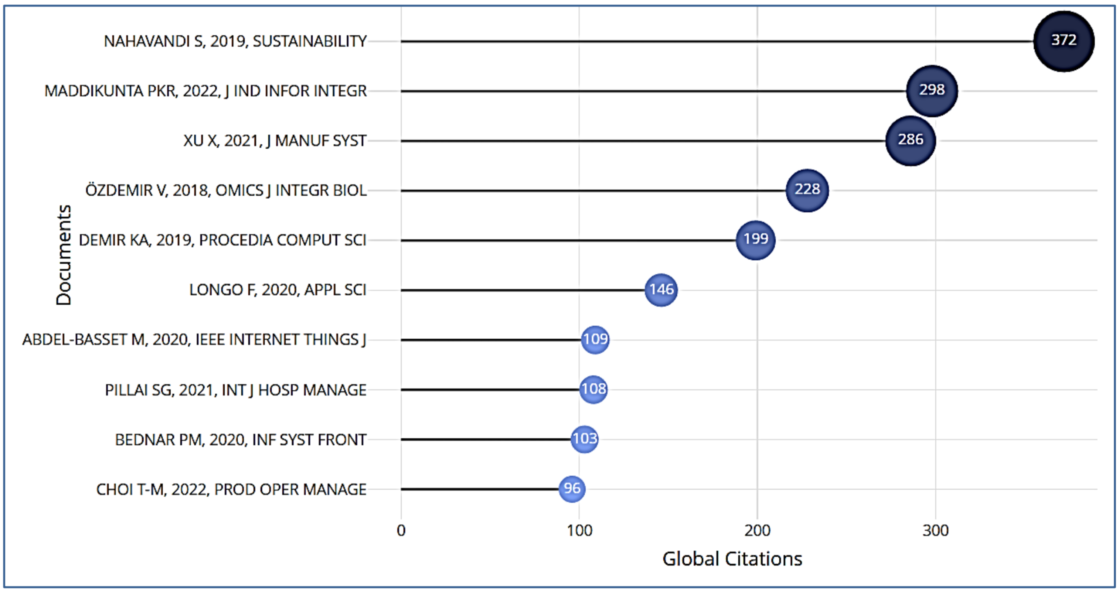


Figure 22 - I5.0's 10 Most Global Cited Documents in Scopus (through Bibliometrix/Biblioshiny)

Table 5 - Industry 5.0 10 Most Local Cited Documents in Scopus

Document	Year	Local Citations	Global Citations	LC/GC Ratio (%)	Normalized Local Citations	Normalized Global Citations
NAHAVANDI S, 2019, SUSTAINABILITY	2019	143	372	38.44	8.00	7.91
XU X, 2021, J MANUF SYST	2021	115	286	40.21	25.62	21.33
DEMIR KA, 2019, PROCEDIA COMPUT SCI	2019	92	199	46.23	5.14	4.23
LONGO F, 2020, APPL SCI	2020	86	146	58.90	10.75	6.12
MADDIKUNTA PKR, 2022, J IND INFOR INTEGR	2022	66	298	22.15	36.46	45.38
ÖZDEMIR V, 2018, OMICS J INTEGR BIOL	2018	64	228	28.07	1.00	1.00
ASLAM F, 2020, INFORMATION	2020	45	80	56.25	5.63	3.35
LU Y, 2022, J MANUF SYST	2022	44	74	59.46	24.31	11.27
JAVAID M, 2020, J IND INTEGR MANAG-a	2020	41	84	48.81	5.13	3.52
LENG J, 2022, J MANUF SYST	2022	31	49	63.27	17.12	7.46

The Most Locally Cited Documents in Scopus are shown in Table 5 and Figure 23.

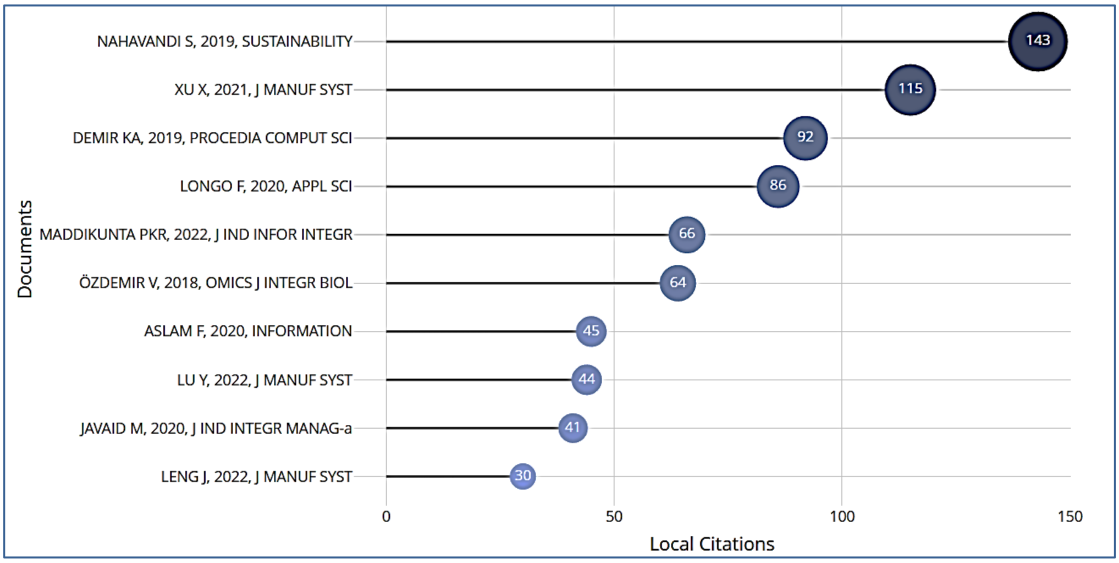


Figure 23 - I5.0's 10 Most Local Cited Documents in Scopus (through Bibliometrix/Biblioshiny)

Table 6 - Industry 5.0 10 Most Global Cited Documents in WoS

Paper	Total Citations	TC per Year	Normalized TC
NAHAVANDI S, 2019, SUSTAINABILITY-BASEL	280	56.00	6.61
MADDIKUNTA PKR, 2022, J IND INF INTEGR	239	119.50	26.65
XU X, 2021, J MANUF SYST	223	74.33	13.49
OZDEMIR V, 2018, OMICS	171	28.50	2.00
ZAMBON I, 2019, PROCESSES	131	26.20	3.09
LONGO F, 2020, APPL SCI-BASEL	115	28.75	3.91
CHOI TM, 2022, PROD OPER MANAG	96	48.00	10.70
PILLAI SG, 2021, INT J HOSP MANAG	93	31.00	5.63
BEDNAR PM, 2020, INFORM SYST FRONT	80	20.00	2.72
JAVAID M, 2020, J IND INTEGR MANAG	71	17.75	2.41

WoS's Most Globally Cited Documents are presented in Table 6 and in Figure 24.

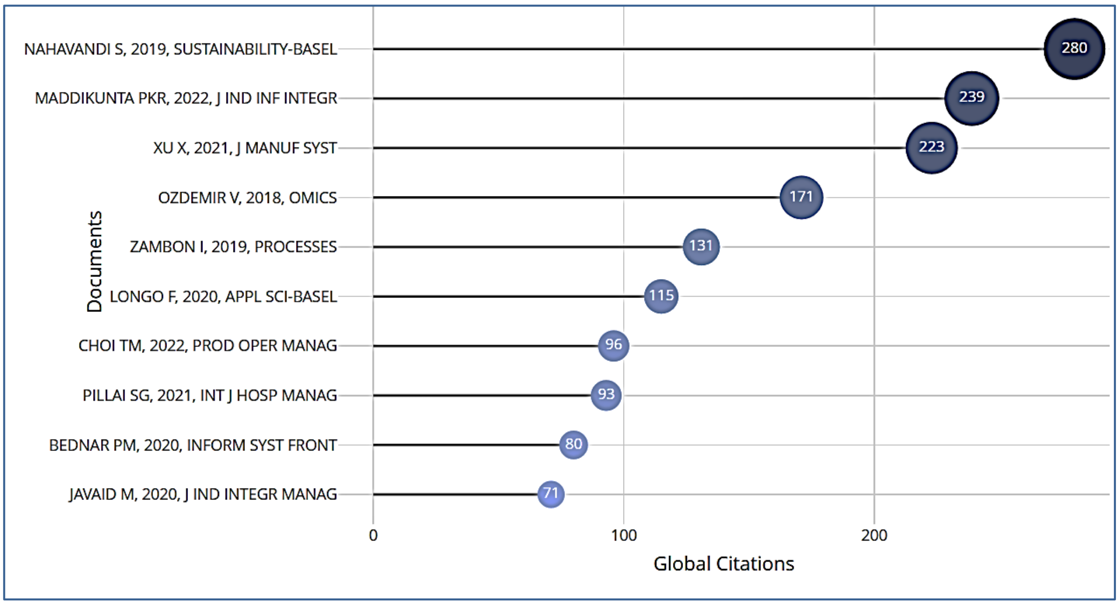


Figure 24 - I5.0's 10 Most Global Cited Documents in WoS (through Bibliometrix/Biblioshiny)

Table 7 - Industry 5.0 10 Most Local Cited Documents in WoS

Document	Year	Local Citations	Global Citations	LC/GC Ratio (%)	Normalized Local Citations	Normalized Global Citations
NAHAVANDI S, 2019, SUSTAINABILITY-BASEL	2019	140	280	50.00	10.55	6.61
XU X, 2021, J MANUF SYST	2021	100	223	44.84	16.28	13.49
MADDIKUNTA PKR, 2022, J IND INF INTEGR	2022	91	239	38.08	32.54	26.65
OZDEMIR V, 2018, OMICS	2018	64	171	37.43	2.00	2.00
LONGO F, 2020, APPL SCI-BASEL	2020	64	115	55.65	5.93	3.91
ASLAM F, 2020, INFORMATION	2020	36	69	52.17	3.34	2.35
LU YQ, 2022, J MANUF SYST	2022	33	59	55.93	11.80	6.58
JAVAID M, 2020, J IND INTEGR MANAG-a	2020	30	56	53.57	2.78	1.90
JAVAID M, 2020, J IND INTEGR MANAG	2020	27	71	38.03	2.50	2.41
ELFAR OA, 2021, ENERG CONVERS MAN-X	2021	27	54	50.00	4.40	3.27

The Most Locally Cited Documents in WoS are illustrated in Table 7 and in Figure 25.

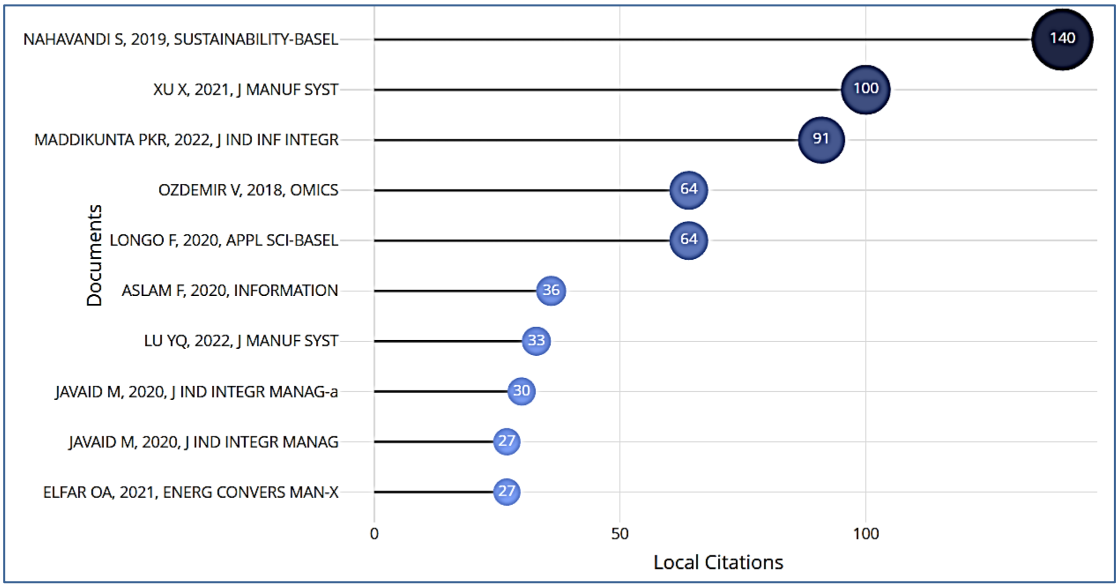


Figure 25 - I5.0's 10 Most Local Cited Documents in WoS (through Bibliometrix/Biblioshiny)

3.6 *Most relevant and most influential authors*

In order to first get a hint upon the productivity per author through Bibliometrix/Biblioshiny, the Lotka's law shows useful information regarding the author's productivity. The authors that are productive and influencing this research field are those belonging to the "core" authors publishing at least 3 related documents.

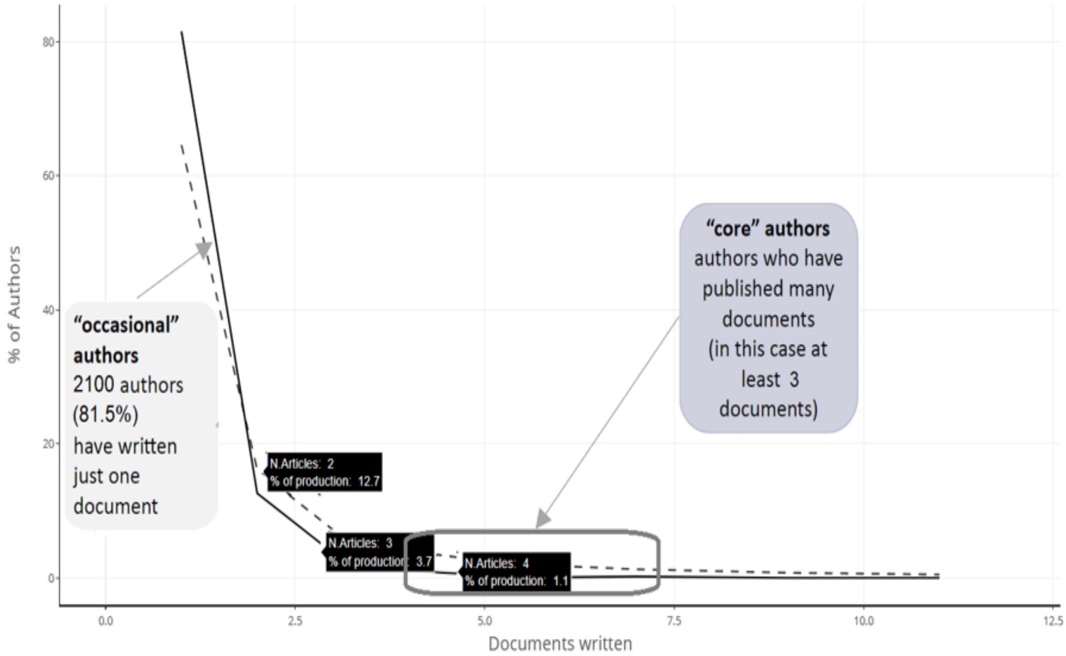


Figure 26 - I5.0's Lotka's Law (through Bibliometrix/Biblioshiny)

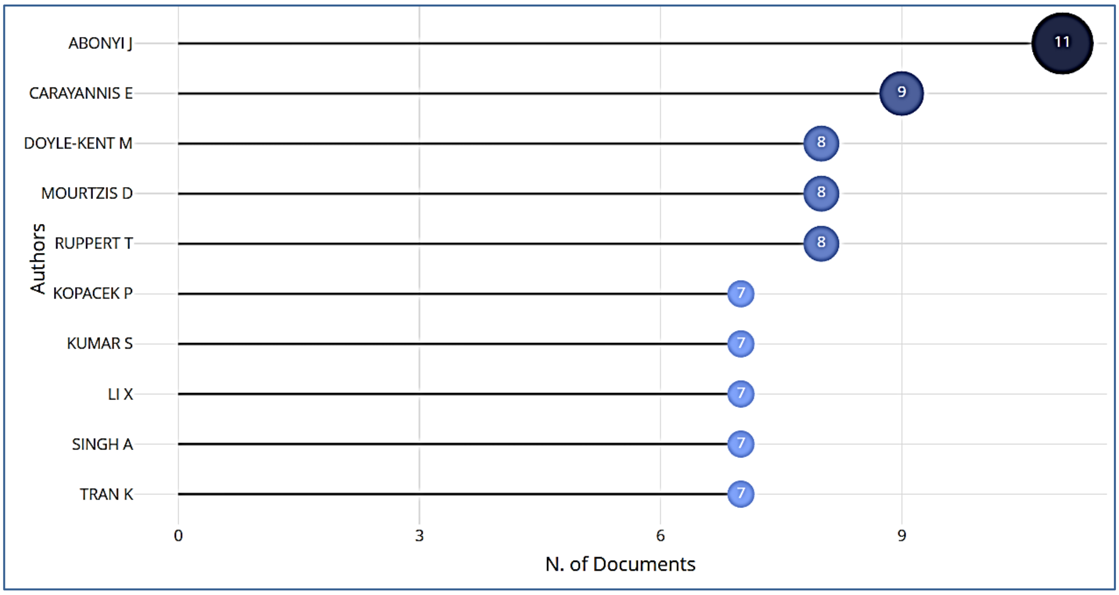


Figure 27 - I5.0's Most Relevant Authors (through Bibliometrix/Biblioshiny)

Next, by the scatter graph presented in Figure 27, containing the number of publications, the aim is to obtain important for the research field Authors.

The productivity of the authors over time is estimated in the following plot, in terms of publications and total citations annually. The color intensity is proportional to the annual sum of citations, while the bubble size is proportional to the number of papers.

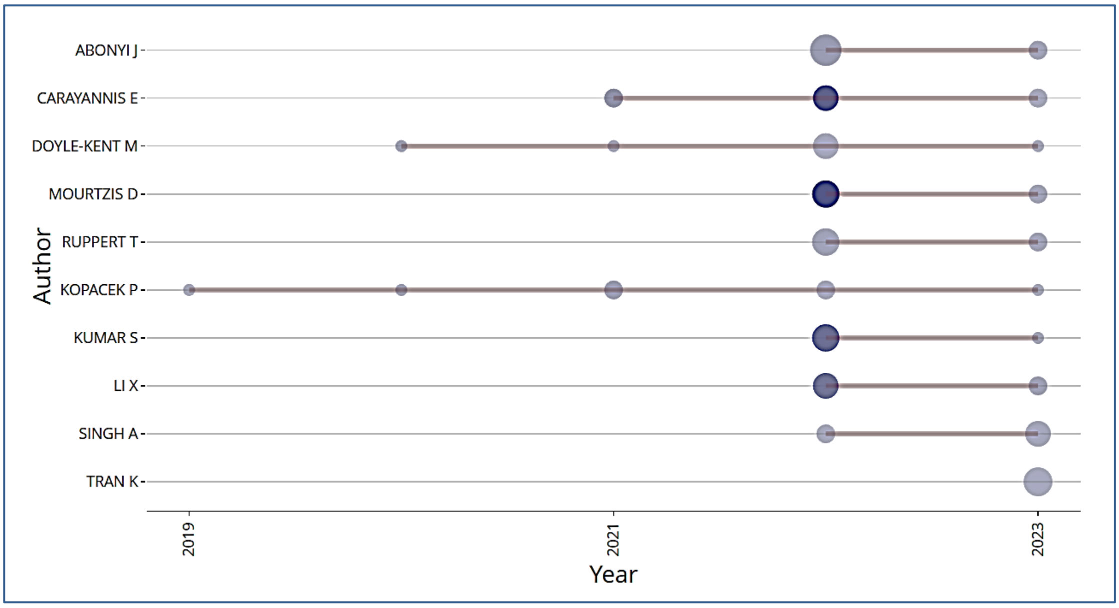


Figure 28 - I5.0's Authors' Production over Time (through Bibliometrix/Biblioshiny)

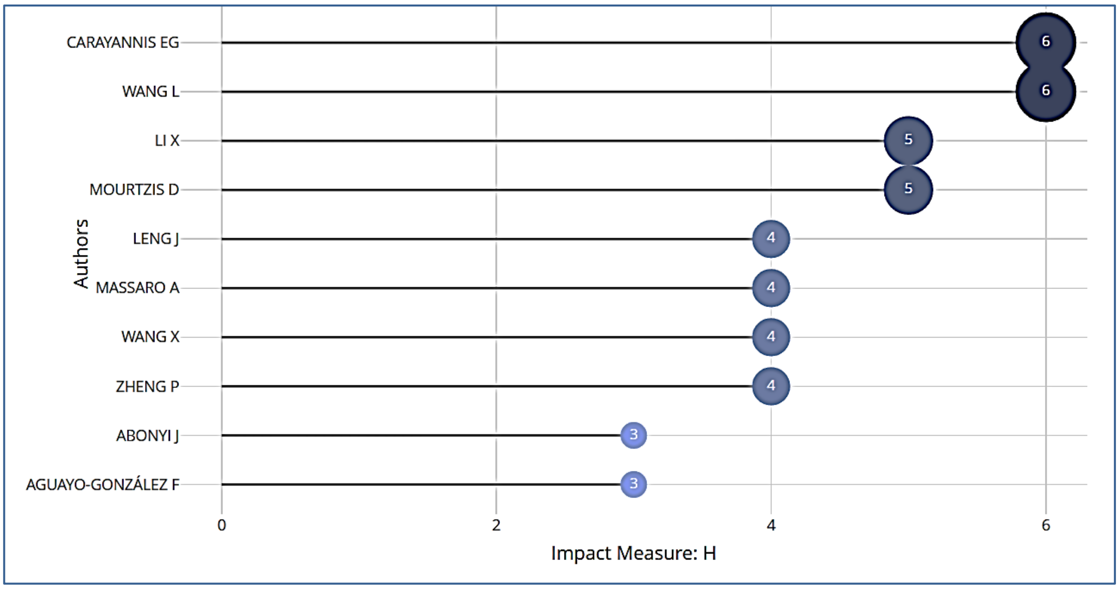


Figure 29 - I5.0's Authors' Local Impact in Scopus (through Bibliometrix/Biblioshiny)

For the above and below plots, the local impact by the h-index is calculated. As h-index is calculated differently by the two databases, it will be presented separately by the two datasets.

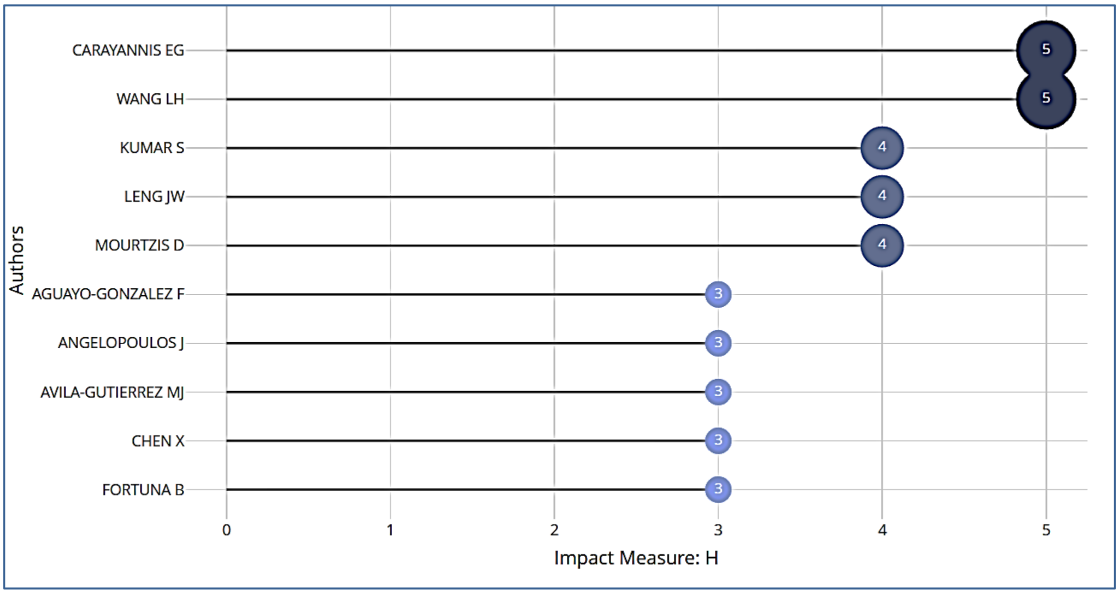


Figure 30 - I5.0's Authors' Local Impact in WoS (through Bibliometrix/Biblioshiny)

Table 8 - Various Scientometric indicators to evaluate an author's impact on Scopus dataset (through Bibliometrix/Biblioshiny)

Element	h-index	g-index	m-index	TC	NP	PY_start
CARAYANNIS EG	6	8	2.000	195	8	2021
WANG L	6	6	2.000	467	6	2021
LI X	5	7	2.500	109	7	2022
MOURTZIS D	5	8	2.500	153	8	2022
LENG J	4	5	2.000	72	5	2022
MASSARO A	4	5	1.000	46	5	2020
WANG X	4	4	2.000	34	4	2022
ZHENG P	4	5	2.000	103	5	2022
ABONYI J	3	4	1.500	23	9	2022
AGUAYO-GONZÁLEZ F	3	3	1.000	25	3	2021

Furthermore, there are other indicators (h-index generalizations) to evaluate an author's impact. Above are various scientometric indicators from the Scopus dataset and below from the WoS.

TC means the Total Citations; NP means number of Publications and PY the Publication Year Start (i.e., the year it was first published). A measure of a scientist's or scholar's production and the significance of their published work is the h-index. For instance, h-index = 6 means that 6 documents from this set have been cited at least 6 times, but the 7th document has been cited less than 7 times.

The m-index is calculated as (h-index)/n, where n is the period of time since a scientist's first article was published (PY_start). The g-index is an enhancement of the h-index for gauging an article set's overall citation performance. The g-index is the unique highest number in which the top g articles received (collectively) at least g^2 citations if this set is ranked in decreasing order of the total amount of citations they got.

Table 9 - Various Scientometric indicators to evaluate an author's impact on WoS dataset (through Bibliometrix/Biblioshiny)

Element	h-index	g-index	m-index	TC	NP	PY_start
CARAYANNIS EG	5	7	1.667	176	7	2021
WANG LH	5	6	1.667	373	6	2021
KUMAR S	4	5	2.000	118	5	2022
LENG JW	4	6	2.000	89	6	2022
MOURTZIS D	4	6	2.000	125	6	2022
AGUAYO-GONZALEZ F	3	3	1.000	16	3	2021
ANGELOPOULOS J	3	4	1.500	46	4	2022
AVILA-GUTIERREZ MJ	3	3	1.000	16	3	2021
CHEN X	3	4	1.000	54	4	2021
FORTUNA B	3	3	1.000	13	3	2021

Thus, for Carayannis m-index = 2 (because it derives from the fraction 6 / 3, where the numerator is the h-index that equals to 6 and the denominator is 3 as it comes from the calculation n = 2023 - 2021 + 1 = 3) and g-index = 8 (as $NP^2=8^2=64$, TC=195 and $NP^2<=TC$) [60].

3.7 Most relevant affiliations

As stated on the Scopus website, the automatic method of identifying name variants and linking them into one profile can never be accurate due to the wide range in how affiliations are represented by writers and publishers. Some variations might be left out, while others might be improperly included [61].

Thus, to get this information, from the merged dataset gave results that were misleading. Therefore, the two datasets from Scopus and WoS were used separately. From the ten most relevant affiliations in the research field examined in the Scopus dataset the most are from Europe. In precise, six are from Europe, three are from Asia and just one is from the USA.

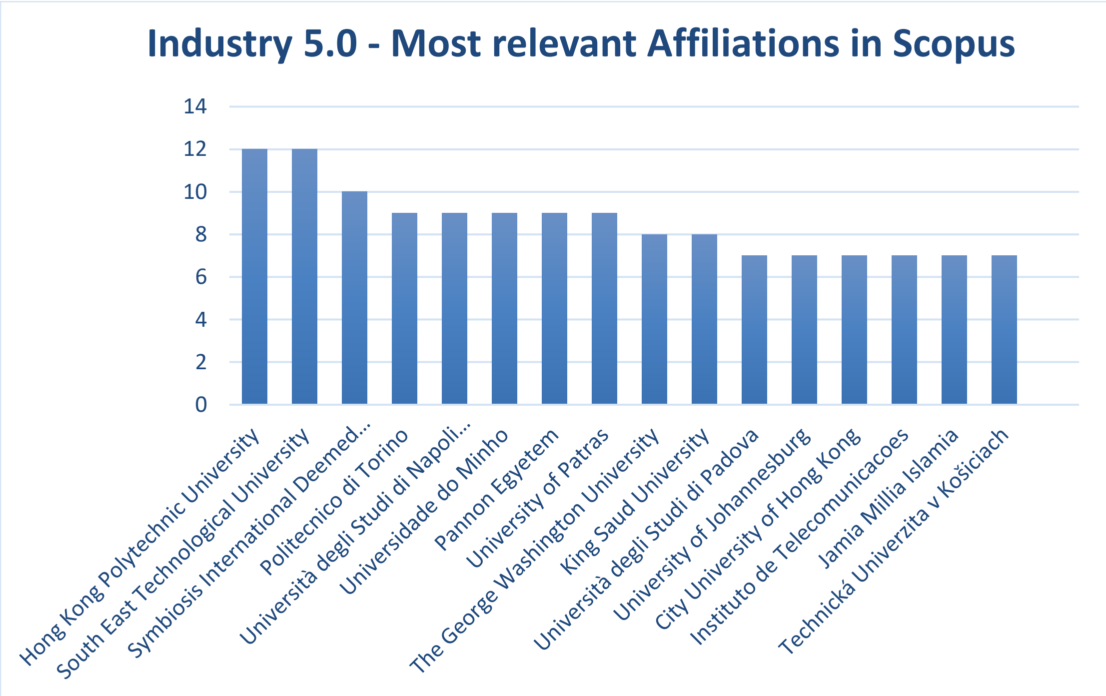


Figure 31 - I5.0's Most Relevant Affiliations in Scopus (Data provided by Scopus)

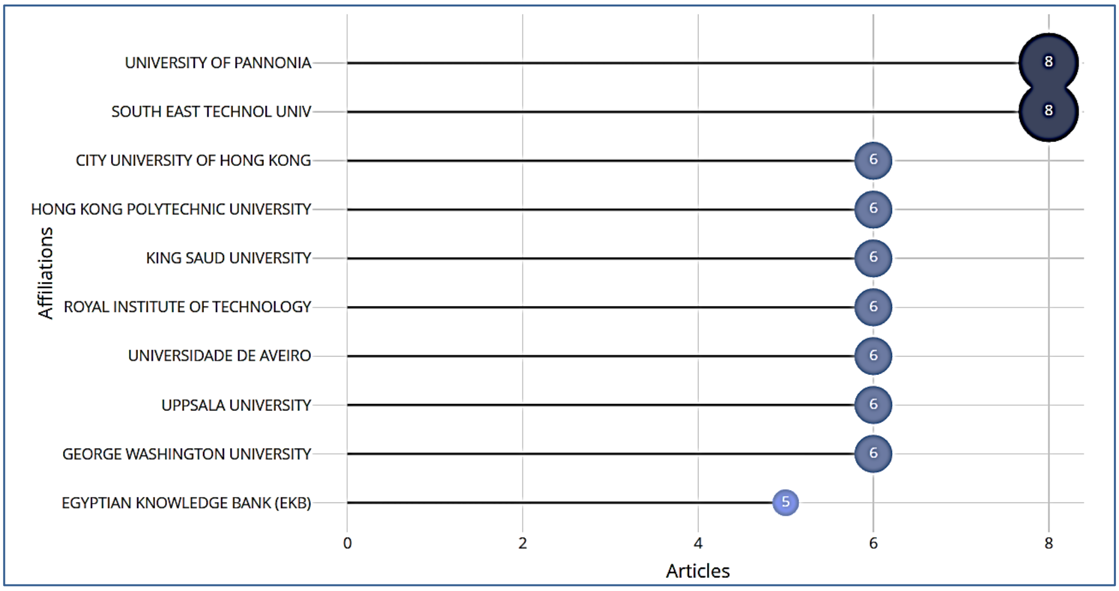


Figure 32 - I5.0's Most Relevant Affiliations in WoS (through Bibliometrix/Biblioshiny)

From the ten most relevant Affiliations in the research field examined, the WoS dataset contains documents by more worldwide distributed Affiliations. Four of them are from Asia, four from Europe, one from the USA and one is from Africa.

3.8 Most relevant and influential sources

In this section the sources are presented based on their production of articles, their impact through various indexes and their classification in zones by the Bradford's law. A journal, book, conference proceeding series, etc. that published one or more documents that are a part of our bibliographic collection is regarded as a source. As the names used by the two databases for the sources are different, for instance a source is named as APPLIED SCIENCES-BASEL in WoS whereas in Scopus is named APPLIED SCIENCES (SWITZERLAND), thus, errors are found in the merged dataset information and therefore the information is been taken separately from the two datasets. The journals derived from both datasets in the top 10, are almost the same (7 out of the 10), although the ordering of the top 2 journals is vice versa in the two datasets.

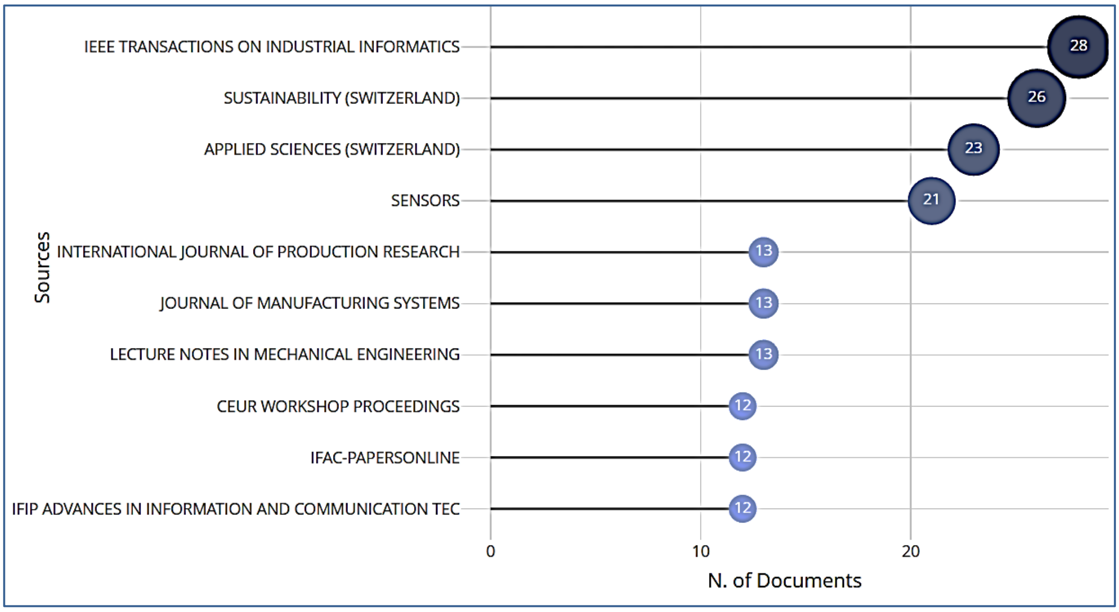


Figure 33 - I5.0's Top 10 Most Relevant Sources in Scopus (through Bibliometrix/Biblioshiny)

Scopus top sources on Industry 5.0 can be found in Figure 33 and in Figure 34.

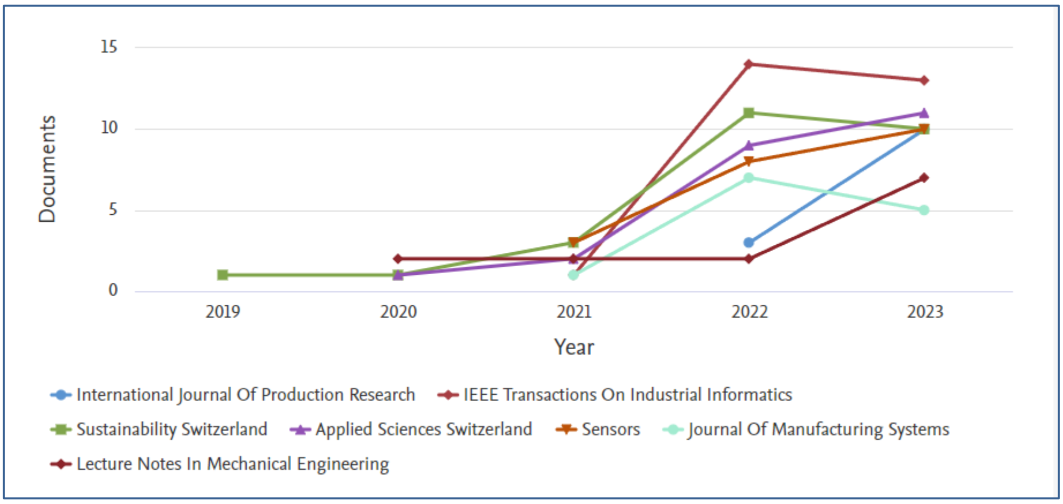


Figure 34 - I5.0's Top 7 Sources' Production over Time/Document per year by source in Scopus (graph provided by Scopus)

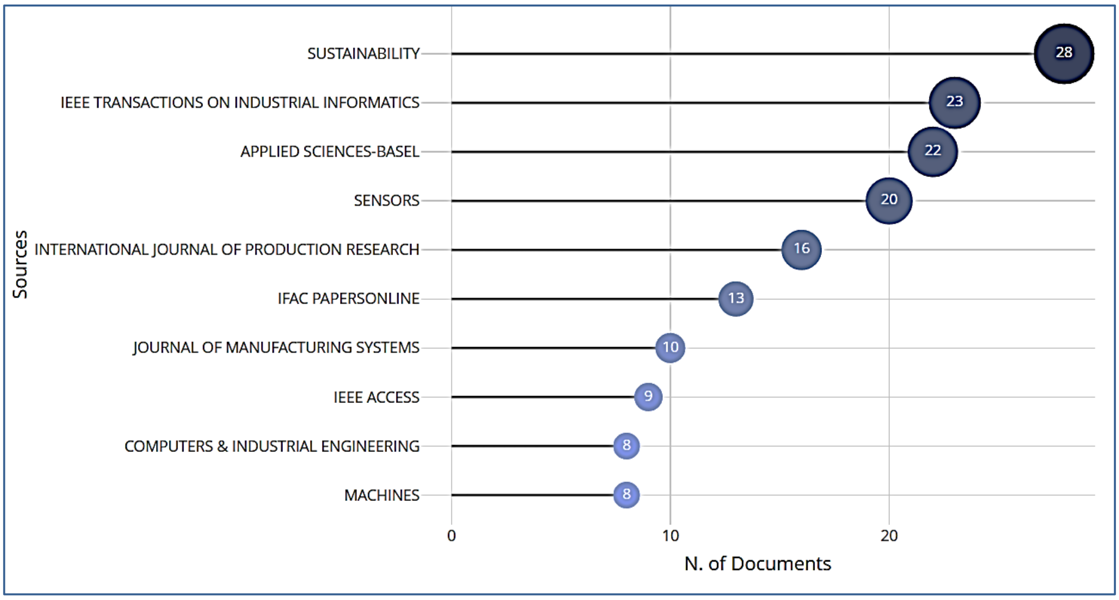


Figure 35 - I5.0's Top 10 Most Relevant Sources in WoS (through Bibliometrix/Biblioshiny)

WoS's top sources on Industry 5.0 can be found in Figure 35 and in Figure 36.

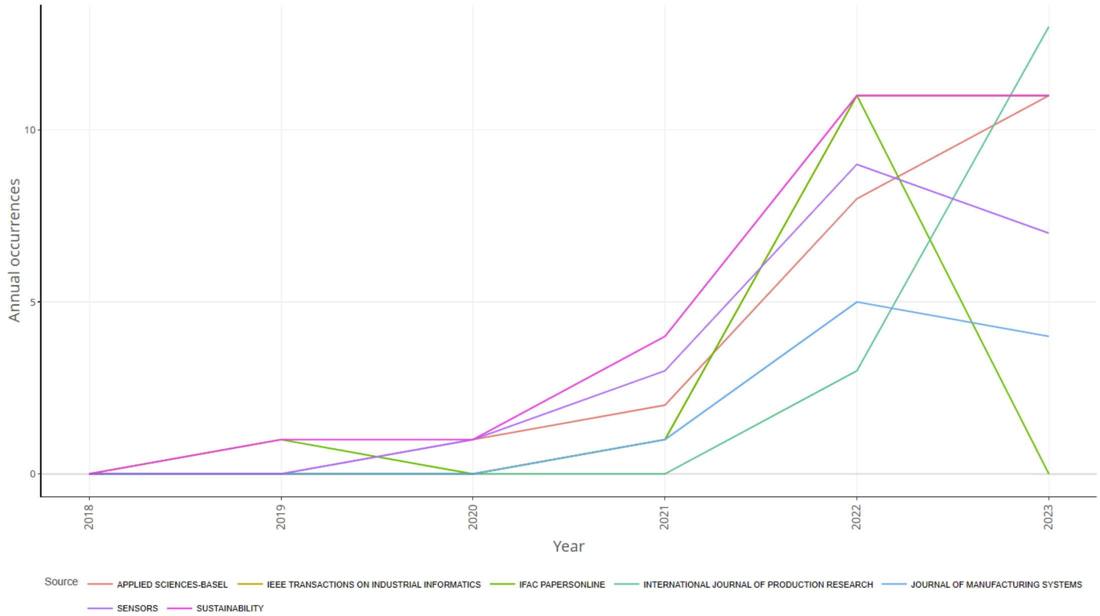


Figure 36 – I5.0's Top 7 Sources' Production over Time in WoS (through Bibliometrix/Biblioshiny)

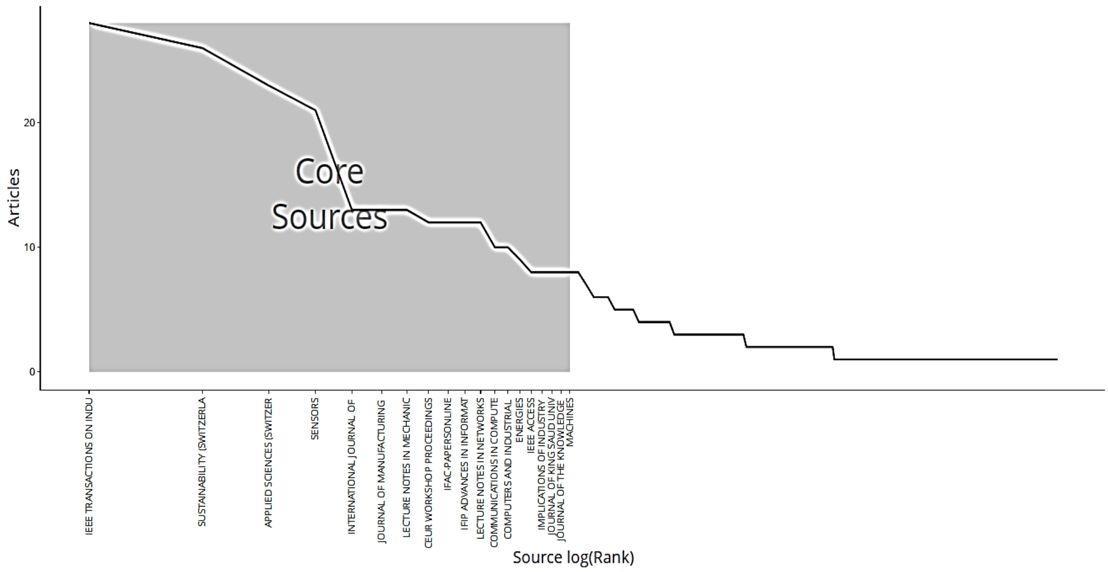


Figure 37 - I5.0's Bradford's Law in Scopus (through Bibliometrix/Biblioshiny)

Subsequently sources were clustered using the Bradford's Law. According to Bradford's Law, the geometric series 1: ns: ns^2: ns^3 is created if journals are arranged in descending order of the number of articles, they include on a given topic, with each zone holding an equal number of articles. Bradford referred to the first zone as the nucleus of journals that were especially focused on the specific subject [62].

Core Zone in Scopus is composed of 19 journals out of 377. More analytically (Figure 38):

- Core Zone (Zone 1): 19 journals, 254 articles,
- Middle Zone (Zone 2): 109 journals, 254 articles,
- Minor Zone (Zone 3): 249 journals, 249 articles.

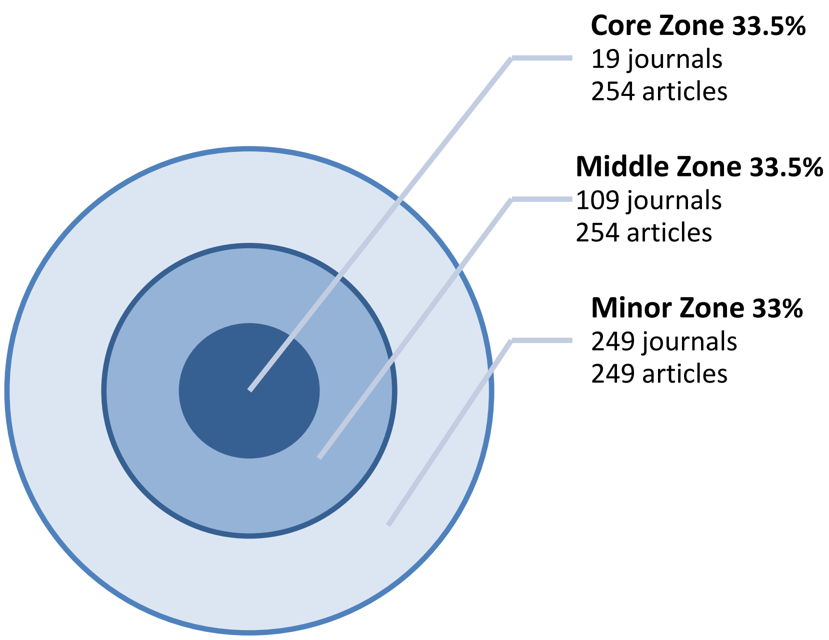


Figure 38 - I5.0's Source Clustering through Bradford's Law with Scopus

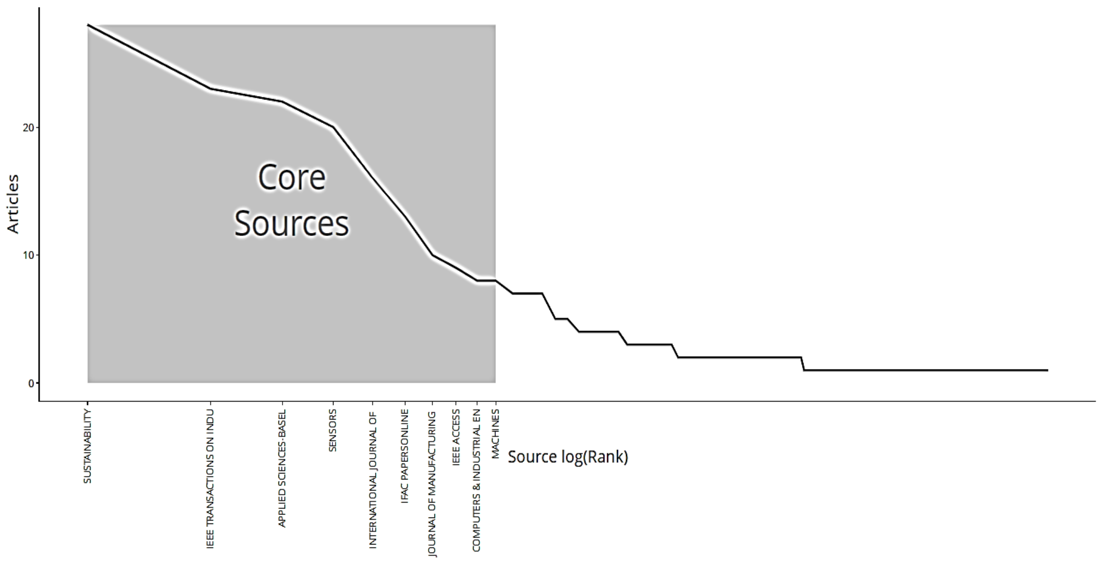


Figure 39 - I5.0's Bradford's Law in WoS (through Bibliometrix/Biblioshiny)

Core Zone in WoS is composed of 10 journals out of 226. More analytically (Figure 40):

- Core Zone (Zone 1): 10 journals, 157 articles,
- Middle Zone (Zone 2): 66 journals, 150 articles,
- Minor Zone (Zone 3): 150 journals, 150 articles.

Bibliometrix/Biblioshiny offers an option to focus only on the first zone's sources, but it was not selected to have as many sources for the current research.

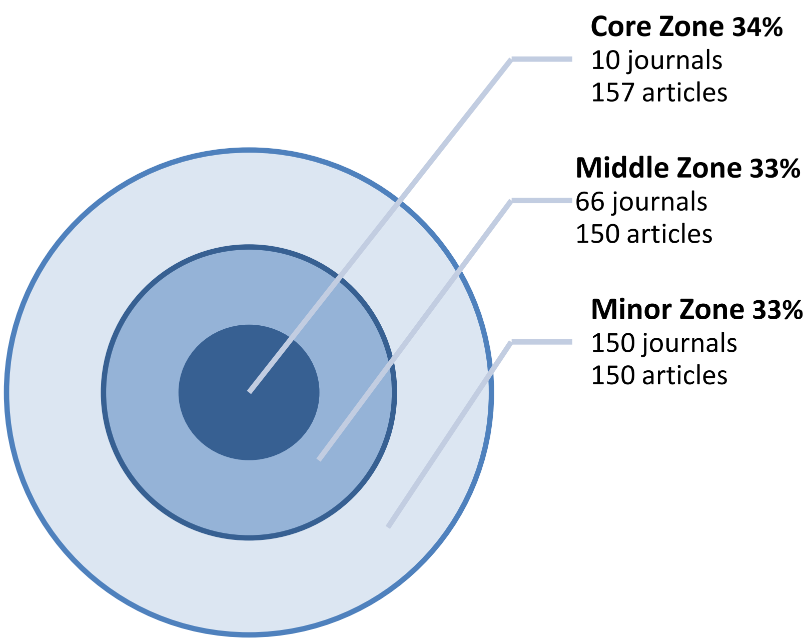


Figure 40 - I5.0's Source Clustering through Bradford's Law with WoS

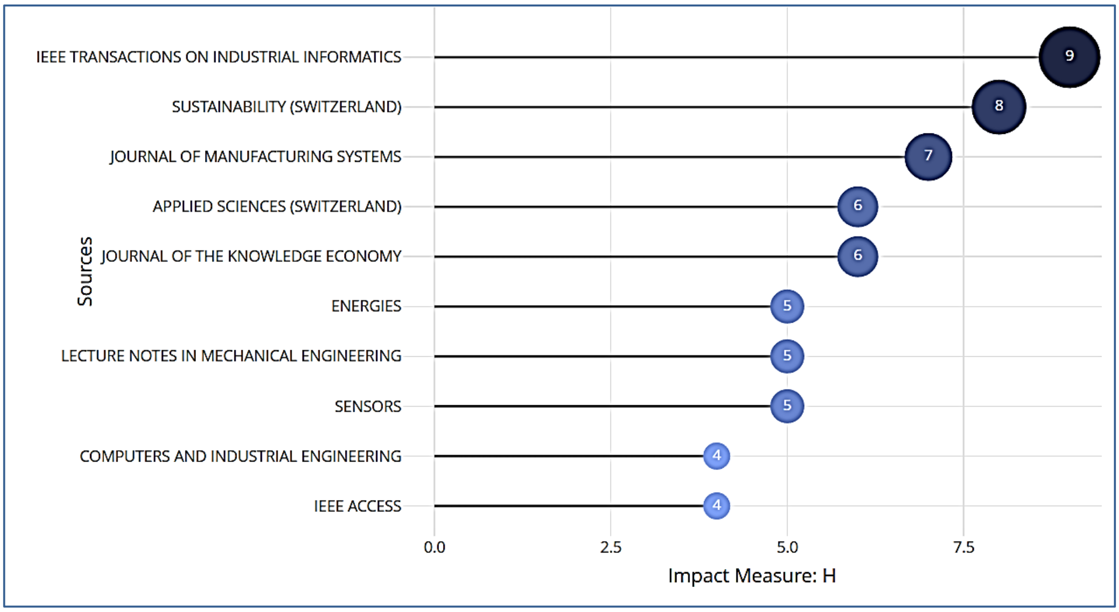


Figure 41 - I5.0's Top 10 Sources' Local Impact in Scopus (through Bibliometrix/Biblioshiny)

The top Industry 5.0 sources according to their local impact in Scopus are shown in Figure 41 and in Table 10.

Table 10 – Top 10 Sources' Local Impact in Scopus

Element	h-index	g-index	m-index	TC	NP	PY_start
IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS	9	14	3.000	244	28	2021
SUSTAINABILITY (SWITZERLAND)	8	22	1.600	510	26	2019
JOURNAL OF MANUFACTURING SYSTEMS	7	13	2.333	502	13	2021
APPLIED SCIENCES (SWITZERLAND)	6	14	1.500	217	23	2020
JOURNAL OF THE KNOWLEDGE ECONOMY	6	8	2.000	193	8	2021
ENERGIES	5	9	1.667	107	9	2021
LECTURE NOTES IN MECHANICAL ENGINEERING	5	9	1.250	85	13	2020
SENSORS	5	10	1.667	114	21	2021
COMPUTERS AND INDUSTRIAL ENGINEERING	4	8	1.333	71	10	2021
IEEE ACCESS	4	6	1.333	45	8	2021

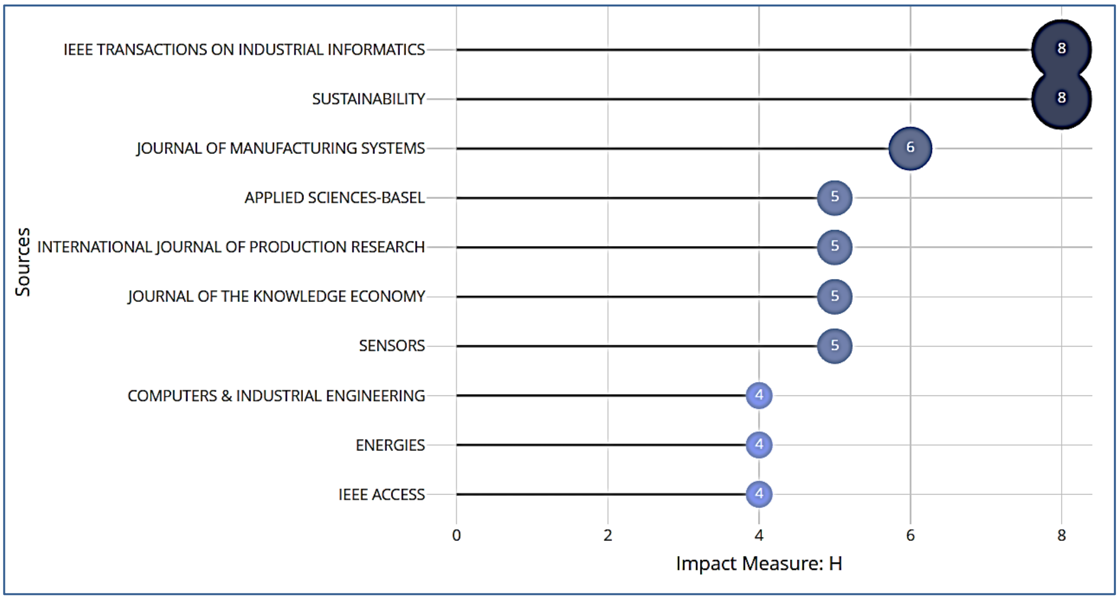


Figure 42 - I5.0's Top 10 Sources' Local Impact in WoS (through Bibliometrix/Biblioshiny)

The top Industry 5.0 sources according to their local impact in WoS are shown in Figure 42 and in Table 11.

Table 11 - Top 10 Sources' Local Impact in WoS

Element	h-index	g-index	m-index	TC	NP	PY_start
IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS	8	13	2.667	191	23	2021
SUSTAINABILITY	8	20	1.600	418	28	2019
JOURNAL OF MANUFACTURING SYSTEMS	6	10	2.000	405	10	2021
APPLIED SCIENCES-BASEL	5	13	1.250	181	22	2020
INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH	5	9	2.500	98	16	2022
JOURNAL OF THE KNOWLEDGE ECONOMY	5	7	1.667	173	7	2021
SENSORS	5	10	1.250	108	20	2020
COMPUTERS & INDUSTRIAL ENGINEERING	4	7	1.333	60	8	2021
ENERGIES	4	7	1.333	88	7	2021
IEEE ACCESS	4	6	1.333	40	9	2021

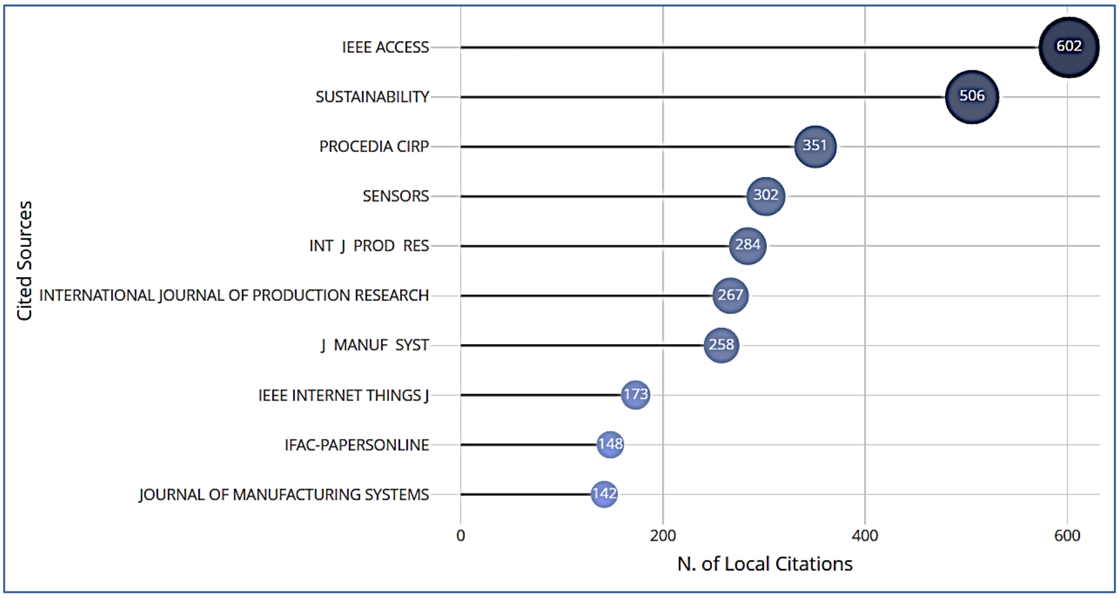


Figure 43 - I5.0's 10 Most Local Cited Sources in Scopus (through Bibliometrix/Biblioshiny)

Any publication, such as a journal, a book, or a collection of conference proceedings that is listed minimum in one of the references lists or bibliographies of the documents set is considered to be a cited source. Above (Figure 43) and below (Figure 44), are presented the top 10 Local Cited sources in the two datasets. From the two scatter graphs presented, it can be seen that in the first 5 places the 4 sources are in both datasets although not in the same place except Sustainability which is in the second place in both datasets.

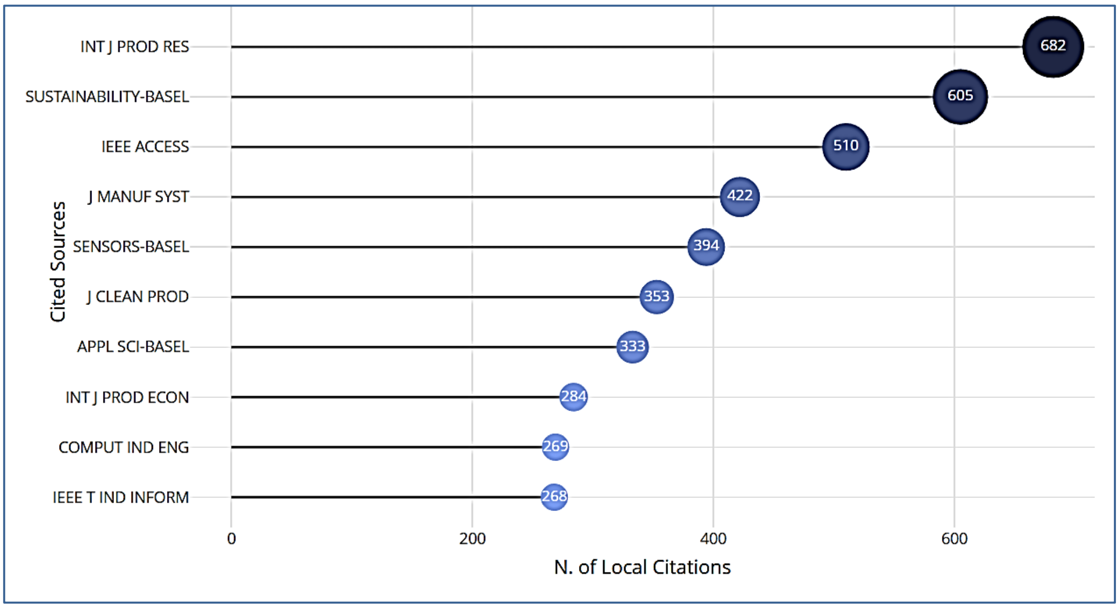


Figure 44 - I5.0's 10 Most Local Cited Sources in WoS (through Bibliometrix/Biblioshiny)

3.9 *Funding Sponsors*

It should be noted that the sponsor field is typically left blank in documents but from those that have it, the sponsors are primarily from Europe and more specifically these are mostly EC fundings but also fundings from several European countries such as Portugal, Spain, Hungary, Italy, Slovakia, Slovenia, Ireland and UK. The origin of top sponsors is as well China, South Korea, Saudi Arabia, Australia and few more countries.

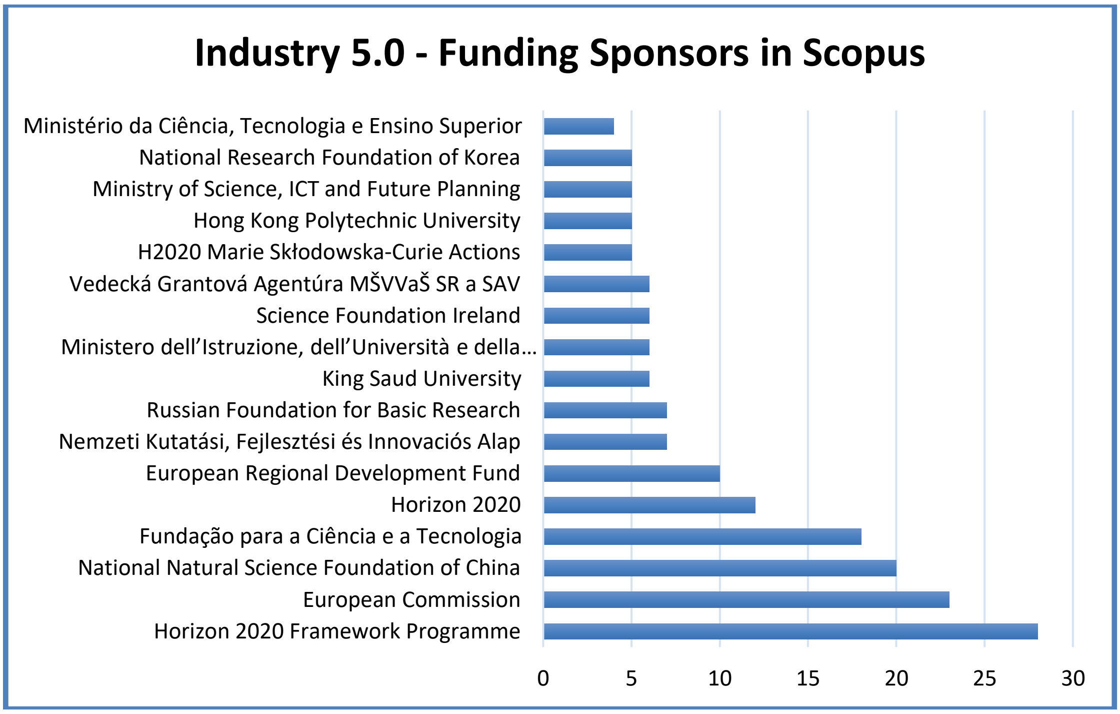


Figure 45 - Industry 5.0 Funding Sponsorship in Scopus (graph from Scopus data)

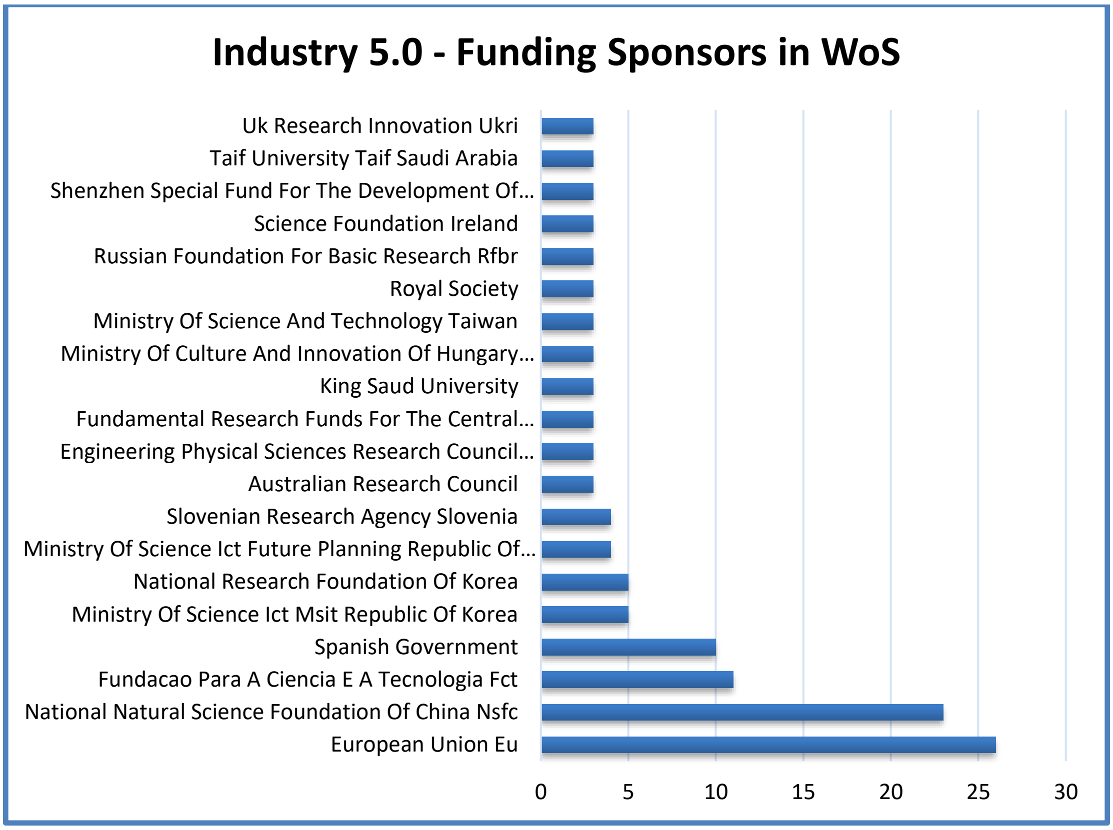
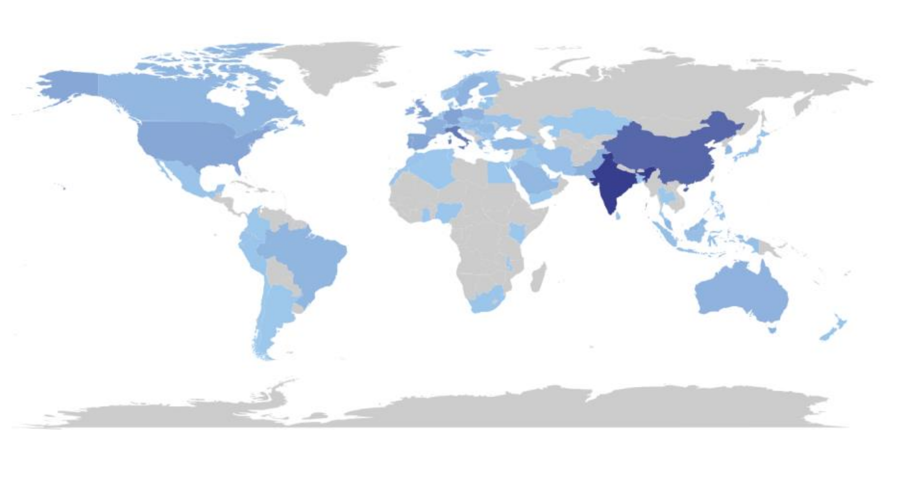


Figure 46 - Industry 5.0 Funding Sponsorship in WoS (graph from WoS data)

3.10Country Scientific Production

Author appearances by country of association are counted as a component of country scientific production. This implies that if an article features three authors, each of whom originate from a different country, the appearances counter for each of those three countries will be raised by one. In other words, each article will be counted as many times as there are writers because it is assigned to the nations of all of its co-authors. In the aforementioned case, it occurs three times. It follows that, the sum of the production indicator must be more than the number of articles, except if all of the articles are written by one author.

The country scientific production is visualized in Figure 47, and the darkest the blue color mean more production per country, as it measures a total of authors who appear according to their country affiliations. The graph had to be run separately for each dataset as the merged dataset due to missing references produced wrong output.



Region	Frequency
INDIA	403
CHINA	281
ITALY	220
UK	106
GERMANY	104
PORTUGAL	101
USA	94
SPAIN	92
IRELAND	73
PAKISTAN	72
FRANCE	68
AUSTRALIA	63
POLAND	60
SWEDEN	60
BRAZIL	55
CANADA	51
GREECE	51

Figure 47 - Country Scientific Production in Scopus (through Bibliometrix/Biblioshiny)

From India are the most document produced for Industry 5.0 in Scopus. From 2020 India was in the 1st place but the amount of research produced raises more compared to other countries. China and Italy are in the second and third place.

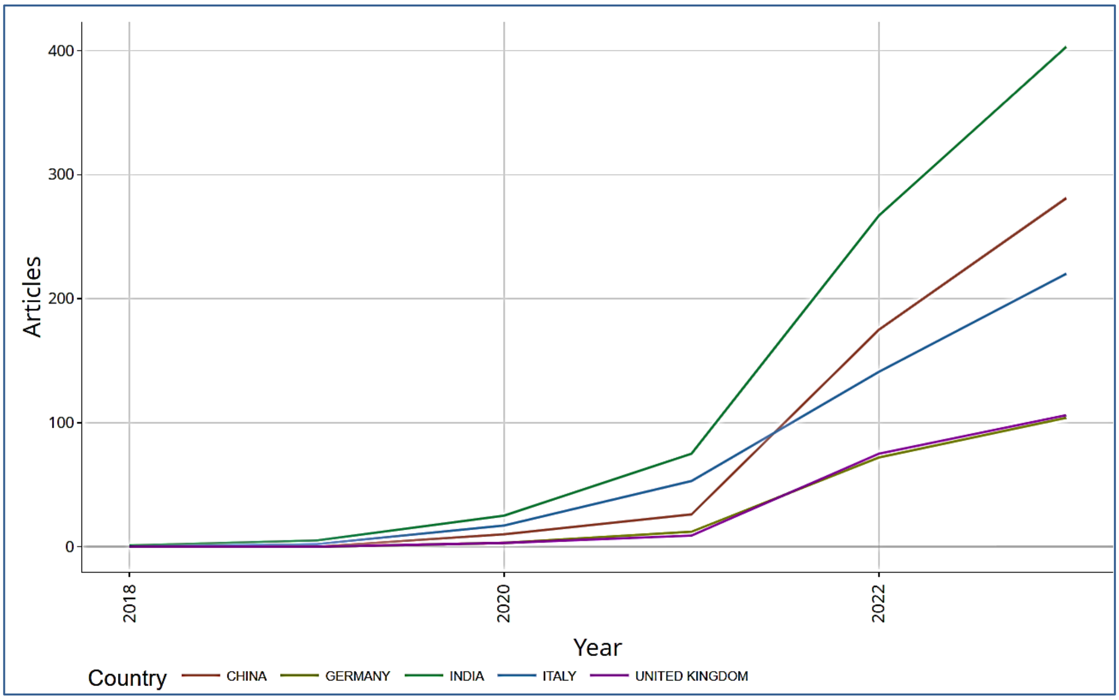


Figure 48 - Country Production over Time in Scopus – top 5 countries (through Bibliometrix/Biblioshiny)

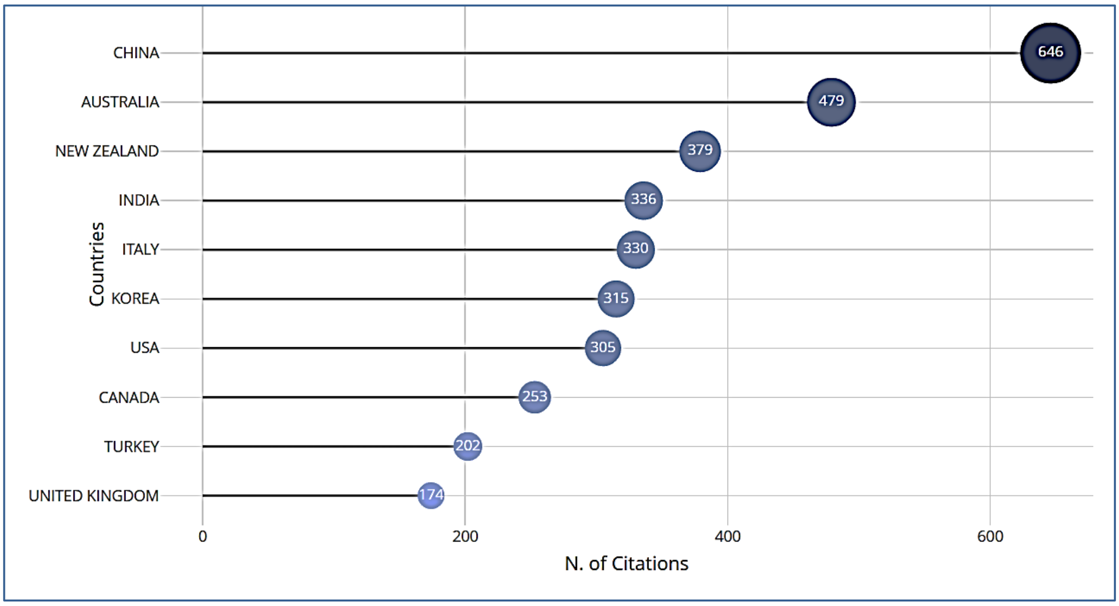
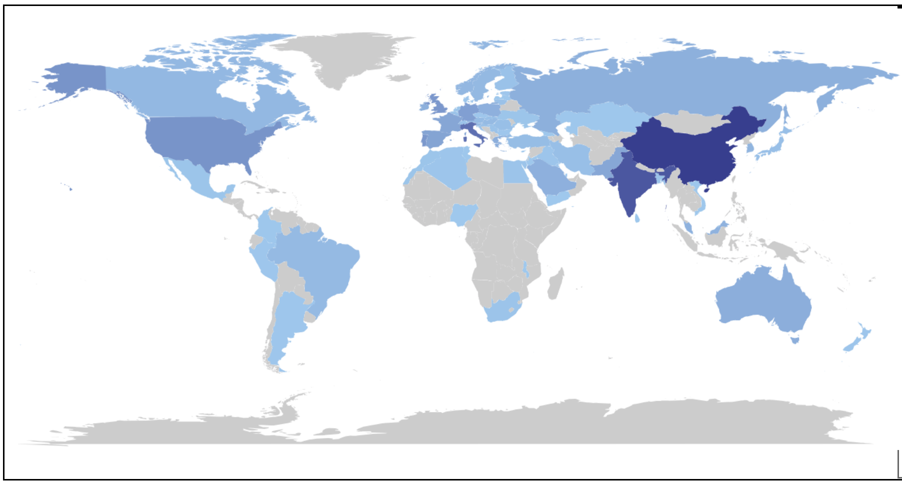


Figure 49 - Most Cited Countries in Scopus (through Bibliometrix/Biblioshiny)

Although India is more productive, China is the most cited country in Scopus regarding the Industry 5.0 field, followed by Italy, Australia, New Zealand, India, USA, S. Korea and Canada.

Table 12 - Most Cited Countries in Scopus (through Bibliometrix/Biblioshiny)

Country	TC	Average Article
CHINA	646	12.20
AUSTRALIA	479	43.50
NEW ZEALAND	379	94.80
INDIA	336	5.30
ITALY	330	7.50
KOREA	315	26.20
USA	305	20.30
CANADA	253	19.50
TURKEY	202	50.50
UNITED KINGDOM	174	7.60
POLAND	159	8.80
LITHUANIA	121	13.40
SPAIN	115	5.00
EGYPT	109	109.00
MALAYSIA	109	18.20
IRELAND	88	8.00
MEXICO	75	25.00
GREECE	72	7.20
GERMANY	62	3.30
PAKISTAN	61	10.20
PANAMA	56	56.00
NORWAY	51	5.70
JAPAN	48	9.60



Region	Frequency
CHINA	159
INDIA	129
ITALY	100
USA	60
UK	56
PORTUGAL	55
GERMANY	46
SPAIN	42
FRANCE	39
PAKISTAN	38
AUSTRALIA	30
GREECE	30
IRELAND	28
RUSSIA	28
POLAND	27
SAUDI ARABIA	27

Figure 50 - Country Scientific Production in WoS (through Bibliometrix/Biblioshiny)

China, India and Italy are in the top 3 places in the WoS database. Italy was in the 1st place until 2021 but the last two years is in the third place.

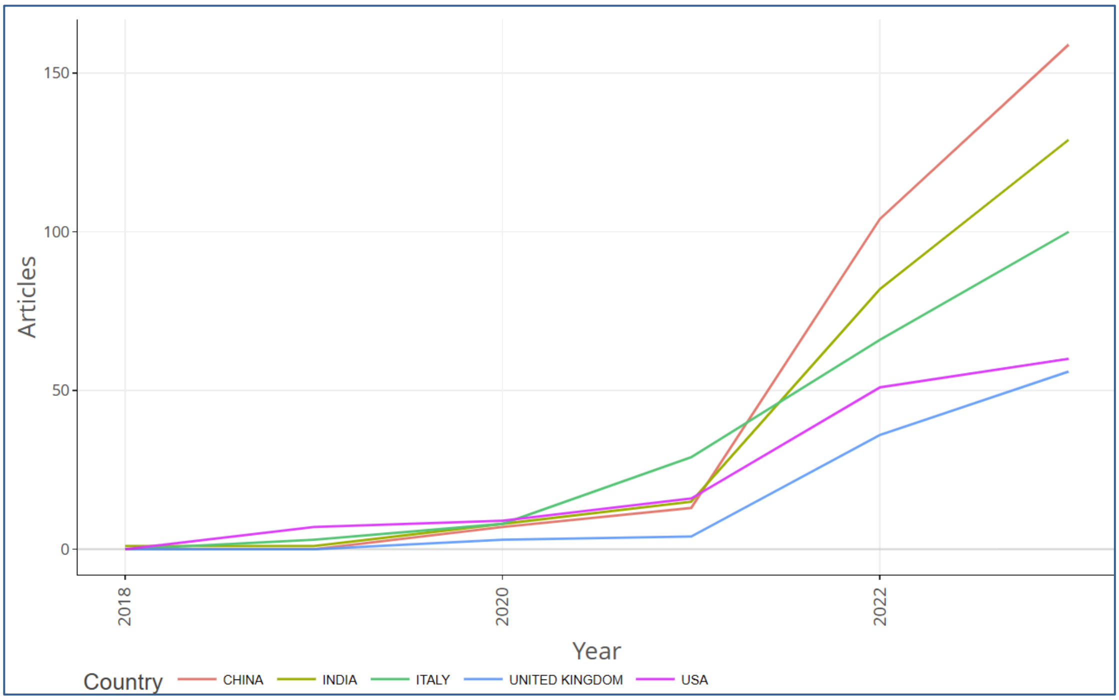


Figure 51 - Country Production over Time in WoS - top 5 countries (through Bibliometrix/Biblioshiny)

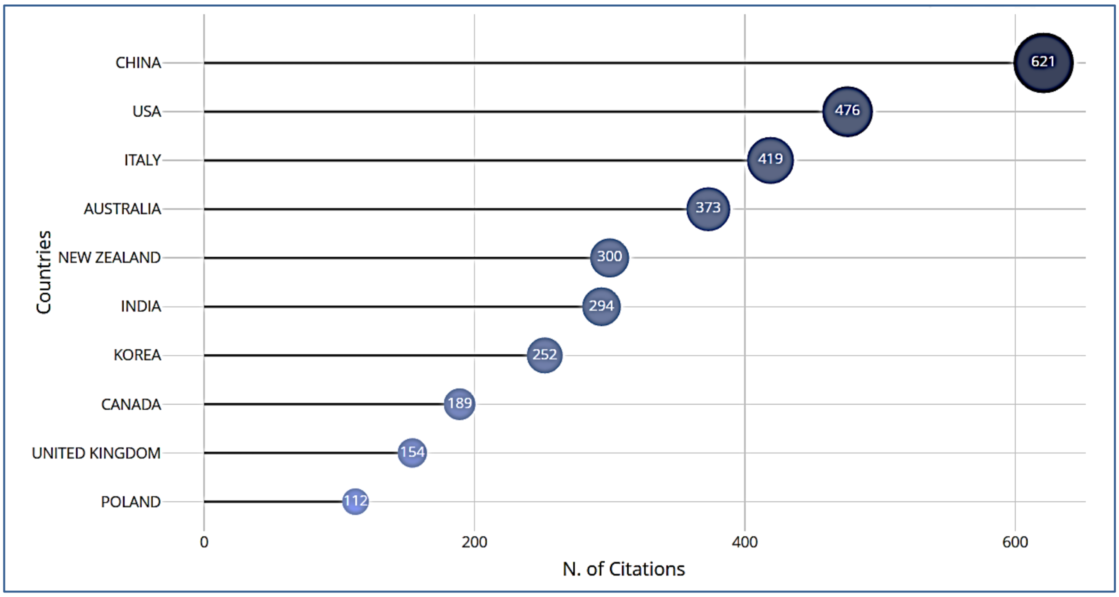


Figure 52 - Most Cited Countries in WoS (through Bibliometrix/Biblioshiny)

China is the most cited country in WoS regarding the Industry 5.0 field, followed by USA, Italy, Australia, New Zealand, India, S. Korea and Canada. The top 8 countries are the same in both databases, just a few are in different places.

Table 13 - Most Cited Countries in WoS (through Bibliometrix/Biblioshiny)

Country	TC	Average Article Citations
CHINA	621	11.90
USA	476	25.10
ITALY	419	9.10
AUSTRALIA	373	28.70
NEW ZEALAND	300	75.00
INDIA	294	8.40
KOREA	252	22.90
CANADA	189	27.00
UNITED KINGDOM	154	6.70
POLAND	112	8.00
SPAIN	99	5.80
MALAYSIA	98	19.60
GERMANY	96	5.10
LITHUANIA	83	13.80
PAKISTAN	63	10.50
GREECE	56	7.00
FRANCE	51	4.60
IRELAND	46	3.10
NORWAY	43	5.40
BRAZIL	39	6.50
U ARAB EMIRATES	33	11.00
ISRAEL	31	15.50
JAPAN	31	7.80

The "Corresponding Author's Country", is an alternative analysis of a country's dimension, suggested by Bibliometrix/Biblioshiny. It assigns each article to a single country according to the corresponding author's affiliation. The person who, when working on a paper with several authors, assumes primary responsibility for corresponding with the journal to be published in is known as the corresponding author. In this instance, the overall number of articles and the frequency per country are equivalent.

MCP stands for Multiple Countries Publication and SCP for Single Country Publication. The number of documents with at least one co-author from a nation other than the corresponding author's is shown by MCP for each country. The number of documents with at least one co-author from a nation other than the corresponding author's is shown by MCP for each country.

MCP as a result measures the degree to which a nation collaborates internationally. As noted before the merging process yields an issue regarding this information and the results of this graph are misleading. Therefore, separate runs made with the Scopus and the WoS datasets yielding:

- The Corresponding Author's Countries from Scopus: A remarkable difference between China and India or Italy, the three first in publications countries, where for China around 60% are international collaborations whereas for India it is about one third and for Italy a quarter of total country's publications.

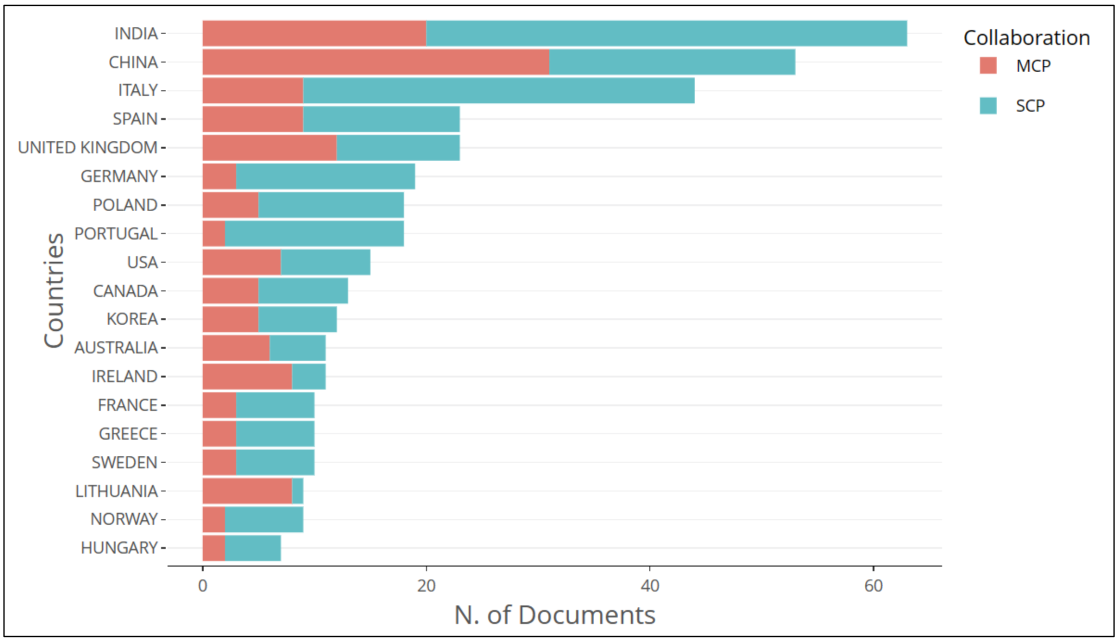


Figure 53 - Corresponding Author's Countries in Scopus (through Bibliometrix/Biblioshiny)

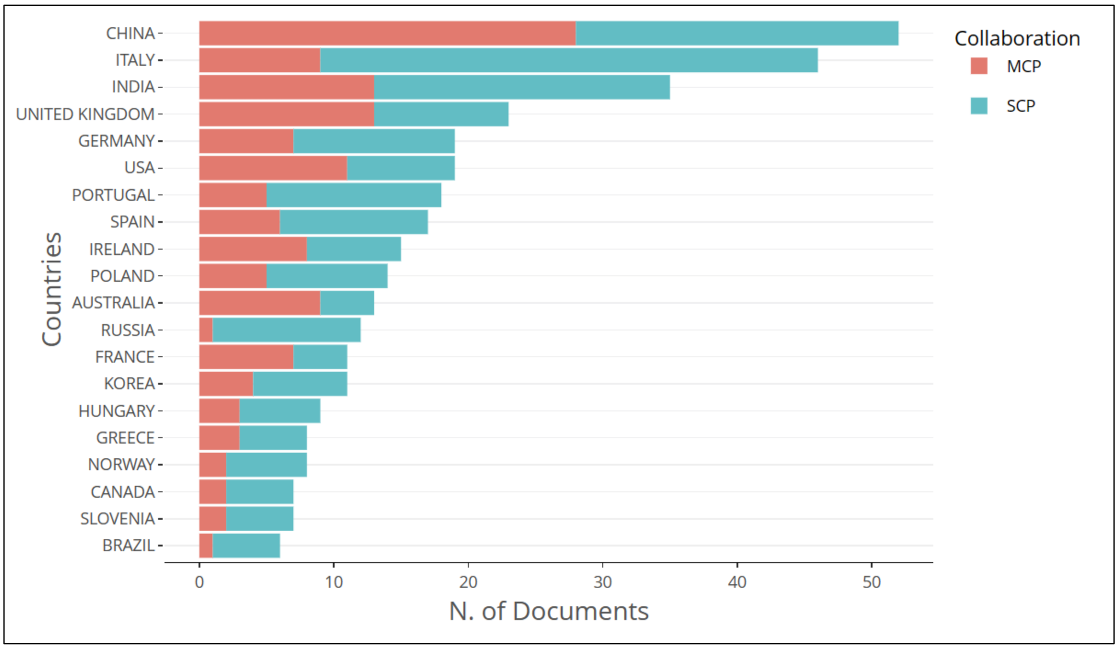


Figure 54 - Corresponding Author's Countries in WoS (through Bibliometrix/Biblioshiny)

- The Corresponding Author's Countries from WoS: The results, as can be seen in Figure 54, were similar to the Scopus dataset, at least for the top in publications countries.

As VOSviewer cannot use the merged dataset, the Scopus and the WoS datasets were used separately, to examine any underlying relationships between countries via the VOSviewer tool through the Bibliographic coupling analysis by country, citations by country and co-authorship by countries.

Typically, with VOSviewer, a network is first constructed using the data made accessible to VOSviewer when a map is to be developed via bibliographic or text data. The next step is the creation of a map by using the network. A network of relationships involving co-authorship, co-occurrence, citation, bibliographic coupling, or co-citation can be created using bibliographic data. VOSviewer is a distance-based method to visualize bibliometric networks, where the distance between two items indicates how strongly they are related to one another. In a bibliometric network, the number of edges that individual nodes have with other nodes can vary significantly. One typically does a normalization for these large differences between nodes in the analysis of bibliometric networks. The association strength normalization is used by default, as a normalization mechanism, in VOSviewer. After creating a normalized network, the next step in creating a network graph is the process of locating the network's nodes in a two-dimensional space so that strongly associated nodes are close to one another and weakly related nodes are far apart. As we previously stated, VOSviewer implements the "Visualization Of Similarities" (VOS) mapping approach. [41] [63].

A cluster is a collection of nodes that are closely related to one another. By default, VOSviewer assigns the network nodes to clusters. Each node in a network receives a cluster. A resolution parameter determines the number of clusters. With a higher value for this parameter, there are more clusters. In this research, the default value of 1.00 was used, and the default value of 1 was also used for the minimum size of the cluster. The cluster that a node has been assigned is denoted by an alternative color in the graphic representation of a bibliometric network by VOSviewer. The clustering method used by VOSviewer is discussed in [64]. An algorithm must be used in the technique to solve an optimization problem. VOSviewer uses the clever local movement technique described in [65] for this purpose.

Researchers have usually utilized the full counting method to build bibliometric networks. A more realistic viewpoint than full counting is provided by fractional counting. Many argue that full counting results could rather easily cause inaccuracies whereas by employing fractional counting, this can be prevented. [66].

Before running the tool, the parameters used are analyzed. As noted above, Association strength normalization is employed by VOSviewer to adjust for variations in the number of edges that each node has when compared with other nodes. Since VOSviewer considers all networks as undirected, it is necessary to normalize the co-occurrence matrix, or correct the matrix for variations in the total number of either occurrences or co-occurrences of items, in order to ensure that the weight of the edge between any two nodes is the same. The cosine and the Jaccard index are the most widely used similarity measures for normalizing co-occurrence data. However, none of these similarity metrics are applied by VOSviewer. Instead, it makes use of a probabilistic similarity metric known as the association strength. Observed cooccurrence frequencies are measured against expected cooccurrence frequencies under the assumption of independence, can be understood as probabilistic similarity normalization measures [41]. Curiously, despite their popularity, the cosine and Jaccard indexes have proven inadequate for normalization in certain contexts. It is argued that a more suitable normalization measure for co-occurrence data is the association strength, also known as the proximity index or the probabilistic affinity index. While less known, this measure possesses the necessary theoretical properties for normalizing co-occurrence data effectively [67].

In scientometric research, similarity measures often serve for normalization. It is contended that, especially in this context, probabilistic similarity measures like the association strength outweigh set-theoretic alternatives. Therefore, for most applications of direct similarity measures in scientometric research, the use of set-theoretic similarity measures is discouraged, and instead, the adoption of probabilistic similarity measures is recommended.

Regarding Network visualization, items are represented in the network representation by their label and by default, a circle as well. The weight of an object determines the size of the circle and label for that item. In terms of network visualization, each object in the network representation gets a circle by default and is also represented by its label. The size of the circle and label for an item are dependent on its weight. An object's label and circle enlarge in proportion to its weight. Labels in VOSviewer are only displayed for a subset of all nodes to prevent labels from overlapping with one another. In order to present as many labels as feasible, the selection prioritizes labels of more significant nodes, the nodes that have more edges, above labels of less significant nodes [63]. An item's color is determined by the cluster to which it belongs. Links are denoted by lines between items.

In the Visualization Network graph, the approximate distance between two nodes shows how closely associated the nodes are in terms of co-citation relationships. In general, the more geographically closer two nodes are to one another, the more closely they are related. Additionally, lines show the strongest journal-to-journal co-citation connections.

Additional differences in the context of citation relationships can be drawn between direct citation relationships, both co-citation relationships, and bibliographic coupling ties. Weighted networks are typical of bibliometric networks. Therefore, edges show the strength of the relationship as well as whether there is a relationship between two nodes.

The next network graph is the Bibliographic coupling analysis. Two articles are considered to be bibliographically coupled if at least one mentioned source can be found in the citations of both. The relationship among multiple documents that cite a third document is known as bibliographic coupling. Bibliographic coupling can be thought of as the mirror image of co-citation. Bibliographic coupling is predicated on the idea that two papers can be highly connected even if they do not directly cite one another since they share at least one bibliographic reference. On the other side, co-citation analysis is mostly based on finding pairs of frequently referenced works. These show to be reliable indicators of the appearance of fresh subjects. While co-citation mostly has a forward-looking perspective, bibliographic coupling is retrospective [68] [69].

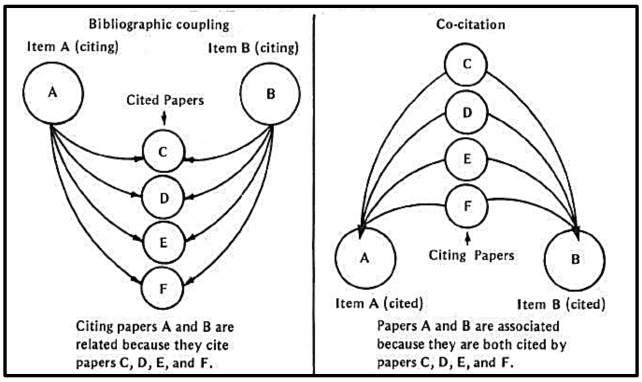


Figure 55 - Bibliographic coupling vs co-citation [69]

As a result, Bibliographic coupling analysis can offer a picture of the state of the research field presently [70]. Bibliographic coupling analysis with VOSviewer by country follows (using: fractional counting, association strength as normalization method and min occurrences = 5).

As significant countries have been already identified, and can be seen in the following networks by the size of the circle, the goal is to find the connections between the countries. This can be found by the clustering procedure, the placement on the network map and by the lines that connect the countries. The closest two nodes are on the map, the more related to each other. Additionally, the thickness of a line conveys the volume of collaboration among two countries.

The Scopus Clusters are: the Yellow Cluster containing China, Taiwan, Hong Kong, Sweden etc., the Green Cluster containing Italy, USA, Poland, Austria, etc., the Orange Cluster containing India and Russia, the Purple Cluster containing UK, Portugal, Greece, Ireland, etc., the Red Cluster containing Australia, Pakistan, Saudi Arabia, Canada, S. Korea, Turkey, Malaysia, U.A.E. etc., and the Azzurro Cluster containing Germany, Brazil, Norway, Netherlands, Iran, etc.

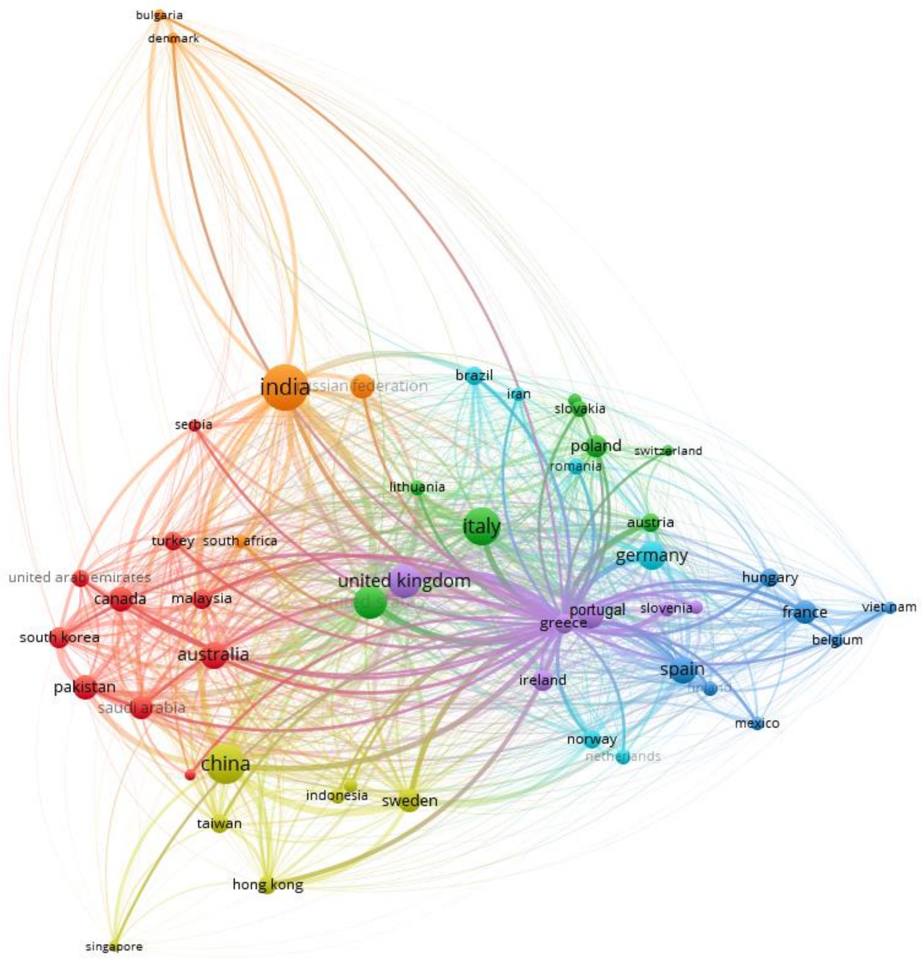


Figure 56 - I5.0's Bibliographic coupling by countries in Scopus (through VOSviewer)

The WoS Clusters are slightly different. England is in the China's Yellow Cluster, as is Scotland and Sweden. USA and Lithuania form a small Cluster as they are highly related (as the thickest line of the network connects them). Portugal, Greece and Ireland are again together in a Cluster the Blue one, with many European countries such as Spain, France, Croatia, Finland, Slovenia and Austria. The Red Cluster is mainly made by European countries such as Italy, Germany, Poland, Netherlands, Norway, Hungary but also Brazil, Iran and Japan. The Green Cluster looks like the Scopus Red Cluster containing Australia, Pakistan, Saudi Arabia, Canada, S.Korea, Turkey, Malaysia, U.A.E. but also containing India. There is also a small Purple Cluster with Russia and Taiwan.

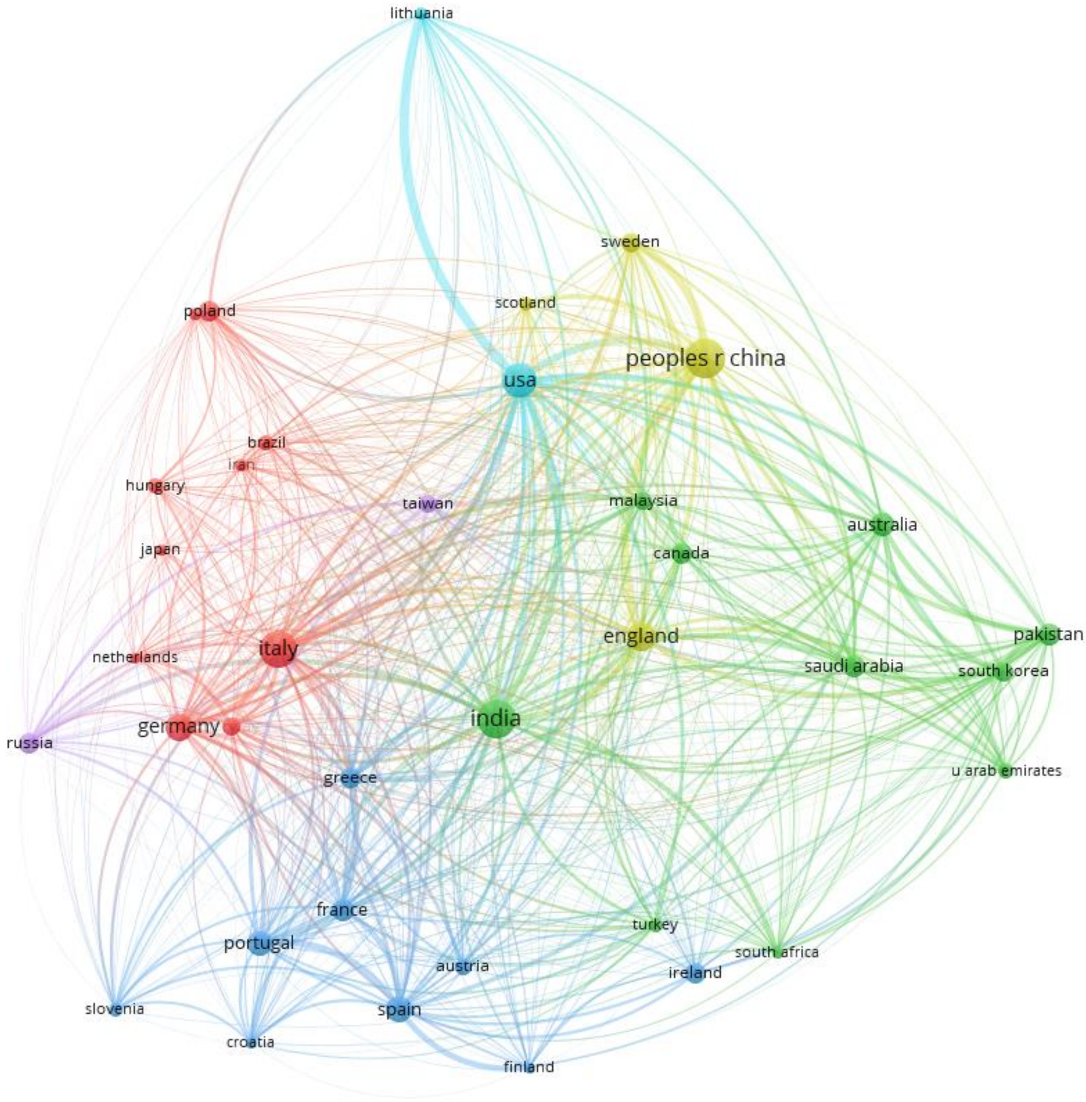


Figure 57 - I5.0's Bibliographic coupling by countries in WoS (through VOSviewer)

The next Network graph is the Citation by countries made with VOSviewer (using: fractional counting, association strength as normalization method, weighted by Documents and min occurrences = 5). The relatedness of articles is more clearly demonstrated through direct citations, also known as cross citations.

Some observations from the Network maps are: India, Italy, Saudi Arabia and Brazil in both Network graphs belong to the same cluster, same with China and Pakistan, USA and Spain, Greece and Canada, Poland, Sweden, Hungary and Slovakia, Austria, Ireland and Iran. Also, although not in the same cluster in both graphs, Germany is related with Portugal and France (when selecting Germany in the graph in the Scopus Network they are connected with very thick edges).

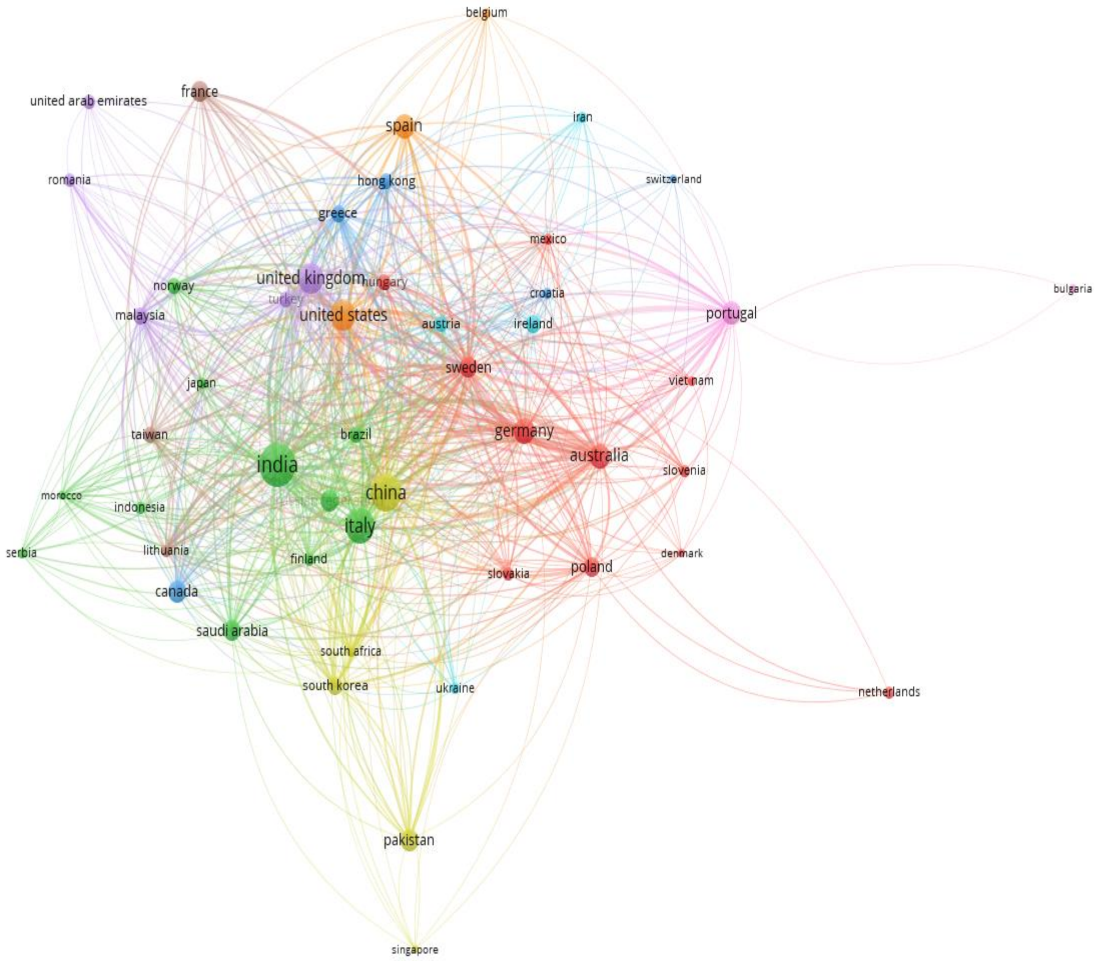


Figure 58 - I5.0's citations between countries in Scopus (through VOSviewer)

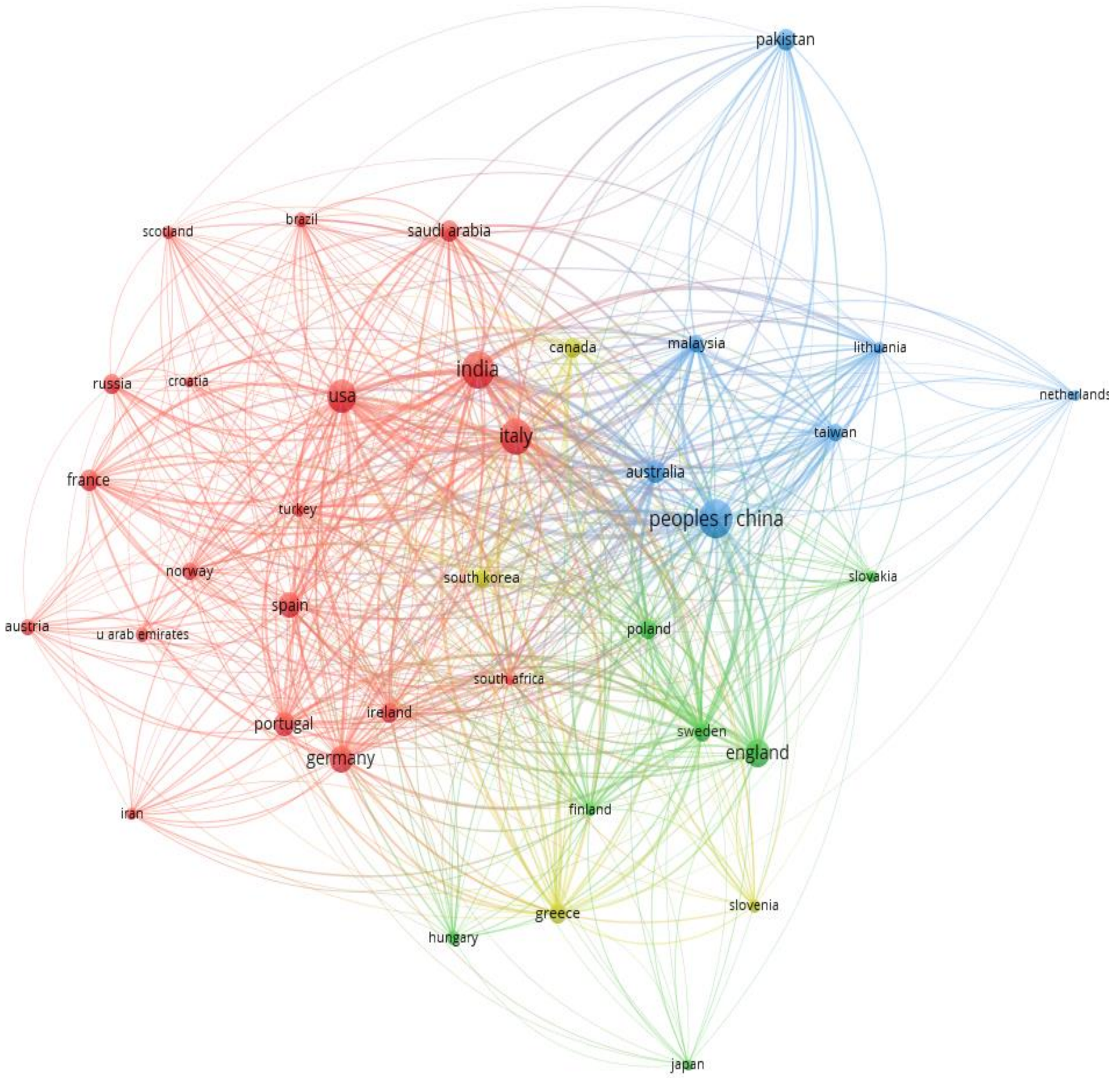


Figure 59 - I5.0's citations between countries in WoS (through VOSviewer)

Co-authorship by countries are the next two network graphs, made from both datasets (Figure 60 and Figure 61 respectively) via the VOSviewer tool. Co-authorship is the process of writing a study with another author. It is among the most well-known and transparent forms of scientific cooperation. By looking at co-authorship networks and applying bibliometric approaches, nearly every characteristic of scientific collaboration networks may be precisely recorded [71].

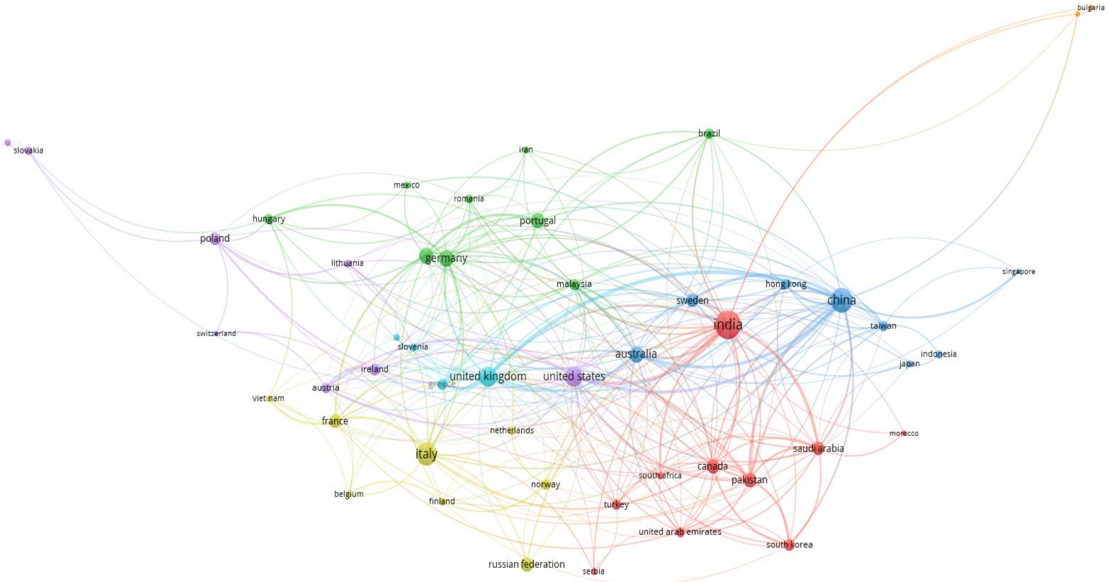


Figure 60 - I5.0's Co-authorship by countries in Scopus (through VOSviewer)

From the Networks can be obtained the international co-authorship information of each country. Co-authorships occur between authors from: Greece and for instance UK (or England in WoS), UK (or England in WoS) and China, China and USA, Germany and Hungary, China and Australia, India and Saudi Arabia, India and USA, China and Sweden, Portugal and Spain, Italy and France, China and Sweden, Poland and Lithuania, Poland and Slovakia, Italy and Germany, Germany and France etc.

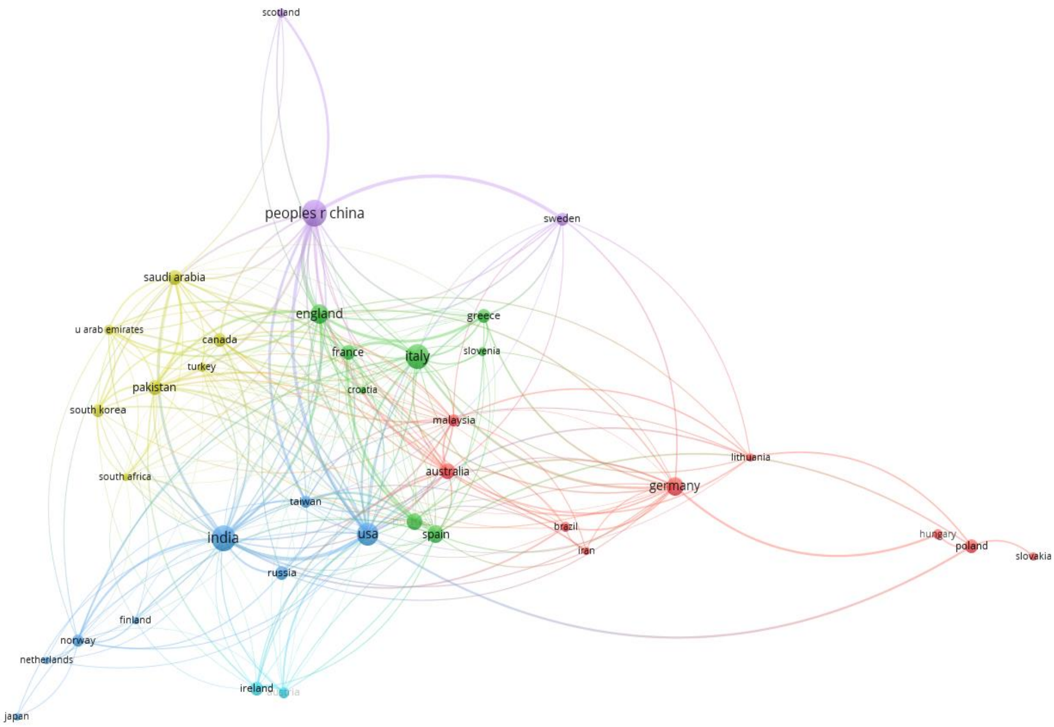


Figure 61 - I5.0's Co-authorship by countries in WoS (through VOSviewer)

The last in this category graph is a Collaboration Network of the Countries on the merged dataset with Bibliometrix/Biblioshiny. The Network layout is Sphere because it avoids overlaps and visualizes better the connections between the countries displayed, the Clustering algorithm is Walktrap and the Normalization method is association. The Walktrap algorithm, proposed by Pon & Latapy, is a hierarchical clustering method based on the tendency of short-distance random walks to stay within the same community, iteratively merging adjacent communities to update distances [72].

To analyze the mapping of Countries' collaboration network, the emphasis is placed on the size of each circle as well as the width of the lines that connect them. The bigger the circle, then the country is of greater significance in the network, thus, wider the countries' collaboration network; and when the lines' association is thicker, the more collaboration occurs between the countries connected. India is the most significant county in the network, followed by Italy and China. India and USA have the most synergies followed by India-Portugal, India-China and China-USA collaborative couples. Two are the most significant clusters. India, China, USA, Portugal, Russia, Germany and Malaysia form the one Cluster. The other significant cluster is with Italy, Spain, France, Croatia, Greece, South Africa, Turkey, Saudi Arabia, Norway, Slovenia and Austria.

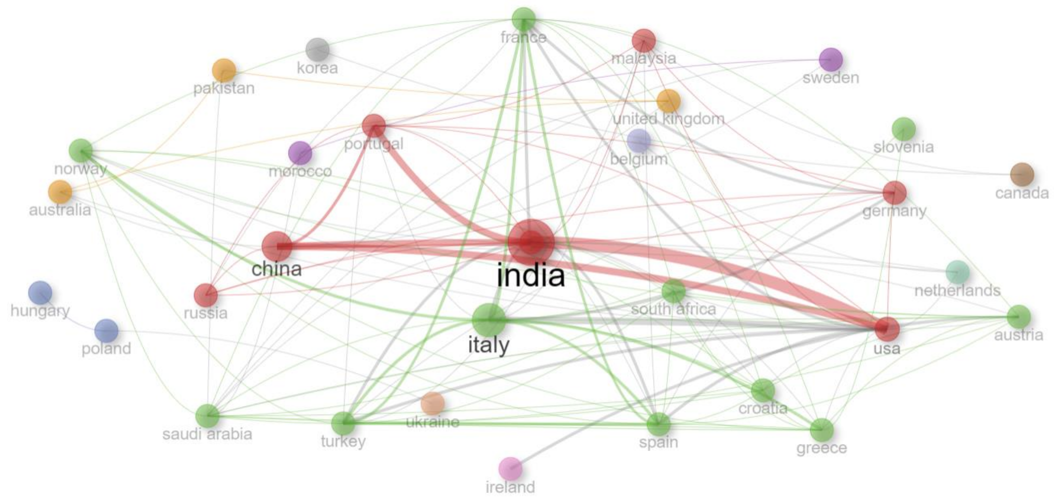


Figure 62 - Collaboration Network of the Countries (through Bibliometrix/Biblioshiny)

4

Literature findings on Industry 5.0

After revealing the Environment in which Industry 5.0 evolves, the current research directions in the area of Industry 5.0 have to be identified. They will be determined with the aid of a Bibliometric analysis. Bibliometric analysis, which has its roots in library science, is essentially a taxonomy of literature, and might be an effective technique for revealing complex networks of connections among an extensive collection of literature. And for this study, being done for Industry 5.0, it can help to reveal the current status of the research for Industry 5.0 and its progress through out these few years. Due to the recent rapid growth of the body of academic literature, in general but certainly for Industry 5.0, such a research strategy is especially important nowadays, as the manual review procedure for content analysis is time-consuming [73].

Using various tools science mapping will be performed. By taking a statistical perspective, Science Mapping reveals concealed patterns and facilitates insights into the overarching themes and trends that underpin scientific discourse while empowering statistical analysis of scientific information. Knowledge synthesis of what is written in academic literature research about Industry 5.0, gives its Conceptual structure. Science mapping, in this study, represents relations among concepts or words in the set of Industry 5.0's publications, revealing the main themes and trends of Industry 5.0 [74].

In order to determine the co-occurrence counts of chosen terms in literature and to characterize the interconnections that exist between various phases of the invention processes, co-word analysis, a type of bibliometric method, was developed. A co-word network analysis may offer supplementary perspectives for examining the conceptual organization of research keywords [75].

Therefore, to identify the development trends of research about Industry 5.0, this study conducted a series of co-word network analysis of the related literature. A co-word network analysis looks at the structure of keyword co-occurrence. A comprehensive representation of the central themes addressed in the literature can be achieved through a co-word analysis, depicting the extent and intensity of keyword collaboration. This network visualization elucidates the keyword structure by highlighting co-occurrence connections [73].

Moreover, bibliometric data can be used to create sophisticated "Word Clouds" and frequency charts of the most popular terms. In the generated visual, word size grows proportionally with the frequency of its occurrence in the analyzed text, making word clouds increasingly popular for swiftly grasping the primary concept conveyed within written content [76].

In addition to mapping, clustering can help to the analysis of the research field. Clustering and mapping are complementary techniques. Mapping bibliometric networks provides an accurate image of their structure, yet due to practical constraints, this visualization is usually confined to two dimensions, obscuring relationships in higher dimensions; in contrast, clustering remains unaffected by dimensionality but is constrained to binary dimensions rather than continuous ones, offering only a general glimpse into the structure of bibliometric networks [64].

Moreover, as Bibliometrix/Biblioshiny offers a different approach to perform a conceptual analysis using Factorial Analysis (FA). FA is a data reduction technique and is a well-known approach in Text Mining domain but it is still little used in science mapping. The main goal of FA, is to make data less dimensional and represent it in a low-dimensional space. The proximity between words corresponds to the shared-substance principle. When two terms are used together frequently in articles, they are close to one another on the map, however when they are used rarely together in articles, they are far apart. The origin of the map represents the average position of all column profiles, representing the heart of the research field, or the common and widely discussed topics of the research field [39] [74].

The last method used was a sentiment mining tool. ATLAS.ti opinion mining carries out a sentiment analysis on the collection’s abstract fields evaluating key points as positive or negative. The outcome of this process helps to get a bird's eye review of the relevant literature and gather key insights about Industry 5.0.

Furthermore, as a variety of analysis methods were used, to get sufficient answers, the data given as inputs to these methods used, are an important parameter. Thus, for each method the selection of data for the particular method was seen as significant and adequate attention was paid, as content validity is considered to be the key to a good measure [77].

Therefore, in order to answer the second Research Question, this study aims to identify research trends in the field of Industry 5.0. To this end, co-occurrence analysis of 4 periods (years: 2019-2020, 2021, 2022 and 2023) and co-word analysis was conducted to examine the selected articles published in the Scopus and Web of Science's Scientific bibliographic databases. Furthermore, trend topics were identified and even the spread of the interest for trend topics through the connectivity of terms and the countries of origin of the Authors, using a three-field plot was examined. Moreover, the word's frequency over time to help identifying the developing trends in the context of Industry 5.0 over the years. Lastly, from the most frequent words used, various word clouds and concept clouds were made and analyzed to understand whether the outcome of the research for Industry 5.0 signifies a transition from emphasizing economic value to prioritizing societal value. Before conducting the Bibliometric analysis, it is important to understand the current state of Industry 5.0 and the technologies involved, in order to more effectively examine and combine the information from the literature.

4.1 Literature review on Industry 5.0

Production systems have seen significant changes over the last ten years, largely as a result of the wave of digitization. Complex issues have been created in the technological, logistical, organizational, and environmental domains as a result of the ICT integration into every stage of production. It is crucial to handle this transformational process well. Innovative technologies have an impact on daily living and the workforce in addition to operations. In order to adapt to changing circumstances and embrace continual learning, workers and consumers play critical roles. Decentralization is increasingly prevalent in modern organizational structures, which use data and technology to speed up decision-making [20] [3].

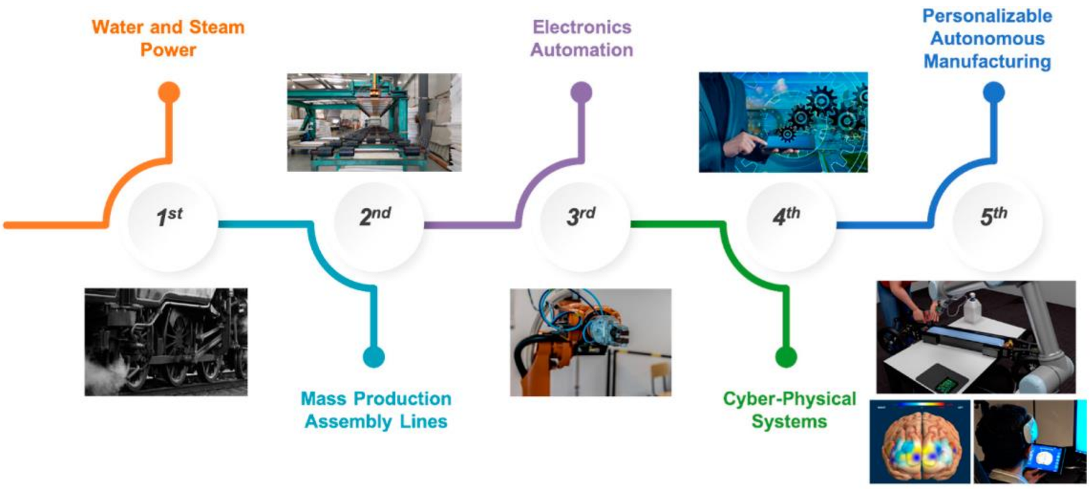


Figure 63 - Industrial revolutions - The advances in technology that drove them were agents of changes and emerged as revolutions in business, economy and manufacturing [78]

Industry 4.0 resulted in a major improvement in human-machine interaction, but it also necessitates careful consideration of the crucial role that people play. This paradigm is based on the idea of "smart factories," which are areas of cyber-physical production systems where intelligent equipment, products, storage systems, and data combine. The pandemic highlighted the importance of the workforce, leading to a review of Industry 4.0 and the creation of Industry 5.0, which adds elements of societal and environmental impact [20] [3].

Several countries are promoting initiatives to advance technologies, systems, and services centered around human needs, termed as Industry 5.0, with a consequential impact on societal transformation culminating in the emergence of a new society. This shift will prioritize the human and social facets of tools and technologies introduced under the ambit of Industry 4.0, placing sustainability and human well-being at the forefront of the forthcoming Industry 5.0, which forms an integral part of the new improved society, Society 5.0. Industry 5.0 shifts toward embracing resilience, sustainability, and human-centricity as essential parts of value generation, assisted by enhanced technological capabilities, in contrast to Industry 4.0, which was primarily focused on technology-driven breakthroughs [20] [30].

Personalized products and the difficulties faced by SMEs were two elements that fueled a reevaluation of the barriers encountered in implementing Industry 4.0. Although these businesses are essential to economies, the technology requirements of Industry 4.0 present significant obstacles. The assessment of change readiness and the careful selection of suitable technology become crucial factors. The idea of placing people at the core of manufacturing emerges during these discussions. Industry 5.0's fundamental goal is to use new technologies to generate wealth, not just to create jobs and economic progress. Moreover, Industry 5.0 goes beyond these goals by respecting ecological restrictions and putting the welfare of industrial employees first [20] [3].

Figure 64 - UN's SDGs [79]

Presently, a number of countries including the EU, Japan, and the USA, are steering toward the realization of the human-centric epoch of Industry 5.0. The Industry 5.0 concept extends to Society 5.0, that cares for each and any human and the environment, and equips people with the tools they need to lead active, satisfying lives. These intertwined notions represent two parallel frameworks for the imminent industrial and societal horizons to lead humanity in a society that can both promote economic development and find solutions to social problems [30] [31].

We now present certain key facts that led to the EC definition of Industry 5.0. With the adoption of the "2030 Agenda for Sustainable Development" in 2015, the United Nations General Assembly made an important step towards protecting Earth. The agenda, which were adopted by all UN Member States, outlined a 15-year plan for achieving 17 Sustainable Development Goals (SDG). The importance of science, technology, and innovation as a key force behind sustainability has been publicly acknowledged for the first time at this level. The ability of states to integrate science into the core of their national development programs will determine how well they are able to address difficulties, some of which are still unidentified. A vision for a systemic shift toward an economy that is more sustainable and beneficial to both people and the environment [62] [63].

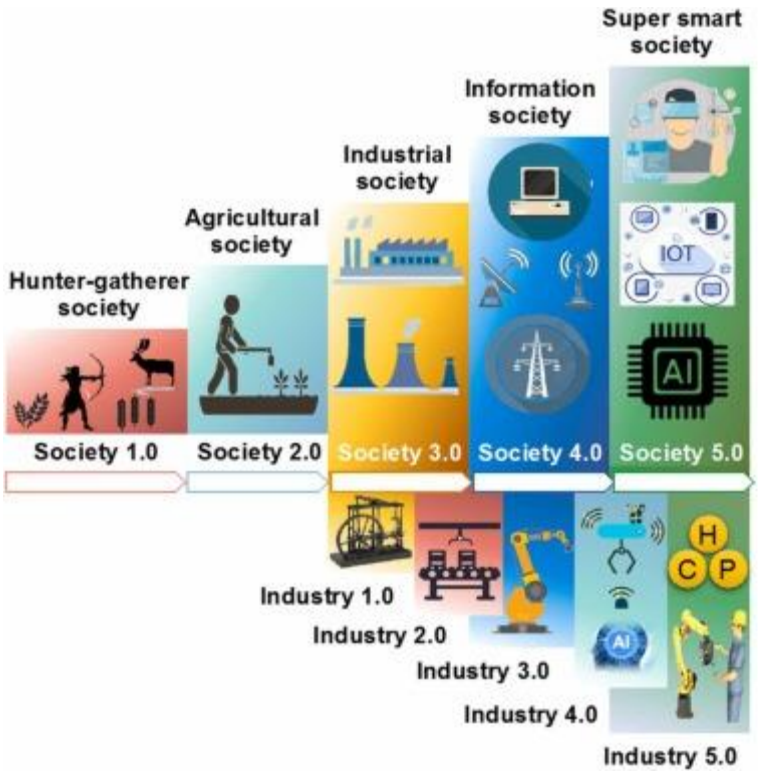


Figure 65 - Society5.0 and Industry 5.0 comparison [29]

In an article titled "Industry 5.0 from virtual to physical" that was published in 2015, Michael Rada presented a method he called "industrial upcycling" and began putting it into practice in the actual commercial and industrial environment of Czechia. He emphasized the value of real tools and environments and treated virtual tools and environments equally to other tools that are present in the physical world, allowing them to work with humans as tools. He also stressed-out concerns for the environment [80].

The concept of a new improved society known as “super-smart society” or Society 5.0 was proposed in Japan in 2016 by the Japanese government. The proposed Society 5.0, which is not aimed at productivity, but is intended to achieve UN’s SDGs. The idea is to help deal with social issues and improve many aspects of society [31]. The Society 5.0 concept thus, seeks to use the most recent technological advancements, including digital systems, AI, cloud computing, IoT, and automation, to address larger social and environmental concerns [81].

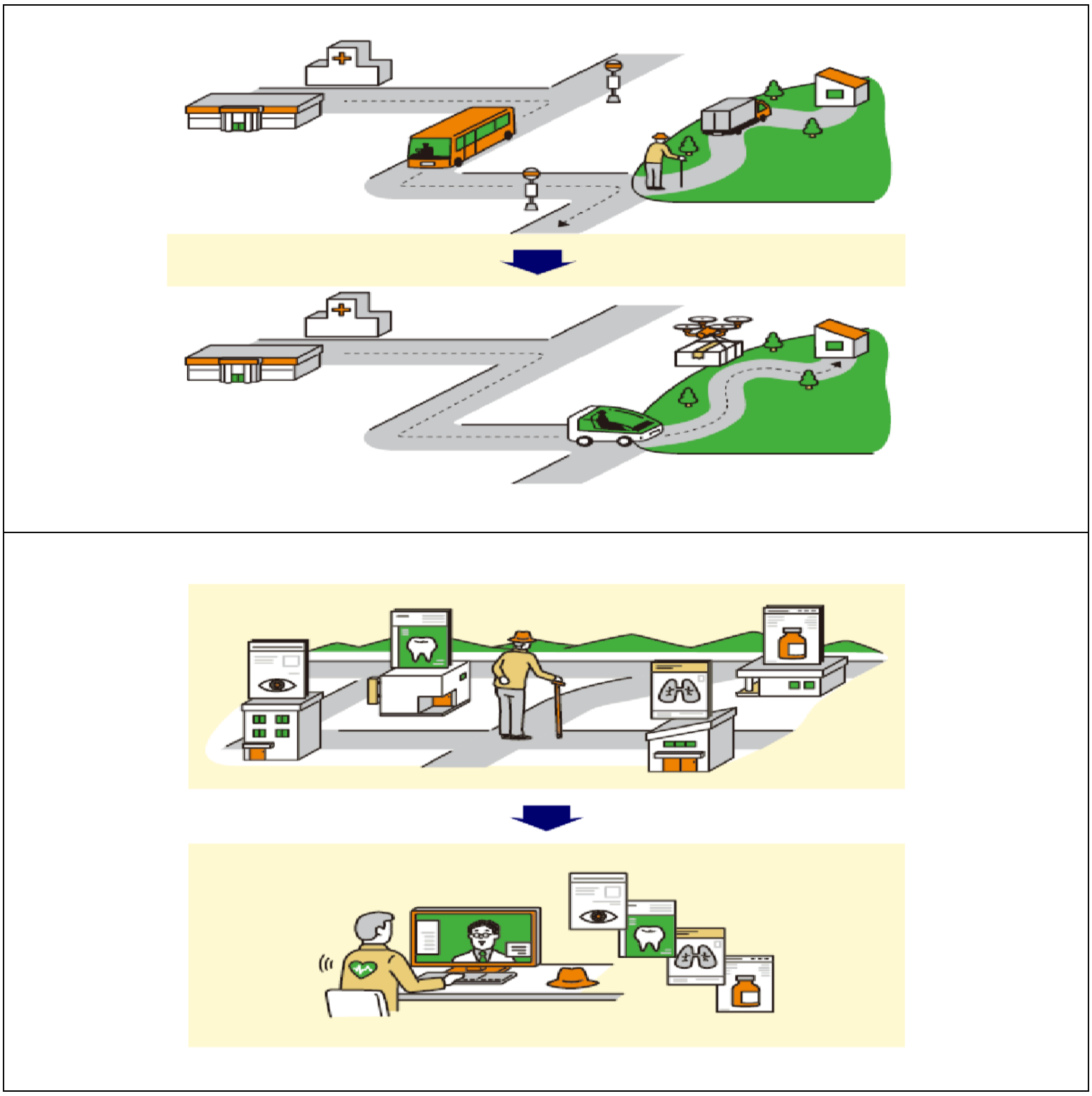


Figure 66 - Society 5.0 [31]

In 2018, in a paper published by Özdemir and Hekim, it was announced the emergence of Industry 5.0. They stated that Industry 4.0 was a high-tech approach to automate manufacturing utilizing the Internet of Things to create smart factories, but that this level of extreme automation still had numerous flaws. As a result, they suggest Industry 5.0, which uses new ideas from symmetric innovation to democratize the knowledge co-production of large data. Although the Internet of Things is used in their proposed Industry 5.0, as their perspective of Industry 5.0 builds on the ideas and methods of Industry 4.0, it tries to fix the existing asymmetries and limitations of Industry 4.0. Thus, they are proposing Industry 5.0 as an evolutionary, crucially important advancement to them of Industry 4.0 for the design of a resilient, responsible, and sustainable innovation ecosystem in the digital era [82].

The Organization for Economic Co-operation and Development (OECD) defined the economy of well-being in 2019, stating that there is now a strong and well-established case for looking "beyond GDP", using well-being metrics in the policy process, and evaluating economic growth in terms of its impact on people's well-being and on societies' standard of living [83].

In 2021, the EC unveiled the concept of Industry 5.0, envisioning workplaces marked by inclusivity, the establishment of resilient supply chains capable of withstanding disruptions, and the adoption of sustainable production methods. The EC emphasizes that the significance of Industry 5.0 transcends mere employment generation and economic advancement. It requires manufacturing to operate within planetary boundaries and to prioritize the well-being of industry workers, thus positioning human-centricity and sustainability at the heart of the production process.

More precisely for Human-Centricity, addressing education, training, and skills is crucial for digital transition. Retraining won't be feasible for everyone. As for Sustainability, embracing the principle "Better with less", that means optimizing output and resources. This includes end-of-life considerations and a circular economy shift. Finally, for Resiliency, basically adapting to change. Global value chains face geopolitical shifts (such as the Ukraine war, Brexit, trade disputes, protectionism) and natural threats (like pandemics and climate change consequences). Industries must swiftly adjust for long-term prosperity. Resilience spans factory, supply, and system levels. Focus on cost-efficiency might lead to fragility [84].

The United Nations' Agenda 2030 and specifically its 9th and 12th SDGs for "Industry, Innovation and Infrastructure" and "Responsible Consumption and Production" are directly tied to the EC's adoption of innovative resource efficiency serves as the model for a new economy, in 2021 [84].

In contrast to Industry 4.0, which was primarily focused on technology-driven advancements, Industry 5.0 pivots towards embracing resilience, sustainability, and human-centricity as intrinsic elements of value creation, facilitated by advanced technological capabilities.

At its core, Industry 5.0 strives to utilize emerging technologies not merely for generating employment and economic growth, but to transcend these objectives, honoring ecological constraints, and prioritizing the well-being of industrial workers.

The obstacles encountered in implementing Industry 4.0 spurred a reassessment, fueled by factors like personalized products and the challenges faced by SMEs. These enterprises are fundamental to economies; however, the technological requisites of Industry 4.0 pose substantial barriers.

Being known for their constraints in human, technical, and financial resources, SMEs struggle in the transition phase during introducing industry 4.0. SMEs do not only struggle with the resources, but also with the expertise and the management support in terms of difficulties concerning new technologies [85].

The evaluation of preparedness for change and the judicious selection of appropriate technologies become pivotal considerations. Amid these deliberations, the notion of putting humans at the center of production gains prominence.

Industry 5.0 fits three of the priorities set forward by the EC for the five years between 2019 and 2024, namely: "An economy that works for people", "European Green Deal" and "Europe fit for the digital age" [86].

With the help of a new generation of technology, the "Europe fit for the digital age" digital plan will give people more control. People's lives are altering due to digital technology. By making this shift beneficial to both individuals and companies, the EU hopes also to meet its goal of having a climate-neutral Europe by 2050.

The EC has created the European Green Deal, a package of policy initiatives with the overarching goal of achieving the European Union (EU) climate neutral by the year 2050. In order to reduce net greenhouse gas emissions by no less than 55% by 2030 in comparison with 1990 levels, it is planned to evaluate each existing policy according to how well it addresses climate change. Additionally, new legislation regarding the circular economy, energy-efficient building renovation, biodiversity, farming, and clean technological innovation will be introduced.

Figure 67 - EC Priorities 2019-2024 [86]

The European Green Deal aims at improving the health and well-being of its citizens and future generations by providing, among other things:

- clean air and water,
- healthy soil,
- resilient goods that can be repaired, recycled, and repurposed,
- nutritious food at affordable prices,
- a more sustainable use of plant and soil natural resources,
- transition-proof jobs, training for new skills, and
- a worldwide competitive and resilient industry [69].

SMEs serve as the core of the EU's economy; hence it is vital that the EC take efforts to support them. That is one of the objectives of the EC's action plan for the social economy, "An economy that works for people." The EU needs to improve the environment for investments and promote quality job creation, particularly for young people and small firms. Additionally, steps should be taken to mitigate inequality and poverty [69].

Finding an approach that would assist SMEs in the transition to automated and semi-automated systems was one of the most crucial elements of Industry 5.0. The emphasis will be on reorganizing the work while maximizing the human factor to comply with the strategic values of the business. Therefore, it is essential to guarantee that human demands are given equal priority to the adopted technology in order for this new system to succeed. These human demands must be a major consideration in the design of the system if the work involved is to be regarded beneficial [87].

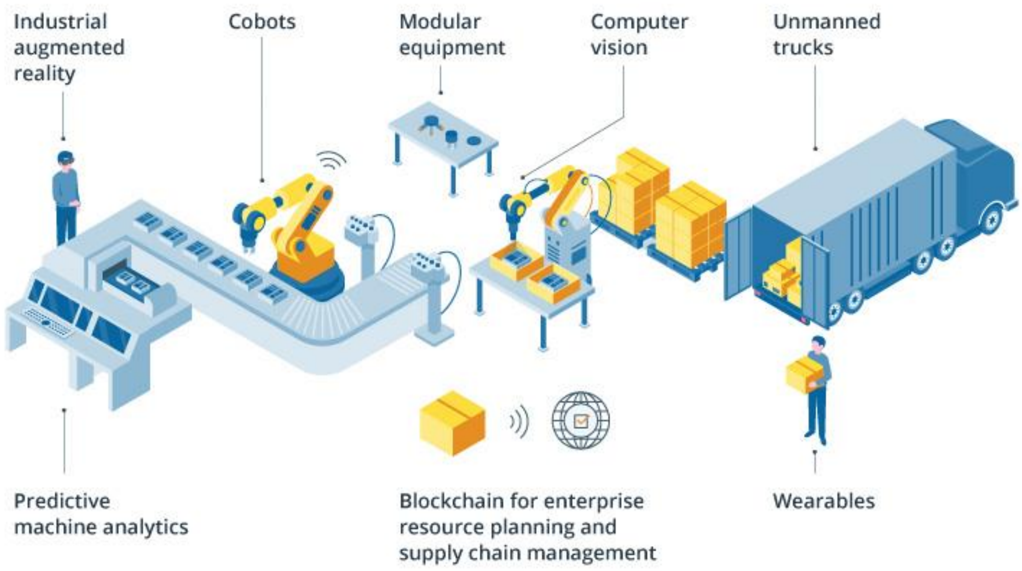


Figure 68 - Factory of the future in Industry 5.0 [58]

The Covid-19 outbreak highlighted the important role of employees, and the pandemic itself led to a reconsideration of the Industry 4.0 concept. As a result, the concept of Industry 5.0 emerged bringing social and environmental dimensions to Industry 4.0. The workforce has to continually change, from the economic value and profitability perspective of Industry 4.0 to the value to society and human well-being perspective in Industry 5.0. The need of putting employee well-being first is only increasing, and it won't go away anytime soon [3].

Younger generations, notably Millennials and Zoomers, are some of the most passionate advocates of worker welfare and they emphasize the value of human factors in the workplace of the future.

Industry 5.0, also refers to the use of technologies like artificial intelligence (AI) and robotics to improve the overall customer experience. Eliminating the gap between humans and technology to enable seamless integration and interaction between the two is one of the guiding principles of Industry 5.0 [9].

Therefore, Industry 5.0 is divided into two main areas: the one is the Human-Centric approach, that it acknowledges the value of human employees and focus on their skills, knowledge, and capacities to cooperate and collaborate with machines and robots, and the second is flexibility, innovation and quality in the production process and the impact it has on the environment.

4.2 Exploring the Industry 5.0 related terms

The terms identified from the datasets, can help in investigating the Industry 5.0 paradigm to better understand which particular terms the researchers had been concentrating on. In this part of the analysis the ATLAS.ti tool was used. The datasets from Scopus, WoS and the merged dataset had to be transformed to a format that is acceptable by the tool.

As already noted, there are different types of keywords used. Basically, each database has an alternative keyword field to the author- defined keyword field. The Author keywords are filled in by the Author to best reflect the content of the document. Scopus uses an index keyword field, which contains keywords chosen by Scopus and are standardized to vocabularies derived from an Elsevier owned thesaurus. Unlike Author keywords, Indexed keywords take into account synonyms, various spellings, and plurals. For some recently added articles, as it is not filled in automatically, may take a period to appear. Thus, there are documents that this field is empty in the Scopus dataset used. WoS uses the keyword plus field that are words or phrases that are frequently found in the titles of an article's references, yet are absent from the article's title [54] [55].

The combination of keyword terms not only broadens the perspective offered by a particular term, but it may also draw the attention to elements or perspectives that might have otherwise been missed [88].

The first analysis was made by the Author’s keywords. For the Author’s keywords the corresponding column from the merged Excel file was saved in a pdf format and consequently it was imported.

Since Kelly back in 1927 defined the concept of validity, as the degree to which a test measures the things that it claims to assess, using author-specified keywords to denote a selected article's major subject is valid in the current analysis [89]. Furthermore, particular value is placed on the authors' selection of keywords since they provide crucial cues for understanding how the research topic was defined [90].

The Word Cloud derived from Author’s keywords is shown in Figure 69 (using Threshold=37, approximately the 1/20 of maximum occurrences of top used term, numbers were included and the infer to base forms was selected).

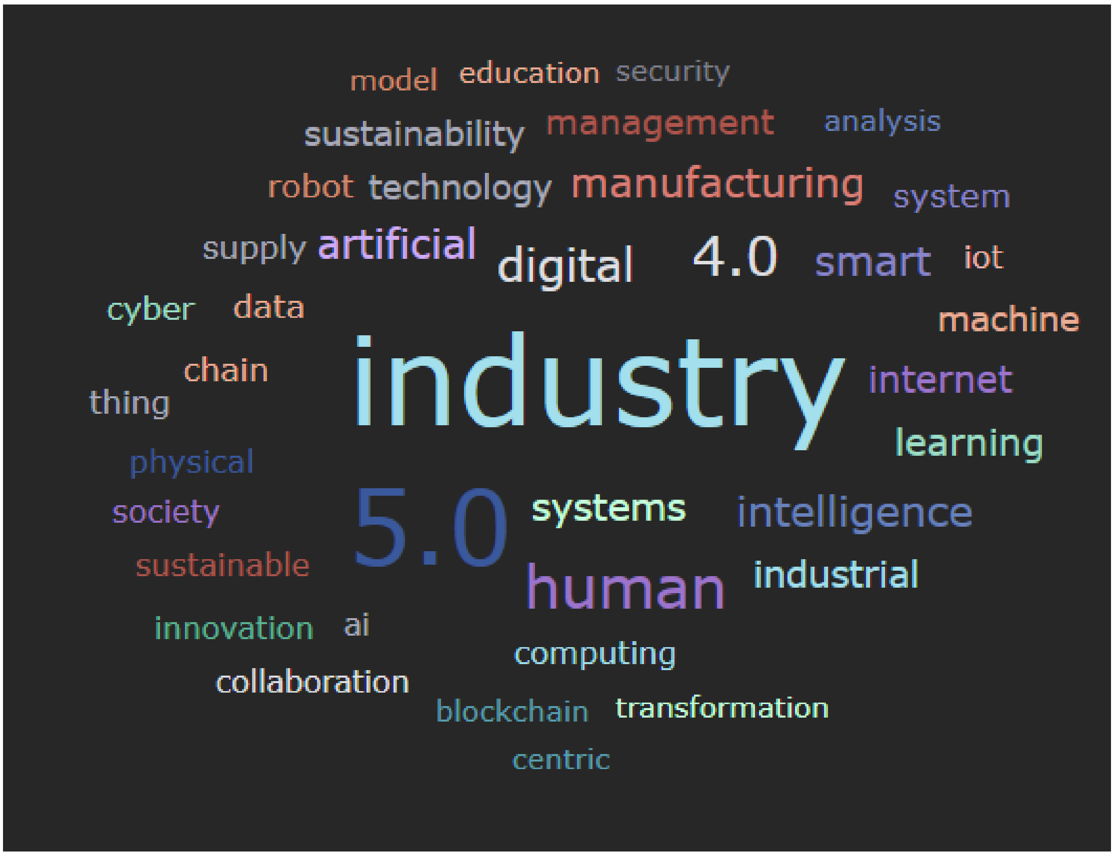


Figure 69 - Word Cloud by Author's keywords through ATLAS.ti

In order to briefly describe the Word Cloud, Industry 5.0 has a human perspective. Digitalization, artificial intelligence, smart manufacturing, technology, internet and machine learning are among the most used terms. Sustainability and sustainable are highly used, society and centric are also terms that often occur. Other used terms are innovation, transformation, IoT, robot, supply chain etc.

The tool includes an algorithm that generates a concept cloud, which is created when the data is split into various categories in order to be classified. The significant noun phrases are initially identified in order to identify the most prevalent concepts in the data. In the second stage of processing, all files are combined to compile the concepts and their frequency. The depth of language can be shaped by machine learning, which can analyze text and determine which words go together. Because of ATLAS.ti's dynamic concept filtering, only the concepts that are the most important are given in the findings.

The creation of a Concepts Cloud using the Author's keywords, is given in Figure 70.

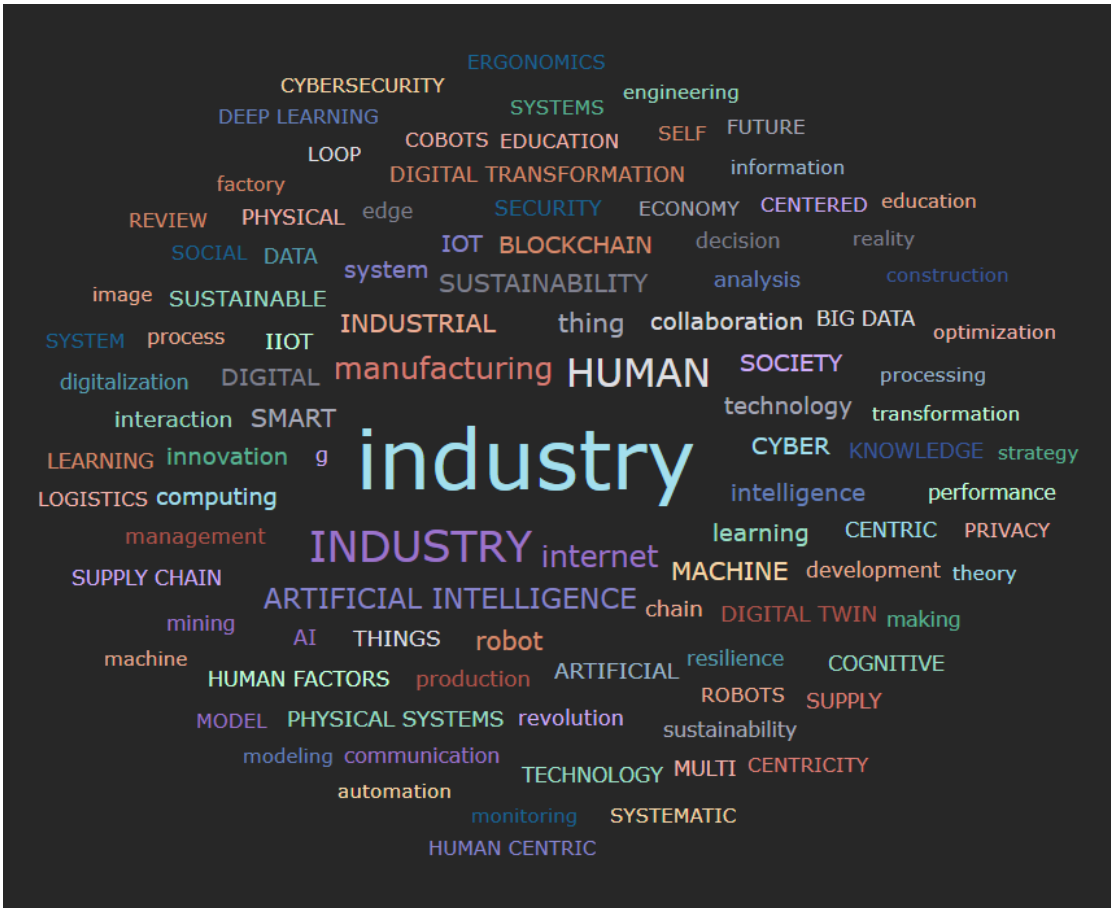


Figure 70 - Concepts by Author's keywords through ATLAS.ti

While for the Word Cloud a selection is available whether or not to ignore case in letters the Concepts analysis does not offer such an option. Thus, terms can be found twice, in lower and upper case, as separate terms. Despite that, the Concepts Cloud is helpful in order to identify what is the Authors focus on their research.

Human is a major term, center, centric, centricity, human centric, human factors, relative terms to human can be found. Sustainability (twice in lower and upper case), sustainable, resilience, social is another group of relative terms.

Thus, the EC definition can be produced by the terms contained in the concept cloud.

Next for the index by Scopus keywords, the corresponding column from the Scopus dataset csv file was saved in a pdf format and imported first. Then, the Word Cloud derived from the index keyword field is shown in Figure 71 (using Threshold=30, numbers were included and the infer to base forms was selected).

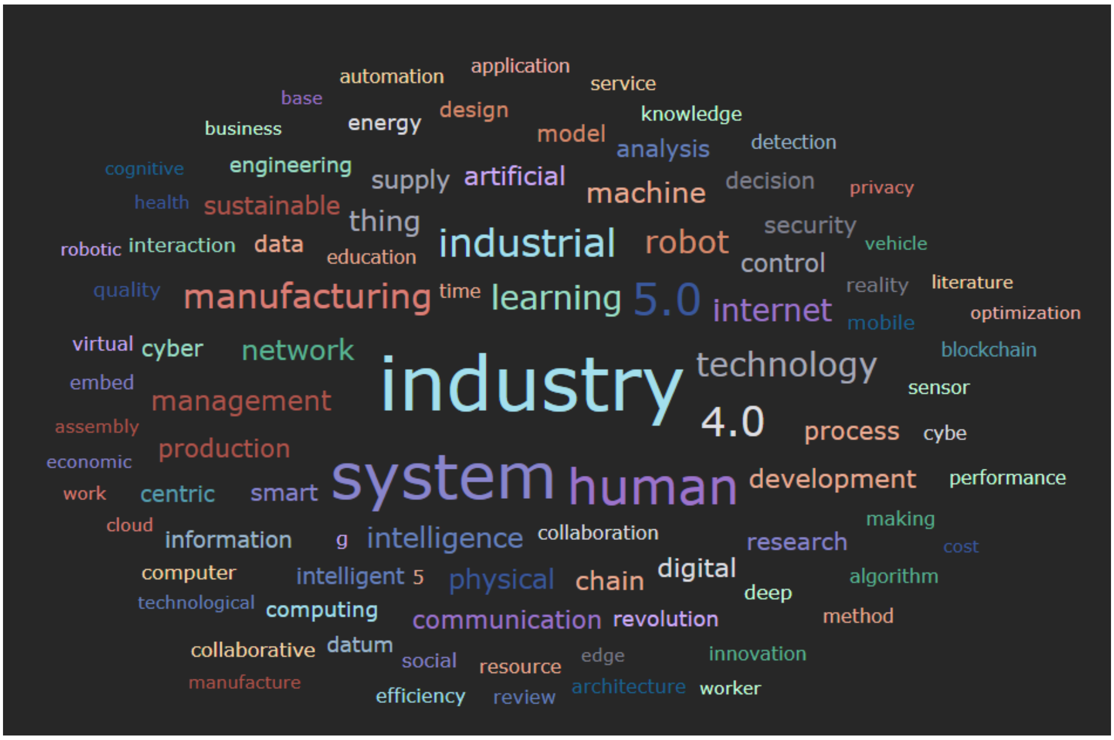


Figure 71 - Word Cloud by keywords index by Scopus through ATLAS.ti

By its nature the terms that appear from the index by Scopus keywords, indicate how the proposed research will be achieved rather than what is the purpose of the research that reflect the Author's keywords. A short description can be that it is similar in content but richer in terms compared with the previous Word Cloud made by Author's keywords. Various Industry 4.0 technologies appear, upon which Industry 5.0 will be based, to achieve the transition from Industry 4.0 to Industry 5.0. The human/social/environmental factors are slightly less present from the previous Word Cloud made by the Author's keywords.

The same can be said, for the Concepts Cloud derived in Figure 72.

Figure 72 - Concepts by keywords index by Scopus through ATLAS.ti

For the Keywords plus field provided by WoS, the corresponding column from the Excel WoS dataset file was saved in a pdf format first before given as input to the ATLAS.ti tool. The Word Cloud derived from Keywords plus can be found in Figure 73 (using Threshold=5, numbers were included and the infer to base forms was selected).

As the keywords plus field consists of terms that come from the titles of the references from which the article was made and should not be in the title of the article, they reflect the theoretical background on which their work is based on. As the words selected are not common to their title, and must appear more than once in the article's bibliography, an additional and, in a sense, broader and with more general terms description of the research fields is achieved. Basically, the keyword plus list of words substantially augments the list of words from the title and from the author-selected keywords [88].

Except from general kind of terms that are most used such as systems, management, framework, model, design, challenges and future, many technology-related terms appear. Among them, artificial intelligence, big (data), internet, cyber physical, digital twin, technology, IoT, things, robot, blockchain, cloud, edge, network, wireless etc. There are also present Industry 5.0's pillars, human, sustainability, resilience but also close to them terms such as collaboration, personalization, cooperation, circular economy, social, energy, satisfaction.

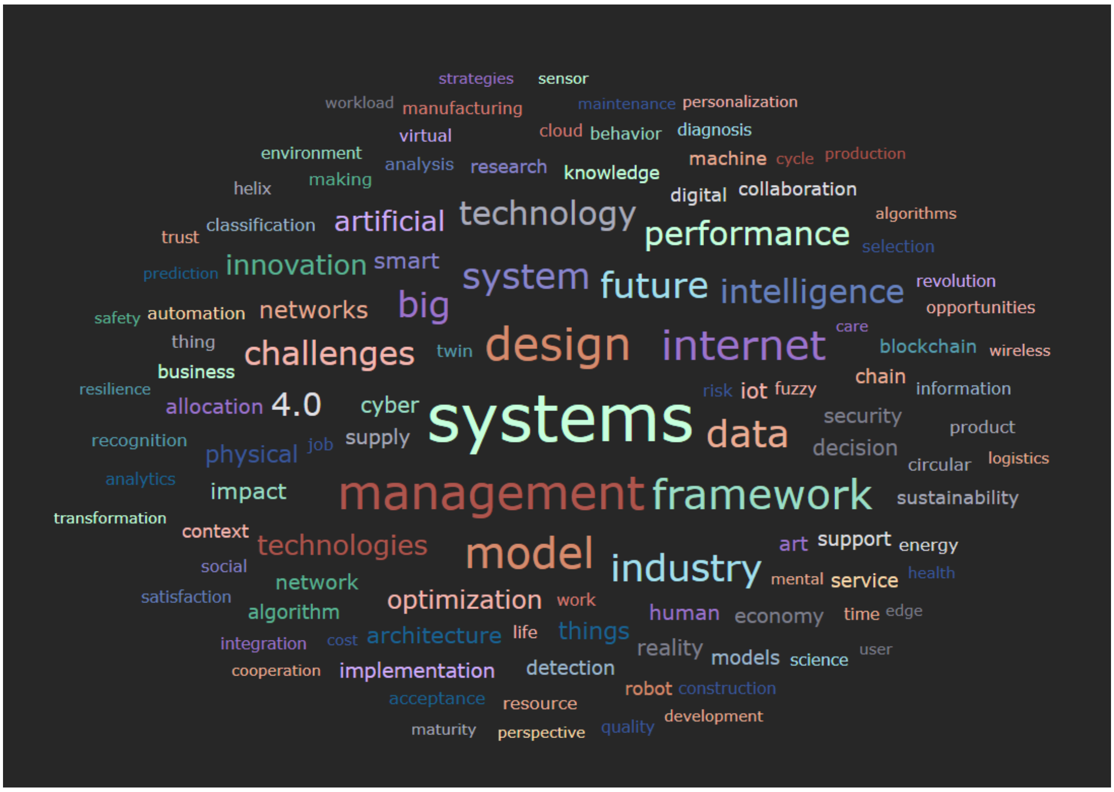


Figure 73 - Word Cloud by keywords plus by WoS through ATLAS.ti

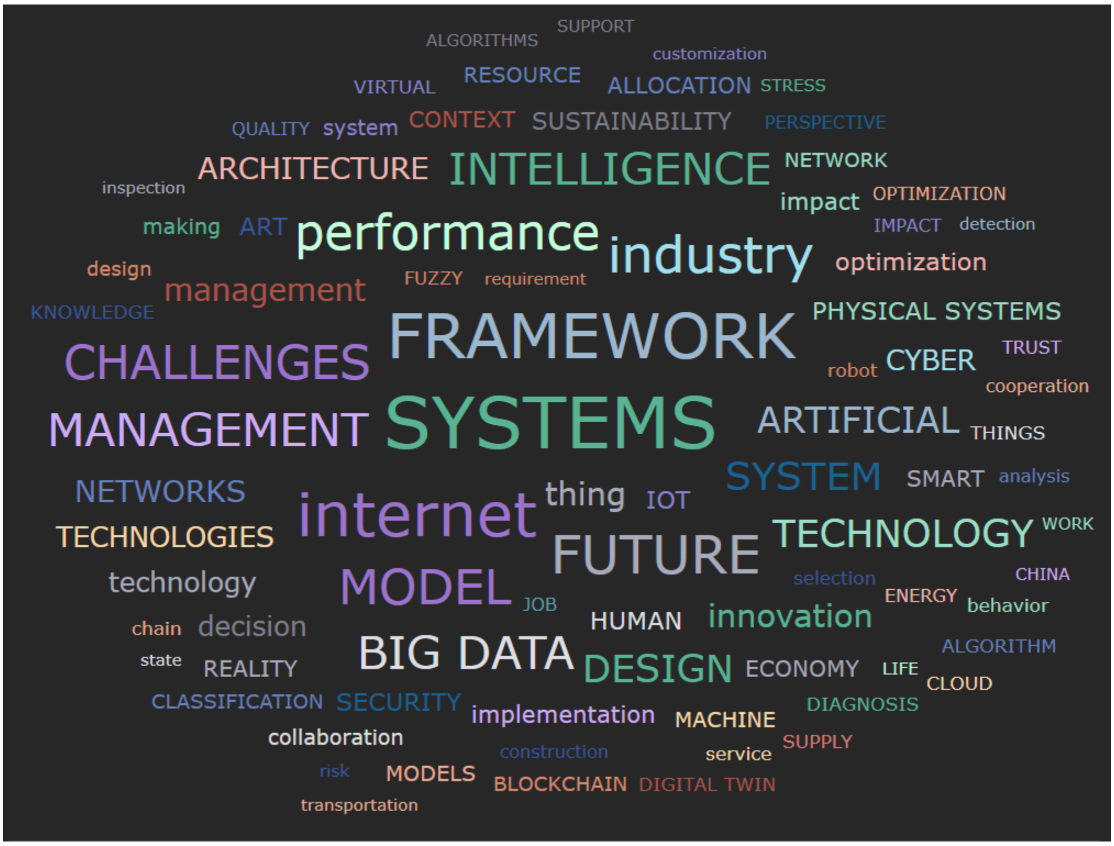


Figure 74 - Concepts by keywords plus by WoS through ATLAS.ti

The respective Concepts Cloud derived is in Figure 74. The description of the above concepts is similar to the Word Cloud made by the keyword plus field.

For the Title field because during the merging process made with the bibliometrix R-function, the merged dataset's title field were changed by NLP (in a tokenized form), it was preferred to avoid using the column from the merged dataset and instead create a better data source for the titles. Thus, manually in an Excel file, first the titles from the Scopus dataset and next the titles from the WoS dataset were copied and through a review the duplicates were deleted. Afterwards, the file was saved in a pdf format.

The Word Cloud derived from the Title field is shown in Figure 75 (using Threshold=25, numbers were included and the infer to base forms was selected).

The description given for the Word Cloud based on Author's keywords fits to this Word Cloud as well. Same applies for the Concepts Cloud made from the titles (Figure 76).

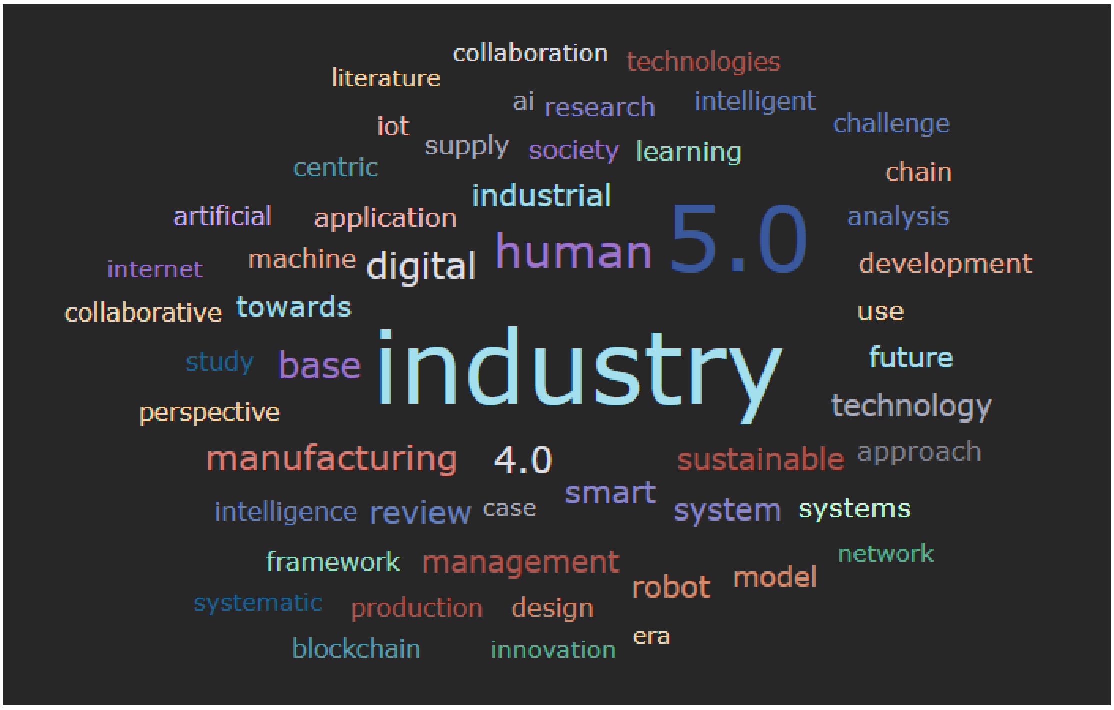


Figure 75 - Word Cloud by titles through ATLAS.ti

Figure 76 - Concepts by titles through ATLAS.ti

Finally, the Abstract field was used. The procedure to import the Abstract data was to copy the column from the merged Excel dataset file and saved it in pdf format to be then recognized by the tool.

The Word Cloud derived from Abstract word frequencies created, shown in Figure 77 (using Threshold=179, numbers were included and the infer to base forms was selected). Again, the Word Cloud is similar to the Word cloud made by the Author's keywords and the Title fields respectively. The creation of similar diagrams increases their usefulness and aids in determining the analysis's conclusion.

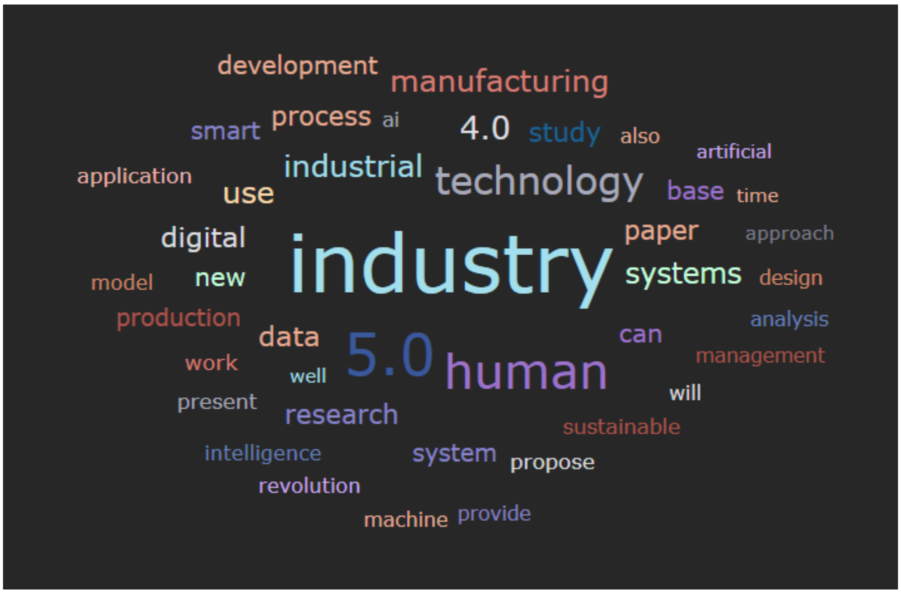


Figure 77 - Word Cloud by abstracts through ATLAS.ti

Figure 78 - Concepts by abstracts through ATLAS.ti

The corresponding Concepts Cloud from Abstract words can be seen in Figure 78, gave also similar to the Word Cloud results.

4.3 Co-occurrence of keywords

To be able to depict the network structure of the keywords' co-occurrence associations, a series of co-word network analysis was used in this study. Applying respectively the Scopus and the WoS datasets, VOSviewer co-occurrence of keywords Network Visualization were created, by using thesaurus, fractional counting and for Normalization the LinLog layout technique and the modularity clustering (as the nodes are not displayed the one on the other).

Based on Garfield's idea that more terms bring more detail, the "All keywords" option was used, that is, both Author's keywords and the Indexed by Scopus keywords for the Scopus dataset giving the following graph [88].

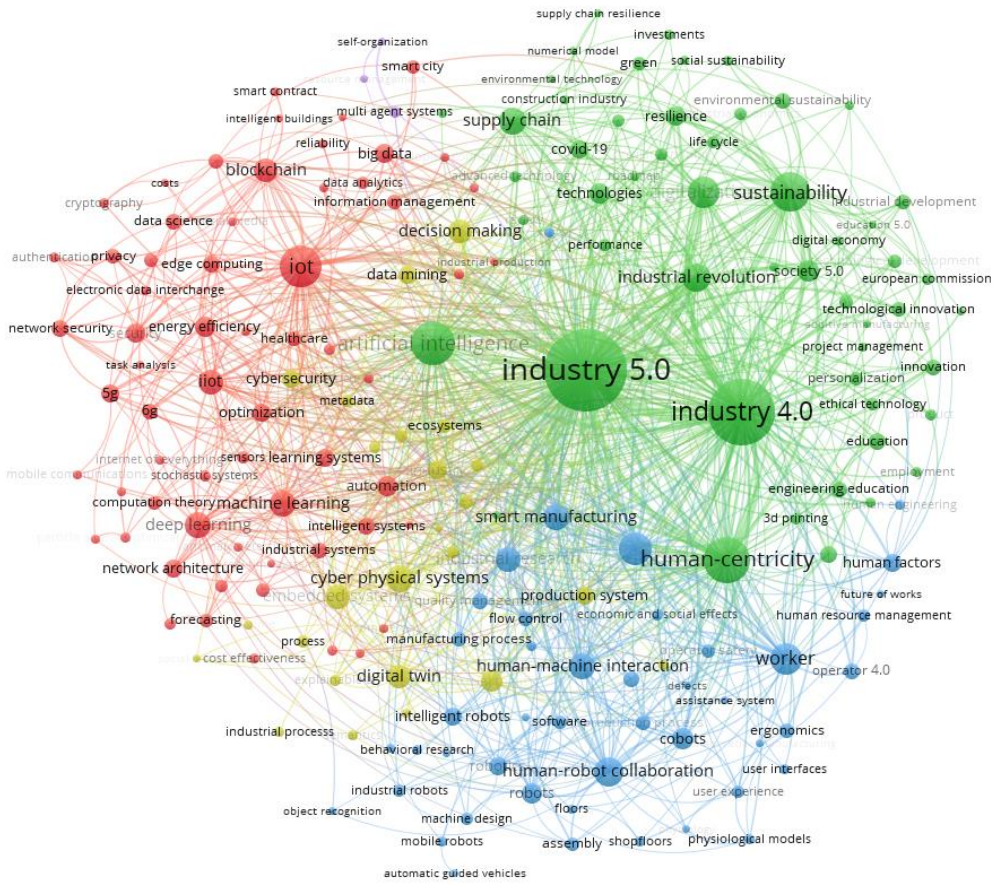


Figure 79 - VOSviewer co-occurrence of keywords Network Visualization using the Scopus dataset

From the above co-occurrence of keywords Network in Figure 79, the below clusters were formed:

- The Industry 5.0 (green colored) cluster containing amongst other topics the Industry 4.0, human-centricity, AI, sustainability, personalization, Society 5.0, green, supply chain, resilience, Covid-19, circular economy, SMEs, digitalization and industrial revolution;
- The IoT (red colored) cluster containing the blockchain, energy efficiency, big data, automation, Industrial IoT, 5G/6G, cloud computing, edge computing, machine learning, deep learning, security;
- The manufacturing (blue colored) cluster containing worker, operator 4.0, smart manufacturing, industrial research, robot, industrial robots, cobots, robotics, intelligent robots, behavioral robots, and various human and robot related topics such as human-robot collaboration and human-machine interaction;
- The cyber physical systems (yellow colored) cluster containing the topics like digital twin, VR, AR, decision making, data mining, metaverse, embedded systems, cybersecurity.

- The small multi agent systems (purple colored) cluster containing the resource management and self-organization, thus containing only 3 topics.

The Knowledge that yields from the relationships in the graph, helps to understand Industry 5.0. For instance, the interest upon human-center issues such as the operator safety. By interpreting the connectivity between nodes in the graph, when the operator safety was selected, the operator safety is an issue related to human-centricity, to worker and sustainability in the Industry 5.0 and Industry 4.0 context. Also, it is related to Human-robot collaboration, as well to accident prevention and to decision support systems.

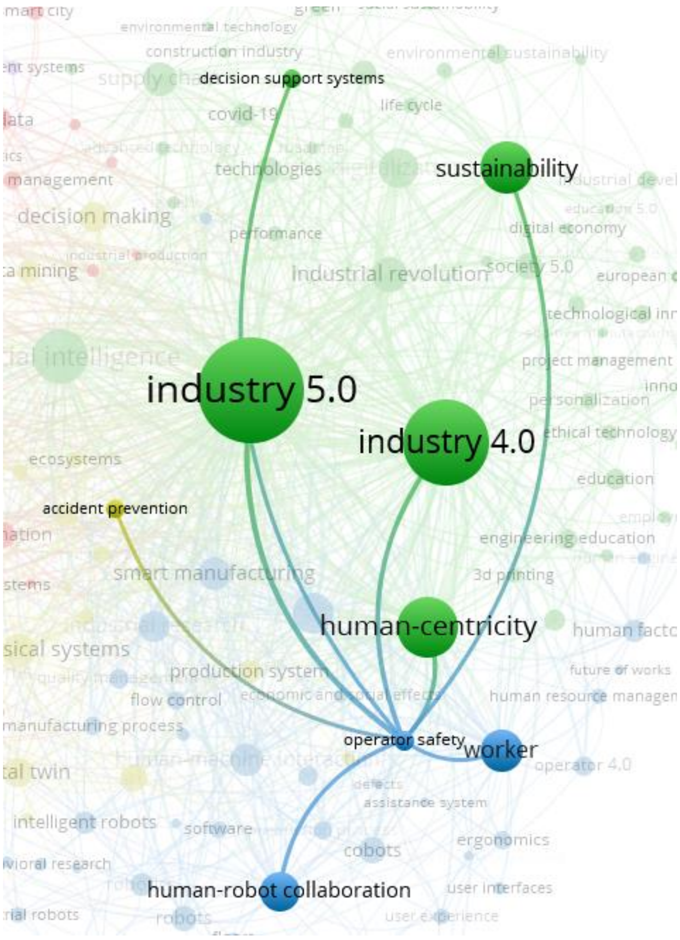


Figure 80 - Operator safety in Scopus VOSviewer co-occurrence of keywords Network Visualization

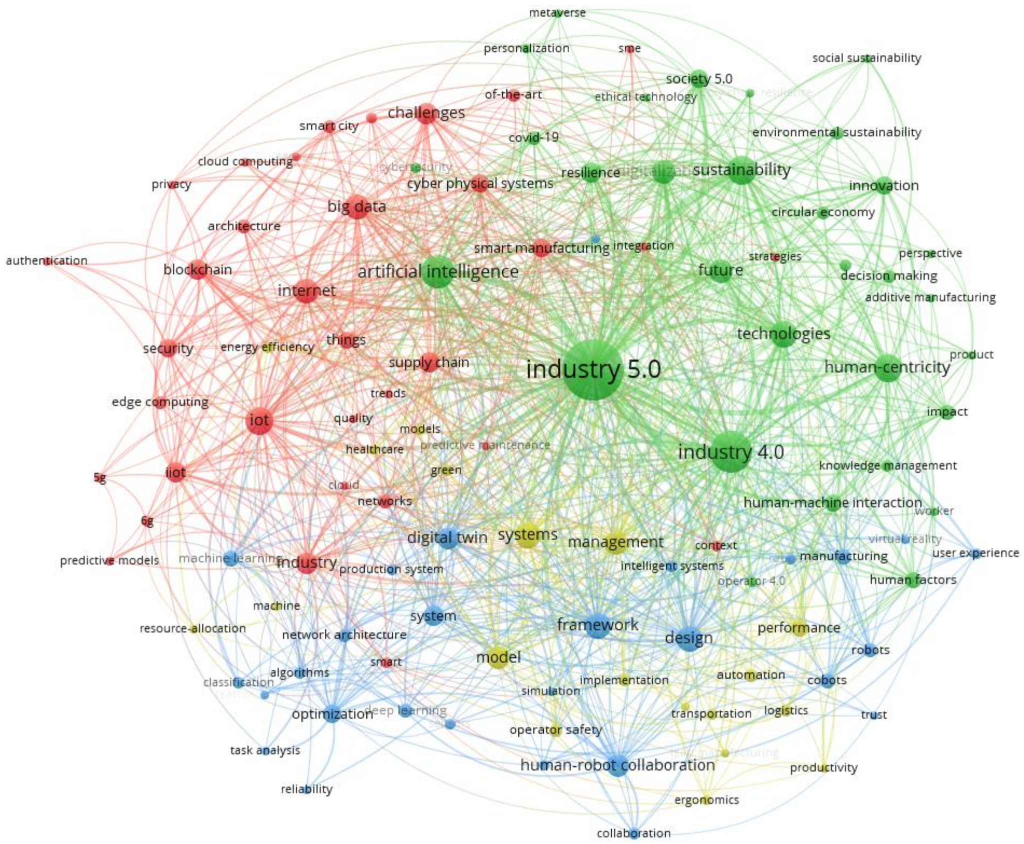


Figure 81 - VOSviewer co-occurrence of keywords Network Visualization using WoS dataset

For the next graph in Figure 81, the “All keywords” option was used, that is, both Author’s keywords and the keyword plus by WoS, built from the WoS dataset.

The WoS data’s clustering derives the below clusters:

- The Industry 5.0 (green colored) cluster, which is containing amongst other topics the Industry 4.0, AI, sustainability, human-centricity, technologies, Society 5.0, environmental sustainability, resilience, decision making, circular economy, digitalization, SMEs, personalization, metaverse, worker, operator 4.0, human factors, human-machine interaction, future and innovation;
- The IoT (red colored) cluster, which contains the internet, industry, blockchain, security, authentication, privacy, challenges, big data, automation, supply chain, Industrial IoT, 5G/6G, cyber physical systems, smart city, cloud and edge computing;
- The Human-robot collaboration (blue colored) cluster, that contains smart manufacturing, framework, design, machine learning, deep learning, digital twin, VR, AR, robotics, robots, human-robot collaboration, cobots, reliability, optimization;
- The systems (yellow colored) cluster, that contains the topics like management, operator safety, healthcare, lean manufacturing, logistics, automation, green, energy efficiency, performance, transportation.

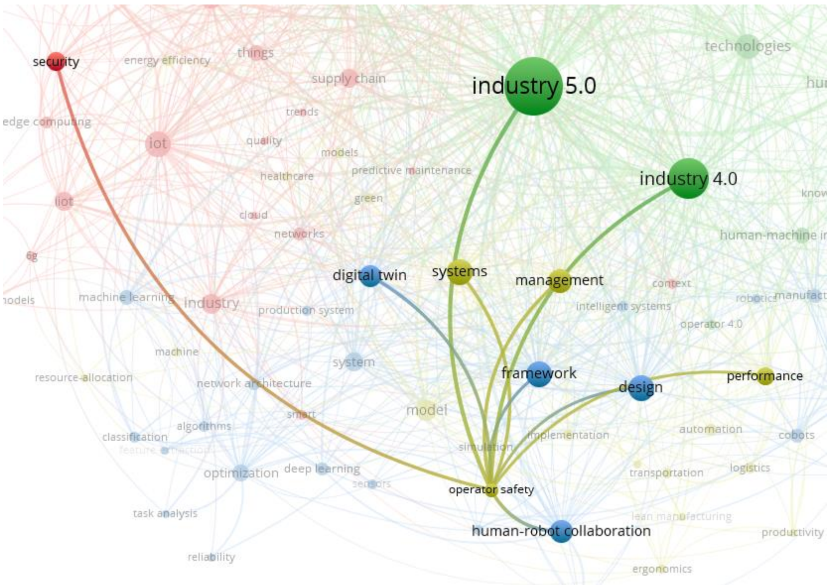


Figure 82 - Operator safety in WoS VOSviewer co-occurrence of keywords Network Visualization

Again, when the operator safety was selected, it's connections illustrate that the operator safety is an issue related to human-robot collaboration, Industry 5.0, Industry 4.0, digital twin, security and through a broader view to systems, management, performance, framework and design.

When selecting personalization, it is found that personalization is an issue related to Industry 5.0, Industry 4.0, AI, technologies, human-centricity, Society 5.0, metaverse and privacy.

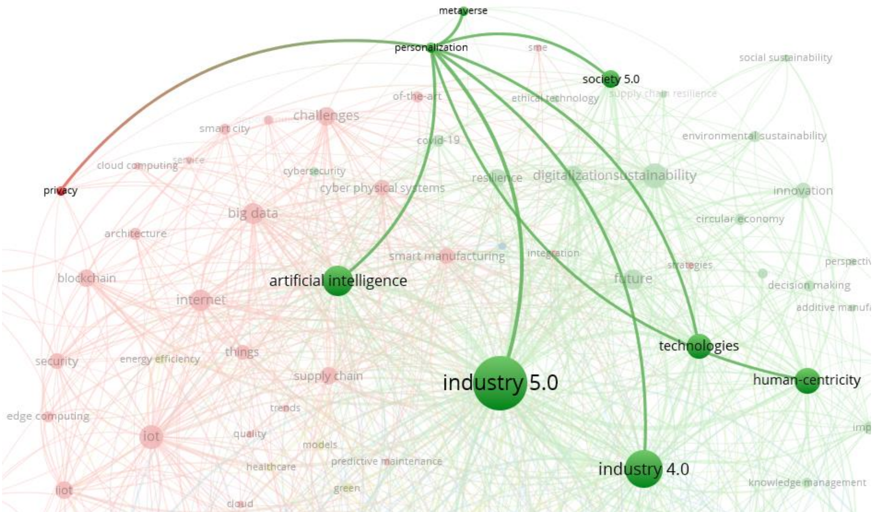


Figure 83 - Personalization in WoS VOSviewer co-occurrence of keywords Network Visualization

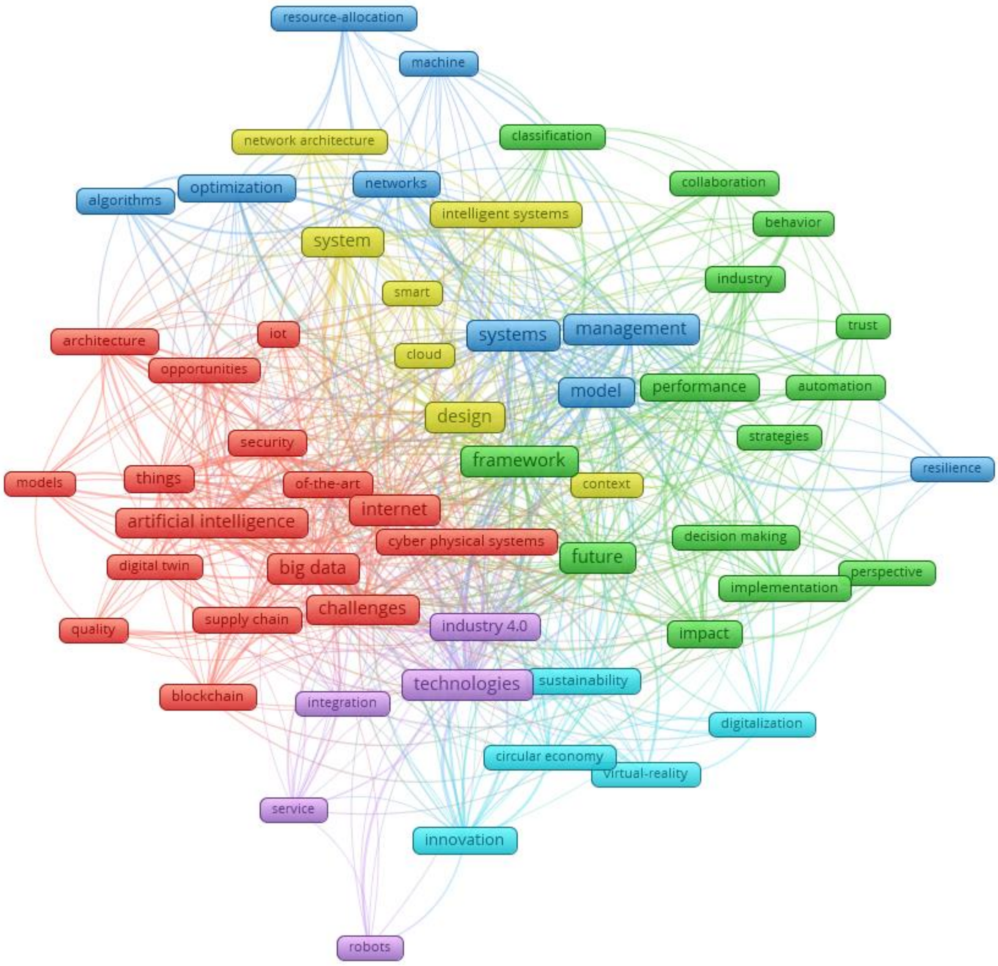


Figure 84 - VOSvViewer co-occurrence of keywords plus Network Visualization using WoS dataset

The next graph in Figure 84, is a Keyword-plus derived co-occurrence graph using the WoS dataset. Frames instead of circles were used and the association strength method for normalization. The terms and clusters derived are easily viewed. As already mentioned, due to the nature of the keyword-plus field, the terms are from the references used by the authors of the documents, so these terms reflect the conceptual basis upon which the Authors work was based on.

The absence of the term human is worth to be noted. 6 clusters were formed. One is the system, management, model cluster that contains the resilience term. Also contained in this cluster are terms such as optimization, algorithm, networks, resource allocation and machine. The AI, CPS, Big data, Internet, supply chain, digital twin, blockchain, things, IoT, security is the largest cluster. The technologies cluster with Industry 4.0, integration, service and robots. The framework, future cluster, with terms such as performance, decision making, impact, implementation, collaboration and more. And finally, the sustainability cluster containing circular economy, VR, digitalization and innovation.

4.4 Trends – Topics

The below Trend Topics Bibliometrix/Biblioshiny graph that uses the Author's keywords field, shows the trend topics as they evolve.

Resilience is found as a promising topic in 2023, as Human-Centricity was found in 2022 and SMEs in 2021.

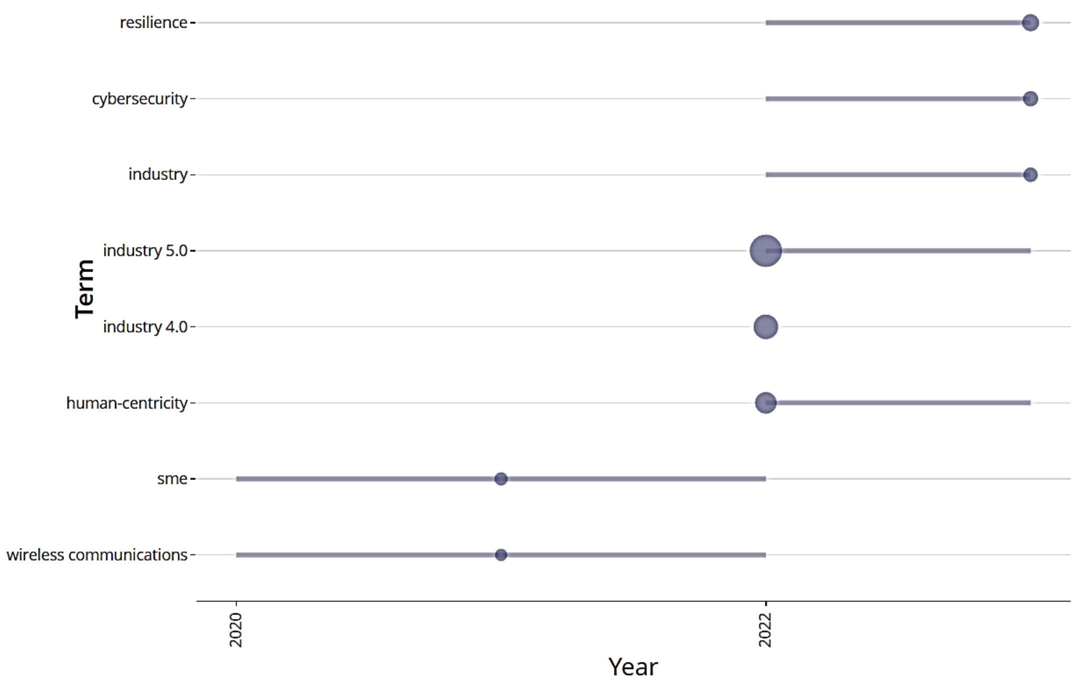


Figure 85 - Trend Topics by Bibliometrix/Biblioshiny

4.5 Three-field plot

Another overview through the Three-Field Plot, where Title, Countries and Author's keywords were selected having 13 items on each category, showing the connection between the countries of the Authors, and the titles and keywords that they use.

The relationship among Top Keywords, Top Countries and Top Title's words summarized by a Sankey Plot can gives information on the status of Industry 5.0. For instance, sustainable is a term that appears in the title of all countries displayed for at least one document except for Germany. Sustainability as an Author's keyword appears in at least one document from all countries appeared in the graph except Turkey and Pakistan, whereas resilience appears in at least one document from China, Italy, UK, Portugal, USA, Spain, Germany and Australia. Furthermore, Society 5.0 does not appear in the keywords list to any document retrieved from USA, Germany and Poland.

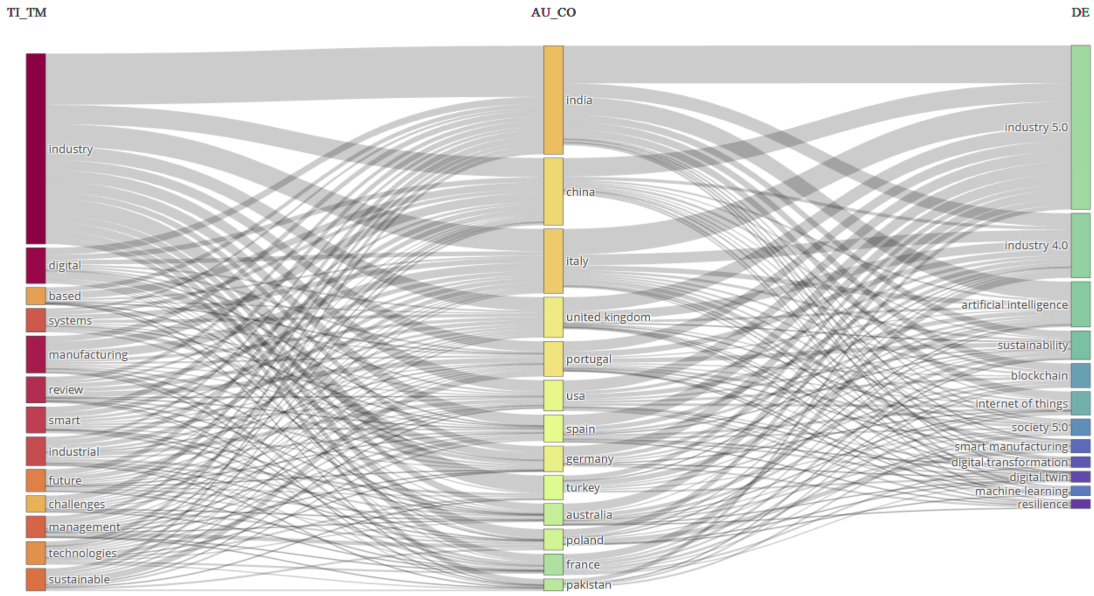


Figure 86 - Three-Field Plot, where Title, Countries and Author's keywords by Bibliometrix/Biblioshiny

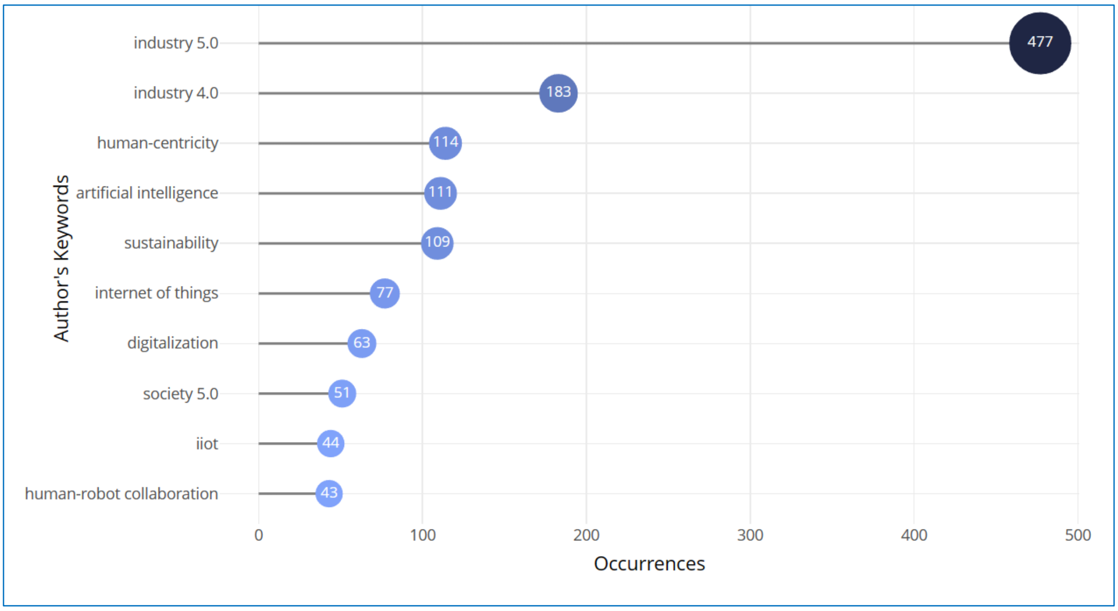


Figure 87 - Most Relevant Words by Bibliometrix/Biblioshiny

4.6 Most Frequent Words

Most Frequent Words, is a graph made by the Bibliometrix/Biblioshiny tool, based on Author's keywords generated by the merged dataset and after applying a thesaurus. As can be seen in Figure 87, Industry 5.0 as expected is the top frequent used word, followed by Industry 4.0, human-centricity, AI and sustainability. IoT, digitalization, Society 5.0, IIoT and Human-Robot collaboration complete the top 10.

Below, is a Word cloud from the merged dataset was made with the Bibliometrix/Biblioshiny tool using the Abstract's bigrams. Artificial Intelligence has the most occurrences, followed by industrial revolution, supply chain, machine learning, sustainable development, digital transformation and digital twins.

Figure 88 - Word cloud using Abstract's bigrams by Bibliometrix/Biblioshiny

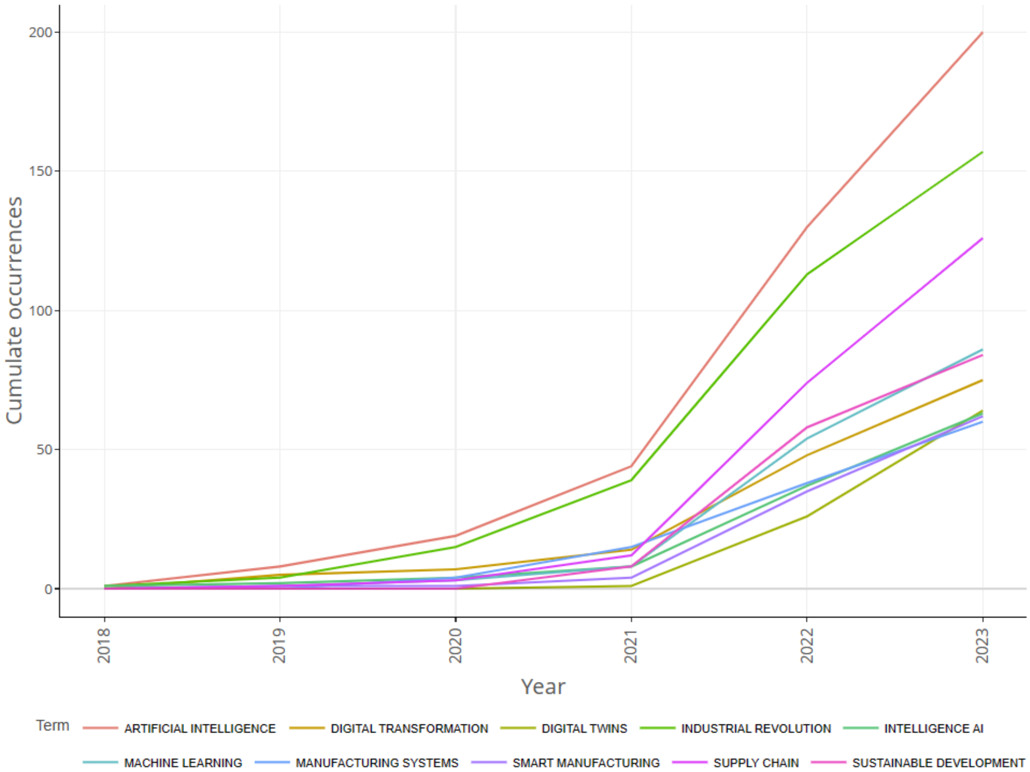


Figure 89 - The Abstract's bigrams Word frequency over time by Bibliometrix/Biblioshiny

And for the most frequently used bigrams from the Abstract field, their frequency over time is presented in Figure 89.

4.7 Thematic Evolution

4.7.1 Co-occurrence analysis in different periods

Analyzing counts of co-occurring entities within a collection of units is the main goal of co-occurrence analysis. The co-occurrence matrix is a common type of data used in co-occurrence analysis; the intersection of the row and column represents the co-occurrence. The items constitute the row and column headers. Co-occurrence analysis in bibliometrics is used to investigate the possible association between two bibliographic entries that are present in the same study. Over the past two decades, bibliometrics' co-occurrence analysis techniques have advanced [91].

The Industry 5.0 evolution was examined through the VOSviewer tool. Firstly, the Co-occurrence of keywords Network Visualization and Density Visualization with the Scopus dataset was made, where the type of analysis performed was with all keywords, fractional counting as counting method and association strength normalization to Normalized link strengths and then they are inputs for the VOS layout method and the VOS clustering method, respectively, for all examined periods.

As 2018 has only one paper, the first period was set to 2019-2020. From the graph made through VOSviewer with the Scopus dataset, the papers of this period mostly reflect technology values.

The minimum number of occurrences was set to 3 as the number of sources of the period was small.

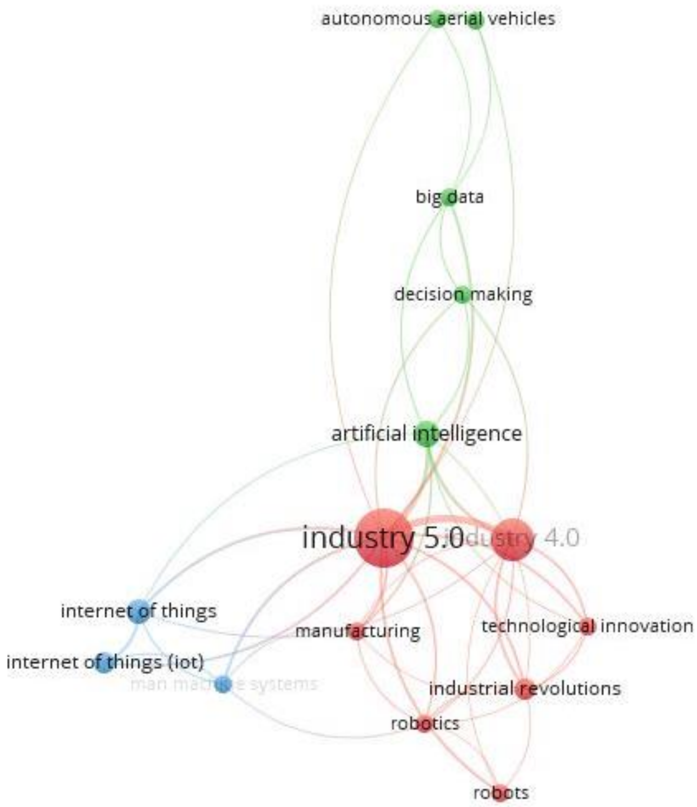


Figure 90 - VOSviewer co-occurrence Network Visualization 2019-2020 using the Scopus dataset

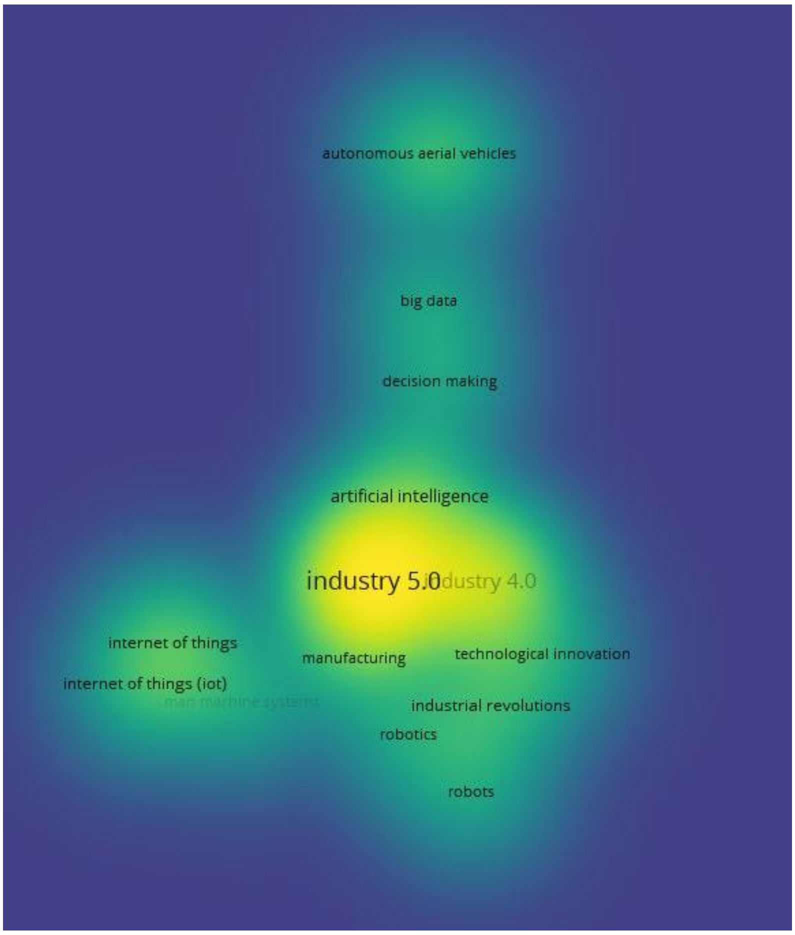


Figure 91 - VOSviewer co-occurrence Density Visualization 2019-2020 using the Scopus dataset

Same co-occurrence graph was made with the WoS dataset having the same parameters as the previous graph with the Scopus dataset and the output was alike the Scopus one.

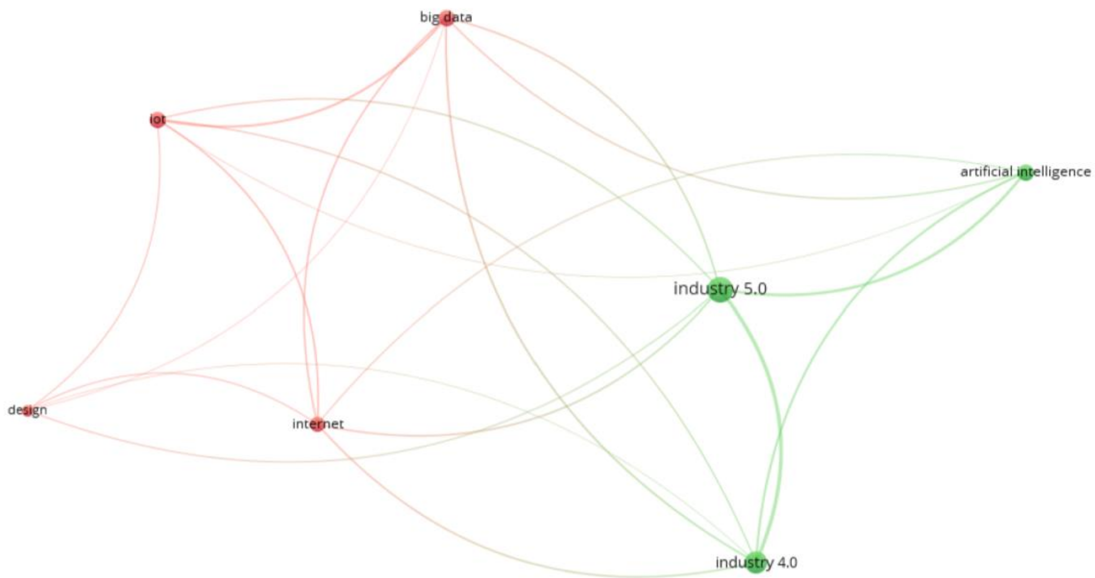


Figure 92 - VOSviewer co-occurrence Network Visualization 2019-2020 using the WoS dataset

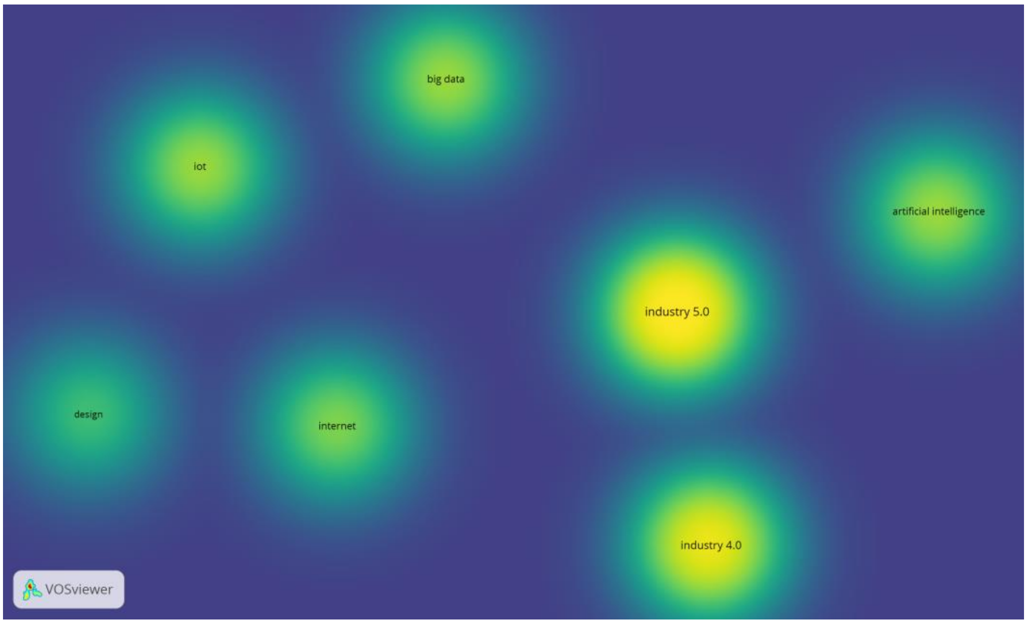


Figure 93 - VOSviewer co-occurrence Density Visualization 2019-2020 using the WoS dataset

The next period was set to 2021. The first couple of graphs made with the Scopus dataset, having the same parameters of the first period. The only difference is that the minimum occurrences was set to 4. Interesting output as beside technology factors the new dimensions introduced with Industry 5.0 can be found in this graph: Sustainability, humans (workers, human-robot collaboration, Operator 4.0, human, humans) and Society 5.0.

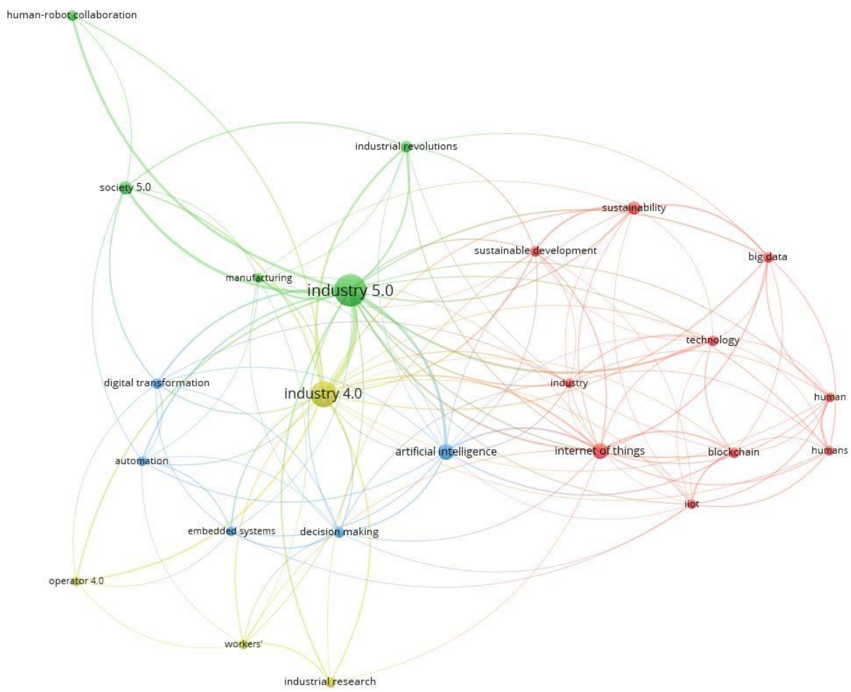


Figure 94 - VOSviewer co-occurrence Network Visualization 2021 using the Scopus dataset

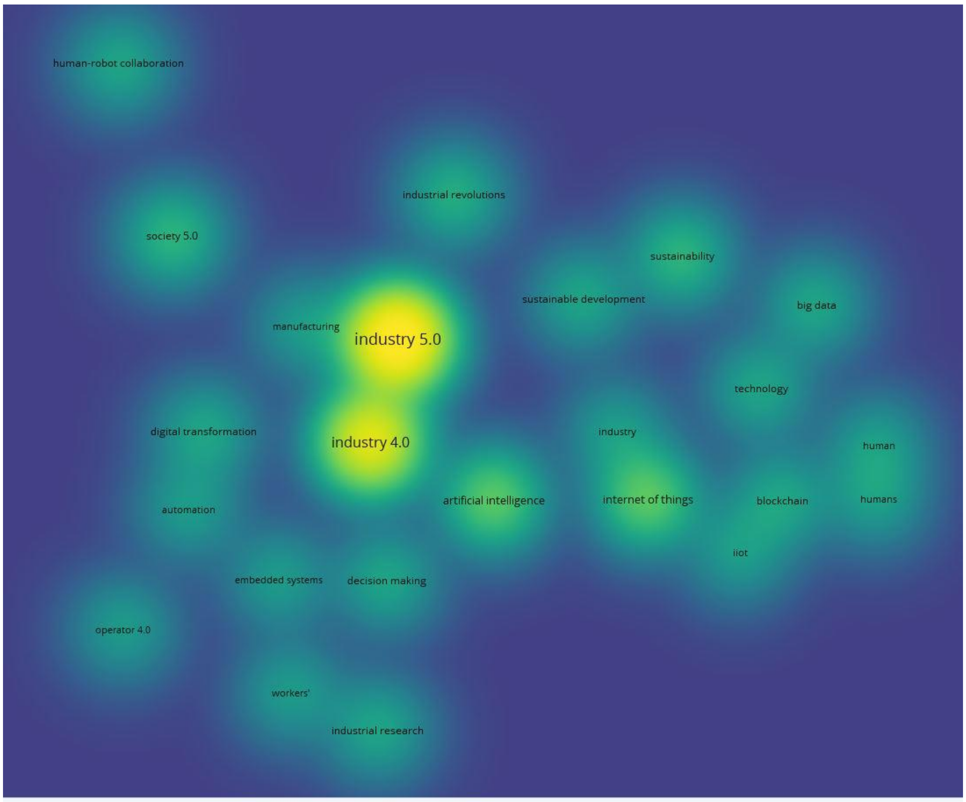


Figure 95 - VOSviewer co-occurrence Density Visualization 2021 using the Scopus dataset

The corresponding graphs with the WoS dataset are next. In these graphs beside technology factors the new dimensions introduced with Industry 5.0 can be found such as sustainability, human-centricity, operator safety, human-robot collaboration and society 5.0.

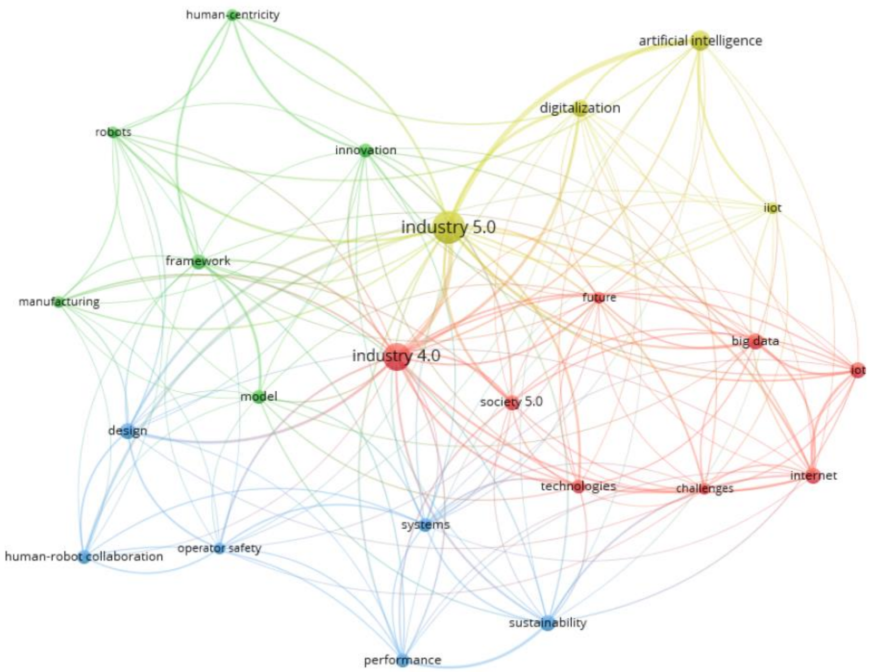


Figure 96 - VOSviewer co-occurrence Network Visualization 2021 using the WoS dataset

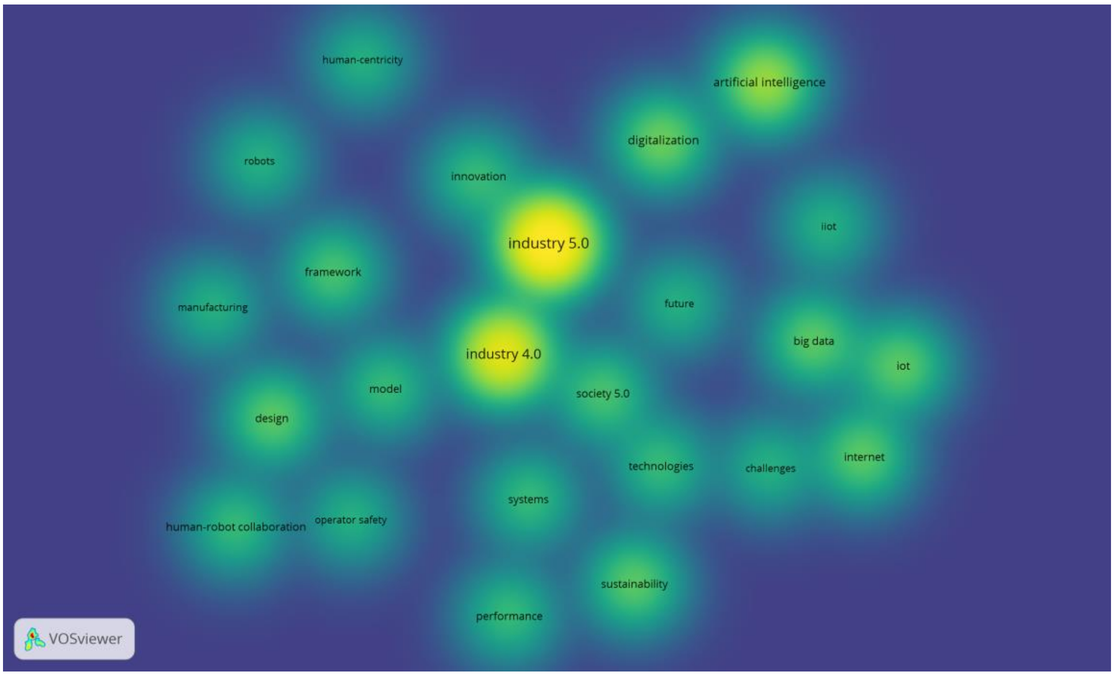


Figure 97 - VOSviewer co-occurrence Density Visualization 2021 using the WoS dataset

The following period was set to 2022. The VOSviewer parameters remain the same, only the minimum occurrences field was set to the default value that is 5. From the Scopus dataset, 2022 was richer in concepts than the previous year. In the new concept's list, included terms are such as, resilience, wellbeing, personnel etc.

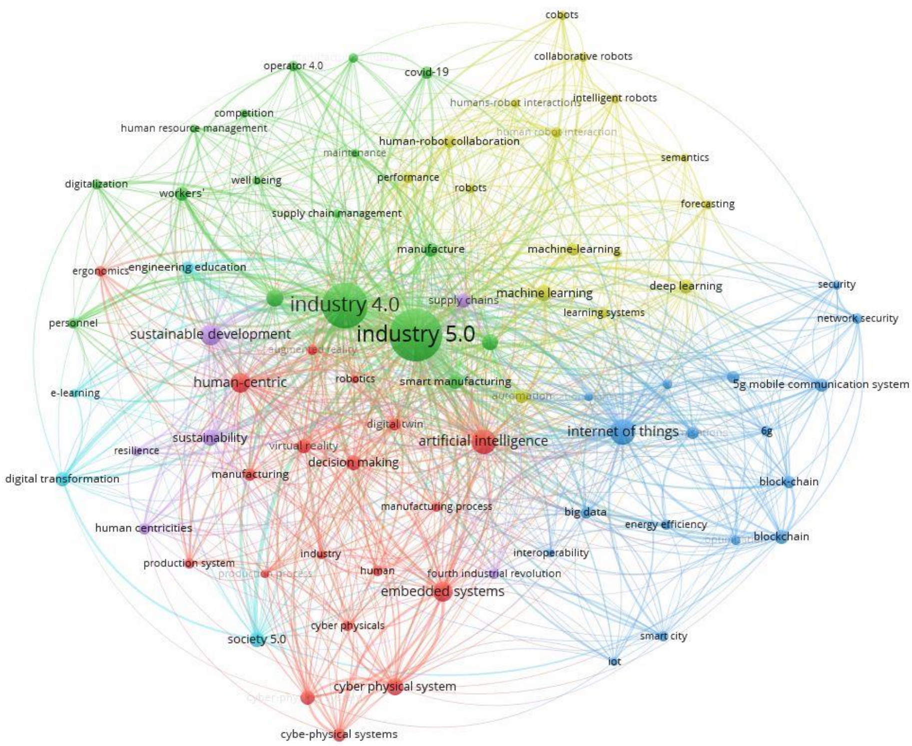


Figure 98 - VOSviewer co-occurrence Network Visualization 2022 using the Scopus dataset

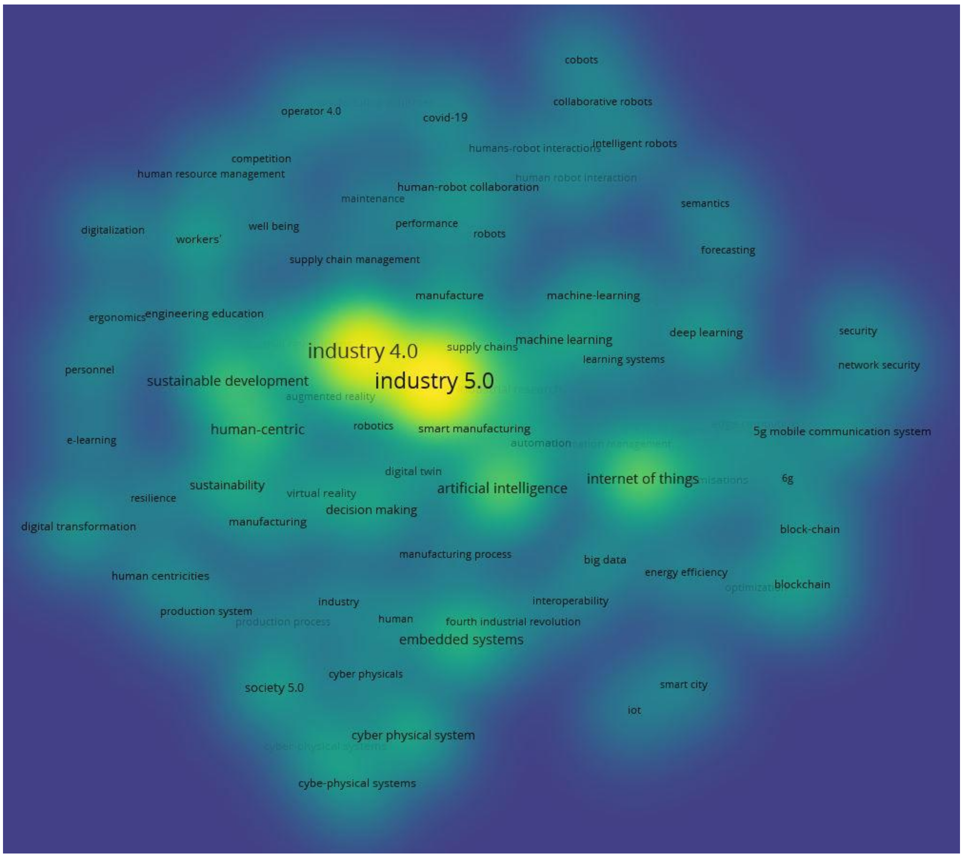


Figure 99 - VOSviewer co-occurrence Density Visualization 2022 using the Scopus dataset

The corresponding WoS graphs are next, and they can be seen as similar to the Scopus graphs of 2022.

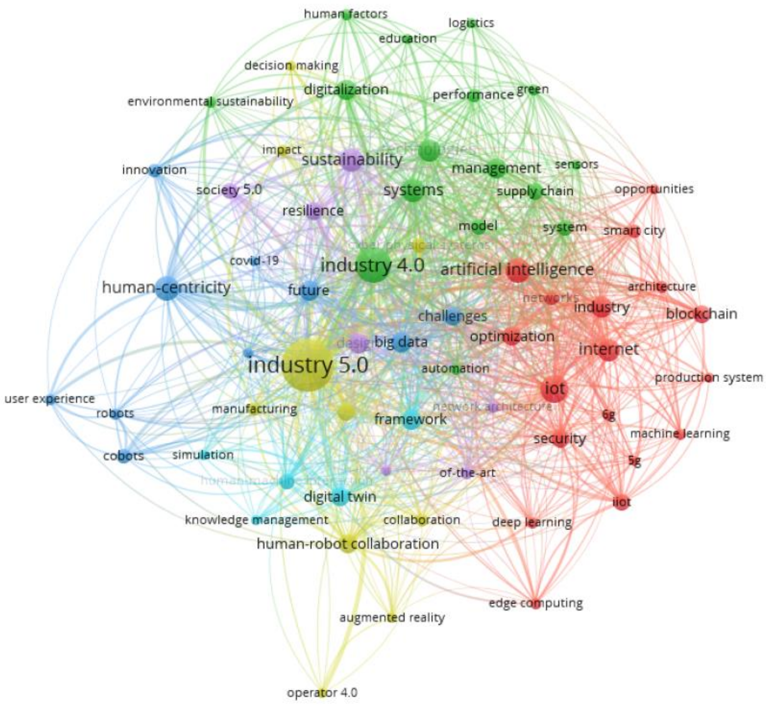


Figure 100 - VOSviewer co-occurrence Network Visualization 2022 using the WoS dataset

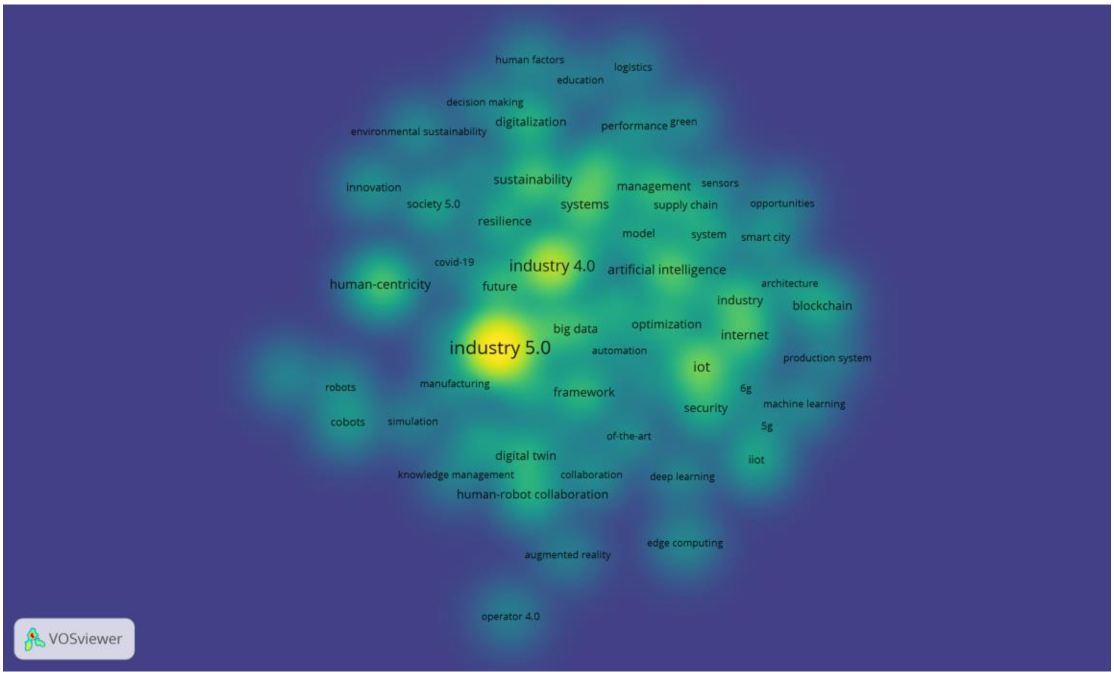


Figure 101 - VOSviewer co-occurrence Density Visualization 2022 using the WoS dataset

Last period is 2023. For the Scopus dataset, the 2023 graph made was similar to 2022. A difference that can be seen is that the sustainability cluster has been expanded.

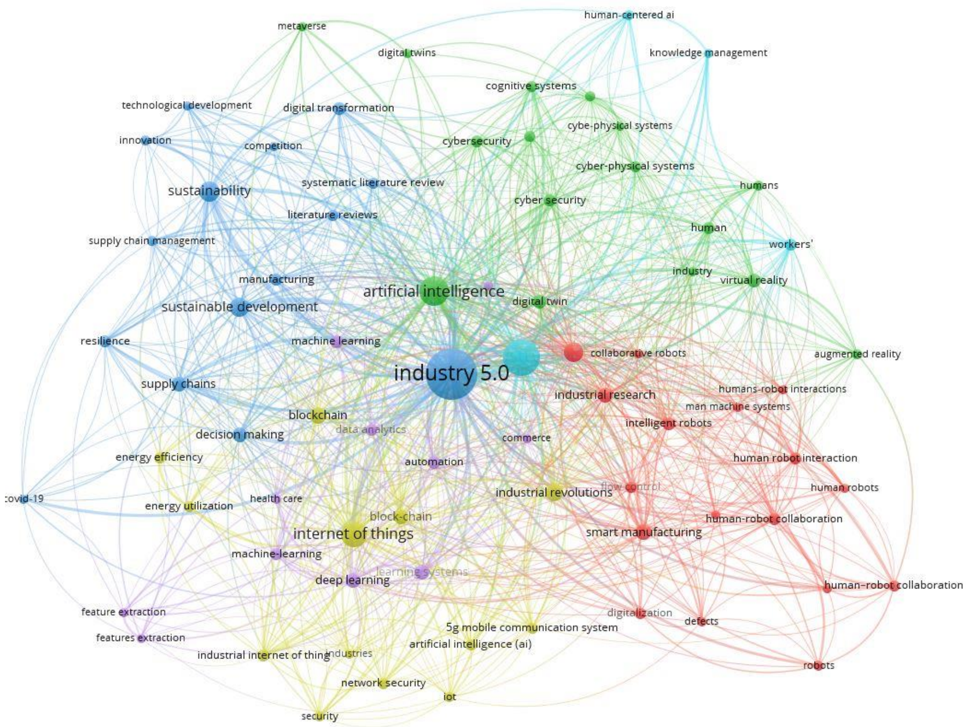


Figure 102 - VOSviewer co-occurrence Network Visualization 2023 using the Scopus dataset

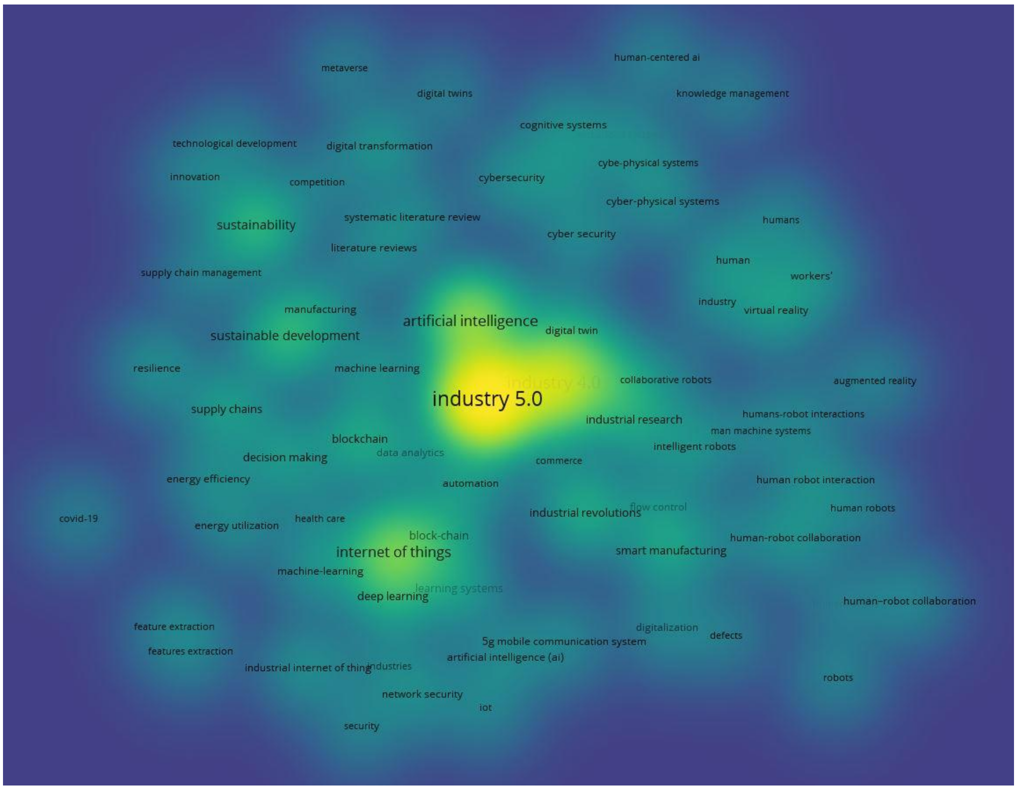


Figure 103 - VOSviewer co-occurrence Network Visualization 2023 using the Scopus dataset

As for the 2023 WoS dataset the obtained graphs, again look alike the Scopus of this period.

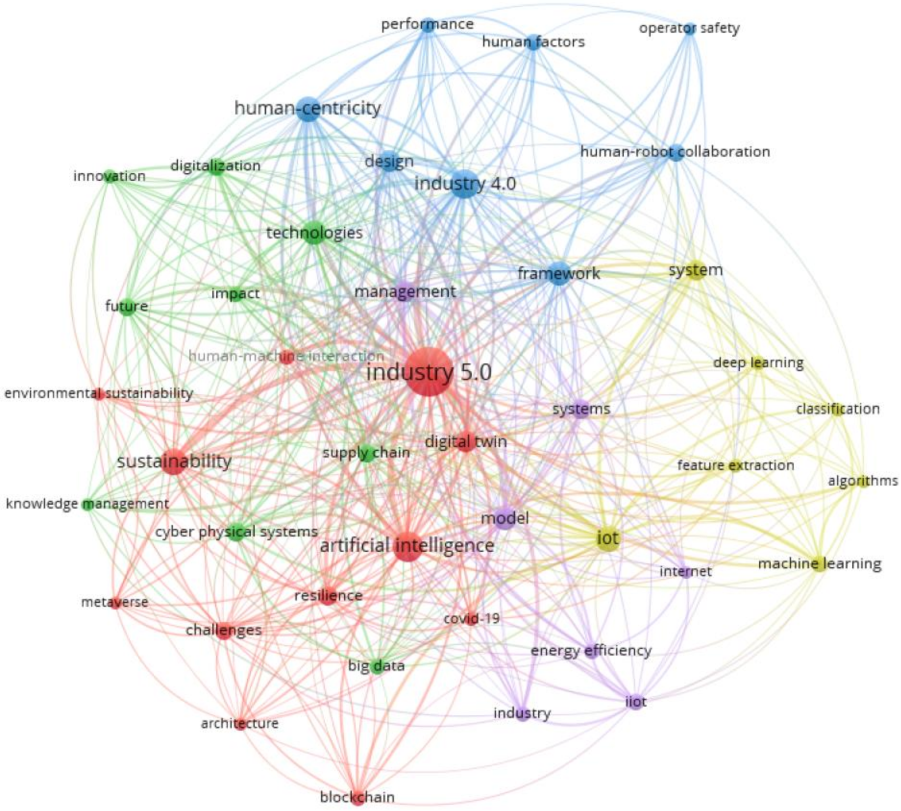


Figure 104 - VOSviewer co-occurrence Network Visualization 2023 using the WoS dataset

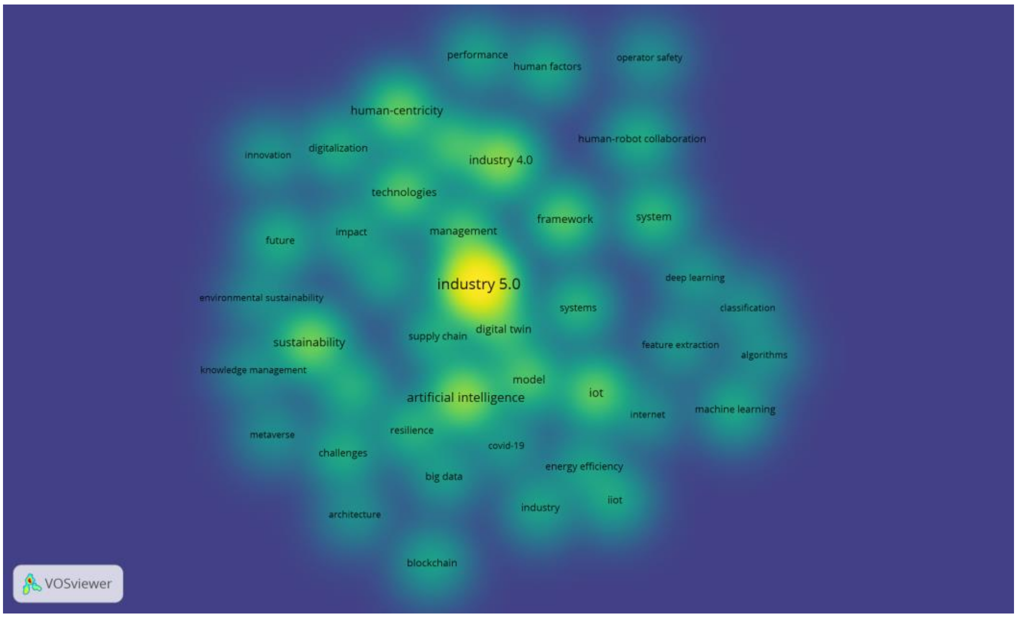


Figure 105 - VOSviewer co-occurrence Density Visualization 2023 using the WoS dataset

4.7.2 Thematic Evolution

The thematic evolution from Bibliometrix/Biblioshiny shows the transition from Industry 4.0 concepts to Industry 5.0 concepts.

Below is the graph made with the merged dataset based on the keywords plus field (a mix of index by Scopus keywords and keyword plus terms). It shows a transition focus from a technology-based perspective to Humans (focus on workers) and Sustainability (plus energy efficiency) perspective. Sustainability was from the beginning in the research focus, as concerns about sustainability was in the focus from Industry 4.0 but human workers concerns raise in recent works.

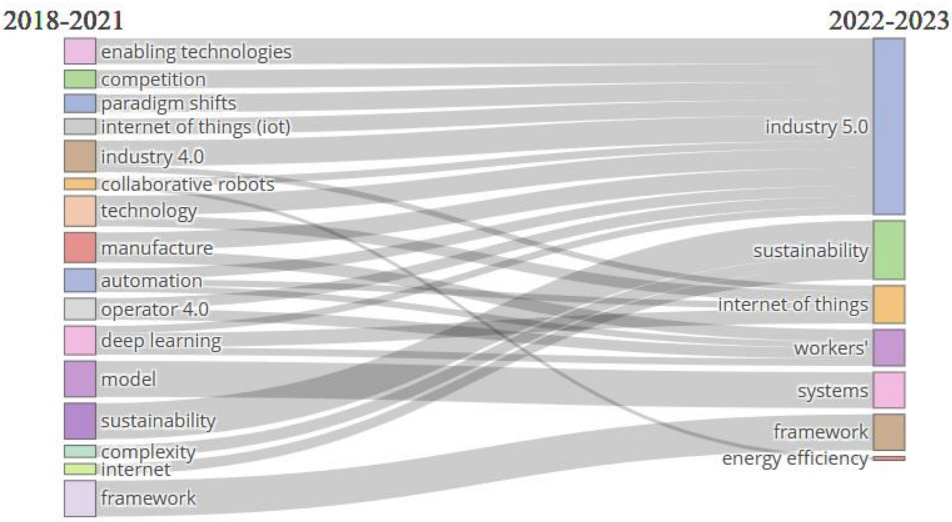


Figure 106 - Bibliometrix/Biblioshiny Thematic Evolution

4.8 Co-word analysis

Co-word analysis is a method used to identify clusters of keywords in a given dataset. These clusters, known as themes, can be classified and visually represented on a two-dimensional thematic map. The position of each theme on the map provides information about its characteristics and significance within the research field. The thematic map is divided into four quadrants. The distribution, development, and importance of themes within Industry 5.0 can be revealed, aiding in the identification of key areas of focus, emerging trends, and potential research directions. The co-word analysis was made through Bibliometrix/Biblioshiny tool using the merged dataset and the Author's keywords. Based on centrality and density, the themes are divided into four groups.

The motor themes are those that have been extensively studied and are significant to the scientific community. Ideas that are equally important but less thoroughly explored make up the core themes. Niche themes are specialized topics with minimal application to the research field but connections to related topics. As a result of their lack of development and marginal significance, developing or declining subjects are grouped under emerging/declining themes. The distribution of these four groups can be seen along two axes: the X-axis represents the level of relevance of a topic, and the Y-axis represents the level of development [92].

The co-word analysis might offer an idea of what the research field can look like in the future [70].

The first period examined was 2018-2021 (Figure 107 and Figure 108).

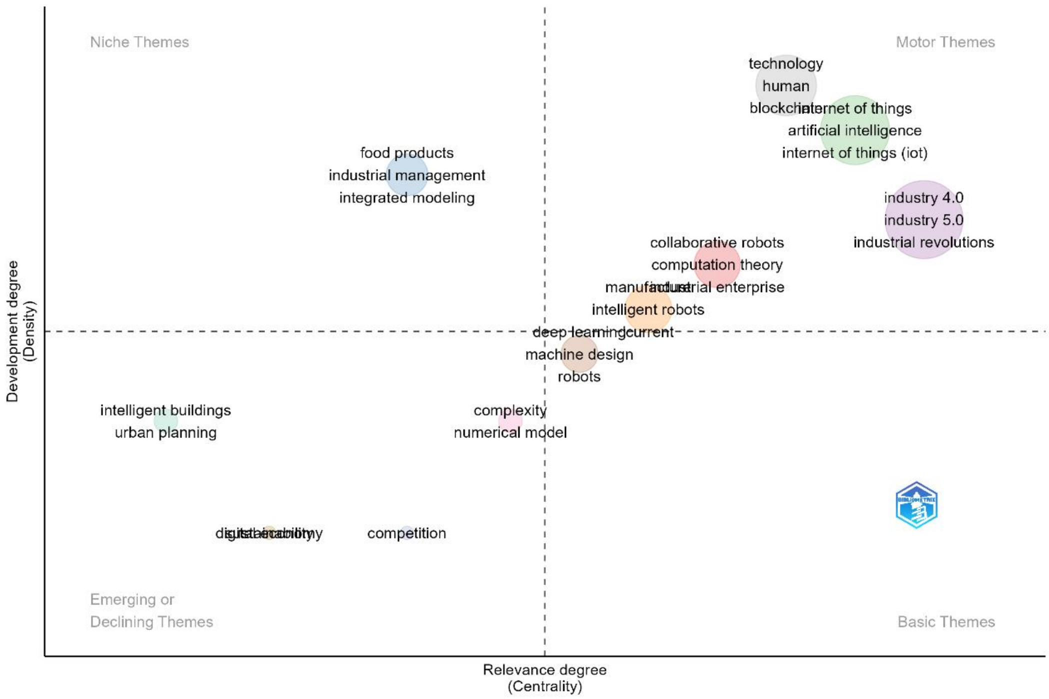


Figure 107 - Industry 5.0's Thematic map 2018-2021 through Bibliometrix/Biblioshiny

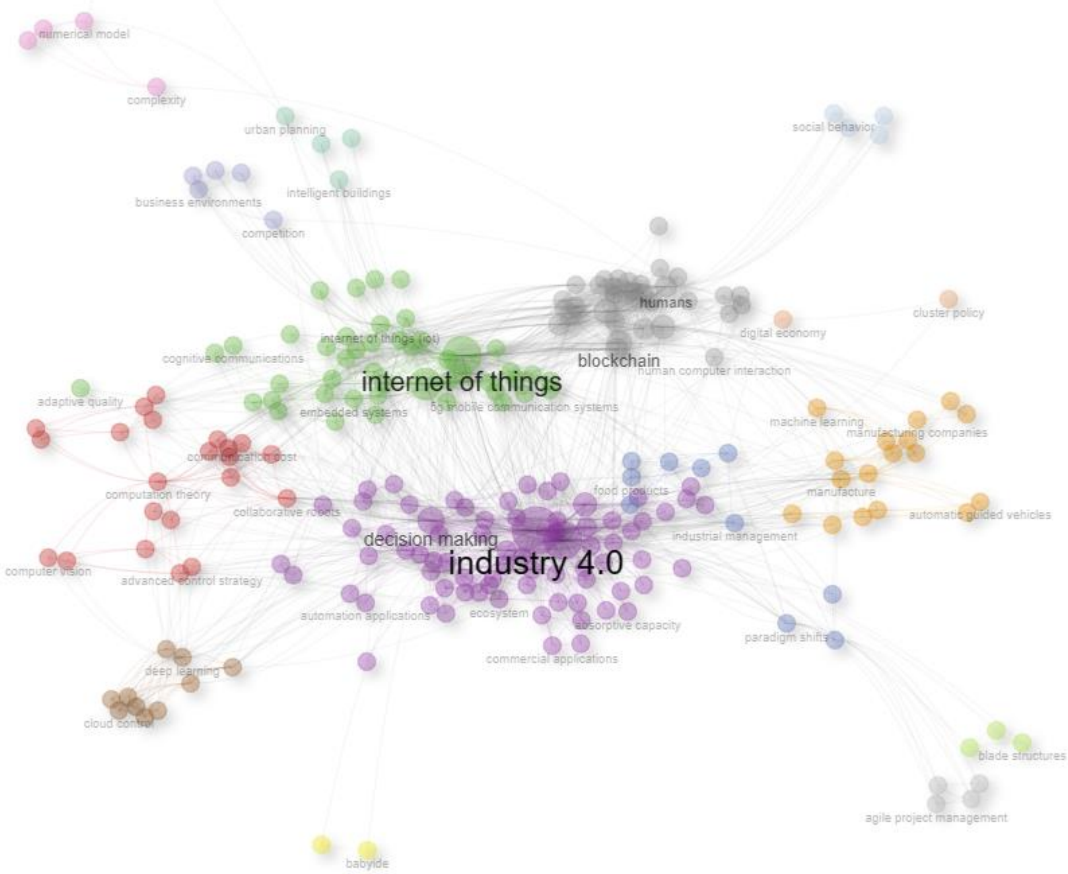


Figure 108 - Industry 5.0's Thematic Map Network 2018-2021 through Bibliometrix/Biblioshiny

The second period was 2022-2023 (Figure 109 and Figure 110).

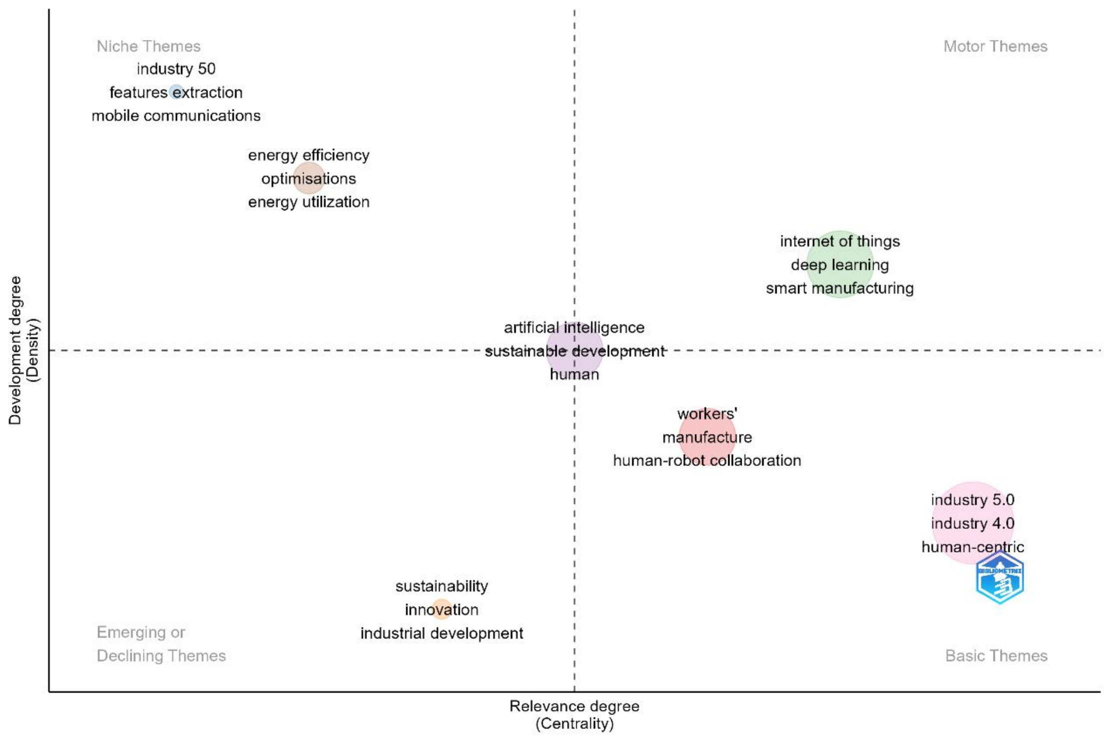


Figure 109 - Industry 5.0's Thematic map 2022-2023 through Bibliometrix/Biblioshiny

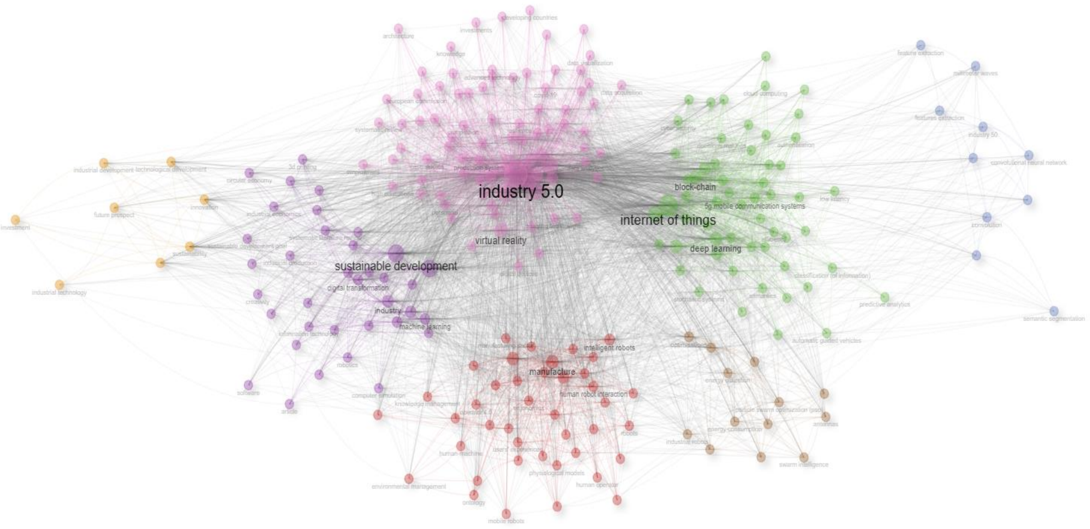


Figure 110 - Industry 5.0's Thematic Map Network 2022-2023 through Bibliometrix/Biblioshiny

In the early years 2018-2021 many clusters have been identified as Motor Themes. They primarily include technological factors. In the next period only one cluster (the IOT, AI, blockchain cluster) remains in the Motor Themes. The Industry 5.0 cluster in the last period while probably has changed its focus and is more human-centric, is placed in the Basic Themes.

It is expected that the relevance degree of the Industry 5.0 cluster will be high, that is why it can be found in both maps in the rightest position.

In the first period that the tool interprets the Industry 4.0 - Industry 5.0 cluster, the technology with human interaction cluster and blockchain cluster, the IoT and AI cluster, the cobots cluster and the manufacturing cluster were well developed, sustainability is emerging.

Whereas, in the second period Industry 5.0 cluster is decreasing its density degree as it has a human-centricity focus and resilient is a new topic in this cluster. Moreover, Sustainable development with AI and human form a cluster positioned in the map's center.

Human factors and cobots may not be extensively developed but are relevant across different research areas and sustainability in a different cluster is still emerging.

The Thematic map for the whole period of our research (2018-2023) through Bibliometrix/Biblioshiny using the Author's keywords was also made and can be found next in Figure 111.

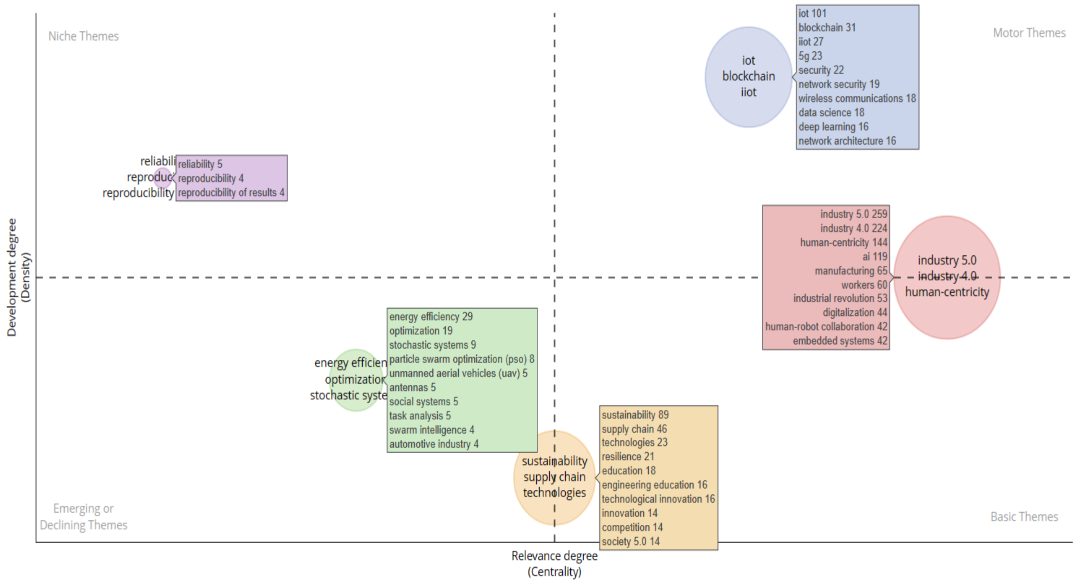


Figure 111 - Industry 5.0's Thematic map through Bibliometrix/Biblioshiny

This map shows 5 clusters. The cluster with the highest centrality, that is the most relevant to the topic cluster, is the Industry 5.0 – Industry 4.0 – human-centricity cluster but with medium density, that is, it is not fully developed. That is why it is half in the Motor Themes quadrat and half to the Basic Themes quadrat. With less centrality but more density from the previous cluster is the IoT – blockchain - Industrial IoT cluster and it is placed in the Motor Themes quadrat. The next cluster based on the order of the centrality degree is the sustainability – supply chain – technologies – resilience cluster that half belongs to the basic and half to the Emerging or Declining Themes quadrat. The next cluster with less centrality than the previous one but with little more density of it is the Energy efficiency cluster belonging as well to the Emerging or Declining Themes quadrat. Finally, the smaller cluster is the reliability cluster that has low centrality but high density and belongs to the Niche Themes quadrant.

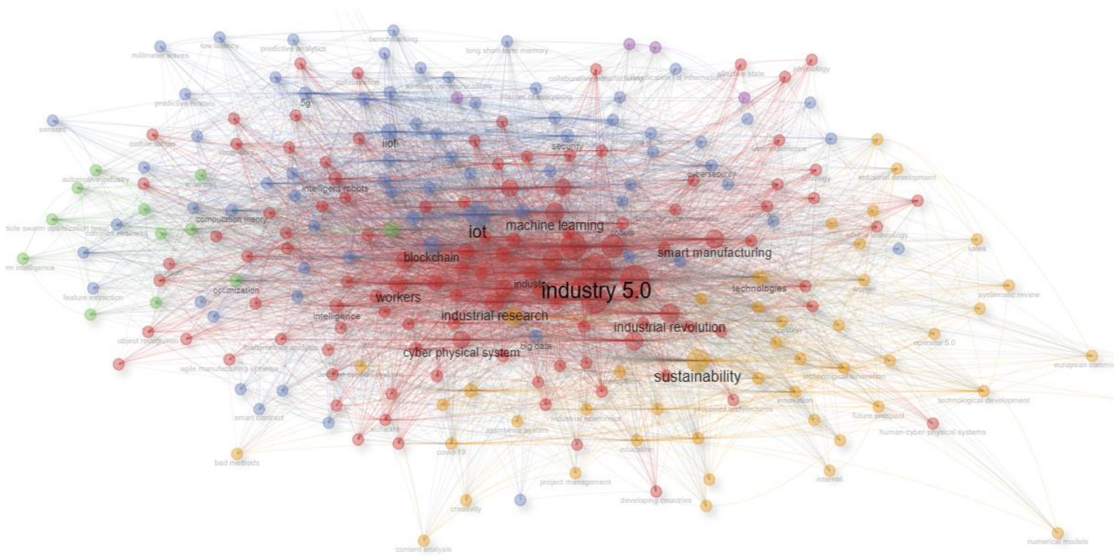


Figure 112 - Industry 5.0's Thematic Map Network through Bibliometrix/Biblioshiny

4.9 *Factorial Analysis*

Factorial analysis was employed to construct a conceptual structure map utilizing Multiple Correspondence Analysis (MCA), which serves as a descriptive technique for assessing two-dimensional and multiplexed tables of corresponding metrics between rows and columns. This method effectively groups indicator levels with shared traits, revealing their coherence within a two-dimensional plot forming clusters of points.

The proximity of keywords in the plot reflects their degree of relatedness, with closer keywords exhibiting greater association. Additionally, hierarchical clustering was applied to cluster keywords with the utmost similarity, yielding a tree graph that intricately delineates the interplay and divergence of keywords [74].

Thus, it can be identified in the generated graph that resilience and sustainable development are very close thus they are related. Also, human centricity is not far away from both resilience and sustainable development. Furthermore, Sustainability is close to human-robot interaction and supply chain. Industry 5.0 and Industry 4.0 are very close. Moreover, close are Human centric to human robot collaboration, and human robot collaboration to Operator 4.0 and digitalization. And again, it is noted that their closeness indicates a degree of relevance between the topics. Another, worth mentioned observation is that all terms belong to one cluster, meaning this type of analysis found a high degree of relevance in between the themes of the Industry 5.0 topic.

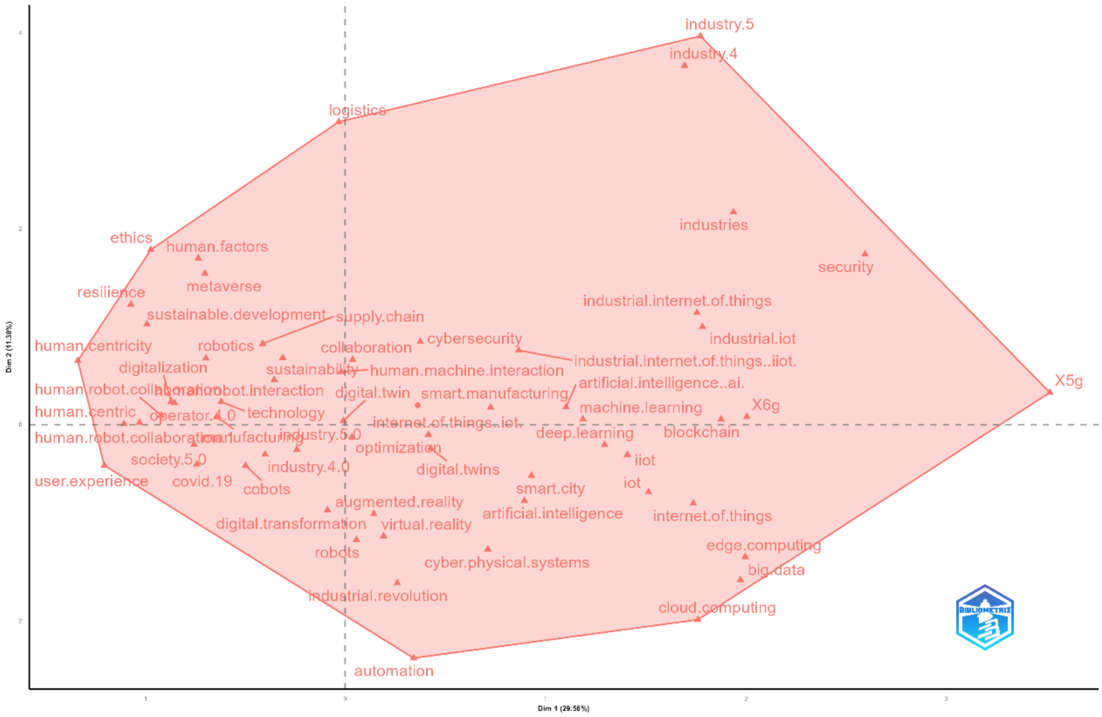


Figure 113 - Factorial Analysis - Conceptual Structure Map using MCA by Bibliometrix/Biblioshiny

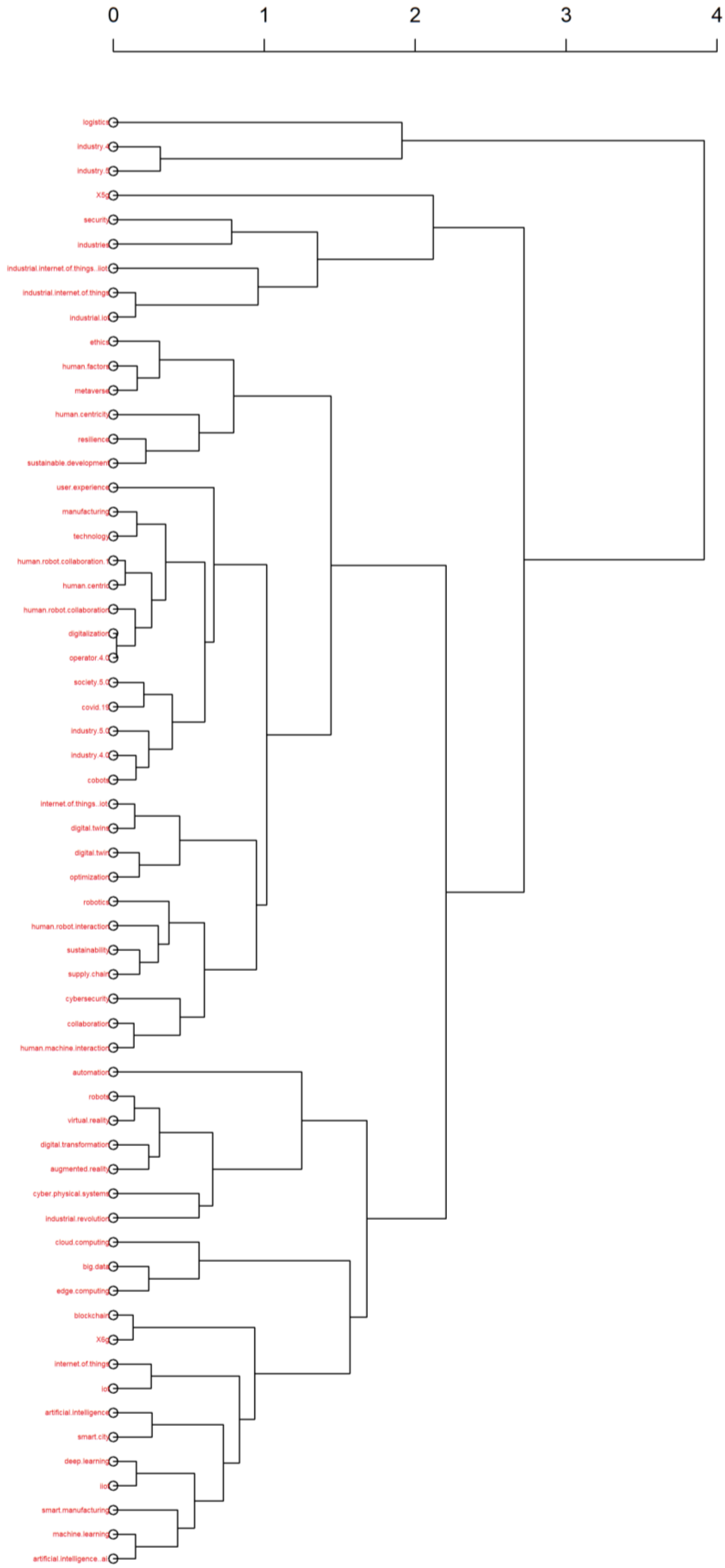


Figure 114 - Factorial Analysis - Topic Dendrogram using MCA by Bibliometrix/Biblioshiny

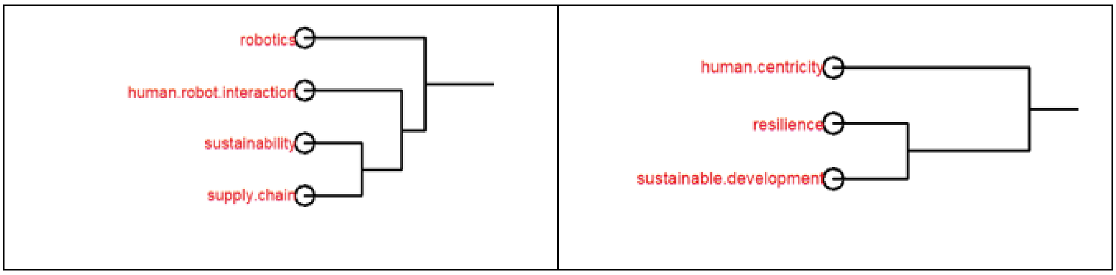


Figure 115 - Factorial Analysis - Parts of the Dendrogram 1

Interpreting parts of the dendrogram, make logical sense, and helps to understand the relationships among terms. Therefore, follows an observation of certain parts of the dendrogram. The above left part of the dendrogram may be explained as for supply chains sustainability is an important aspect and human robot interaction can help on this as well the robotics may help. For the above right part, sustainable development and resilience are close related and together are strong related to human centricity. Also, manufacturing may rely on them.

For the below left part, three different ways to express Industrial IoT were identified and connected. Industries and Security are obviously related and both are connected to Industrial IoT.

For the right part, Augmented Reality is a key factor for digital transformation, and Robots and Virtual Reality are close together. These terms are then connected with the pair CPS and Industrial Revolution. And to all these terms automation is a related term.

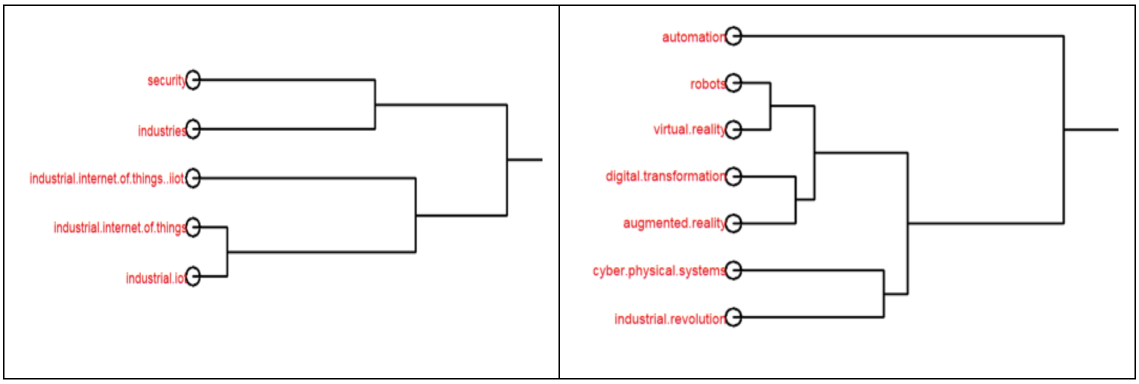


Figure 116 - Factorial Analysis - Parts of the Dendrogram 2

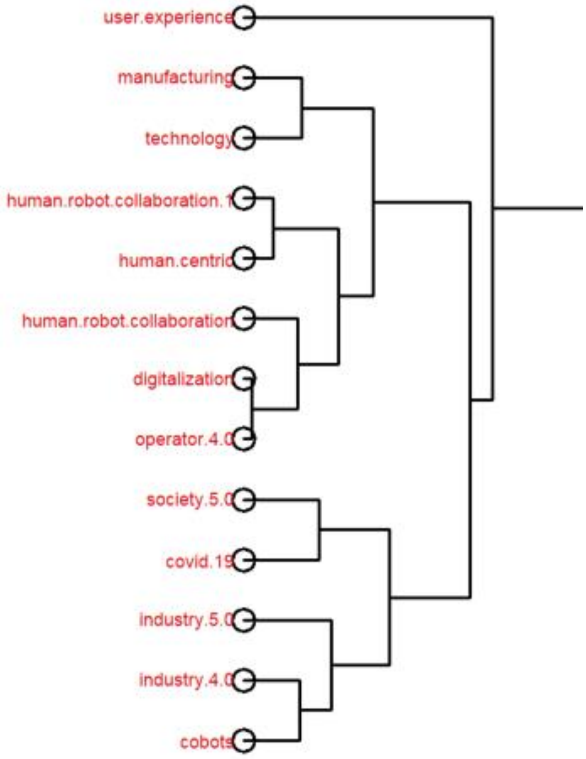


Figure 117 - Factorial Analysis - Parts of the Dendrogram 3

A connection exists between digitalization and Operator 4.0 that then they are connected to human robot collaboration. Human centric and human robot collaboration (different instance) are also connected and then they have a relationship connection with the previous block. Manufacturing and technology forming a relationship and after they are connected with the previous human-related block of terms.

Industry 4.0 and cobots have a connection and help to accomplish Industry 5.0. The Covid-19 and Society 5.0 connection may be interpreted as Society 5.0 cares about society, thus for its citizens and their Health Care. And then Industry 5.0 and Society 5.0 are together related.

The two big blocks of terms, described, are then connected and all together are related to User experience.

4.10 Opinion Mining

The last analysis method for the second research question to discover emerging fields and research trends, conducted using the ATLAS.ti tool, was Opinion Mining. It is an AI technology that can find sentiments in concepts. It is sentiment mining, also known as opinion mining, which involves creating a way to find authors' ideas provided in documents. Its purpose is to ascertain an author's attitude about a particular subject.

It is possible to extract insights from data by using natural language processing to find feelings that are embedded in text. Text analysis can reveal the sentiments that underlie words and sentences, in addition to their meaning. Opinion mining is a Sentiment analysis of the papers in the collection to determine whether a context is favorable or unfavorable. The Opinion Mining program can recognize frequently occurring words in key phrases, display descriptive statistics of the words connected to each term, and suggest sentiment and opinion codes for every relevant quotation. This makes it simple to comprehend both what is being discussed in the literature data and how individuals feel about that particular item. Therefore, it might be interpreted as the author making an optimistic or pessimistic declaration about a subject.

Opinion mining therefore, can be regarded as a sentiment analysis of citations in research articles to spot trends and suggest novel directions for future research. The goal of the sentiment analysis approach, which is part of the machine learning family, is to find relevant patterns contained in a database. The primary objective of sentiment analysis is, by using text analysis tools, to determine the polarity of citations (positive, negative, and neutral) made in various research articles.

In general, sentiment classification is to assign either a positive or negative polarity to the review materials. It doesn't look into the preferences of the reviewer or opinion container. If someone has a favorable impression of a document, it does not always follow that they feel the same way about every part of the document. An unfavorable opinion of a product does not necessarily imply that the person disapproves of all aspects of it. Although in general opinions may be positive or negative, the opinion container in an analysis document writes both the positive and negative essence of the item [43] [93].

The Scopus and WoS datasets that were collected were exported to BibTeX format and imported in the ATLAS.ti tool and the duplicate records were deleted manually through a search procedure provided by the tool. This format helps to have a detailed record of the document where a positive or a negative opinion occurs. In advance, it helps to make quick reviews on large collections of papers identifying spots on these papers that contain particular terms. The opinion mining process performed a sentiment analysis that it can help to reveal the author's optimism or pessimism (skepticism maybe is a better term to express the negative sentiment of an author regarding a field in the present use of Sentiment Analysis) upon the issues addressed in their works. Thus, by using the aforementioned different approach, the directions of the research on Industry 5.0 should be clearer.

The positive quotes produced by ATLAS.ti Opinion Mining are more than the negative in our collection. More specifically, the positive quotations in Scopus are 1042, whereas the negatives are 904. In WoS respectively 258 versus 111. In the merged dataset (Scopus and WoS) there are 1094 positive compared to 928 negatives quotations. As positive sentiment may imply something new, that will bring changes with positive impact whereas negative sentiments may imply the obstacles to achieve the transition from Industry 4.0 to Industry 5.0, by reading these quotes either positive or negative, helps any researcher to develop his/her understanding on the evolution of Industry 5.0.

Studying the output of the Opinion Mining process helped to have an in depth understanding and gather key insights of the research field, because it may disclose numerous unknown or hidden facts. Through the tool's interactive environment, it is possible to quickly and thoroughly overview the scientific area and support knowledge that has already been obtained using other techniques.

In the Appendix A, a collection of screenshots from the output of the Opinion Mining process is included. Both positive or negative quotes are presented. Reading them, aim for the qualified analysis of the academic articles collection, substantiated the findings of this research regarding Industry 5.0.

5

From Industry 4.0 to Industry 5.0

Industry 5.0 is a novel paradigm and as so it is evolving. Regarding what the Industry 5.0 concept should be about, several authors have varied perspectives as what it is [16]. Based on the definition coined by EC a definition in [20], identifies it as a set of organizational principles and technological tools for designing and running supply chains and operations as resilient, sustainable, and human-centric systems. As Industry 5.0 has many definitions, the directions pointed by the researchers can also vary. In order to identify the direction Industry 5.0 is heading, the analysis will focus on identifying the portion of Industry 5.0 articles in the two databases that contains at least one of the three pillars of Industry 5.0 and compare the impact of the articles containing one of the three pillars to those not containing. Further, the direct and indirect presence of the three pillars in the research literature is to be examined.

5.1 The 3 pillars in Scopus for Industry 5.0

The below table present the percentage of Articles in Scopus databases containing the keyword "Industry 5.0" and some subqueries using logical operators to discover the portion of documents covering the concepts of Human-centricity, Sustainability and Resiliency. As it can be seen there is an increasing interest for the 3 Industry 5.0 pillars. The majority of articles, more than three quarters of articles, that are published discuss a concept regarding the 3 Industry 5.0 pillars.

Table 14 - Industry 5.0 Articles in Scopus

Articles in Scopus						
Industry 5.0						
Year	2018	2019	2020	2021	2022	2023 (until 1st of July 2023)
Doc	1	17	36	90	369	244
Industry 5.0 And Human-centric						
Doc	1	6	12	47	221	158
%	100	35,29	33,33	52,22	59,89	64,75
Industry 5.0 And Sustainability						
Doc	0	1	5	23	129	84
%	0	5,88	13,89	25,56	34,96	38,11
Industry 5.0 And Resiliency						
Doc	0	0	0	7	55	43
%	0	0	0	7,78	14,91	18,03
Industry 5.0 And (Human or sustainability or resiliency)						
Doc	1	7	17	62	270	184
%	100	41,18	47,22	68,89	73,17	75,41

In order to have a better view on the Industry 5.0 documents stored in the Scopus database, a Venn chart has been created. The data comes from relative keyword searches on Scopus.

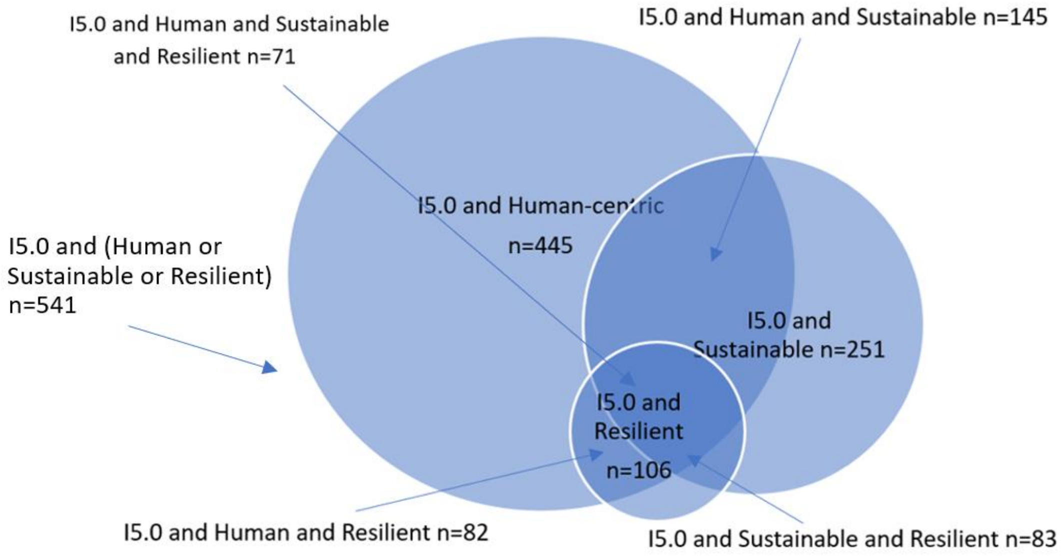


Figure 118 - Venn chart of Scopus various datasets formed after applying relative keyword searches

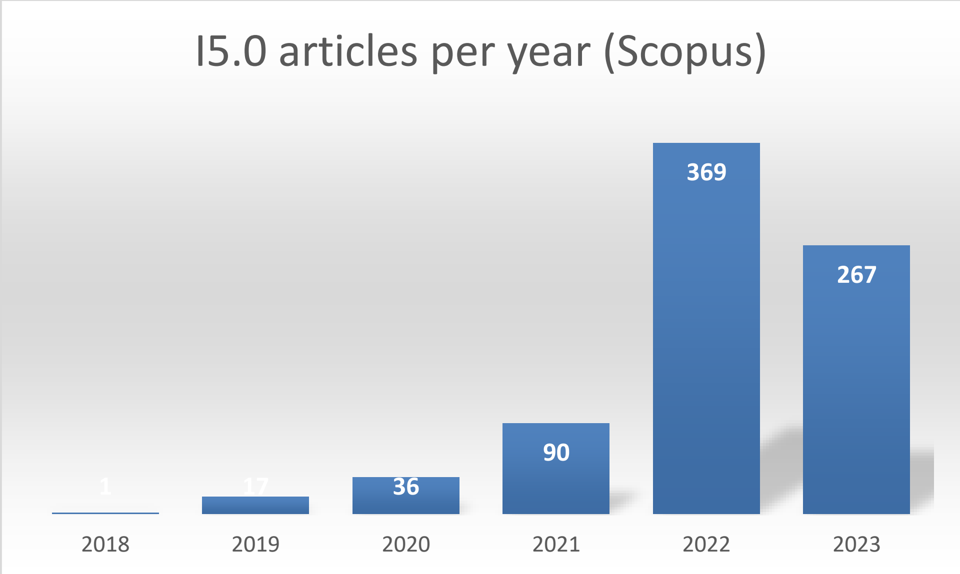


Figure 119 - Industry 5.0 articles per year in Scopus

From the Scopus dataset, several graphs were produced showing the growth of interest for the 3 Industry 5.0 pillars.

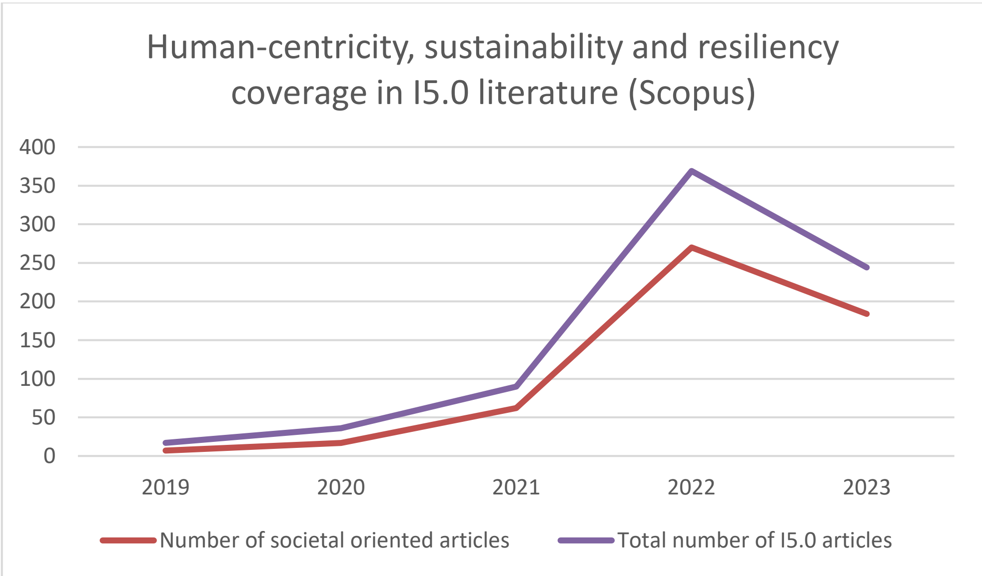


Figure 120 - Industry 5.0 articles in Scopus covering any of the 3 pillars

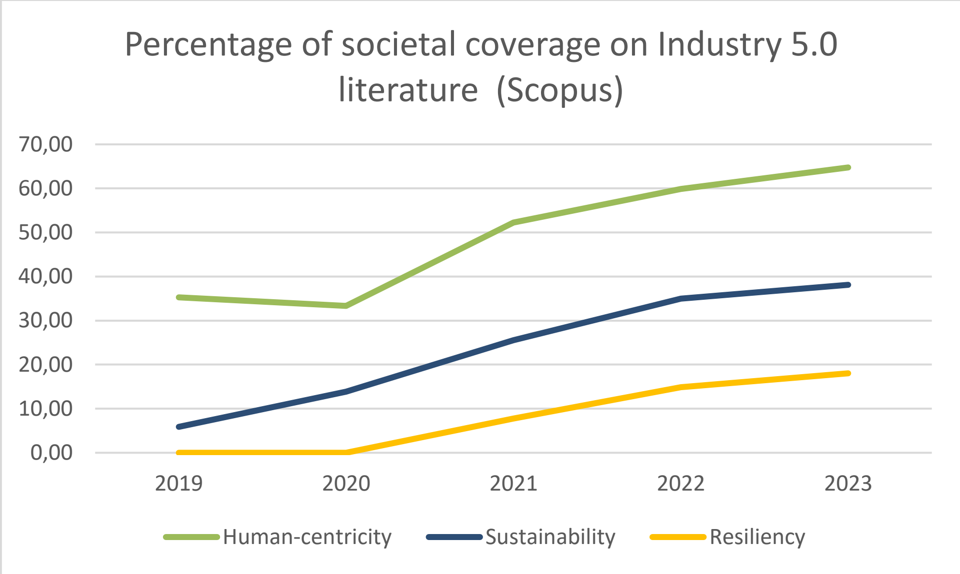


Figure 121 - Percentage of Industry 5.0 articles in Scopus covering any of the 3 pillars

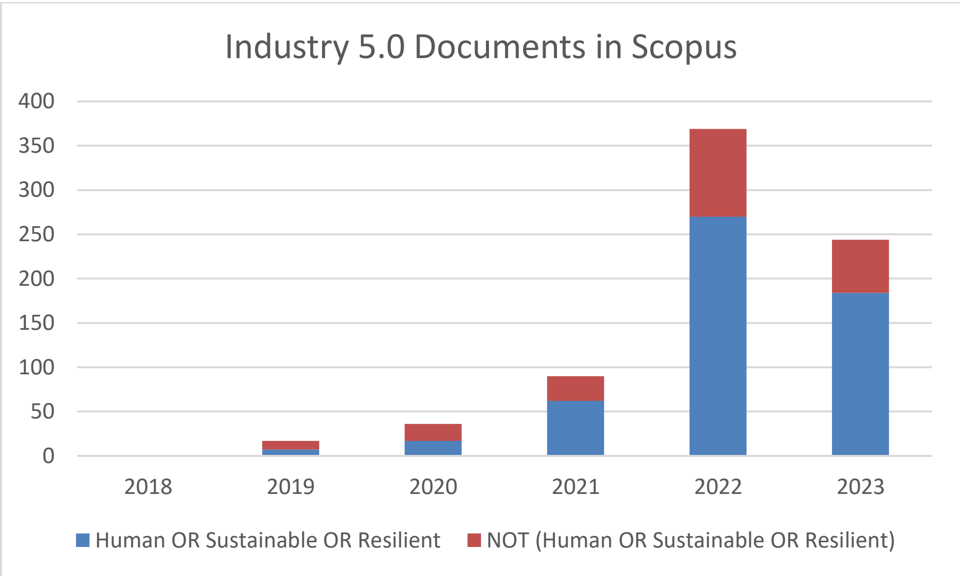


Figure 122 - Overview of Industry 5.0 articles in Scopus

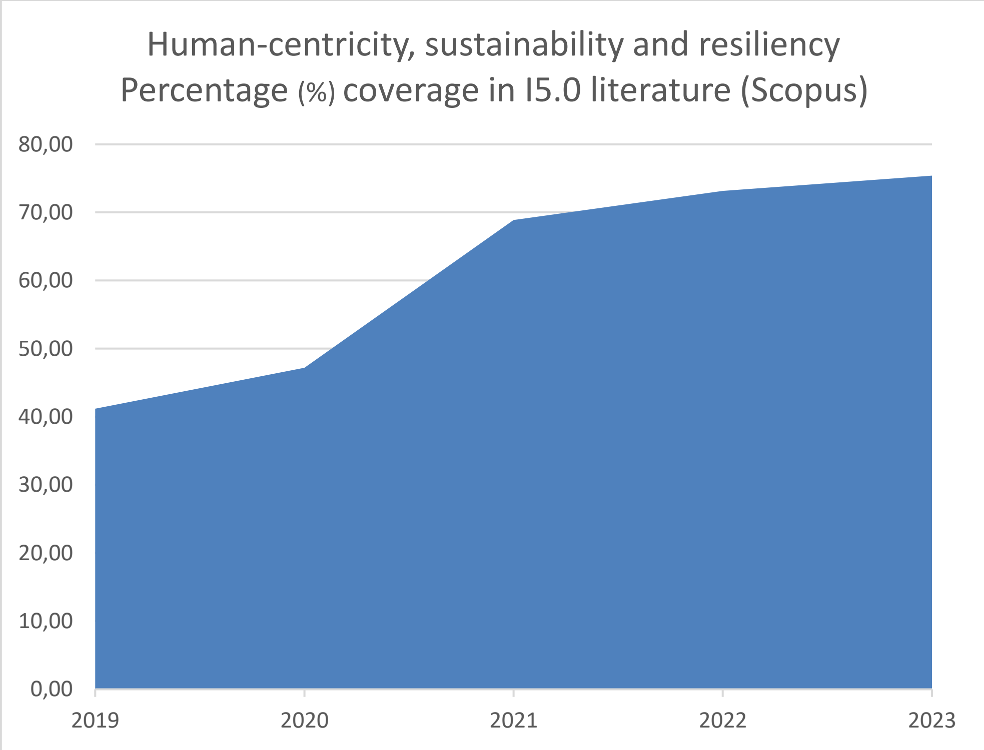


Figure 123 - Area Graph presented the percentage of Industry 5.0 articles in Scopus covering any of the 3 pillars

5.2 The 3 pillars in WoS for Industry 5.0

The below table presents the percentage of Articles in WoS database containing the keyword "Industry 5.0" and some subqueries using Logical operators to discover the portion of documents covering the concepts of Human-centricity, Sustainability and Resiliency. As it can be seen there is an increasing interest for the 3 Industry 5.0 pillars. The majority of articles, more than three quarters of articles, that are published discuss a concept regarding the 3 Industry 5.0 pillars.

Table 15 - Industry 5.0 articles in WoS

Articles in Web of Science						
Industry 5.0						
Year	2018	2019	2020	2021	2022	2023 (until 1st of July 2023)
Doc	2	11	20	59	233	132
Industry 5.0 And Human-centric						
Doc	2	3	5	39	142	85
%	100	27,27	25,00	66,10	60,94	64,39
Industry 5.0 And Sustainability						
Doc	0	2	6	22	87	51
%	0	18,18	30,00	37,29	37,34	38,64
Industry 5.0 And Resiliency						
Doc	0	0	0	7	45	28
%	0	0	0	11,86	19,31	21,21
Industry 5.0 And (Human or sustainability or resiliency)						
Doc	2	4	10	49	177	109
%	100	36,36	50,00	83,05	75,97	82,58

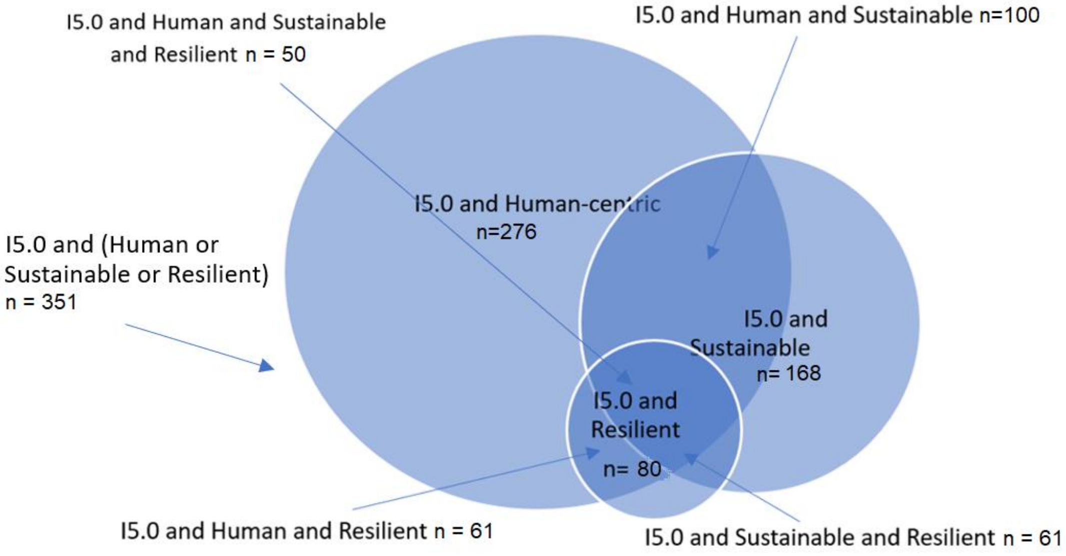


Figure 124 - Venn chart of WoS various datasets formed after applying relative keyword searches

In order to have a better view on the Industry 5.0 documents stored in the WoS database, a Venn chart has been created. The data come from relative keyword searches on WoS.

Similarly, with the Scopus dataset, the below graphs are produced from the WoS dataset, showing the growth of interest for the 3 Industry 5.0 pillars.

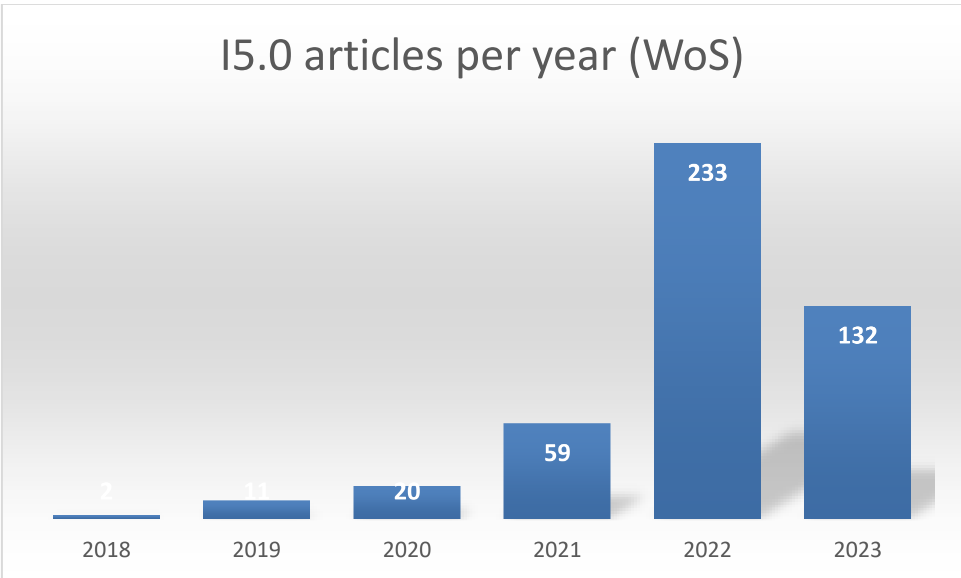


Figure 125 - Industry 5.0 articles in WoS

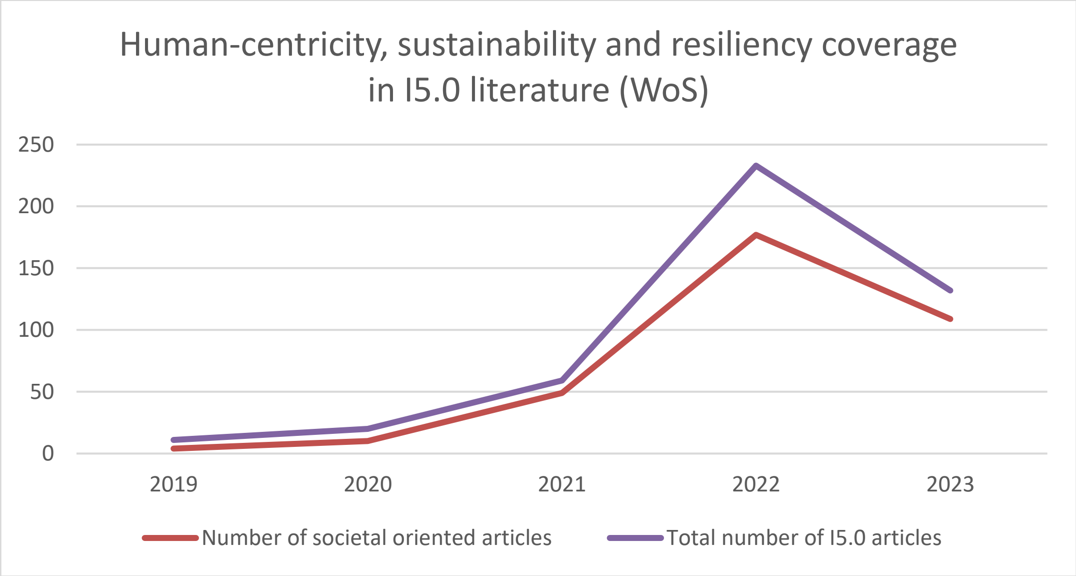


Figure 126 - Industry 5.0 articles in WoS covering any of the 3 pillars

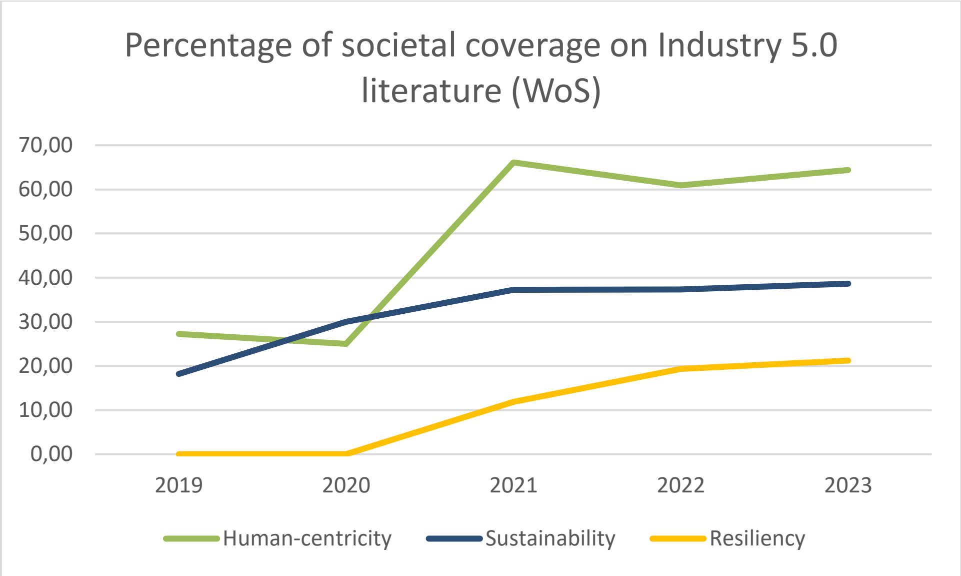


Figure 127 - Percentage of Industry 5.0 articles in WoS covering any of the 3 pillars

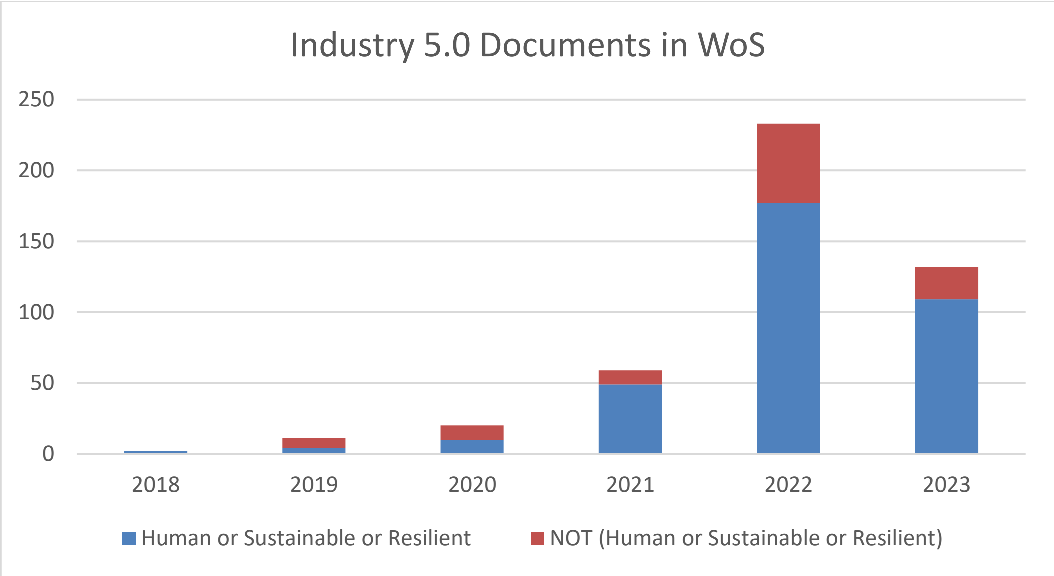


Figure 128 - Overview of Industry 5.0 articles in WoS

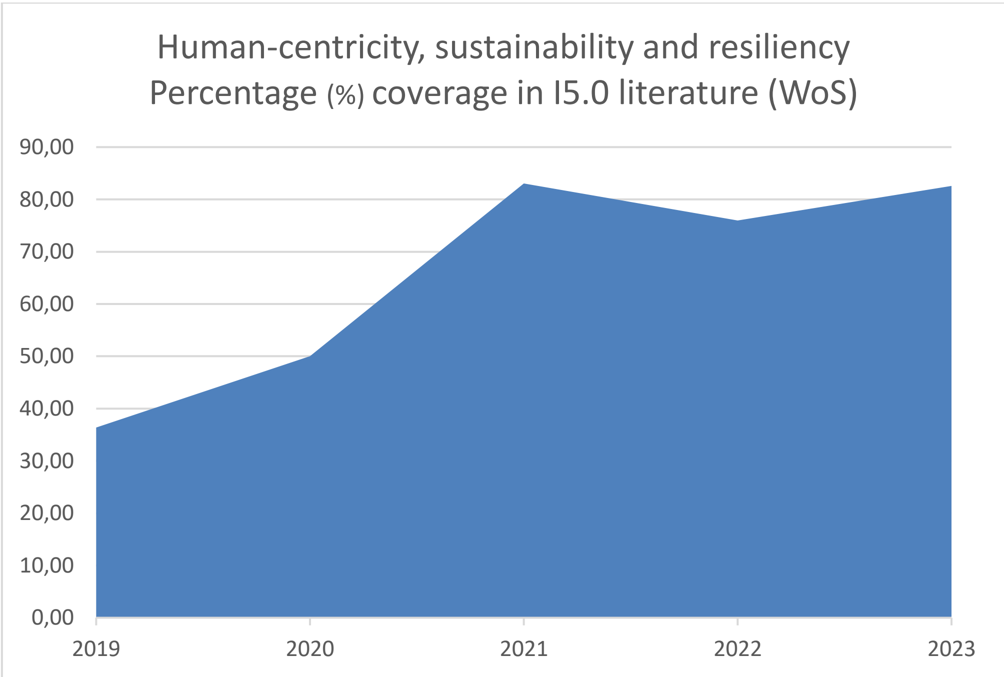


Figure 129 - Area Graph presented the percentage of Industry 5.0 articles in WoS covering any of the 3 pillars

5.3 *Comparing the Impact of the papers*

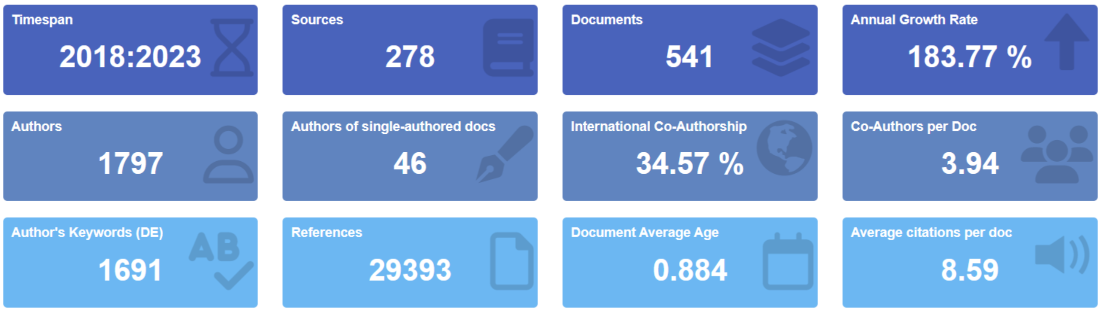


Figure 130 - Overview of Scopus Industry 5.0 dataset containing any of the 3 pillars (Human, Sustainable, Resilience)

The impact of the Industry 5.0 documents with interest on any of the 3 pillars will be compared with those not containing any of the 3 pillars.

Two datasets were obtained from Scopus. One using the search string: "Industry 5.0" AND ("Human*" OR "Resilien*" OR "Sustain*") and the second using the search string: "Industry 5.0" AND NOT ("Human*" OR "Resilien*" OR "Sustain*")

The Citation Overview on the Scopus dataset shows by comparing the two sets of documents that the documents that contain Human-centricity, Sustainability and Resiliency are used on average more as references from the researchers than the other set of documents.

The overview of the dataset follows. First observation is that the set containing any of the 3 pillars in the title, abstract or keywords fields has the h-index = 32 while the second set that does not contain any of the 3 pillar terms has the h-index = 16. Moreover, the first set has an annual growth of 184% whereas the second has 57%. Furthermore, although the first set has as document average age 0.89 less than 1.17 that the second, so documents of the second are published less time on average, the first dataset has as average citations per document a score of 8.59 bigger than 5.52 of the second one.

Figure 131 - Overview of Scopus Industry 5.0 dataset not containing any of the 3 pillars (Human, Sustainable, Resilience)

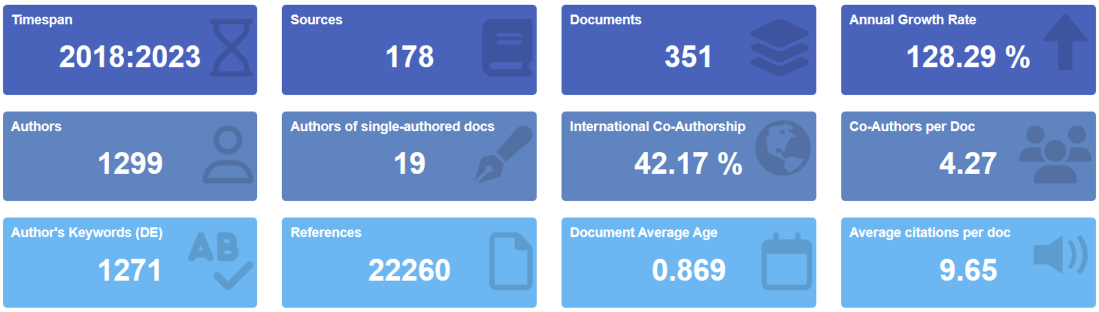


Figure 132 - Overview of WoS Industry 5.0 dataset containing any of the 3 pillars (Human, Sustainable, Resilience)

Similar results are obtained from the WoS database. The dataset was obtained by using the search string in WoS: "Industry 5.0" AND ("Human*" OR "Resilien*" OR "Sustain*"). The dataset not containing any of the 3 Pillar terms was obtained by using the search string Search string in WoS: "Industry 5.0" NOT ("Human*" OR "Resilien*" OR "Sustain*").

If the two WoS datasets are compared, it can be easily observed the differences between them, more annual growth 128% vs 39%, more average citation per document (9.65 vs 8.54) even though the average age of the documents are lower (0.87 vs 1.23) and lastly the h-index of the first set is more than double (= 30) than the h-index of the second set (= 13).

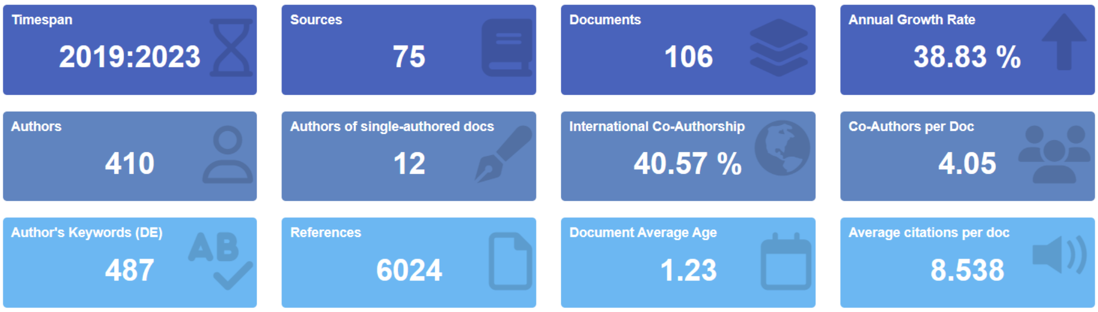


Figure 133 - Overview of WoS Industry 5.0 dataset not containing any of the 3 pillars (Human, Sustainable, Resilience)

5.4 Industry 4.0 and Industry 5.0 coexist.

Industry 4.0 and Industry 5.0 coexist, since they are complementary to one another. As Industry 4.0 is more technological oriented, Industry 5.0 is not an integration of Industry 4.0 but rather is regarded as a new paradigm bringing new societal dimensions to Industry. Thus, Industry 5.0 relies on Industry 4.0's technological improvements but at the same time is oriented towards the 3 pillars as pointed out by EC: Human-Centricity, Sustainability and Resiliency. It helps to assess both their direct and indirect presence in the research literature.

5.4.1 Industry 4.0 and Industry 5.0 complement one another through Co-Occurrence by keyword Network graph

Co-Occurrence by keyword Network graphs will be used to show that Industry 4.0 and Industry 5.0 are complement one another. Several topics are to be selected from the Co-Occurrence Network graphs described in Chapter 4 (paragraph 4.3). Scopus and WoS Industry 5.0 papers, through the VOSviewer co-occurrence by keyword Network graph, were used to reveal the impact of selected topics. As the option "All keywords" was used, both Author's keywords and Index by Scopus or Keyword Plus for Scopus and WoS datasets respectively, were used.

The first two images are taken from the Scopus and WoS made graphs respectively when Human-Centricity was selected.

Human-centricity is a notable topic and is connected, in both graphs, with many other topics amongst them sustainability, resilience, European commission, personalization, society 5.0, human-robot collaboration, supply chain and more.

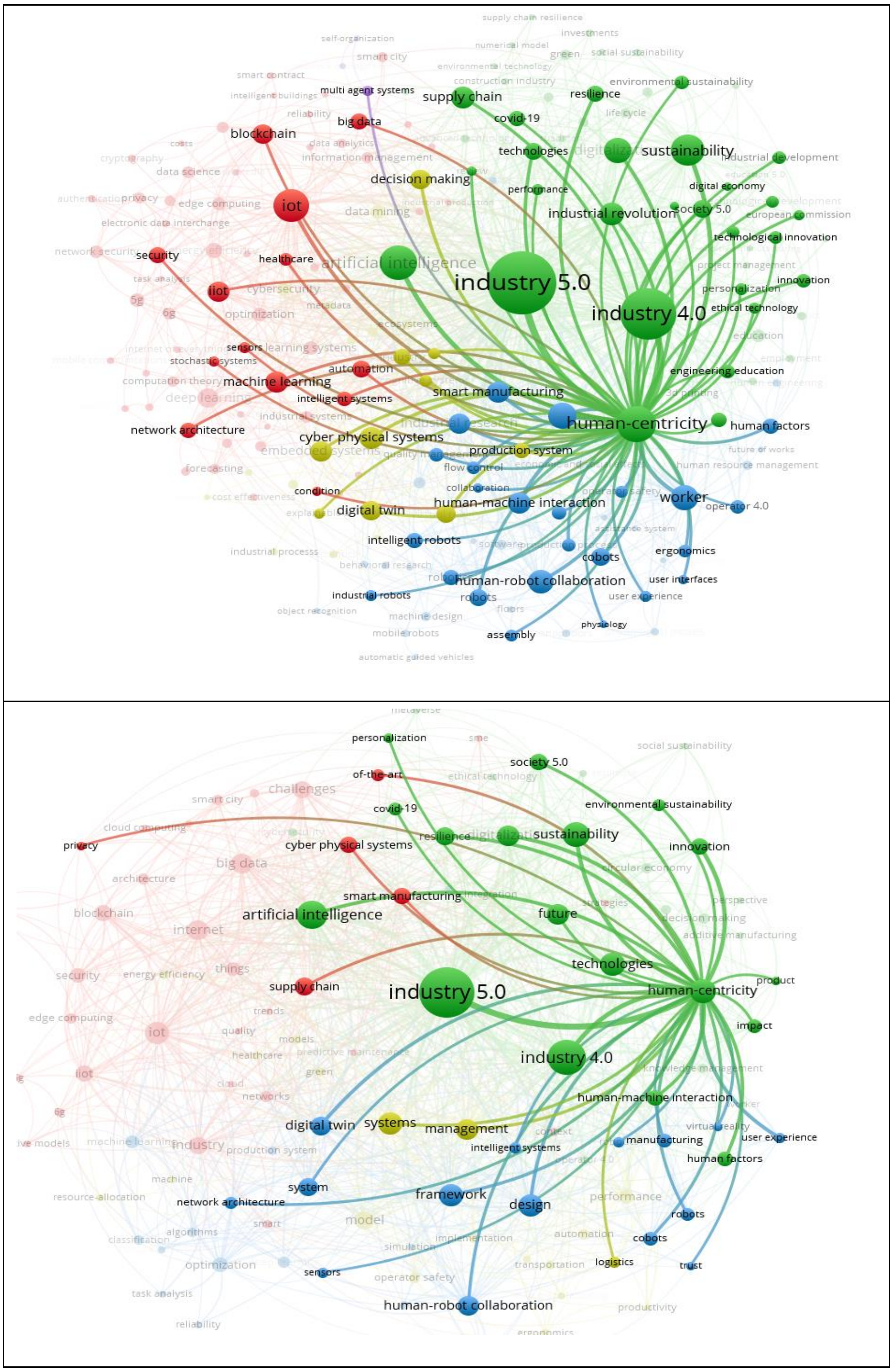


Figure 134 - Co-occurrence by keyword when Human-centricity is selected (Scopus and WoS)

Same as the previous one, to examine in the Industry 5.0 papers the impact of Sustainability the term sustainability was selected. The connections are very similar to Human-centricity mentioned above.

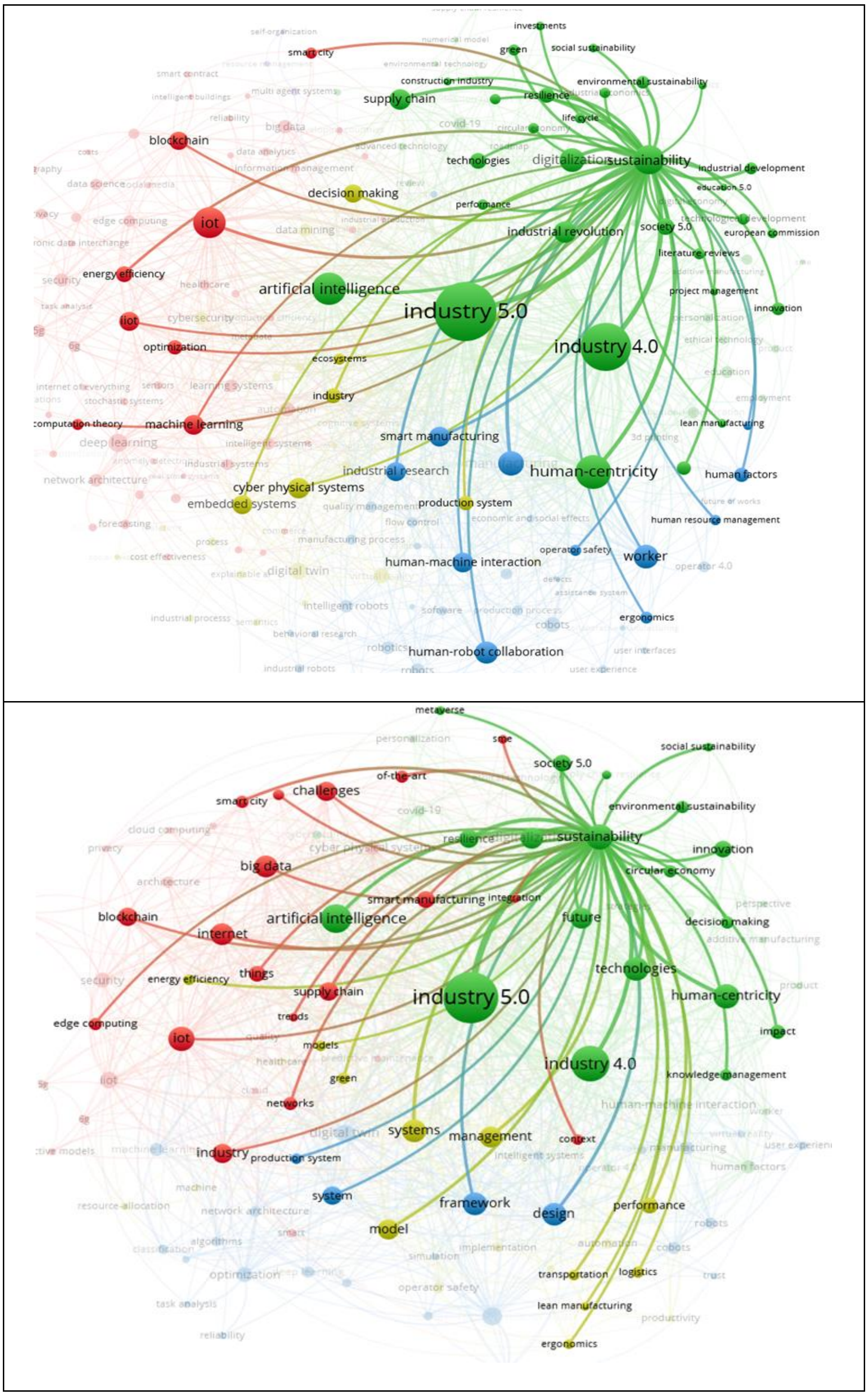


Figure 135 - Co-occurrence by keyword when Sustainability is selected (Scopus and WoS)

Next, the impact of Resiliency is to be examined.

Resilience is connected with just a few topics, such as sustainability, human-centricity, supply chain, uncertainty analysis, society 5.0, digitalization, industrial research, production system and data science in the Scopus graph whereas in the WoS graph resilience is connected to more terms. Sustainability, digitalization, human-centricity, AI, society 5.0, covid-19, supply chain, big data, IoT, challenges, digital twin, future, technologies, innovation and more.

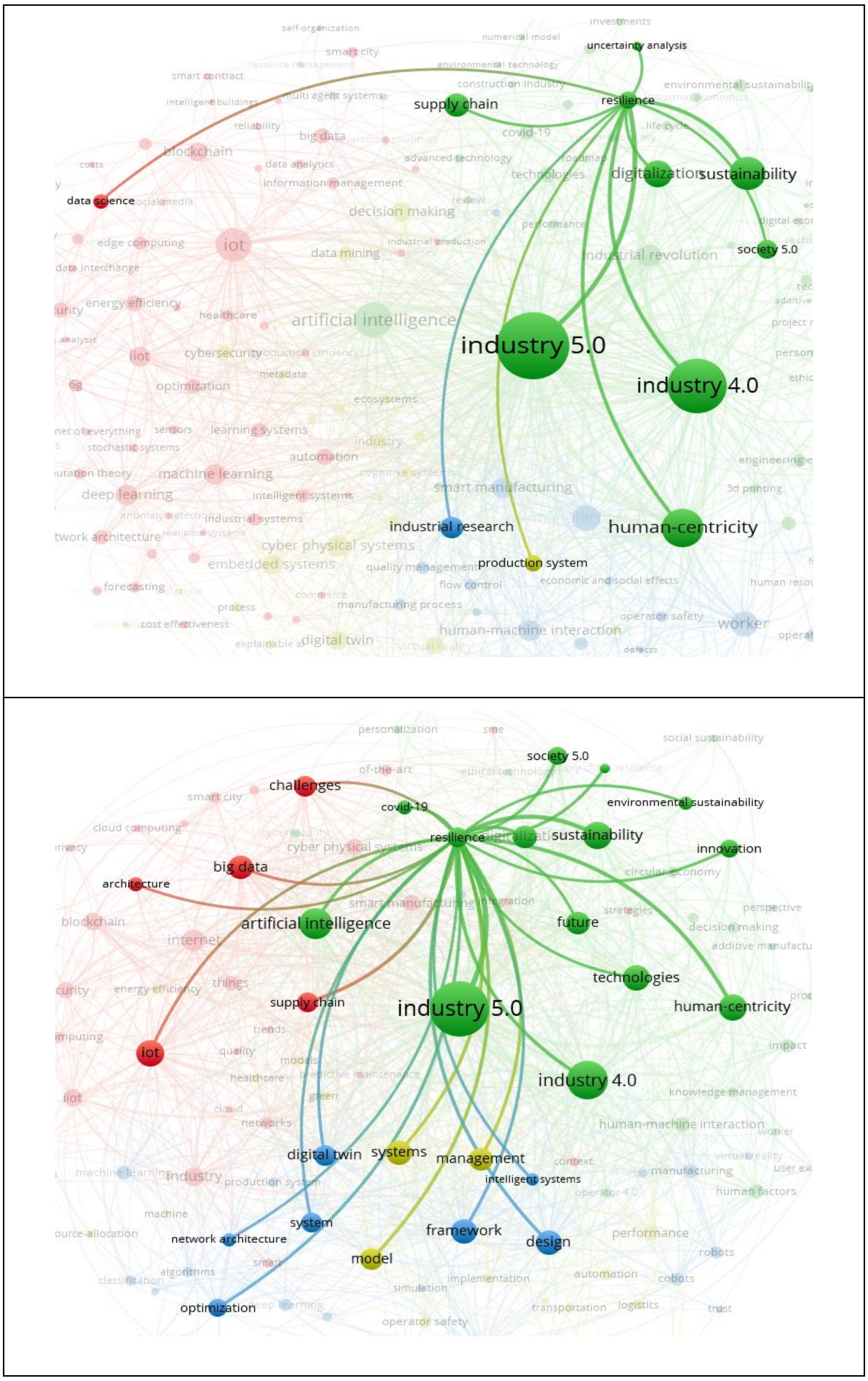


Figure 136 - Co-occurrence by keyword when Resilience is selected (Scopus and WoS)

Not only from those 3 terms, but it can also be seen that Industry 5.0 is a new paradigm. Besides the technological oriented terms coming from Industry 4.0 which are present in the graphs, new dimensions were added and can be found, not only directly but also indirectly, within the Network co-occurrence graphs presented here. The selected terms were respectively, supply chain, supply chain resilience, human factors, social sustainability, human-robot collaboration and human-machine interaction in order to show the size of the new dimensions. The graphs are in pairs as they are taken from the Scopus Network graph the first and from the WoS Network graph the second.

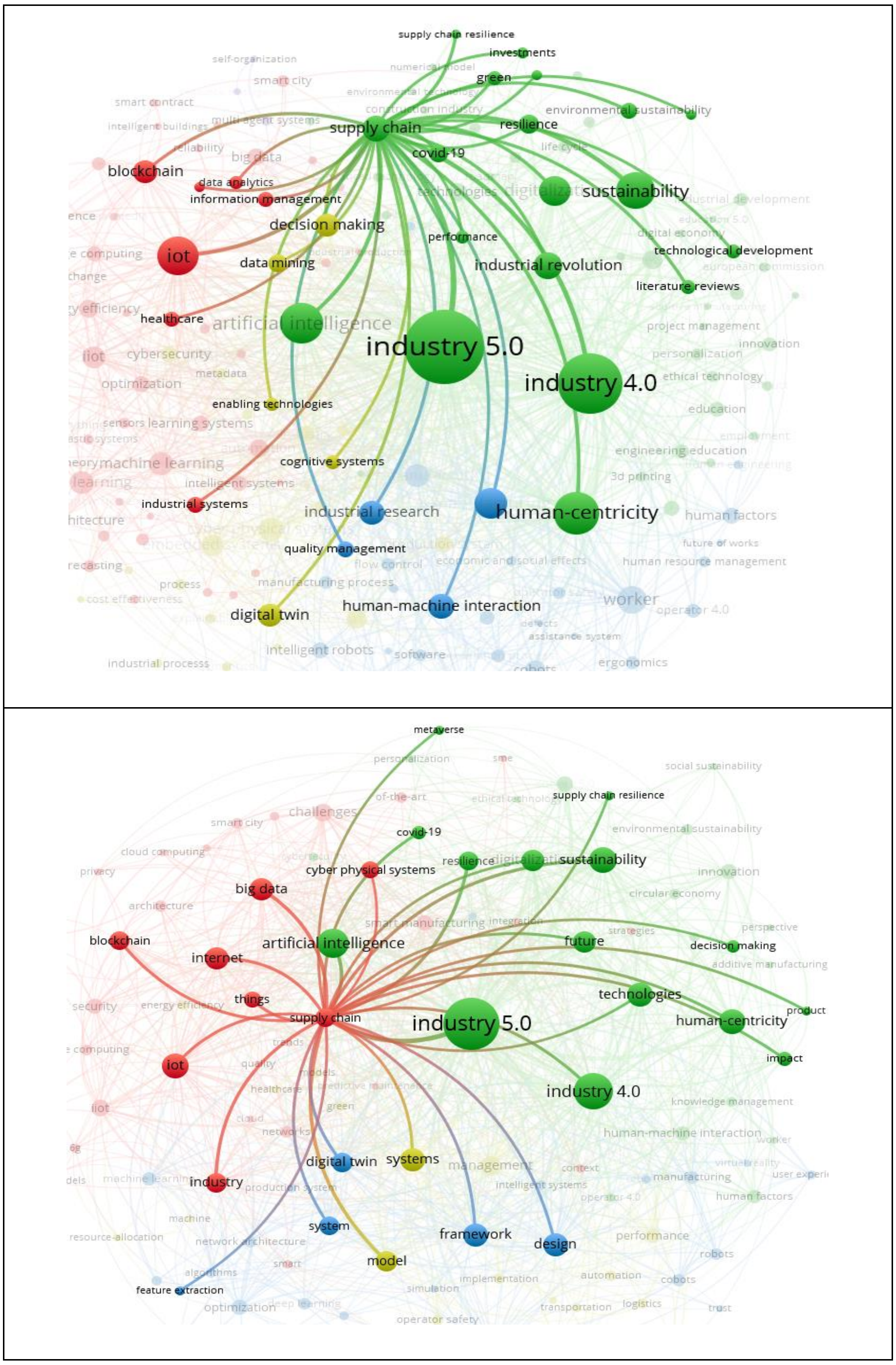


Figure 137 - Co-occurrence by keyword when supply chain is selected (Scopus and WoS)

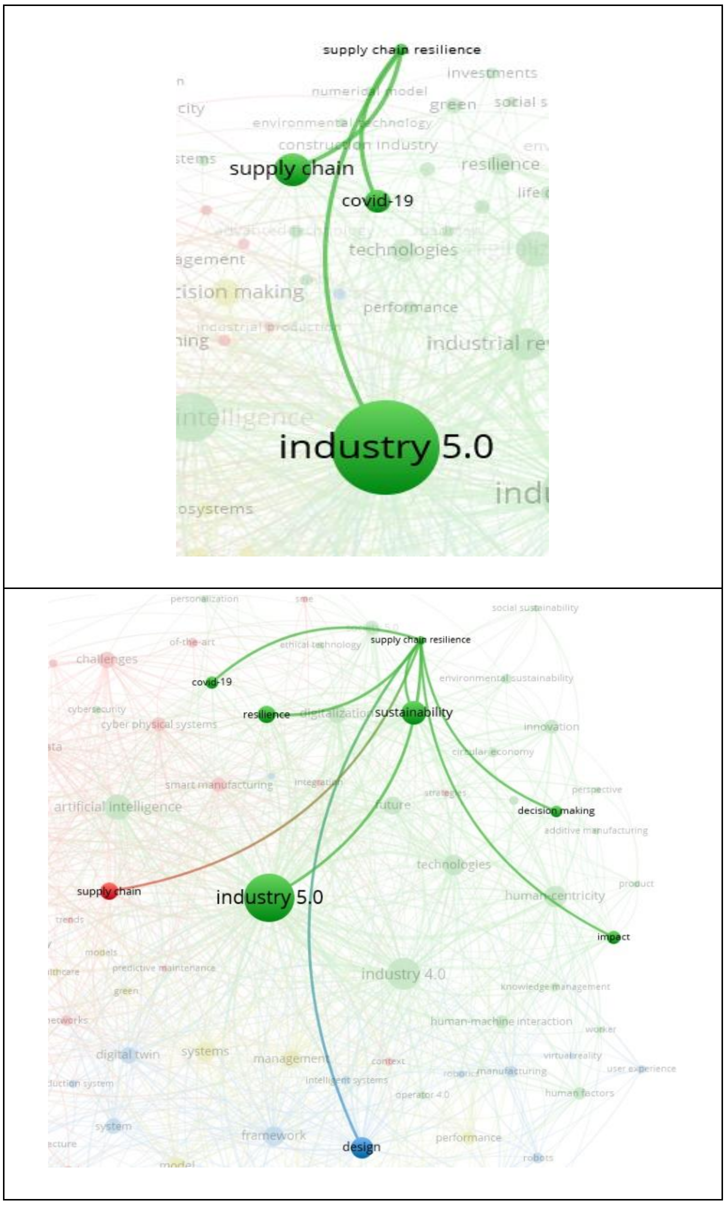


Figure 138 - Co-occurrence by keyword when supply chain resilience is selected (Scopus and WoS)

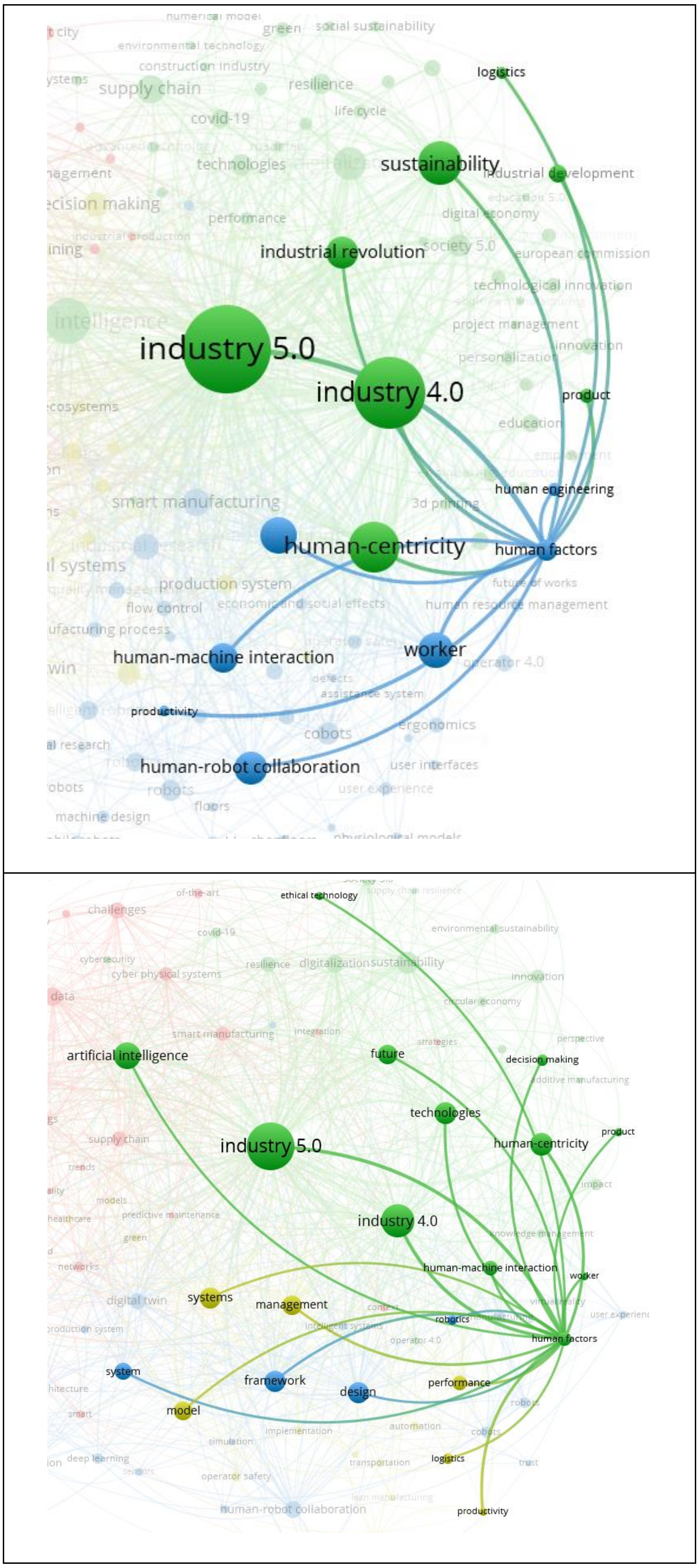


Figure 139 - Co-occurrence by keyword when Human factors is selected (Scopus and WoS)

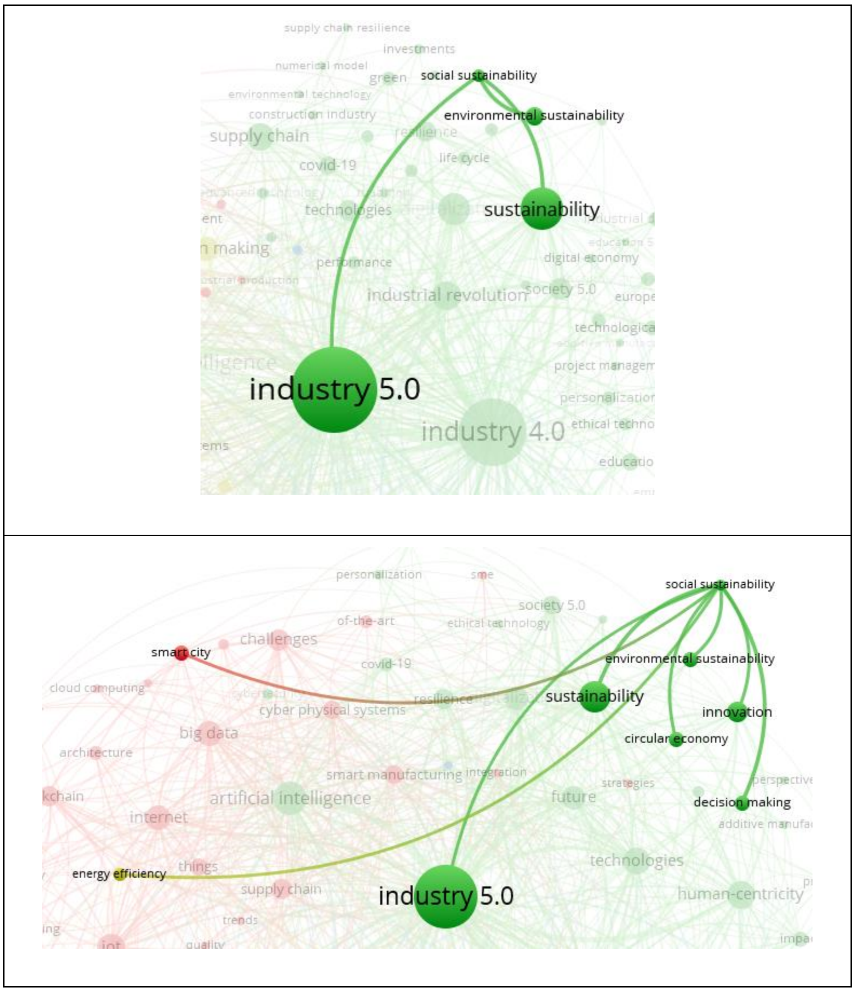


Figure 140 - Co-occurrence by keyword when social sustainability is selected (Scopus and WoS)

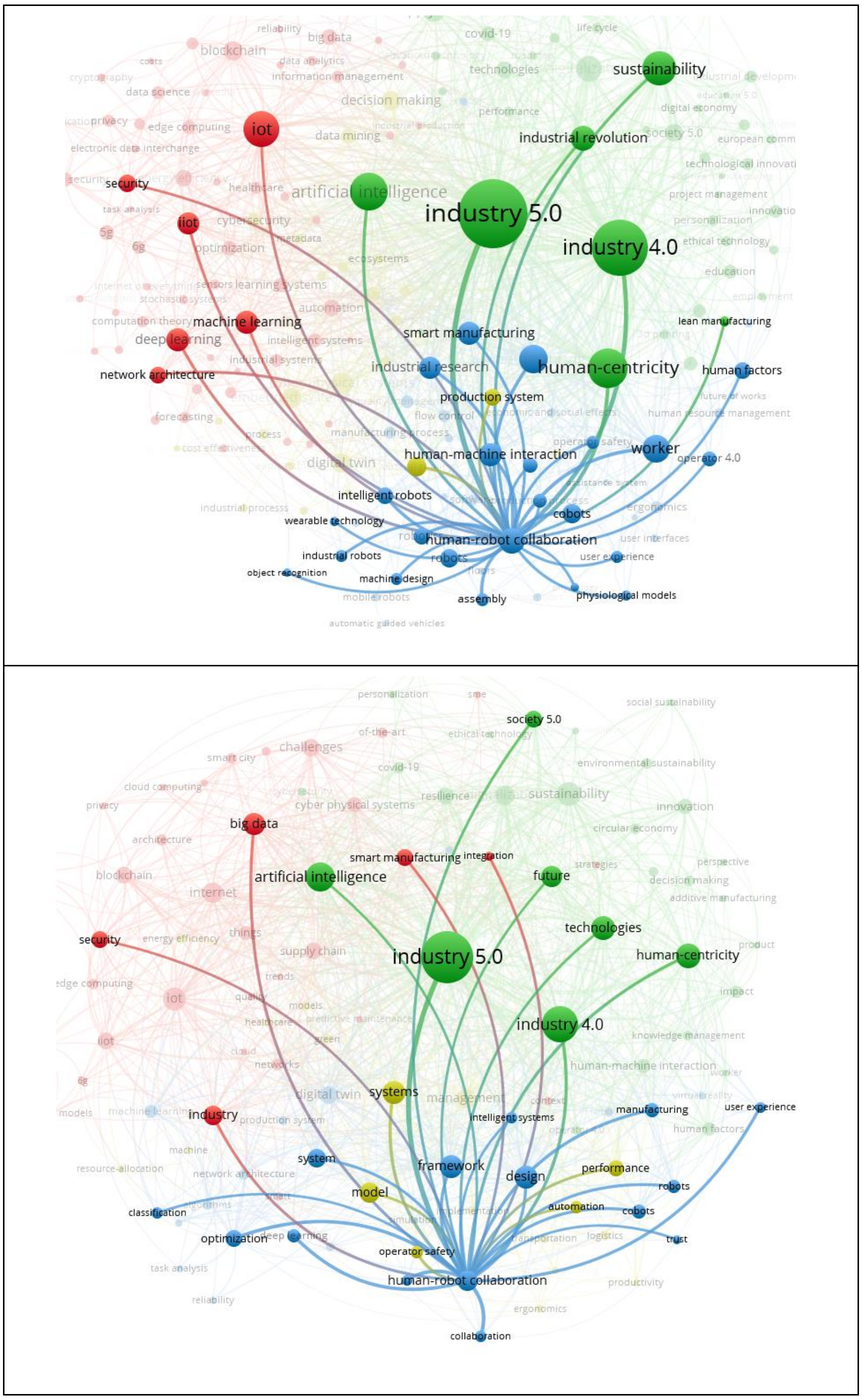


Figure 141 - Co-occurrence by keyword when Human-robot collaboration is selected (Scopus and WoS)

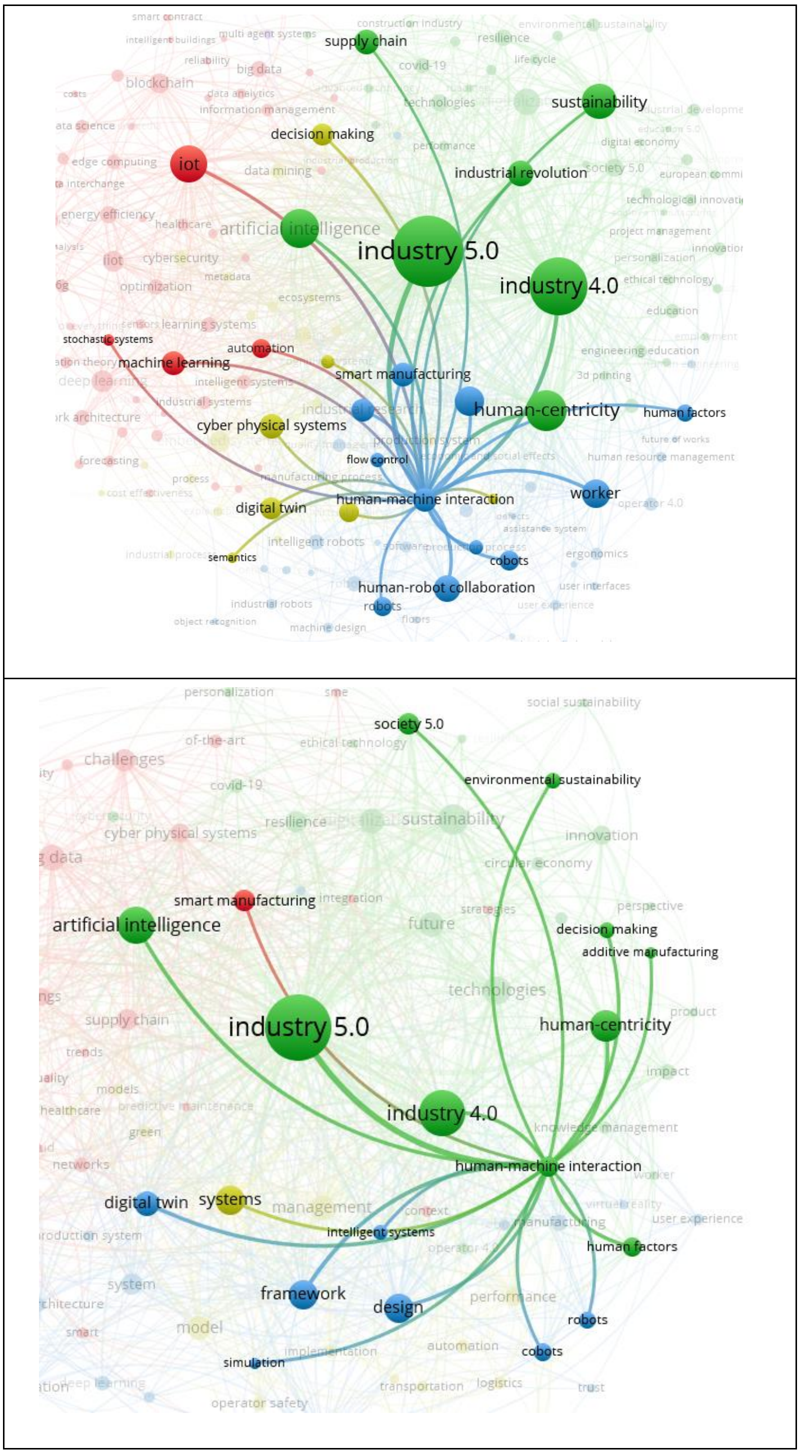


Figure 142 - Co-occurrence by keyword when Human-machine interaction is selected (Scopus and WoS)

5.4.2 *Industry 4.0 and Industry 5.0 complement one another through ATLAS.ti concepts*

ATLAS.ti was used to create, by selecting all contents of the collection of papers (title, abstract and keywords), the Word cloud and the Concept cloud respectively. The presence and the size of terms related to the 3 pillars are indications of their importance in these research works.

Figure 143 - Industry 5.0 Word cloud by ATLAS.ti

Figure 144 - Industry 5.0 Concept Cloud by ATLAS.ti

From the concept cloud various terms related to the 3 pillars were selected, to illustrate from which sentences they were derived from, that might help to understand the way these terms were used, and are presented in Appendix B.

The absence of the term Resilience should be noted, as the tool did not identify the term as important. Maybe this happened because the tool did not aggregate the different forms of expressing resilience as resiliency or resilient. In the contrary, Human centricity, sustainability and also other related to them terms concepts are highly present in the collection of papers examined.

6

Industry 5.0 in EU countries

As Industry 5.0 is a concept introduced by the European Commission, the European Union region shows a greater interest in human-centricity, sustainability, and resiliency than the rest of the world. From the dataset sources a study has been made, based on three different comparisons:

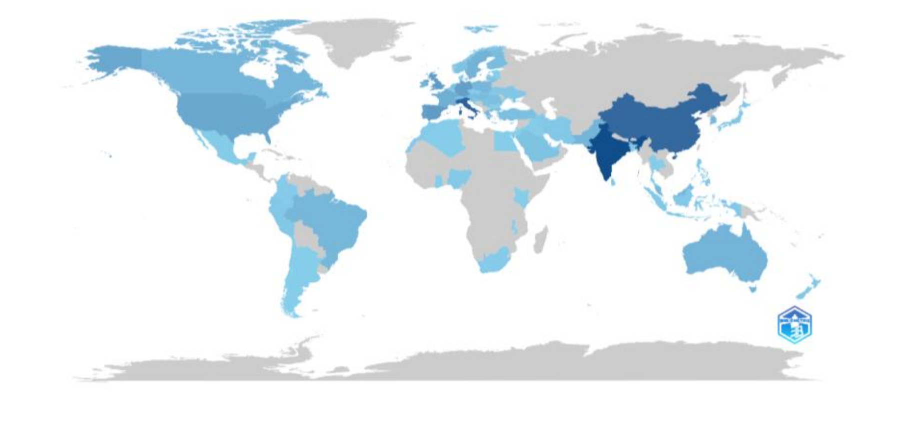
1. A metric to measure scientific production on a country level. The metric counts the number of times authors from a specific country appear in articles. If an article has multiple authors from different countries, each country represented by an author gets a count incremented by 1. However, due to this counting method, the total sum of the production indicator may exceed the total number of articles. This indicates collaborative efforts involving authors from multiple countries in various articles.
2. Following, the comparison between the number of sources, referring to at least one of the three pillars of Industry 5.0 i.e., containing any of the keywords Human-Centricity or Sustainability or Resiliency, from EU countries and non-EU countries.
3. Lastly, the Corresponding Author's Country analysis, which assigns each article to a country based on the corresponding author's affiliation. The frequency count for each country reflects the total number of articles from that country. Additionally, this method calculates the ratio of articles in which at least one author has an affiliation different from the corresponding author's country, called “Multiple Country Publications” (MCP).

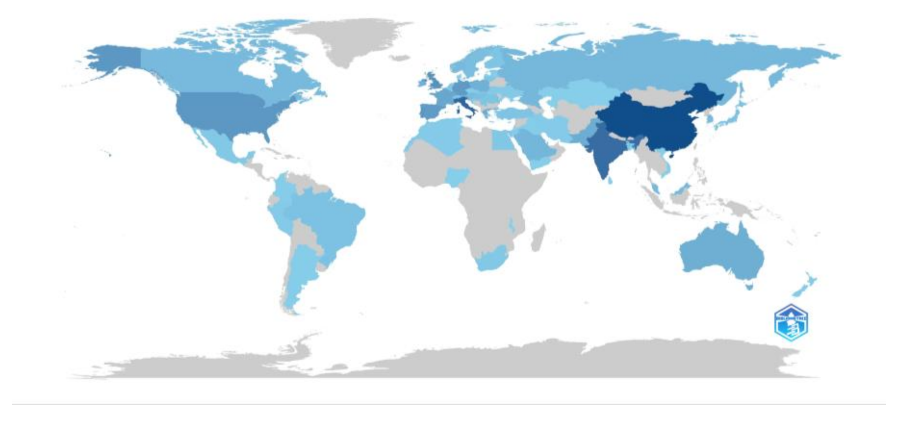
From the 2 databases, Scopus and WoS, different datasets were acquired, either referring to at least one of the three pillars of Industry 5.0 i.e., containing the keywords Industry 5.0 AND (Human-Centricity OR Sustainability OR Resiliency) or Industry 5.0 documents not containing any of the three pillars.

Thus, a Scopus pillars and a Scopus non-pillars datasets and a WoS pillars and a WoS non-pillars datasets were made. A merging of the two pillars and the two non-pillars was made through R, but as has been already analyzed the merging process has some issues and some references were missed in the merging datasets resulting in numbers that were wrong for the Country Scientific Production and the Corresponding Author's Country. Therefore, the comparison was made separately for Scopus and WoS.

6.1 Countries Scientific production

First, from the two dataset sources made a comparison based on the countries scientific production. Authors from EU countries show a bigger interest regarding the new dimensions introduced by EC's Industry 5.0 definition.

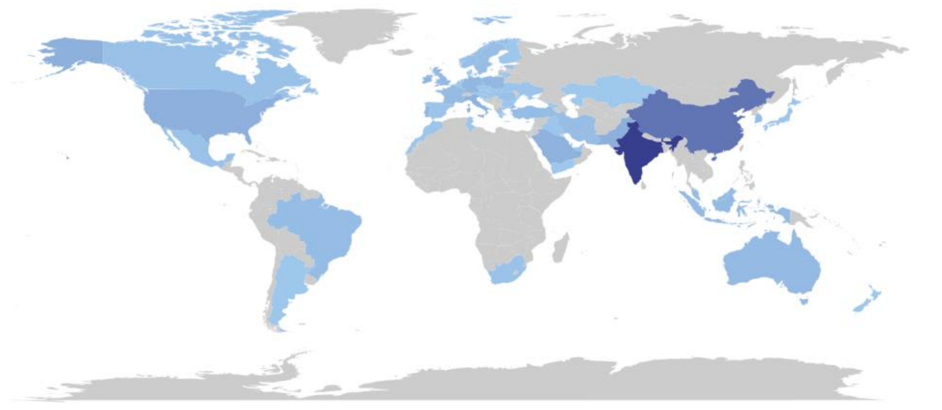


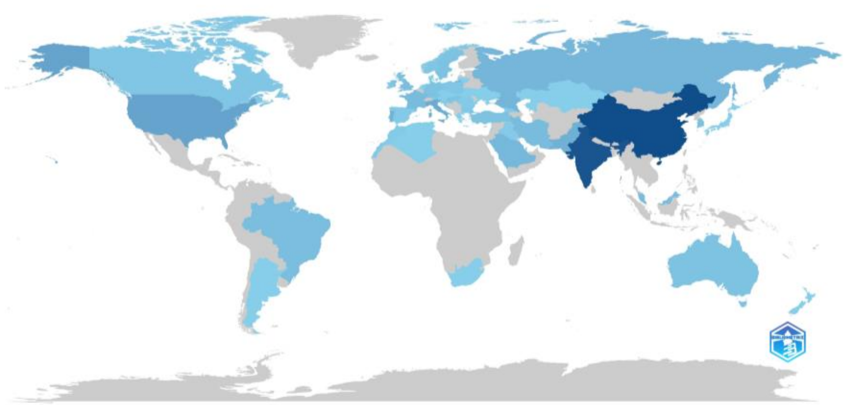


region	I5.0 docs in Scopus	Containing at least one Pillar
INDIA	403	232
ITALY	220	193
CHINA	281	179
UK	106	87
SPAIN	92	87
GERMANY	104	82
PORTUGAL	101	81
USA	94	65
FRANCE	68	52
IRELAND	73	48
SWEDEN	60	47
AUSTRALIA	63	45
PAKISTAN	72	43
GREECE	51	43

region	I5.0 docs in WoS	Containing at least one Pillar
CHINA	159	106
ITALY	100	86
INDIA	129	79
UK	56	49
PORTUGAL	55	44
USA	60	43
GERMANY	46	41
SPAIN	42	40
FRANCE	39	31
GREECE	30	29
PAKISTAN	38	26
AUSTRALIA	30	25
IRELAND	28	24
POLAND	27	23

Figure 145 - Country Scientific production for Industry 5.0 documents containing at least one of the 3 pillars in Scopus (the first map) and WoS (the second map) respectively.





region	I5.0 docs in Scopus	Not Containing any of the 3 Pillars
INDIA	403	171
CHINA	281	102
USA	94	29
PAKISTAN	72	29
ITALY	220	27
SAUDI ARABIA	46	27
IRELAND	73	25
GERMANY	104	22
POLAND	60	21
PORTUGAL	101	20
UK	106	19
AUSTRALIA	63	18
INDONESIA	28	18
FRANCE	68	16

region	I5.0 docs in WoS	Not Containing any of the 3 Pillars
CHINA	159	53
INDIA	129	50
USA	60	17
ITALY	100	14
PAKISTAN	38	12
PORTUGAL	55	11
RUSSIA	28	10
SAUDI ARABIA	27	9
FRANCE	39	8
MALAYSIA	25	8
IRAN	11	8
UK	56	7
BRAZIL	17	7
SOUTH KOREA	23	6

Figure 146 - Country Scientific production for Industry 5.0 documents not containing at least one of the 3 pillars in Scopus and WoS respectively.

The maps comparison shows that in European Union, authors are more interested in promoting the ideas of human-centricity, sustainability and resiliency, on average as a percentage compared to the rest of the world.

Secondly, using again the country scientific production, a comparison was made between sources referring to at least one of the three pillars of Industry 5.0, i.e., containing the keywords (Human-Centricity OR Sustainability OR Resiliency) AND Industry 5.0, from EU countries and non-EU countries.

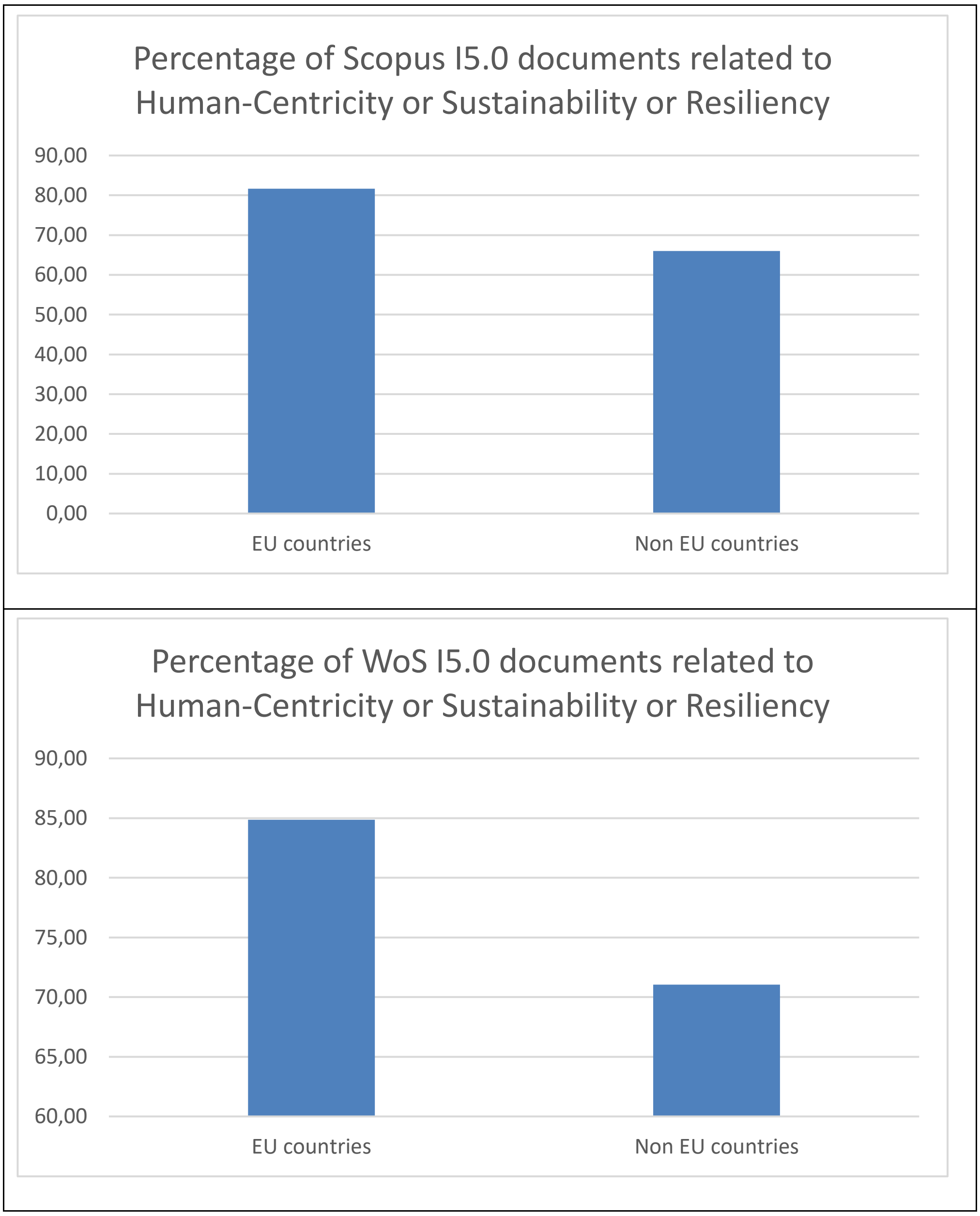
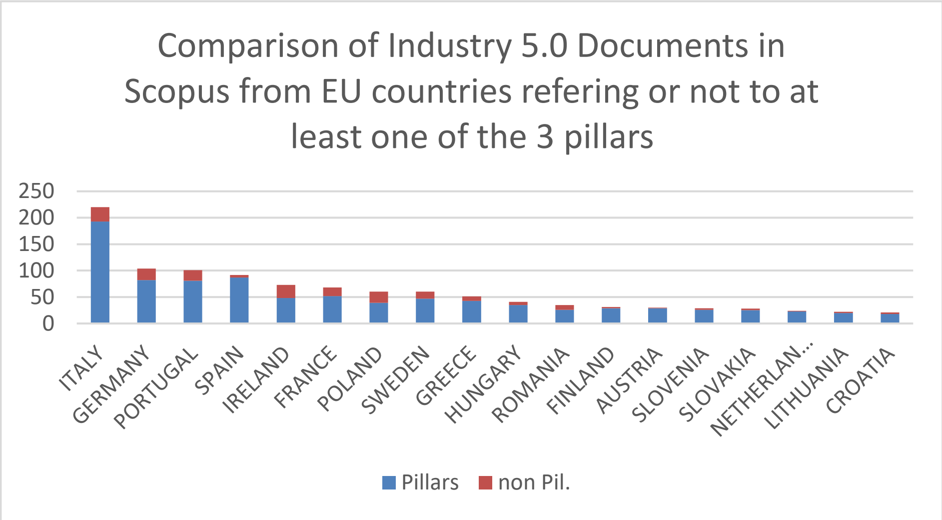
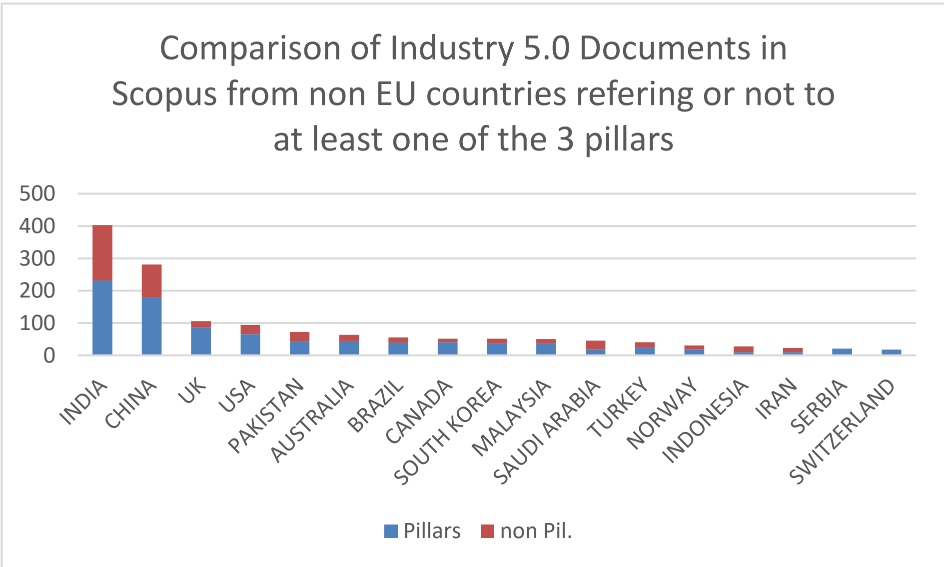


Figure 147 - Percentage of I5.0 documents related to the 3 pillars based on the region

EU region countries show a higher interest in the three pillars. The 82% of the Industry 5.0 documents that originated from EU countries in the Scopus database and 85% in WoS database, are having an interest on human-centricity, sustainability or resiliency, compared to 66% and 71% respectively from the Industry 5.0 documents of non-EU countries. More analytically the data by countries gives in Scopus:



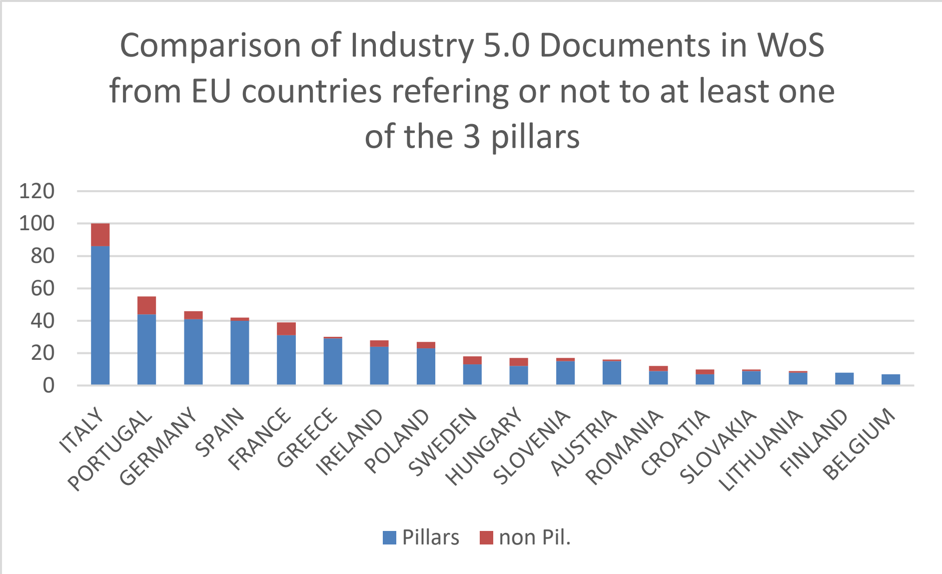


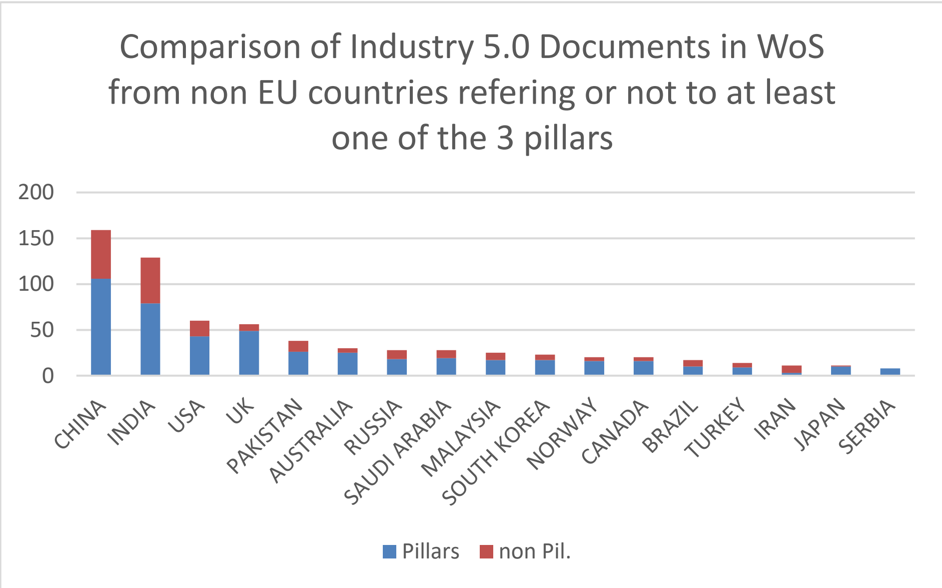
Region (EU)	Frequency	Pillars	Pillars %
ITALY	220	193	87,73
GERMANY	104	82	78,85
PORTUGAL	101	81	80,20
SPAIN	92	87	94,57
IRELAND	73	48	65,75
FRANCE	68	52	76,47
POLAND	60	39	65,00
SWEDEN	60	47	78,33

Region (non EU)	Frequency	Pillars	Pillars %
INDIA	403	232	57,57
CHINA	281	179	63,70
UK	106	87	82,08
USA	94	65	69,15
PAKISTAN	72	43	59,72
AUSTRALIA	63	45	71,43
BRAZIL	55	40	72,73
CANADA	51	41	80,39

Figure 148 - Comparison of Scopus I5.0 documents in regard with the 3 pillars based on the region

The same, as with Scopus, can be observed with the WoS dataset:





Region (EU)	Frequency	Pillars	Pillars %
ITALY	100	86	86,00
PORTUGAL	55	44	80,00
GERMANY	46	41	89,13
SPAIN	42	40	95,24
FRANCE	39	31	79,49
GREECE	30	29	96,67
IRELAND	28	24	85,71
POLAND	27	23	85,19

Region (non EU)	Frequency	Pillars	Pillars %
CHINA	159	106	66,67
INDIA	129	79	61,24
USA	60	43	71,67
UK	56	49	87,50
PAKISTAN	38	26	68,42
AUSTRALIA	30	25	83,33
RUSSIA	28	18	64,29
SAUDI ARABIA	28	19	67,86

Figure 149 - Comparison of WoS I5.0 documents in regard with the 3 pillars based on the region

6.2 *Corresponding Author's Country.*

Thirdly, the Corresponding Author's Country graph in Scopus, derived from Industry 5.0 documents, through Bibliometrix/Biblioshiny. The first graph, from the dataset that contains at least one of the 3 pillars, without containing any of the three pillars the second graph. It can easily be seen that the EU region countries are less present in the second than in the first graph.

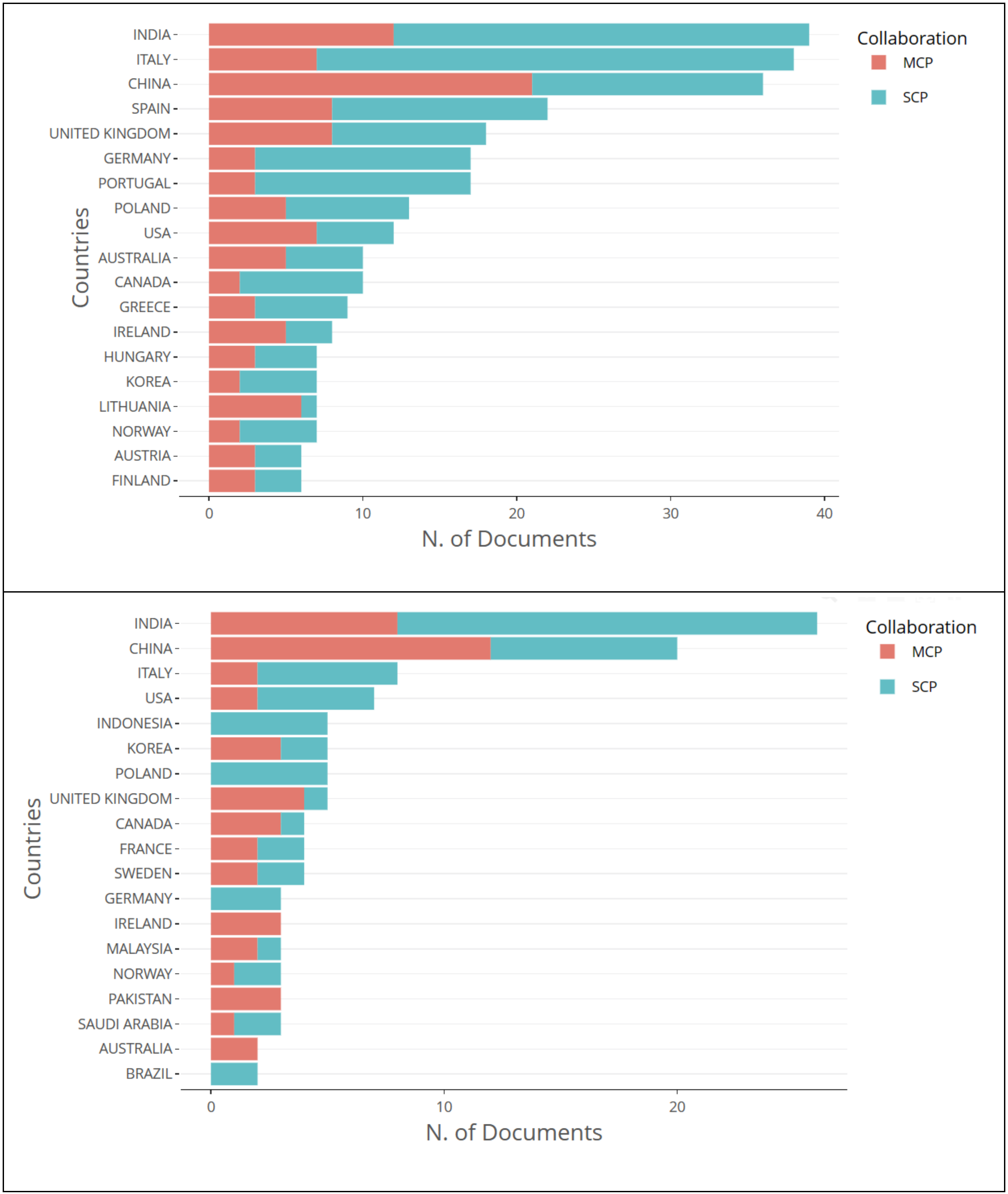


Figure 150 - Corresponding Author's Country in Scopus; the first graph is made from the dataset that contains any of the 3 pillars of I5.0 whereas the second graph is made from the dataset that does not contain any.

Similar results can easily be seen and by the WoS datasets. The EU countries are less present in the second graph than in the first graph, meaning that authors from EU region are more interested in promoting ideas that incorporate with the new dimensions of Industy 5.0.

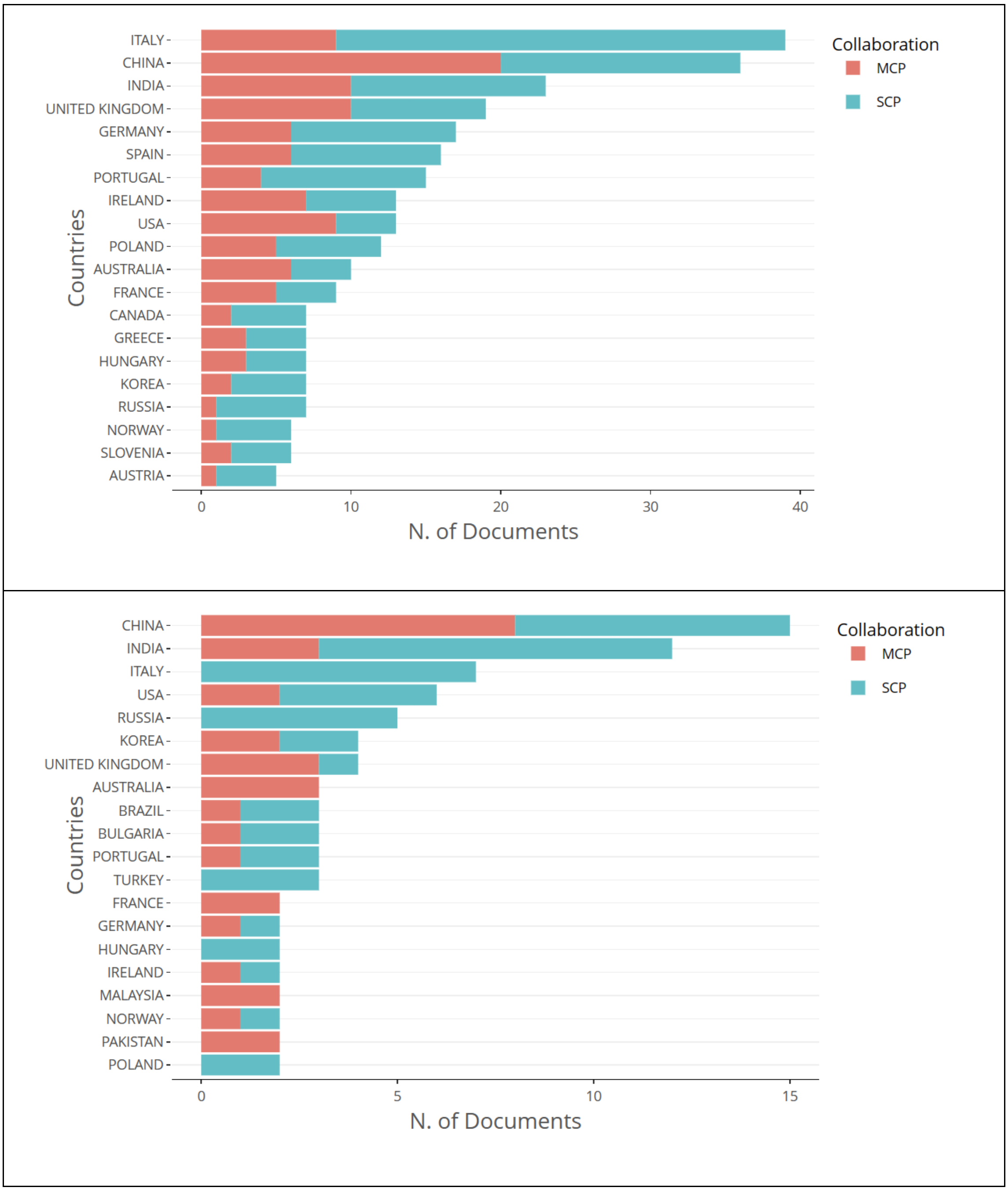


Figure 151 - Corresponding Author's Country in WoS; the first graph is made from the dataset that contains any of the 3 pillars of I5.0 whereas the second graph is made from the dataset that does not contain any.

7

Conclusions and Future Research

The bibliometric analysis performed on this work was held to answer research questions that were aiming in understanding the status of Industry 5.0.

7.1 Results and discussion

7.1.1 Results for the first RQ

Through the first RQ an overview of Industry 5.0 and the social structure of Industry 5.0 was revealed. In order to understand the spread of the topic and its acceptance globally, the following features through the analysis had been obtained:

1. *Research volume and growth trend for Industry 5.0.*
   From 2018, more documents are published every year and from the 2023 it seems that the number of documents will continue to raise indicating an increased interest upon Industry 5.0.
2. *Types of publications.*
   The types of publications are mostly articles and conference papers.
3. *Languages of publications.*
   The vast majority of publications are written in English.
4. *Distribution across different Subject Areas.*
   Engineering and Computer Science are the main Subject areas of the researchers.
5. *Top cited Publications.*
   Top cited publication in both databases is an article by Saeid Nahavandi, "Industry 5.0—A Human-Centric Solution," published in Sustainability- BASEL, in August 2019.

Other top cited publications are:

An article by Maddikunta, Praveen Kumar Reddy et al., “Industry 5.0: A survey on enabling technologies and potential applications.”, published in Journal of Industrial Information Integration, in 2021.

An article by Xun Xu et al., “Industry 4.0 and Industry 5.0—Inception, conception and perception”, published in Journal of Manufacturing Systems, in 2021.

The article that announced the emergence of the Industry 5.0 by Özdemir V, Hekim N., “Birth of Industry 5.0: Making Sense of Big Data with Artificial Intelligence, "The Internet of Things" and Next-Generation Technology Policy”, published in OMICS, in 2018.

6. *Most relevant and most influential Authors.*

   Through Lotka’s law it was found that core authors published at least 3 documents.

   Most productive authors are:

   Abonyi János 11, Elias G. Carayannis 9, Mary Doyle-Kent 8, Dimitris Mourtzis 8, Tamás Ruppert 8.

   Authors with most local impact based on the h-index on both databases are:

   Elias G. Carayannis and Lihui Wang.

7. *Most relevant and most influential Affiliations.*

   In Scopus top affiliations, with 12 publications are: the Hong Kong Polytechnic University and the South East Technological University of Ireland.

   From the ten most relevant affiliations in the research field examined in the Scopus dataset the most are from Europe. In precise, six are from Europe, three are from Asia and just one is from the USA.

   In WoS top affiliations with 8 publications are: the University of Pannonia of Hungary and the South East Technological University of Ireland.

   From the ten most relevant affiliations in the research field examined in the WoS dataset contains documents from more worldwide distributed affiliations. Four of them are from Asia, four from Europe, one from the USA and one is from Africa.

8. *Most relevant and most influential Sources.*

   Most publications were published in below Sources:

   In Scopus:

   - IEEE Transactions on Industrial Informatics 28,
   - Sustainability (Switzerland) 26,
   - Applied Sciences (Switzerland) 23,
   - Sensors 21

In WoS:

- Sustainability (Switzerland) 28,
- IEEE Transactions on Industrial Informatics 23,
- Applied Sciences-Basel (Switzerland) 22,
- Sensors 20

In Scopus to identify the most influential Sources, according to Bradford's Law the Core Zone consists of 19 journals (out of 377) that contain 254 relevant articles.

In WoS to identify most influential Sources, according to Bradford's Law the Core Zone consists of 10 journals (out of 226) that contain 157 relevant articles.

IEEE Transactions on Industrial Informatics and Sustainability are the top 2 sources with local impact based on h-index on both databases.

9. *Major Sponsors.*

It should be noted that while documents usually do not include a sponsor field, from those that have sponsors, they are primarily from Europe, specifically from the European Union and using EC funds but also from several other European countries including Portugal, Spain, Hungary, Italy, Slovakia, Slovenia, Ireland, and the United Kingdom. Leading sponsors have come from a number of other countries, including China, South Korea, Saudi Arabia, and Australia.

10. *Most relevant and most influential Countries.*

India has shown remarkable productivity in producing documents related to Industry 5.0 within the Scopus database. Since 2020, India has consistently held the first place, demonstrating a significant surge in research output compared to other countries. China and Italy secure the second and third positions, respectively. Notably, although India leads in productivity, China garners the highest number of citations in the Industry 5.0 field within Scopus, closely followed by Italy, Australia, New Zealand, India, the USA, South Korea, and Canada.

In the Web of Science (WoS) database, China, India, and Italy hold the top three spots in terms of both publications and citations. Until 2021, Italy held the top spot but has since moved to the third place in the last two years. Similarly, China retains its prominence as the most cited country in WoS for Industry 5.0, followed by the USA, Italy, Australia, New Zealand, India, South Korea, and Canada.

Notably, the top eight countries remain consistent across both databases, with a few variations in their rankings. A unique perspective can be gained by analyzing a country's dimension based on the corresponding author's affiliation. Here, a significant contrast emerges between China, India, and Italy, the leading countries in terms of publication. For China, approximately 60% of publications involve international collaborations, while for India, this stands at around one-third, and for Italy, it's about a quarter of the total publications within the country.

The Bibliographic coupling analysis, the Citation by countries and Co-authorship by countries, were used with VOSviewer and the Collaboration Network of the Countries with Bibliometrix/Biblioshiny to show connections between the countries. By these network graphs the collaboration between authors of different countries can be revealed, of how authors relate to others in the field of Industry 5.0, helping to understand the social structure of the Industry 5.0's research academic community.

The bibliographic coupling analysis is a sign that there is likelihood that the two works cover the same topic of study. Bibliographic coupling analysis, offer a picture of the state of the research field presently [70], shows a connection between many European countries. Brazil and Iran share a connection with Germany, Norway and Netherlands. Sweden is connected with China. Also, a connection exists between Australia, Pakistan, Saudi Arabia, Canada, S.Korea, Turkey, Malaysia and U.A.E.

In the Citation by countries Network graph, the relatedness of articles is more clearly demonstrated through direct citations. Discoveries made include India, Italy, Saudi Arabia and Brazil belong to the same cluster, same with China and Pakistan, USA and Spain, Greece and Canada. Poland, Sweden, Hungary and Slovakia, Austria, Ireland and Iran also construct a cluster. Moreover, although not in the same cluster, Germany is related with Portugal and France.

Co-authorship by countries is the next network graph. Writing a study in collaboration with another author is known as co-authorship. Information about any country's international co-authorship can be gathered via this Network. Co-authorships occur between authors from: Greece and for instance UK (or England in WoS), UK (or England in WoS) and China, China and USA, Germany and Hungary, China and Australia, India and Saudi Arabia, India and USA, China and Sweden, Portugal and Spain, Italy and France, China and Sweden, Poland and Lithuania, Poland and Slovakia, Italy and Germany, Germany and France etc

The last graph is a Collaboration Network of the Countries with Bibliometrix/Biblioshiny. India is the most significant county in the network, followed by Italy and China. India and USA have the most synergies followed by India-Portugal, India-China and China-USA collaborative couples. Two are the most significant clusters. India, China, USA, Portugal, Russia, Germany and Malaysia form the one Cluster. The other significant cluster is with Italy, Spain, France, Croatia, Greece, South Africa, Turkey, Saudi Arabia, Norway, Slovenia and Austria.

7.1.2 Results for the second RQ

For the second RQ the current research directions in the area of Industry 5.0 has been identified and the conceptual structure of Industry 5.0 has been revealed.

1. Based on the *Word cloud and Concept cloud* generated by the ATLAS.ti program with different fields: the Author's keywords, the titles and the Abstract using the merged dataset, the Scopus keywords using the Scopus dataset or the keyword plus field using the WoS dataset, it can be observed that Industry 5.0 has a human/social/environmental perspective. Various Industry 4.0 technologies appear, upon which Industry 5.0 will be based, to achieve the transition from Industry 4.0 to Industry 5.0. Digitalization, artificial intelligence, smart manufacturing, technology, internet and machine learning are among the most used terms in the Word cloud. The human/social/environmental factors to achieve the Industry 5.0's pillars (human, sustainability and resilience) Sustainability and sustainable are highly used, society and centric are also terms that often occur. Other used terms are innovation, transformation, IoT, robot, supply chain etc. In the concept cloud Human is a major term, were center, centric, centricity, human centric, human factors, that are relative terms to human can be found. Sustainability, sustainable, resilience, social is another group of relative terms. Thus, the EC definition can be produced by the terms contained in the concept cloud.
2. For the second analysis a *co-word network analysis* was used. The VOSviewer co-occurrence of keywords Network Visualization helps by various means to identify useful knowledge, first by the formed clusters. Industry 5.0 forms the largest cluster that contains Industry 4.0, human-centricity, sustainability, personalization, Society 5.0, green, supply chain, resilience, circular economy, SMEs, etc. IoT is the second largest cluster that includes blockchain, energy efficiency, big data, automation, Industrial IoT, 5G/6G, cloud computing, edge computing, machine learning, deep learning, security. A third notable cluster is the Human-robot collaboration cluster, that contains smart manufacturing, robotics, robots, human-robot collaboration, cobots and human-machine interaction.

   The relationships in the graph can be studied to learn helpful details. For instance, the operator safety is an issue related to human-centricity, to worker and sustainability in the Industry 5.0 and Industry 4.0 context. Also, it is related to Human-robot collaboration, as well to accident prevention and to decision support systems. Or it can be seen that personalization is an issue related to Industry 5.0, Industry 4.0, AI, technologies, human-centricity, Society 5.0, metaverse and privacy.

The keyword plus WoS field produced a graph that reveals the conceptual basis upon which the Authors work was based on. The absence of the term human is worth to be noted. 6 clusters were formed; One is the system, management, model cluster that contains the resilience term. Also contained in this cluster are terms such as optimization, algorithm, networks, resource allocation and machine. The AI, CPS, Big data, Internet, supply chain, digital twin, blockchain, things, IoT, security is the largest cluster. The technologies cluster with Industry 4.0, integration, service and robots. The framework, future cluster, with terms such as performance, decision making, impact, implementation, collaboration and more. And finally, the sustainability cluster containing circular economy, VR, digitalization and innovation.

3. On the *Trend Topics* derived from the Bibliometrix/Biblioshiny graph, Resilience is found as a promising topic in 2023, as Human-Centricity was found in 2022 and SMEs in 2021.
4. Another overview through the *Three-Field Plot,* by Title, Countries and Author's keywords, shows the connection between the countries of the Authors, and the titles and keywords that they use. Sustainable is a term that appears in the title of all countries displayed for at least one document except for Germany. Sustainability as an Author's keyword appears in at least one document from all countries appeared in the graph except Turkey and Pakistan, whereas resilience appears in at least one document from China, Italy, UK, Portugal, USA, Spain, Germany and Australia. Furthermore, Society 5.0 does not appear in the keywords list to any document retrieved from USA, Germany and Poland.
5. *Most Frequent Words*, is a graph made by Bibliometrix/Biblioshiny, based on Author's keywords top 5 words are Industry 5.0, Industry 4.0, human-centricity, AI and sustainability. The Word cloud from the Bibliometrix/Biblioshiny using the Abstract's bigrams gave as top terms: Artificial Intelligence, industrial revolution, supply chain, machine learning, sustainable development, digital transformation and digital twins.
6. The Industry 5.0 evolution was examined through the VOSviewer tool by the *Co-occurrence of keywords* Network Visualization and Density Visualization. While for the first period, 2019-2020 the papers of this period mostly reflect technology values, in the 2021 papers beside technology factors the new dimensions introduced with Industry 5.0 can be found such as sustainability, human-centricity (workers, human-robot collaboration, Operator 4.0, human, humans) and Society 5.0. The 2022 graph was richer in concepts than the previous year. In the new concept's list, terms included, are resilience, wellbeing and personnel amongst others. Finally, the 2023

graph made was similar to 2022 with the only difference that the sustainability cluster has been expanded.

7. *The thematic evolution* from Bibliometrix/Biblioshiny shows the transition from Industry 4.0 concepts to Industry 5.0 concepts. It shows a transition focus from a technology-based perspective to Human and Sustainability perspective. Sustainability was from the beginning in the research focus, as concerns about sustainability was in the focus from Industry 4.0 but human workers concerns raise in recent works.
8. *Co-word analysis* was the next method used through Bibliometrix/Biblioshiny, in order to identify clusters of keywords, known as themes, that visually represented on a two-dimensional thematic map. The position of each theme on the map provides information about its characteristics and significance within the research field.

   In the early years 2018-2021 many clusters have been identified as Motor Themes. They primarily include technological factors. In the next period only one cluster (the IOT, AI, blockchain cluster) remains in the Motor Themes. The Industry 5.0 cluster in the last period while probably has changed its focus and is more human-centric, is placed in the Basic Themes. It is expected that the relevance degree of the Industry 5.0 cluster will be high, that is why it can be found in both maps on the rightest position. In the first period that the tool interprets the Industry 4.0 - Industry 5.0 cluster, the technology with human interaction cluster and blockchain cluster, the IoT and AI cluster, the cobots cluster and the manufacturing cluster were well developed, sustainability is emerging.

   Whereas, in the second period Industry 5.0 cluster is decreasing its density degree as it has a human-centricity focus and resilient is a new topic in this cluster. Moreover, Sustainable development with AI and human form a cluster positioned in the map's center. Human factor and cobots may not be extensively developed but are relevant across different research areas and sustainability in a different cluster is still emerging.

   The Thematic map for the whole period of our research (2018-2023) through Bibliometrix/Biblioshiny shows 5 clusters. The cluster with the highest centrality, that is the most relevant to the topic cluster, is the Industry 5.0 – Industry 4.0 – human-centricity cluster but with medium density, that is, it is not fully developed. That is why it is half in the Motor Themes quadrat and half to the Basic Themes quadrat. With less centrality but more density from the previous cluster is the IoT – blockchain - Industrial IoT cluster and it is placed in the Motor Themes quadrat. The next cluster based on the order of the centrality degree is the sustainability – supply chain – technologies – resilience cluster that half belongs to the basic and half to the

Emerging or Declining Themes quadrat. The next cluster with less centrality than the previous one but with little more density of it is the Energy efficiency cluster belonging as well to the Emerging or Declining Themes quadrat. Finally, the smaller cluster is the reliability cluster that has low centrality but high density and belongs to the Niche Themes quadrant.

9. Using *factorial analysis*, a conceptual structure map was created. Thus, it can be identified in the generated graph that resilience and sustainable development are related. Also, human centricity is closely related to resilience and sustainable development. Furthermore, Sustainability is close to human-robot interaction and supply chain. Industry 5.0 and Industry 4.0 are very close related terms. Moreover, close are Human centric to human robot collaboration, and human robot collaboration to Operator 4.0 and digitalization.
10. The last analysis method for the second research question to discover emerging fields and research trends, conducted using the ATLAS.ti tool, was *Opinion Mining* a sentiment mining method. The positive quotes produced are more than the negative in our collection. More specifically, the positive quotations in Scopus are 1042, whereas the negatives are 904. In WoS respectively 258 versus 111. In the merged dataset (Scopus and WoS) there are 1094 positive compared to 928 negatives quotations. As positive sentiment may imply something new, that will bring changes with positive impact whereas negative sentiments may imply the obstacles to achieve the transition from Industry 4.0 to Industry 5.0, by reading these quotes either positive or negative, helps any researcher to develop his/her understanding on the evolution of Industry 5.0.

    The tool's interactive interface, helps to have a quick and detailed overview of the scientific field and support previous discoveries made using other methods. The findings of this research regarding Industry 5.0 have been substantiated.

7.1.3 Results for the third RQ

For the third RQ, to determine what trajectory Industry 5.0 is taking, the analysis began on finding the percentage of Industry 5.0 articles in the two databases that contain at least one of the three pillars of Industry 5.0 and consequently comparing the influence of the articles containing one of the three pillars to those not containing.

Firstly, the findings in the Scopus database were:

- in 2019 35% of the Industry 5.0 involved Human-centricity whereas 60% of the Industry 5.0 articles involve it 2023;

- in 2019 6% of the Industry 5.0 involved Sustainability whereas 35% of the Industry 5.0 articles involve it 2023;
- in 2019 0% of the Industry 5.0 involved Resiliency whereas 18% of the Industry 5.0 articles involve in 2023;
- in 2019 41% of the Industry 5.0 involved any of the 3 pillars whereas 75% of the Industry 5.0 articles involve any in 2023.

Respectively the WoS findings were:

- in 2019 27% of the Industry 5.0 involved Human-centricity whereas 64% of the Industry 5.0 articles involve it 2023;
- in 2019 18% of the Industry 5.0 involved Sustainability whereas 39% of the Industry 5.0 articles involve it 2023;
- in 2019 0% of the Industry 5.0 involved Resiliency whereas 21% of the Industry 5.0 articles involve in 2023;
- in 2019 36% of the Industry 5.0 involved any of the 3 pillars whereas 83% of the Industry 5.0 articles involve any in 2023.

The analysis continued, with acquiring two datasets from each of the scientific databases, with one encompassing any of the three pillars and the other devoid of all three.

The documents that contain Human-centricity, Sustainability, and Resilience was found that are used on average more frequently as references from the researchers than the other set of documents, according to the Citation Overview via Bibliometrix/Biblioshiny.

For the Scopus database, the h-index for the set including any of the three pillar terms in the title, abstract, or keywords fields is 32, while the h-index for the second set devoid of any of the three pillar terms is 16. Furthermore, the first set's yearly growth rate is 184%, compared to the second set's 57%. Furthermore, despite the fact that the first dataset's documents are on average 1.17 years older than the second's, meaning that the second's documents have been published for longer on average, the first dataset has an average of 8.59 citations per document, which is higher than the second dataset's average of 5.52.

The results from the WoS database are comparable to those from Scopus because the set containing any of the three pillars has a higher annual growth rate (128% vs 39%), more average citations per document (9.65 vs 8.54) despite a lower average document age (0.87 vs 1.23), and a higher h-index of the first set (= 30 that is more than double) than the h-index of the second set (= 13).

Furthermore, as Industry 4.0 and Industry 5.0 coexist in a complementary manner, where Industry 5.0 introduces new societal dimensions without being a mere integration of Industry

4.0; Industry 5.0 relies on the technological advancements of Industry 4.0 while emphasizing the three pillars of Human-Centricity, Sustainability, and Resiliency as highlighted by the EC. The examination of their presence in research literature involves two approaches: 1) Utilizing the VOSviewer Co-Occurrence keyword network graphs to showcase their mutual reinforcement, and 2) Utilizing ATLAS.ti to create Word Clouds and Concept Clouds from the entire paper collection (titles, abstracts, and keywords), where the presence and size of terms related to the three pillars serve as indicators of their significance in the research works.

The presence of Human/Sustainable/Resilient oriented terms shows the size of the new dimensions introduced by the new paradigm. Human-centricity and Sustainability are notable topics and are connected, with many other topics amongst them sustainability, resilience, European commission, personalization, society 5.0, human-robot collaboration, supply chain and more. Moreover, Resilience relates to just a few topics, such as sustainability, human-centricity, supply chain, uncertainty analysis, society 5.0, digitalization, industrial research, production system and data science in the Scopus graph whereas in the WoS graph resilience is connected to more terms. Sustainability, digitalization, human-centricity, AI, society 5.0, covid-19, supply chain, big data, IoT, challenges, digital twin, future, technologies, innovation and more.

Using the title, abstract, and keywords from each paper in the collection, ATLAS.ti was used to build the Word cloud and the Concept cloud. The presence and prominence of terms connected to the three pillars in these research papers serve as indicators of their significance. Furthermore, different terms relating to the three pillars were chosen from the concept cloud to demonstrate the phrases they were generated from, which helps to clarify how these concepts were employed. It is essential to note that the phrase "resilience" is missing maybe because the tool did not consider it to be significant. This might have occurred because the tool did not combine the many ways to express resilience as resiliency or resilient. On the other hand, the collection of articles under consideration heavily incorporates the concepts of human centricity, sustainability, and other terminology linked to them.

The overall findings show that the 3 new dimensions, human-centricity, sustainability and resiliency, are getting more prevalent in the research literature.

7.1.4 Results for the fourth RQ

For the fourth RQ, the higher interest in human-centricity, sustainability, and resiliency of Industry 5.0 in EU region compared to the rest of the world was examined.

First, from the two dataset sources made a comparison based on the countries scientific production. The maps comparison shows that in European Union, authors are more interested in promoting the ideas of human-centricity, sustainability and resiliency, on average as a percentage compared to the rest of the world.

Secondly, using again the country scientific production, the comparison between sources referring to at least one of the three pillars of Industry 5.0 from EU region countries and non-EU countries. EU region countries show a higher interest in the three pillars. The 82% of the Industry 5.0 documents that originated from EU countries in the Scopus database and 85% in WoS database, are having an interest on human-centricity, sustainability or resiliency, compared to 66% and 71% respectively from the Industry 5.0 documents of non-EU countries.

Thirdly, the Corresponding Author's Country graph in Scopus, derived from Industry 5.0 documents, through Bibliometrix/Biblioshiny. Two graphs, were made by each database, one from the dataset that contains at least one of the 3 pillars, without containing any of the three pillars the second graph. EU region countries are less present in the second than in the first graph, meaning that authors from EU region are more interested in promoting ideas that incorporate with the new dimensions of Industy 5.0.

7.2 Summary and conclusions

Industry 5.0 is a novel concept, currently evolving. As different definitions are given for Industry 5.0, different approaches, have been proposed, on the way it should be implemented. Thus, different ideas on what it involves and how to get there. As the most prominent definition of Industry 5.0 was given by the EC, inspired by that, the majority of Industry 5.0's researchers from EU region countries are emphasizing on the human, environmental and social dimensions of Industry 5.0.

Although the majority of researchers, who are influenced by the EC definition more and more every year as the new dimensions introduced gain popularity, envision Industry 5.0 to represent a fresh phase of industrialization centered around humans, resilience, and sustainability, there are still many researchers, mainly from non-EU region countries, for which Industry 5.0 reflects a new revolution having a technological focus.

The science mapping performed, using structures of Knowledge, through statistical analysis of scientific information, facilitate insights into the overarching themes and trends of Industry 5.0. The COVID-19 pandemic underscored the significance of employees and prompted a reevaluation of the Industry 4.0 concept, culminating in the emergence of Industry 5.0, which integrates social and environmental dimensions into the framework of Industry 4.0. Industry 4.0 is technology-driven, emphasizing efficiency and productivity, while Industry 5.0 prioritizes worker well-being and sustainability, ensuring long-term business viability.

Resource limitations (technological, human resources, financial, knowledge), put barriers in a large percentage of mainly SMEs to adopt the principles of the 4th industrial revolution creating a technological gap between large robust enterprises and small and medium ones. The reevaluation of barriers in Industry 4.0 implementation was prompted by factors such as personalized products and challenges encountered by SMEs, crucial economic contributors facing technology-related hurdles. Readiness assessment and technology selection are pivotal, with emphasis on a human-centric manufacturing approach.

Industry 5.0's overarching objective is not just job creation and economic progress, but wealth generation through technology, respecting ecological limits, and prioritizing the well-being of industrial workers. Human-Centricity necessitates addressing education, training, and skills for the digital shift, acknowledging retraining limitations. Sustainability involves optimizing output and resources with the principle "Better with less", considering circular economy principles. Resiliency involves adapting to global shifts, both geopolitical (e.g., conflicts, trade issues) and natural (e.g., pandemics, climate change), while maintaining resilience across factory, supply, and system levels, despite potential cost-efficiency fragility.

Nevertheless, Industry 4.0 and Industry 5.0 coexist. While Industry 4.0 has already transformed economies and business operations through connected technology, Industry 5.0, seeks to empower humans with advanced technologies like AI and robotics for safer and more meaningful work. Industry 5.0 builds upon Industry 4.0's foundation by emphasizing collaboration between humans and technology, fostering efficiency and productivity. It shifts focus from what workers do with technology to what technology can do for workers, promoting a more cooperative approach. Having a central theme of placing human well-being and creativity at the core, Industry 5.0 expands Industry 4.0.

7.3 The challenges and projected future of Human-Centered Industry

Because of the rapid pace at which technology is developing and the difficulties that lie ahead, industry must adopt more and more cutting-edge and modern technologies but must adopt a human-center perspective. Skilled workers should be in the center of production, with concerns on the Environmental impact. Sustainability and Resiliency are key factors to get to a better society and prioritize human values.

Industry 5.0 emerged due to limitations in the implementation of Industry 4.0. SMEs are significant factors in the development of the global economy and the creation of jobs, could not participate in industry 4.0 due to their well-known resource limitations in terms of personnel, technology, and budget. Major Political, Social and Environmental crises emphasized the importance of workers and generated attention for the environmental and social impact of Industry. Furthermore, young generation of workers, Millennials and Zoomers, are among the most passionate supporters of worker welfare and stress the importance of human aspects in the working environment of the coming years. The bibliometric analysis demonstrates the shift towards a societally focused industry, a more resilient and sustainable industry that is enhancing humanization and protect the environment.

Although the business industry is gradually coming to recognize bibliometric analysis as a valuable tool, not just for academic bibliometricians [94], and the research interest in Industry 5.0 is high while is still evolving, indicating a prominence future for Industry 5.0, the prediction made from the bibliometric analysis of Industry 5.0 cannot be long-term. Any bibliometric analyses are only able to provide short-term predictions for the research sector thus, the direction industry 5.0 appears to be taking may change [70]. Hence, the analysis should be performed again to determine how industry 5.0's will evolve in the future.

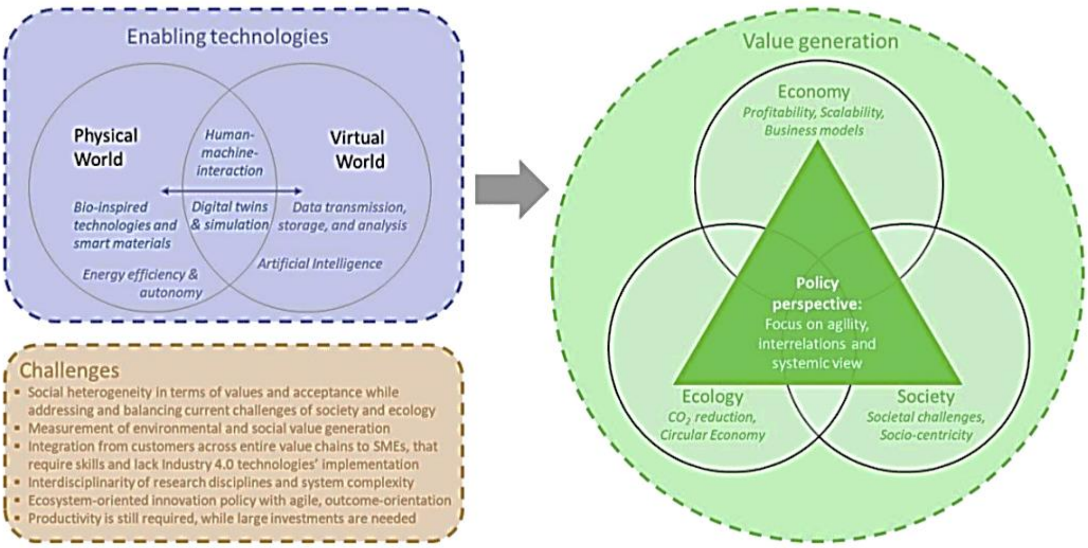


Figure 152 - Industry 5.0 definition by EC – human-centric, resilient and sustainable approach [14]

8

Appendices

8.1 Appendix A – Opinion Mining

The Scopus and WoS datasets that were collected for the purpose of this study, were exported to BibTeX format and imported in the ATLAS.ti tool. The duplicates were removed, and then the opinion mining method was done. From the outcome of this procedure, a number of screenshots were taken, some of which are given below and feature either positive or negative matches of terms in order to address the concept of Industry 5.0.

8.1.1 *Opinion Mining for Revolution*

The Positives matches for the term revolution are presented first:

Figure 153 - Opinion Mining for Revolution - Positive quotes

The Revolution negative matches identified are:

Figure 154 - Opinion Mining for Revolution - Negative quotes

8.1.2 Opinion Mining for Human related terms

Positive quotes for the term Centric:

Figure 155 - Opinion Mining for Centric - Positive quotes

Negative quotations with the term Centric:

Figure 156 - Opinion Mining for Centric - Negative quotes

Centricity positive quotations, and for Centrality one positive quote:

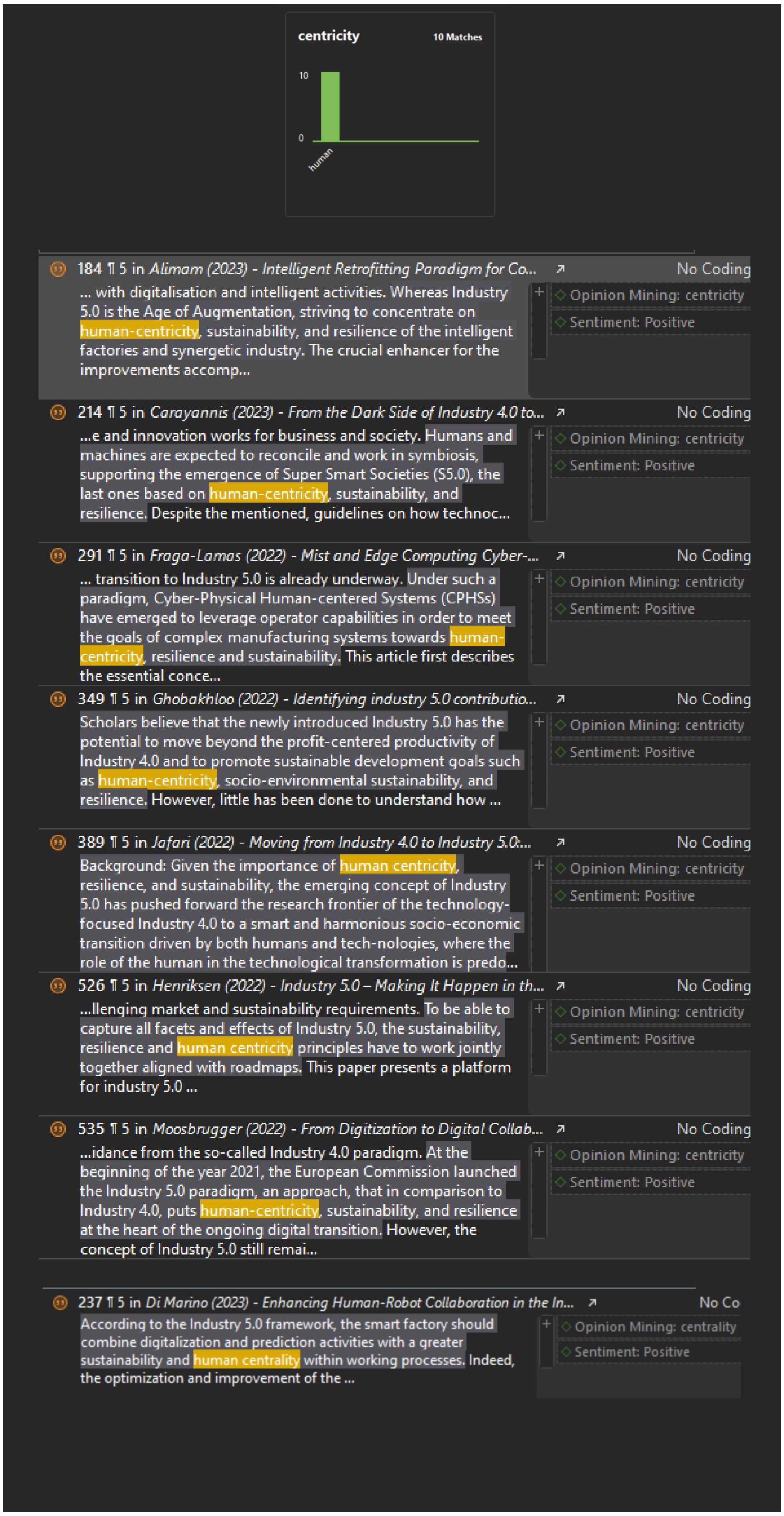


Figure 157 - Opinion Mining for Centricity/Centrality - Positive quotes

Figure 158 - Opinion Mining for Worker - Positive quotes

For the worker positive quotes above and for Human wellbeing one positive quotation below:

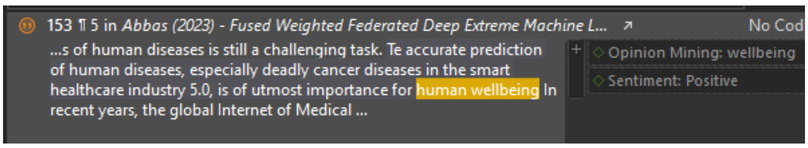


Figure 159 - Opinion Mining for Wellbeing - Positive quote

Human Centricity positive quotations follow:

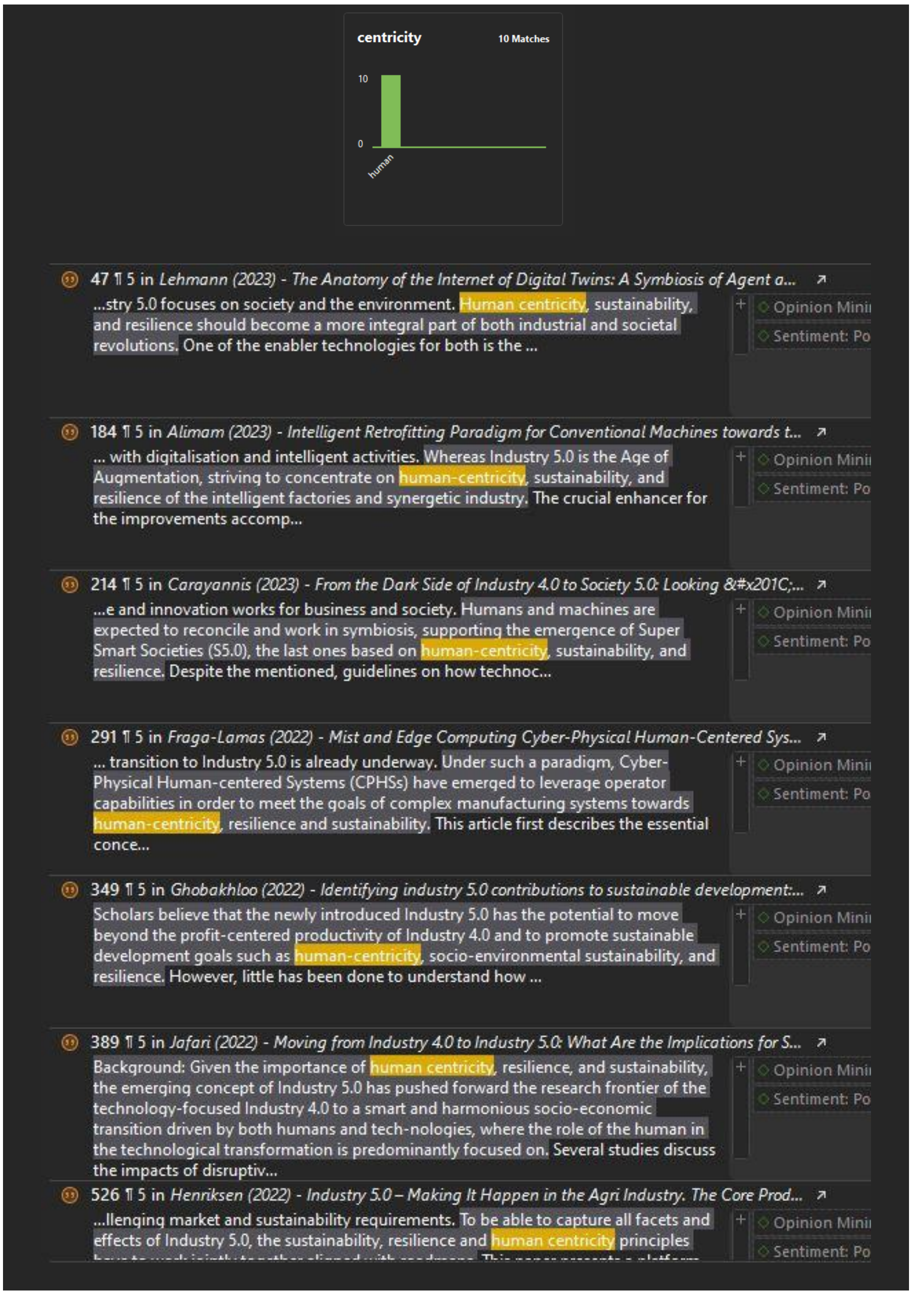


Figure 160 - Opinion Mining for Human Centricity - Positive quotes

Centric negative quotations:

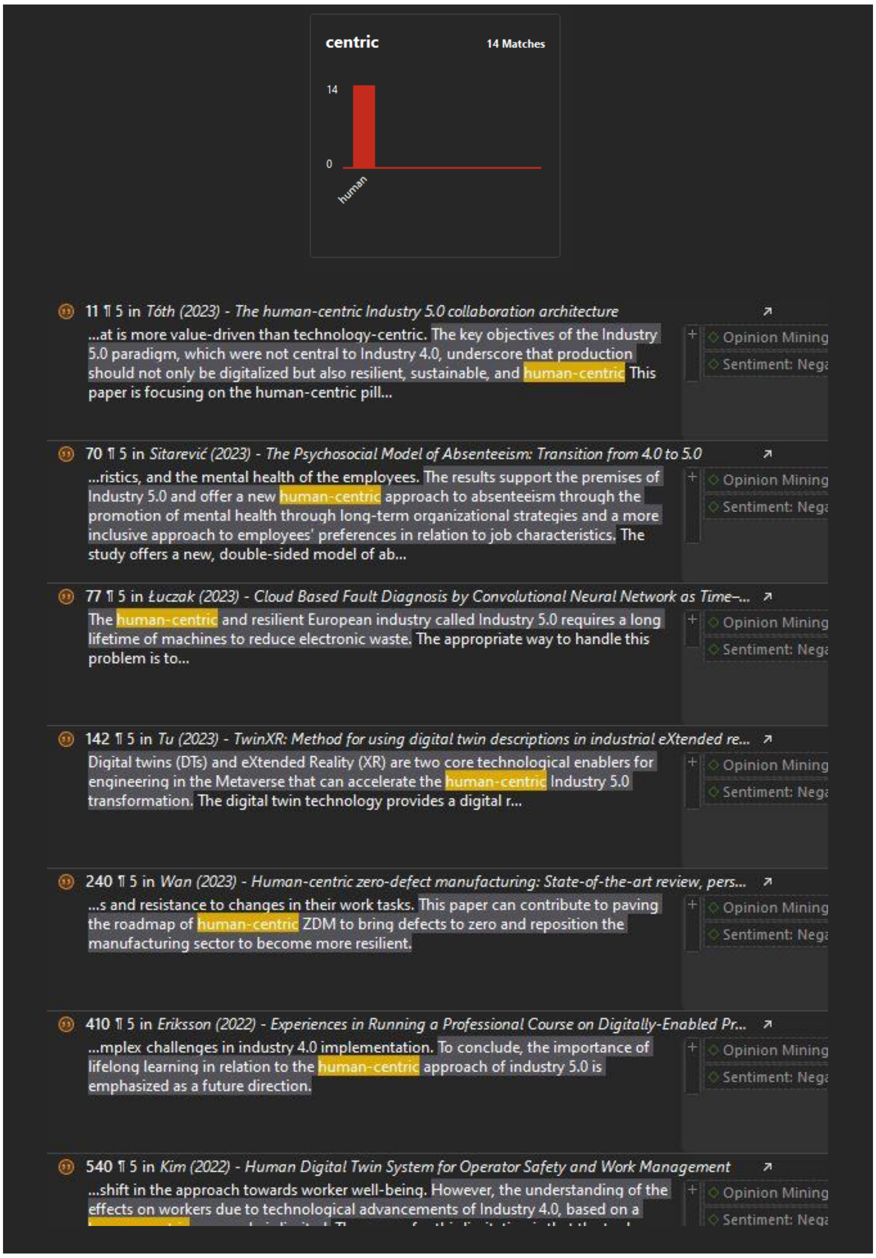


Figure 161 - Opinion Mining for Centric - Negative quotes

Positive for factor:

Figure 162 - Opinion Mining for factors - Positive quotes

Negative for factor:

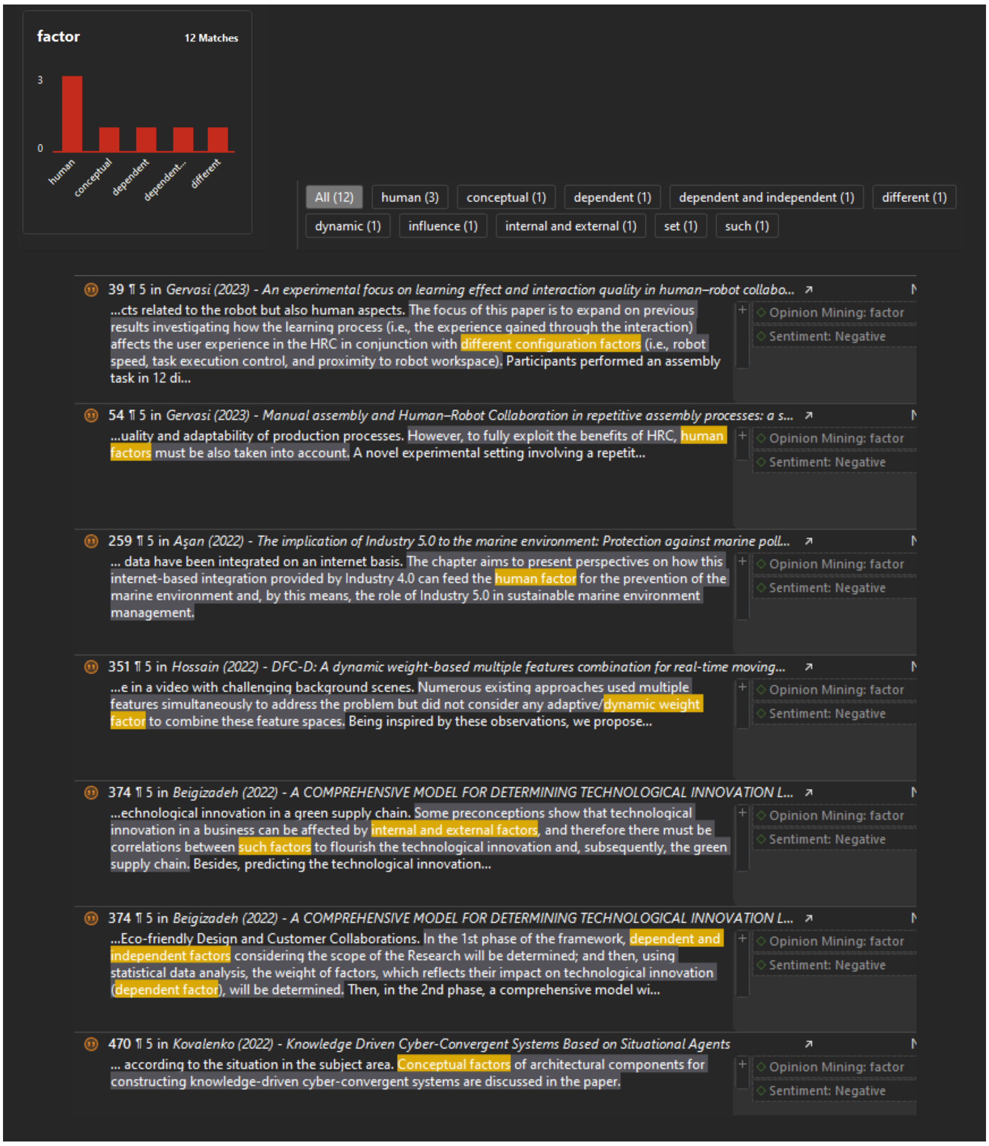


Figure 163 - Opinion Mining for factor - Negative quotes

8.1.3 *Opinion mining for Sustainability*

Positive quotes for Sustainability:

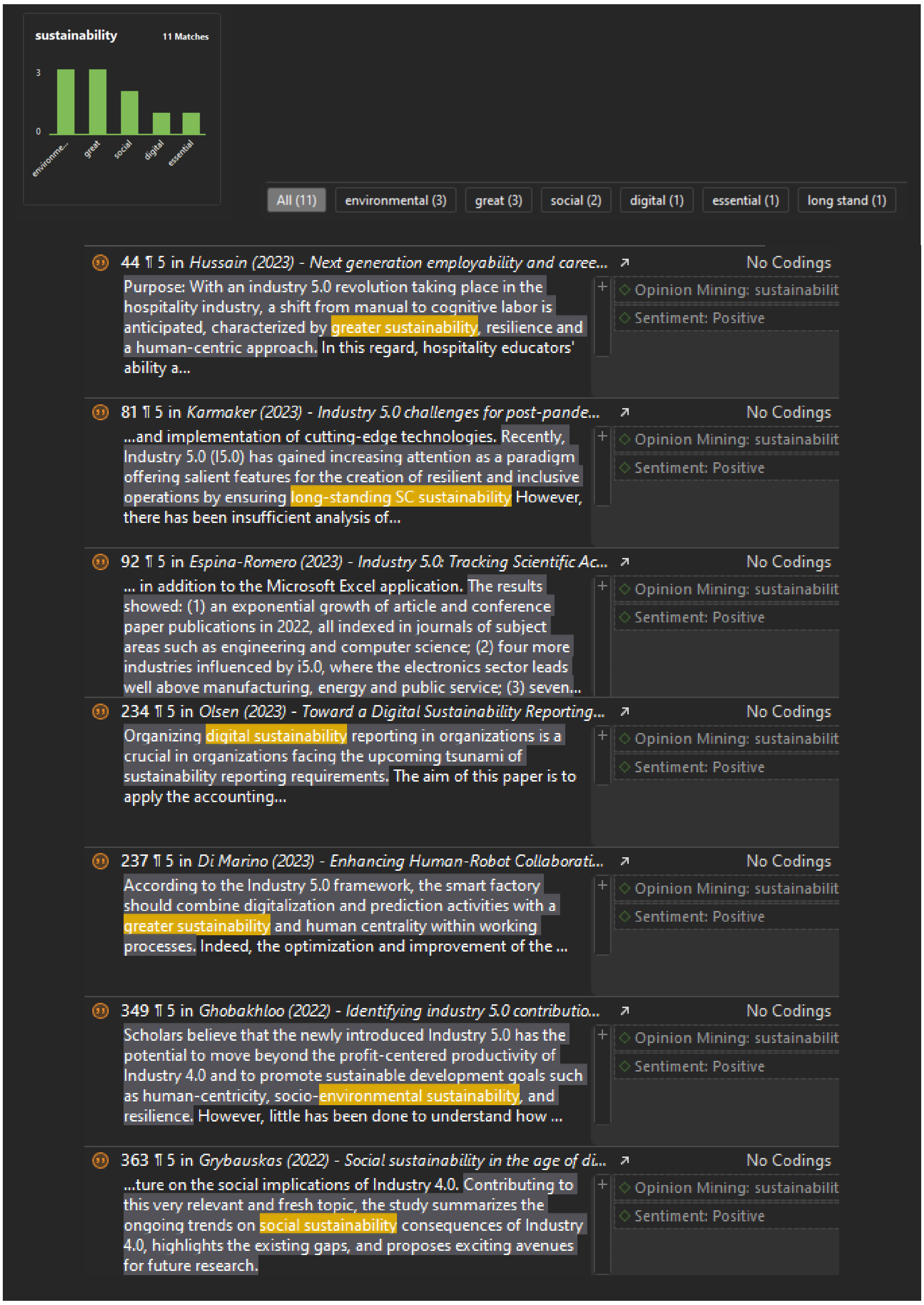


Figure 164 - Opinion Mining for Sustainability - Positive quotes

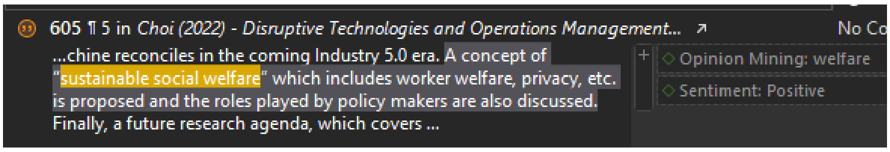


Figure 165 - Opinion Mining for welfare - Positive quote

A Positive quote for welfare above and Negative quotes for Sustainability below:

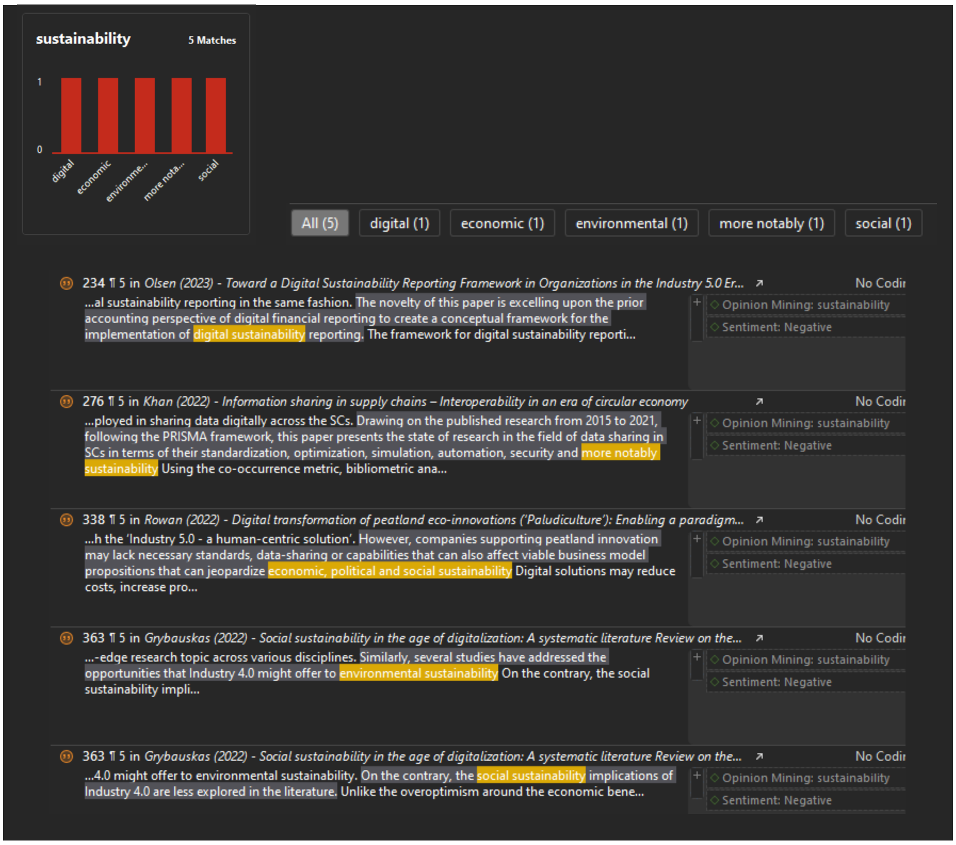


Figure 166 - Opinion Mining for Sustainability - Negative quotes

Positive quotes for development, many of which are related to sustainable development:

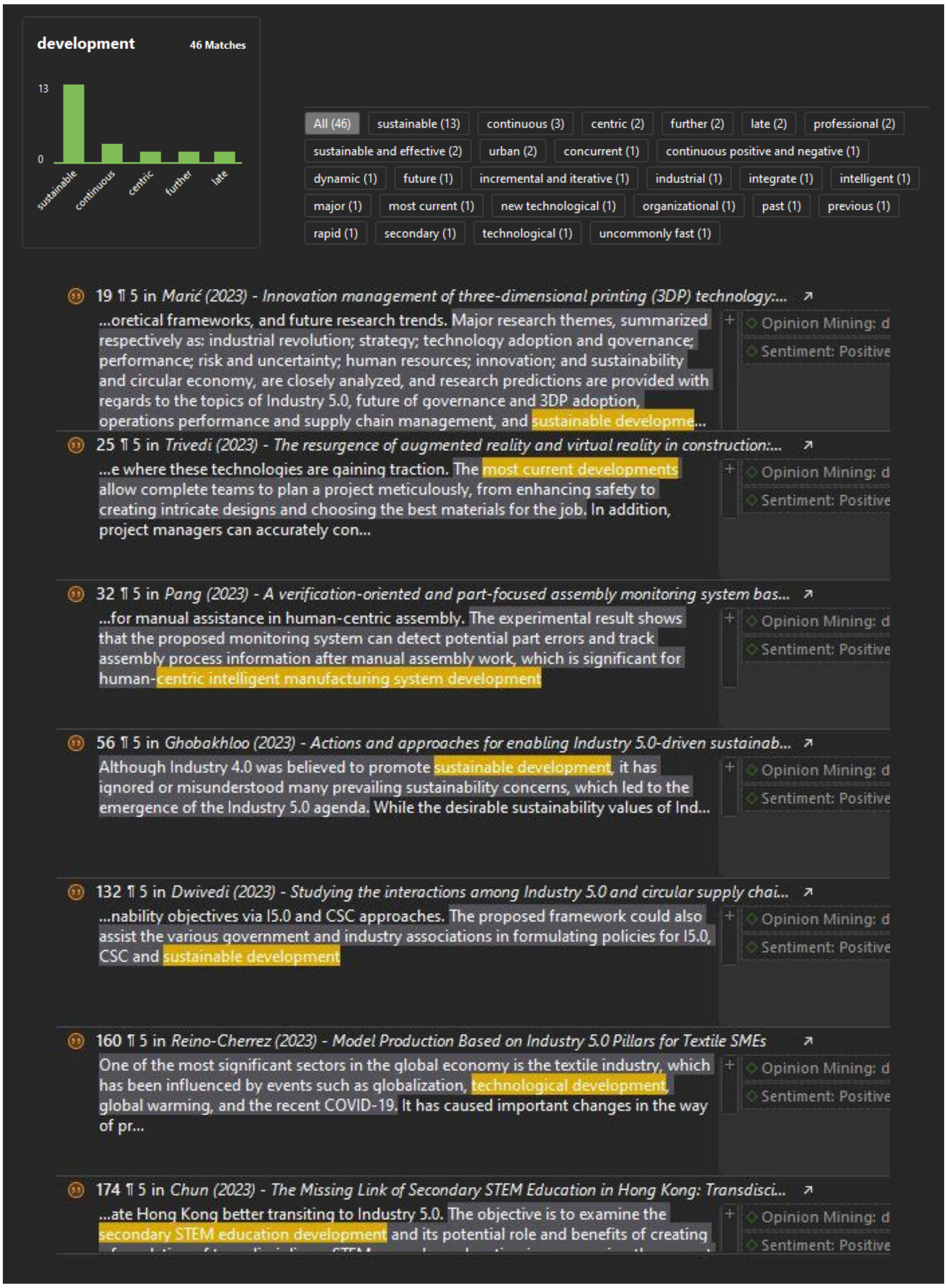


Figure 167 - Opinion Mining for development - Positive quotes

Negative quotes for development:

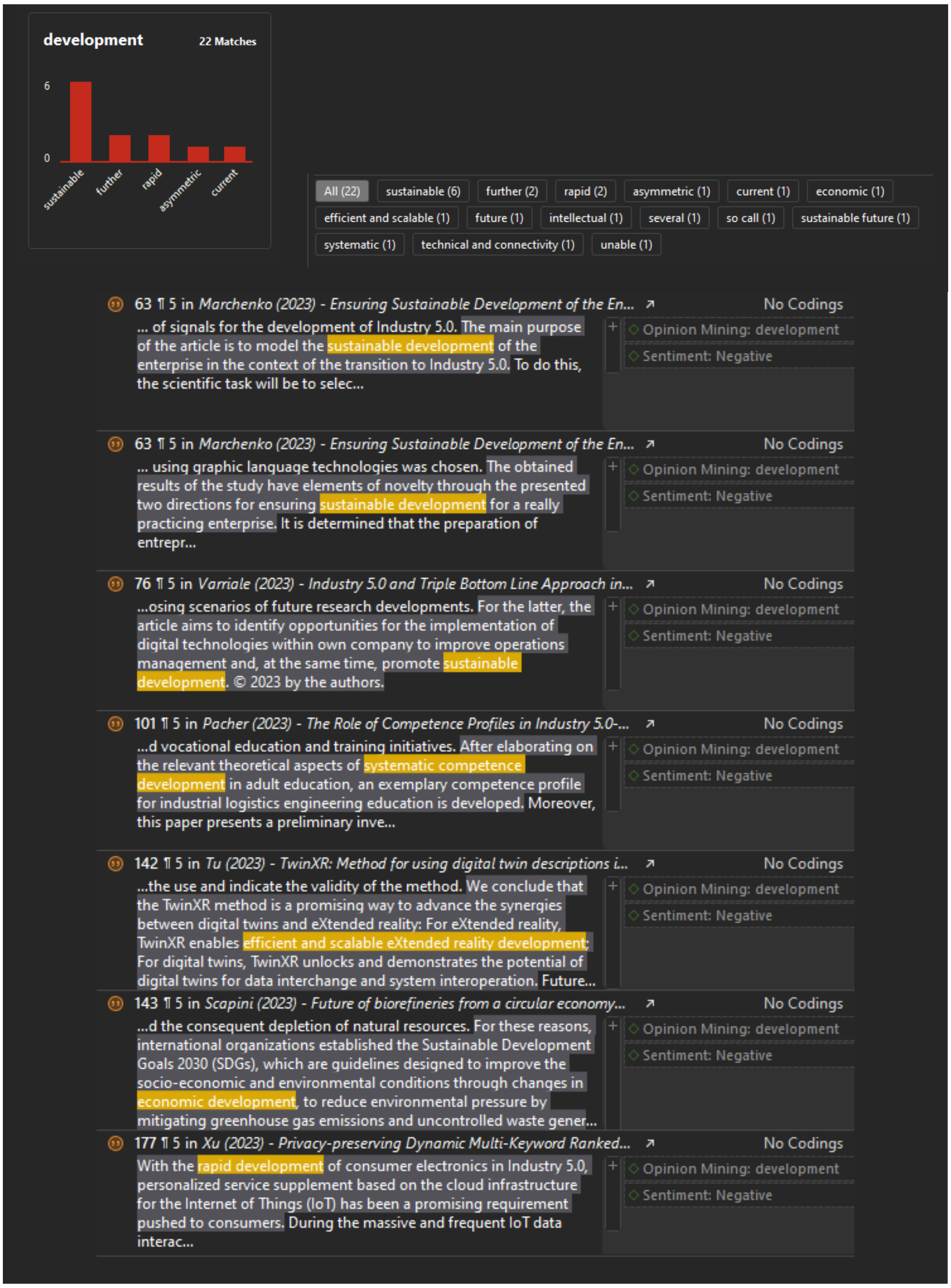


Figure 168 - Opinion Mining for development - Negative quotes

8.1.4 *Opinion Mining for solutions*

Positive quotes for solutions:

Figure 169 - Opinion Mining for solution - Positive quotes

But there been found also many negative quotes for solutions:

Figure 170 - Opinion Mining for solution - Negative quotes

8.1.5 Opinion Mining for Intelligence

Positive quotes for Intelligence:

Figure 171 - Opinion Mining for intelligence - Positive quotes

Negative quotes for intelligence:

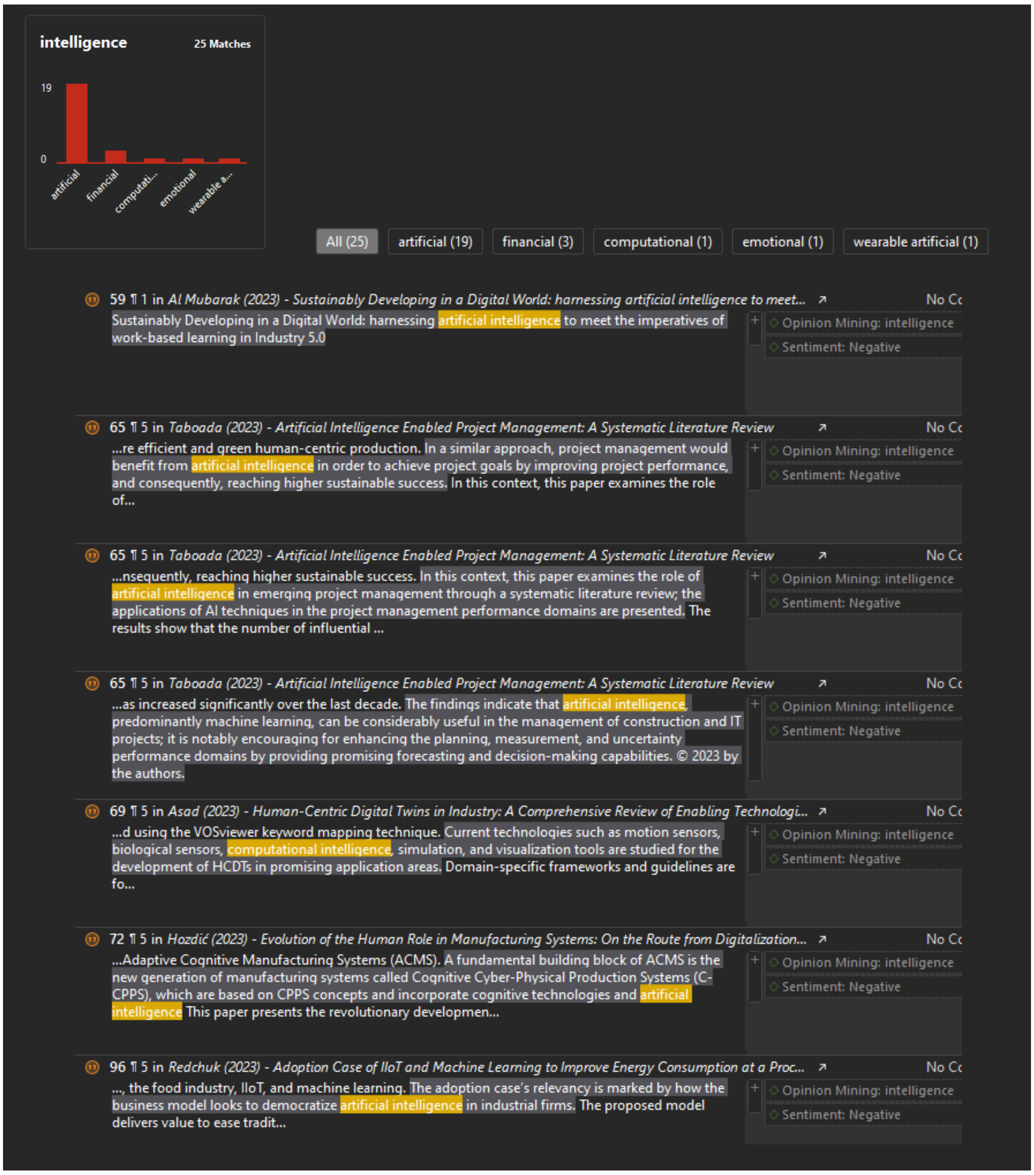


Figure 172 - Opinion Mining for intelligence - Negative quotes

8.1.6 Opinion Mining for Robot and Robotics

Robot positive quotes:

Figure 173 - Opinion Mining for Robot - Positive quotes

Robot negative quotes:

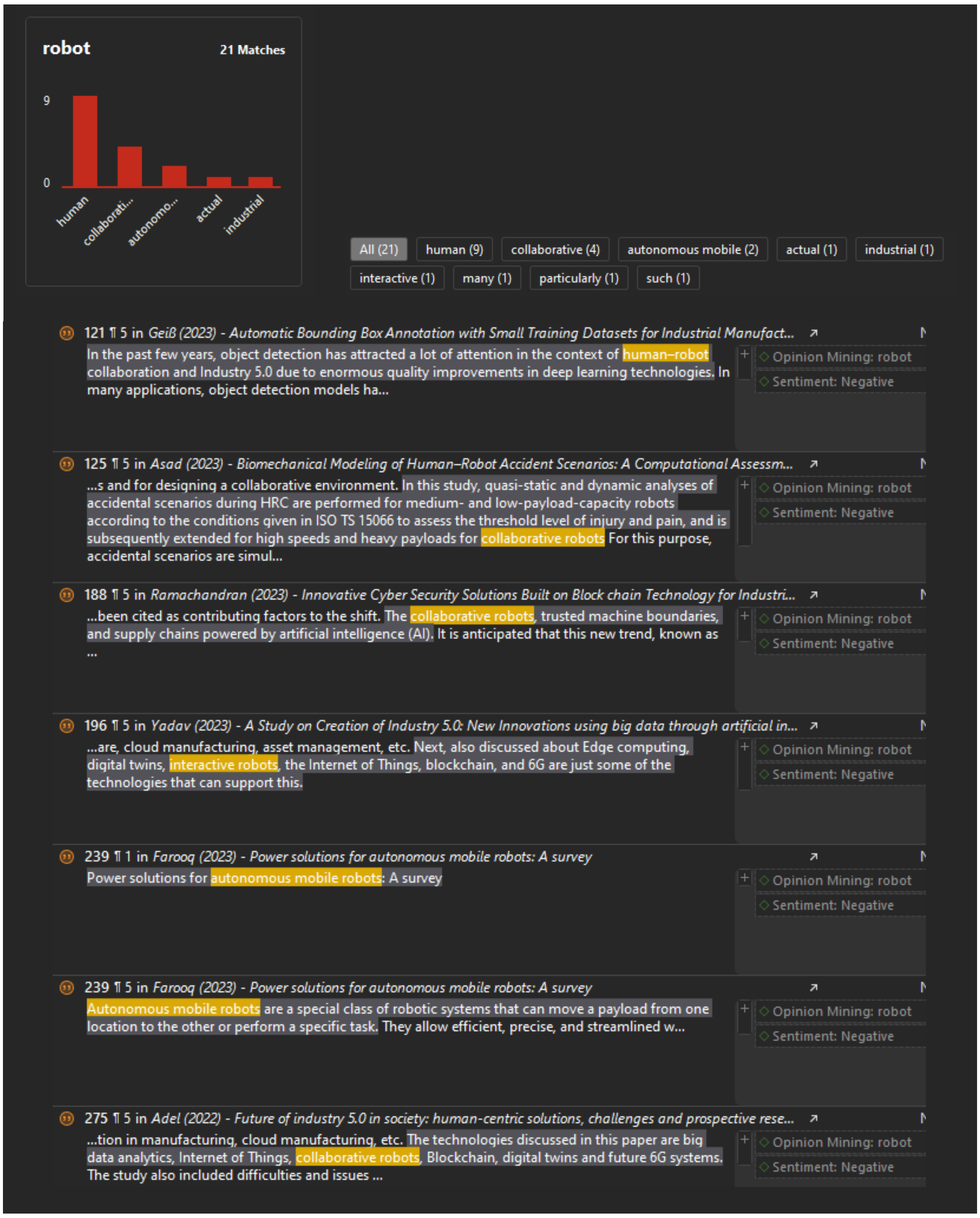


Figure 174 - Opinion Mining for Robot - Negative quotes

Robotic Positive quotes:

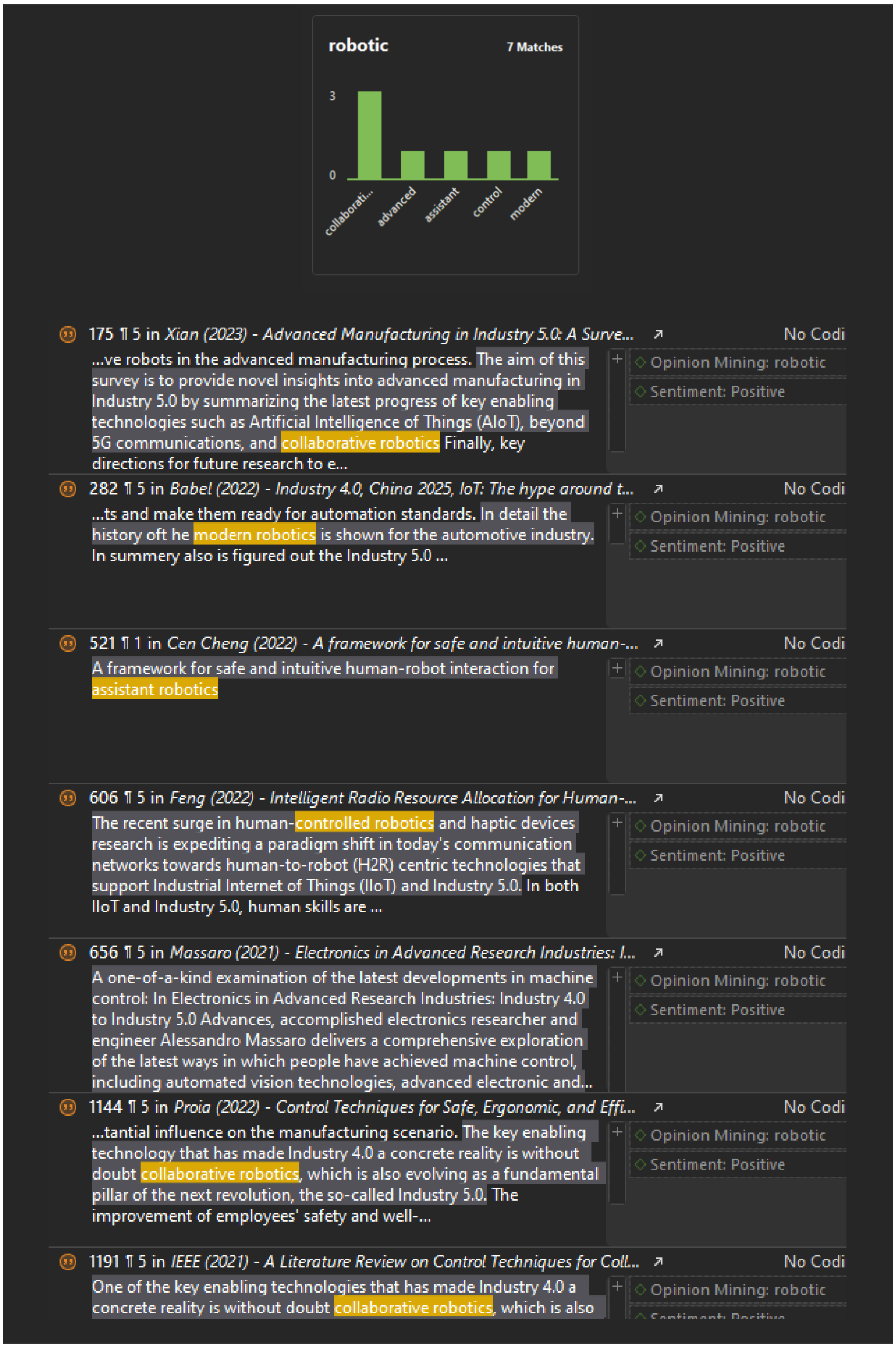


Figure 175 - Opinion Mining for Robotics - Positive quotes

Robotic/Robotics/Robotization/Cobot negative quotes:

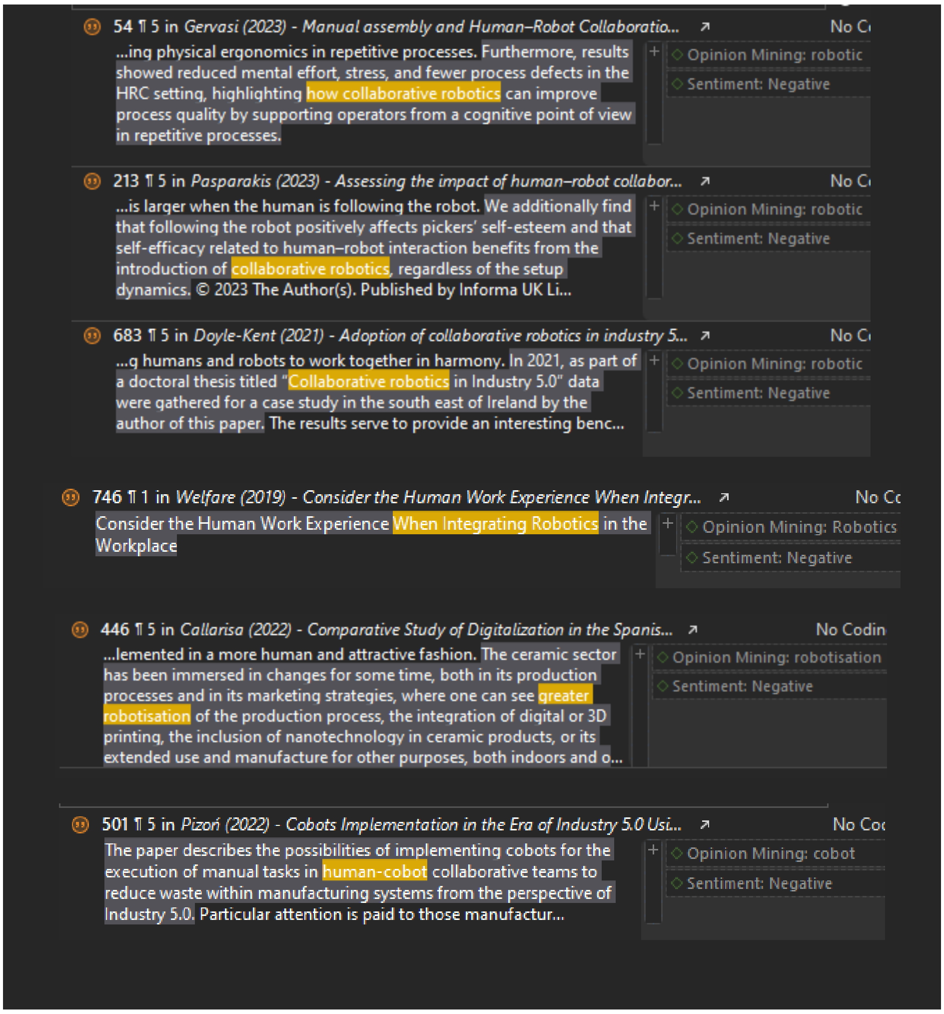


Figure 176 - Opinion Mining for Robotic/Robotics/Robotization/Cobot - Negative quotes

For collaboration and collaborations positive quotes:

Figure 177 - Opinion Mining for collaboration/collaborations - Positive quotes

Collaboration negative:

Figure 178 - Opinion Mining for Collaboration - Negative quotes

Collaborations/Collaboration/Human-Robot Collaboration positive quotes:

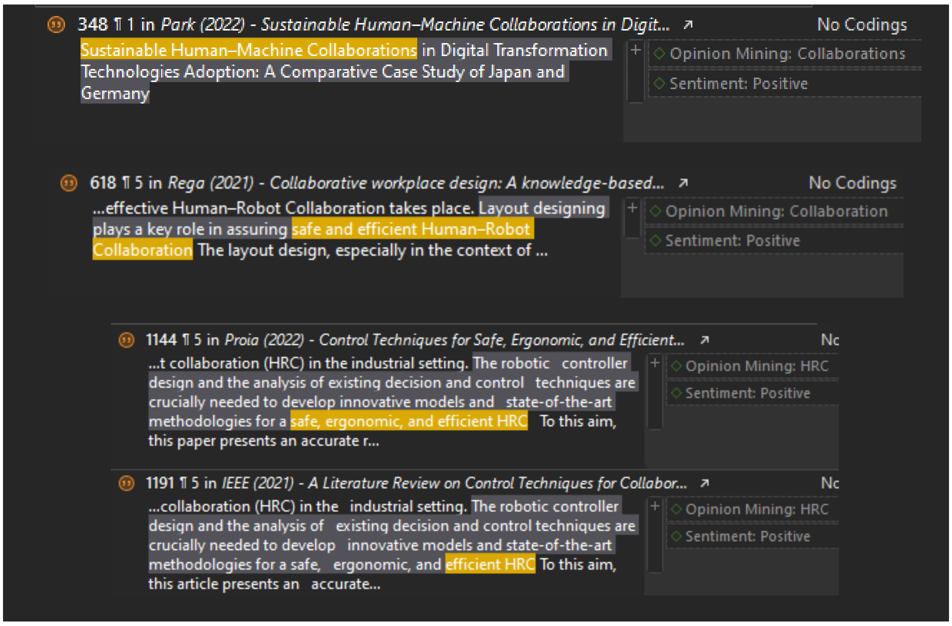


Figure 179 - Opinion Mining for Collaboration/Collaborations/HRC - Positive quotes

Human-Robot Collaboration negative:

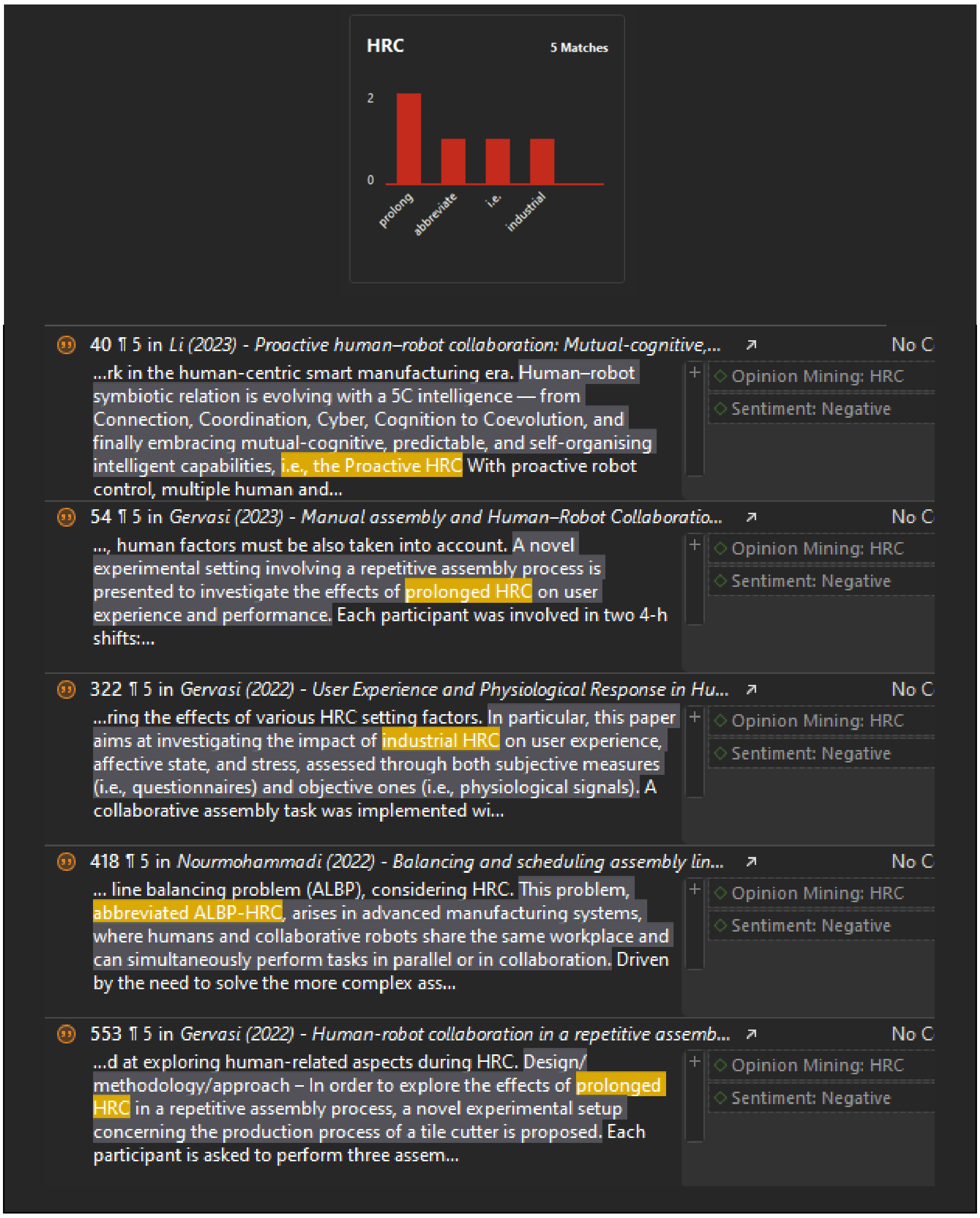


Figure 180 - Opinion Mining for HRC - Negative quotes

8.1.7 Opinion Mining for goal/challenge/change/value

For the goal term positive quotes:

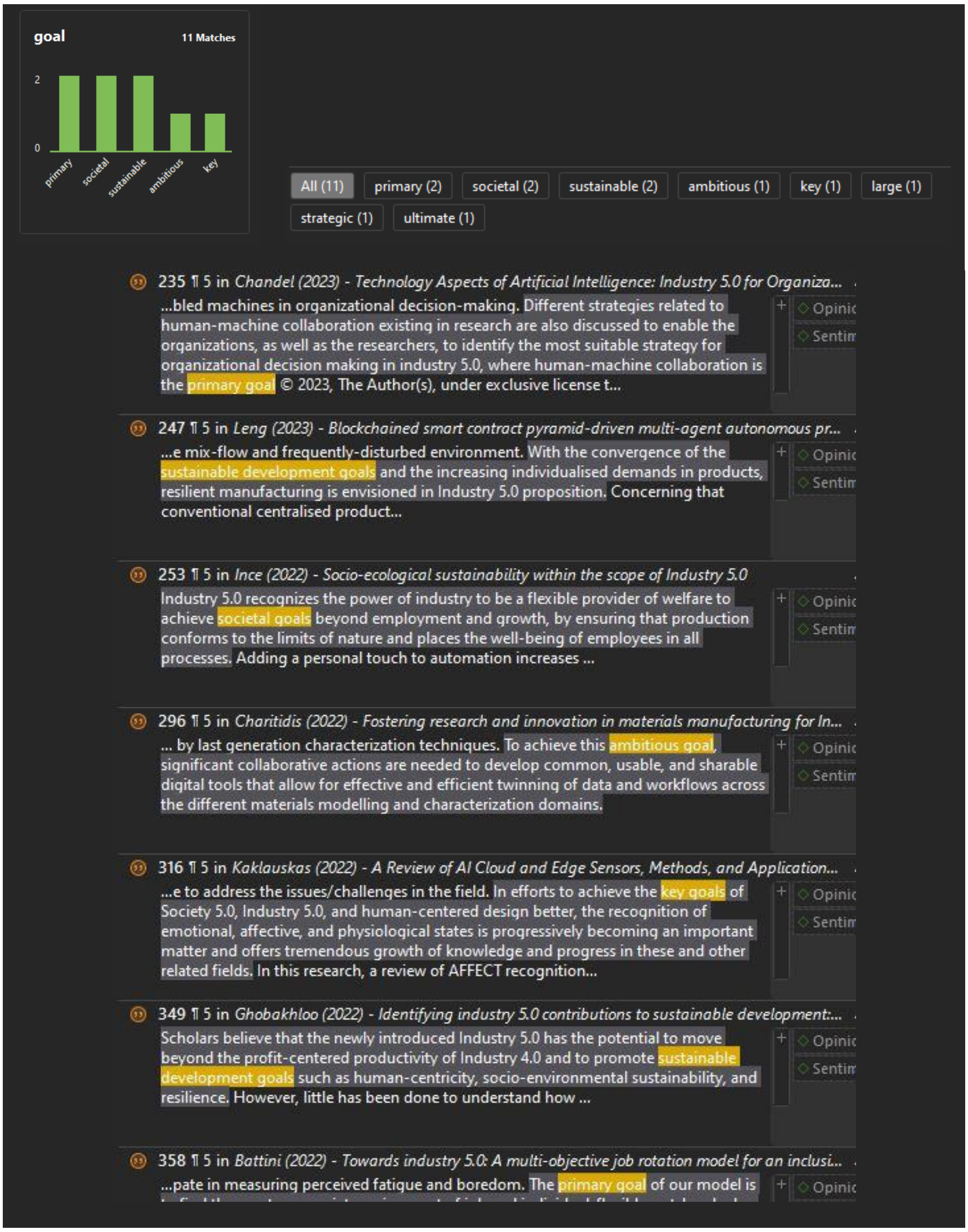


Figure 181 - Opinion Mining for goal - Positive quotes

Negative quotes for the goal term:

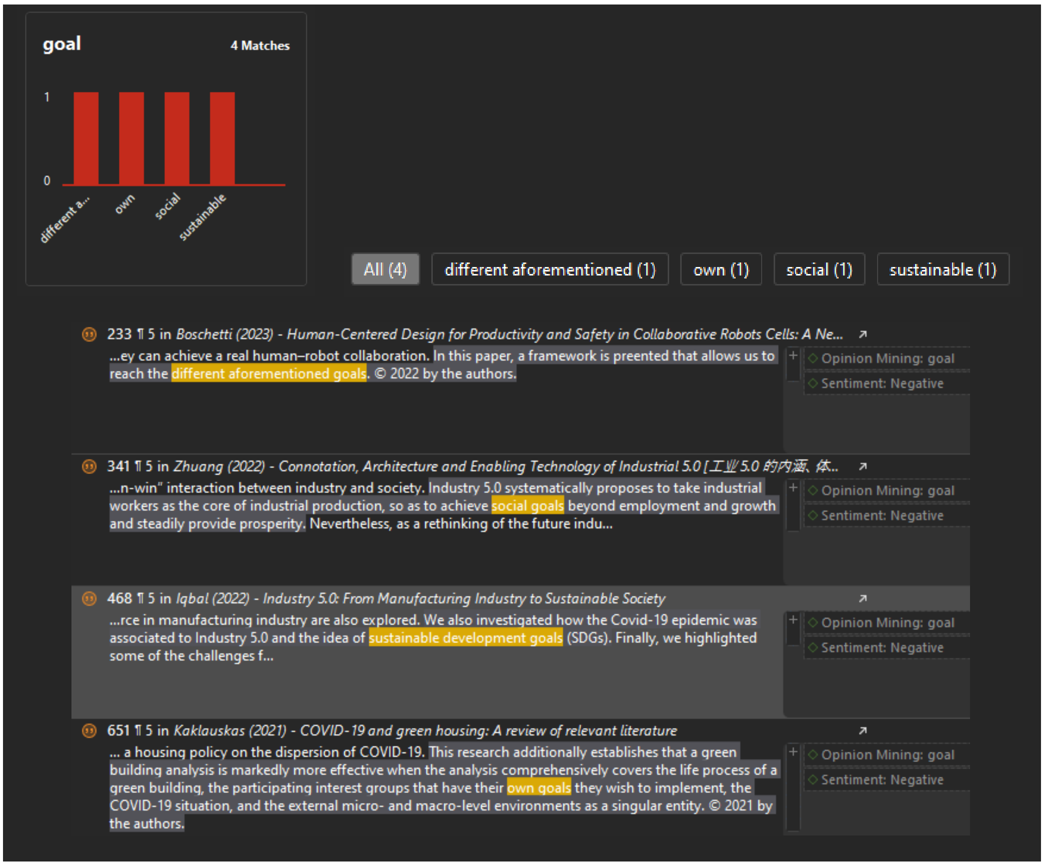


Figure 182 - Opinion Mining for goal - Negative quotes

Through the ATLAS.ti tool the NLP yield to positive opinion with 39 matches for the term challenge.

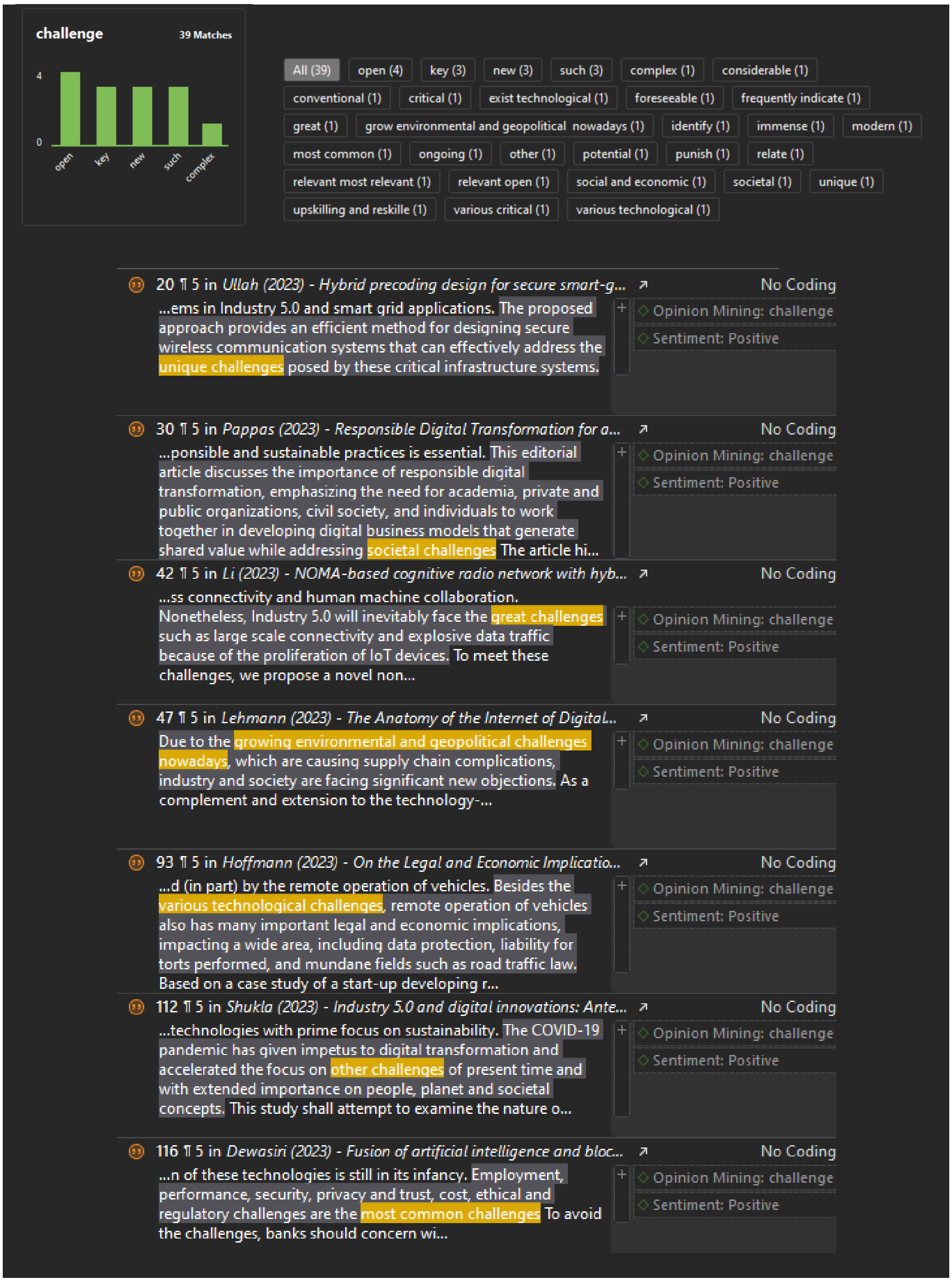


Figure 183 - Opinion Mining for challenge - Positive quotes

Also, for change positive quotes:

Figure 184- Opinion Mining for change - Positive quotes

Moreover, the positive value's quotes:

Figure 185 - Opinion Mining for value - Positive quotes

8.2 *Appendix B – Industry 4.0 and Industry 5.0 complement one another through ATLAS.ti concepts*

Below are a number of concept cloud screenshots, where various terms related to the three pillars of Industry 5.0 have been selected, to show where they originated from and to assist in understanding how these concepts were employed.

Figure 186 - Industry 5.0 Concept cloud by ATLAS.ti – Selecting Sustainability

Figure 187 - Industry 5.0 Concept cloud by ATLAS.ti - Selecting Workers

Figure 188 - Industry 5.0 Concept cloud by ATLAS.ti - Selecting Humans

Figure 189 - Industry 5.0 Concept cloud by ATLAS.ti - Selecting factor

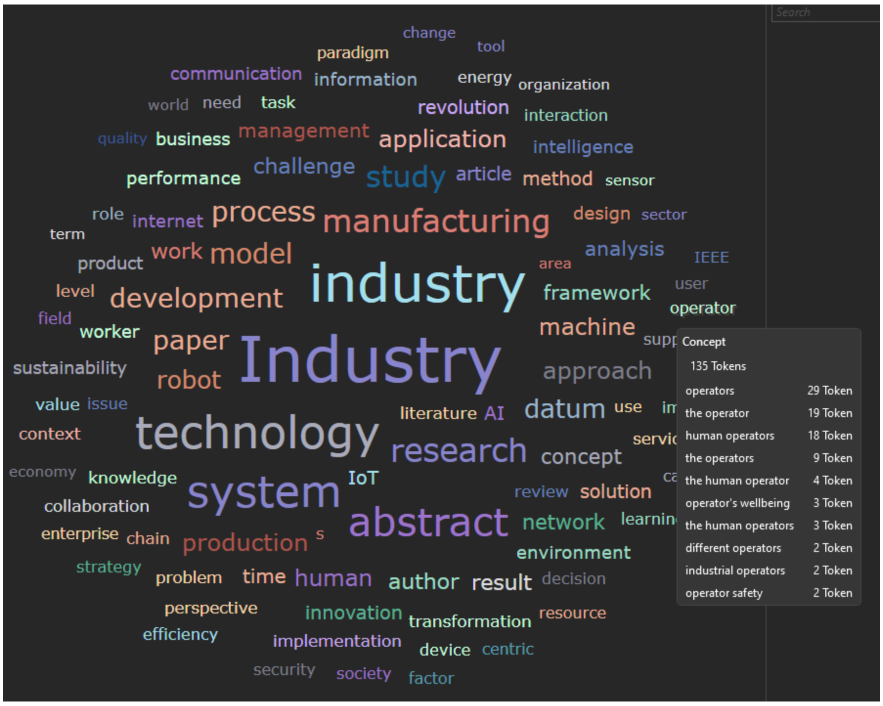


Figure 190 - Industry 5.0 Concept cloud by ATLAS.ti - Selecting operator

Figure 191 - Industry 5.0 Concept cloud by ATLAS.ti - Selecting interaction

Figure 192 - Industry 5.0 Concept cloud by ATLAS.ti - Selecting society

Figure 193 - Industry 5.0 Concept cloud by ATLAS.ti - Selecting centric

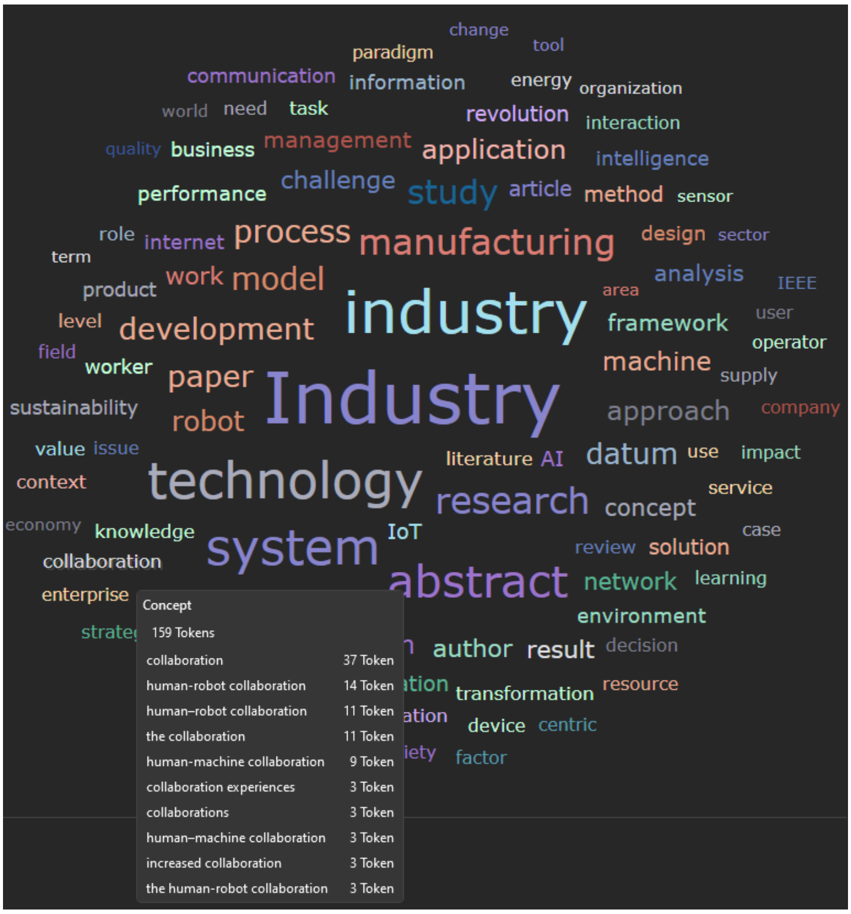


Figure 194 - Industry 5.0 Concept cloud by ATLAS.ti - Selecting collaboration

9

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