Risk Management in the Context of Industry 5.0

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Abstract. Industry 4.0 brought a highly automated and technology-centric environment, now, Industry 5.0 strives to introduce innovation with safety and responsibility beyond industry and thus build a society that contributes to economic growth and social well-being. Thus, this study conducted an analysis of publications on Industry 5.0 from a risk management perspective to investigate trends and analyze metrics related to publications on the topic. The study used the occurrence of a combination of keywords in the Scopus database search. Qualitative analysis of the 64 contents returned from the search was performed using the NVIVO tool and for analysis of other metrics the VOSviewer software was used. The results indicated that: (1) publications have been increasing since 2017; (2) countries such as the United States, Japan, and China dominate the research; (3) the field of Engineering predominates in number of publications; (4) The most found keywords in the publications are Industry 5.0 and Society 5.0. (5) The themes that appear most in discussion in the selected articles are System, Data, Technologies, Risk, Model, Production, Human, and Management. A discussion of these results, including limitations and recommendations for future research, is provided.
Keywords: Industry 5.0; Risk; Risk Management; Society 5.0.

1 Introduction

With the rapid technological advances, human coexistence and the needs of the labor market have been undergoing major transformations. Guided by the fourth industrial revolution, or known as Industry 4.0, organizations, productive sectors, and the market in general have been reconfigured.

Thus, Industry 4.0 came to disrupt the idea of conventional processes and decision-making, bringing new concepts and technologies for the evolution of society. As a result of this highly automated environment that Industry 4.0 provides, attention has turned to manufacturing and the human being has taken a back seat for a moment.

According to [12] the digitalization associated with Industry 4.0 is bringing new challenges and opportunities for occupational health, safety, and productivity for worker well-being. With this motivation, researchers have begun to study Industry 5.0. The introduction of Industry 5.0 announced in 2021 by the European Commission, complements the existing paradigm of Industry 4.0 and revolves around three core values: sustainability, human-centricity and resilience [2].

In the context of the new development concept of Industry 5.0, it is prepared to harness extreme automation and Big Data with safety, innovative technology policy and responsible implementation science, enabled by 3D symmetry in the design of the innovation ecosystem [11].

Thus, Industry 5.0 strives to introduce innovation beyond industry and thus build a society that contributes to economic growth and social well-being [4].

As most existing frameworks are not yet adaptable enough to integrate humans into a technological production, this study is important for practitioners and researchers to understand where Industry 5.0 is heading and how it is relating to risk management.

Thus, this paper aims to analyze the content and metrics related to publications on Industry 5.0 and risk management. To do so, this study used the occurrence of a combination of keywords in the Scopus database search. Content analysis of the 47 materials returned from the search was performed using the NVIVO tool and for analysis of other metrics the VOSviewer software was used.

By investigating what is being published on these topics, it is possible to provide a holistic view for other researchers who wish to contribute to research in areas like this, emerging, but still with few published studies. From this, the study is justified by the need to understand the Industry 5.0 scenario associated with the Risks it can cause in different spheres. The study is also justified for being one of the first to work with the themes of Risk Management and Industry 5.0, which will certainly open up new research possibilities.

2 Theoretical Background

After three industrial revolutions that resulted in mechanization, electricity and information technologies, the fourth industrial revolution has emerged. The term Industry 4.0, according to [3], was first used by the German government, marked by the Physical, Digital and Biological revolution.

Industry 4.0 brought a concept of intelligent manufacturing, whose main goal is to maximize productivity and achieve mass production using high technology. According to [13] the key elements of Industry 4.0 are its nine enabling technologies: Big data; Artificial Intelligence; Virtual Reality; Horizontal and vertical system integration; Internet of Things; Cybersecurity; Cloud Computing and Augmented Reality.

Currently, all developed countries in the world are directing efforts at applying digitalization in industry. Consequently, this has some impacts. The main areas influenced by Industry 4.0 are identified in Figure 1.

Starting from the assumption that Industry 4.0 focuses less on the original principles of social justice and sustainability and more on digitalization and productivity-oriented technologies, the 5th industrial revolution brings the expected response to some of the impacts generated by the fourth industrial revolution [15].

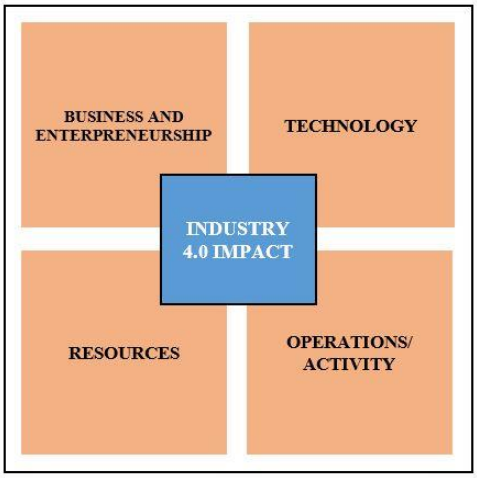

Fig. 1. Areas impacted by Industry 4.0. Source: Adapted [8].

The fifth industrial revolution highlights the importance of developing manufacturing within the limits of the planet and is characterized by the search for a more sustainable economy, more flexible and resilient industry, centered on human beings and their well-being, as shown in Figure 2.

Fig. 2. Industry 5.0 Values. Source: [2].

According to [9] Industry 5.0 is constituted of more sustainable technological workplaces through digitalization, artificial intelligence and robotics, optimizing human-machine-robot interactions and supporting the empowerment of human beings rather than their replacement.

With this, industry 5.0 promotes [14]:

- Advanced Automation: Industry 5.0 uses advanced automation technologies making production more flexible and optimized;
- Mass customization: Industry 5.0 enables the mass production of customized products to meet specific customer needs;
- Better human-machine interaction: Industry 5.0 seeks to use technology to improve workers' quality of life and ensure greater interaction between humans and machines;
- Integration of the production chain: industry 5.0 seeks to integrate the entire production chain;
- Greater sustainability: Industry 5.0 aims to reduce the environmental impact of industrial production through the use of cleaner and more sustainable technologies and the adoption of more responsible production practices.

Consequently, Industry 5.0 also shows its concern for the stress of human-machine cooperation, as well as proposing solutions and management of psychosocial risks, aiming at the well-being of the worker in the workplace.

Risk management becomes a crucial element for the success of Industry 5.0 since the integration of advanced technologies can bring new cybersecurity and data privacy challenges. Likewise, it can bring new risks to the occupational safety of workers and to the physical integrity of machines and equipment.

To deal with these risks, risk management in industry 5.0 must be approached in an integrated manner, including the adoption of risk mitigation and control measures, such as remote monitoring and diagnosis systems, access control and user authentication, systems redundancy and data backup, training for work and security teams and the use of advanced failure detection and prevention technologies.

Thus, it can be said that Industry 5.0 puts human beings at the center and restructures their tasks in the manufacturing domain in order to benefit workers and mitigate risks[8].

3 Methodology

This study performed a content analysis of publications on Industry 5.0 and its relationship with risk management. For this, the study used the occurrence of a combination of keywords in the search field of the Scopus database, and the string used, is presented in Table 1.

Table 1. Search String.

String	Search Field	Returned Items
("Industr* 5.0" OR "Fifth Industrial Revolution" OR "5th Industrial Revolution" OR "Human-centric manufacturing" OR "Human-cyber-physical" OR "Society 5.0") AND (Risk*)	Title, abstract, keywords	64

A chosen database was Scopus because it has some advantages over other databases. It has a wide scope, is one of the largest multidisciplinary databases in the world, has a large number of citations, uses a rigorous indexing system, which includes peer reviews and manual checks, ensuring that the records are accurate and up to date, offers several tools for advanced analysis, in addition to having an intuitive interface and being easy to use. Therefore, it returns a series of articles that also cover searches from other databases.

Content analysis is a widely used qualitative research technique [7]. This method helps to verify the frequency of certain terms or topics, facilitating the identification of the content and characteristics of information present in the text [6]. Content analysis is divided into three different phases as shown in Figure 3.

Some metrics of the 64 materials returned from the search were analyzed in the Scopus database itself and with the help of VOSviewer.

Content analysis was performed on 47 of the 64 materials returned, only those that were not available for download were excluded.

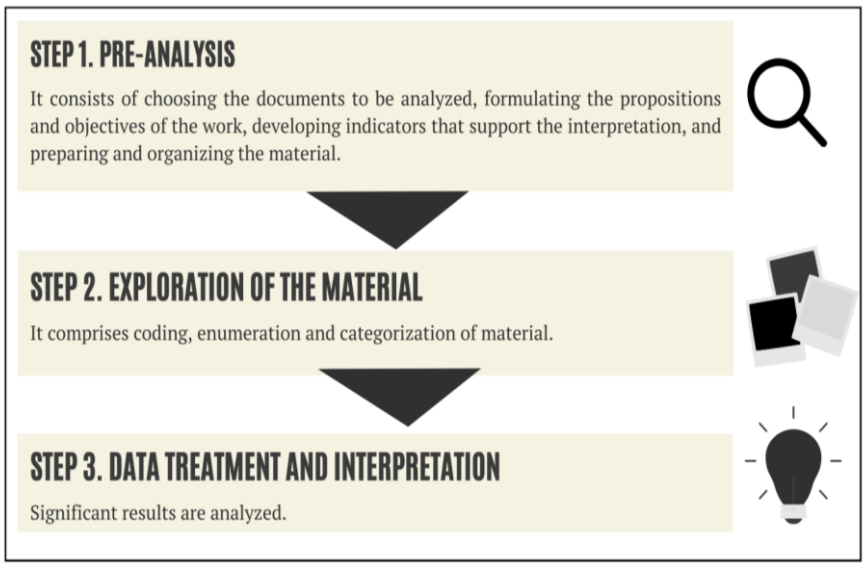

Fig. 3. Phases of content analysis. Source: Adapted [1].

NVIVO is a qualitative research support software that allowed us to organize, evaluate, and interpret the collected data. VOSviewer helped in the construction and visualization of bibliometric and key-word networks.

4 Results and Discussion

From the return of the articles in the database, the main indicators and metrics were analyzed to verify how the themes Industry 5.0 and Risk Management are being discussed. Thus, the first analysis made was in relation to the year of publication of these studies. The objective of Figure 4 is to present the evolution of publication as well as the number of articles published over the years.

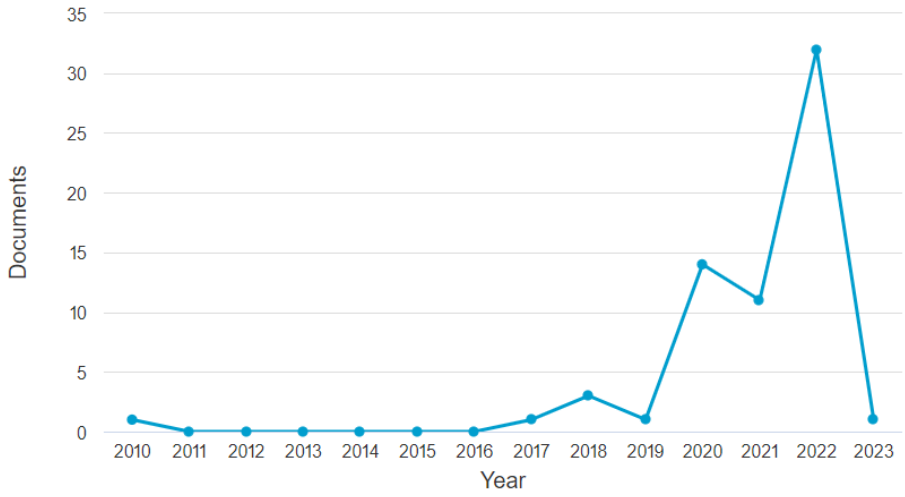

Fig. 4. Publications over the years.

It is observed with Figure 4 that the publications started in 2017 and there is an increase since then. In the year 2022, they had 32 articles (which corresponds approximately to 49% of the total articles) published in the database, while, in the year 2021 they had only 11 articles published (17% of the total articles).

The results found show that researchers have turned their eyes to the theme of Industry 5.0 associated with the risks that may arise from the consolidation of Industry 5.0, so studies in this area are needed to understand what will change in the coming years.

Thus, it was also investigated which countries stand out in the publications related to the themes. Therefore, the objective of Figure 5 is to present the scenario of publications from their respective countries of origin.

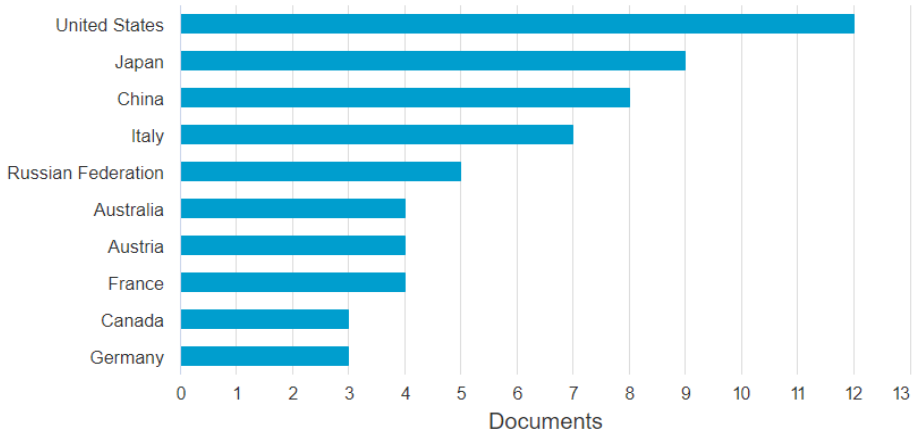

Fig. 5. List of countries that publish the most on this subject.

In Figure 5 shows that the United States, Japan and China are the countries with the largest number of publications on the subject, presenting, 12, 9 and 8 articles, respectively, in each of the countries. This shows that great powers seek to understand the Industry 5.0 scenario and have been the forerunners of studies worldwide.

It was also investigated in which areas of knowledge these articles were published. Therefore, the objective of Figure 6 is to present which areas of knowledge are highlighted.

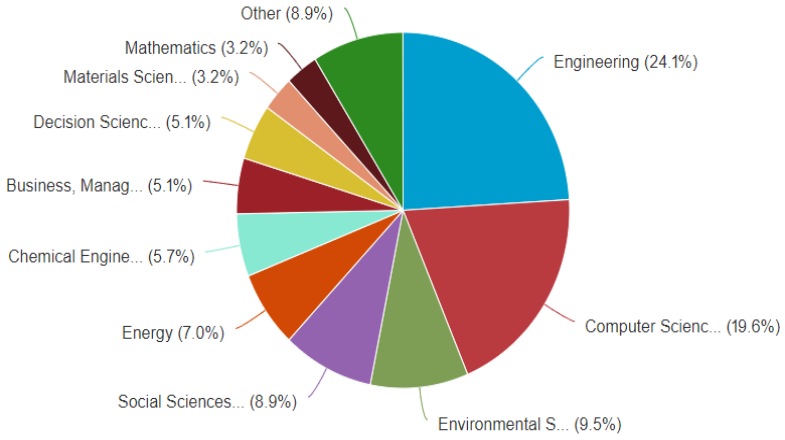

Fig. 6. Publications by area of knowledge.

In Figure 6 it is possible to observe that Engineering is the area that most publishes on the subject, followed by Computer Science and Environmental Science. It can be

seen how the concepts of Industry 4.0 and now also Industry 5.0 are interdisciplinary, several areas of knowledge have shown interest in publishing studies involving the themes, which infers that Production Engineering is also a major propeller of the concepts of Industry 5.0.

After the first analysis of the studies that returned from the database search, the next step was to verify the network analyses performed using the VOSviewer software. Therefore, the objective of Figure 7 is to present the network in relation to the key words most used and found in the studies found, as well as the link between these words.

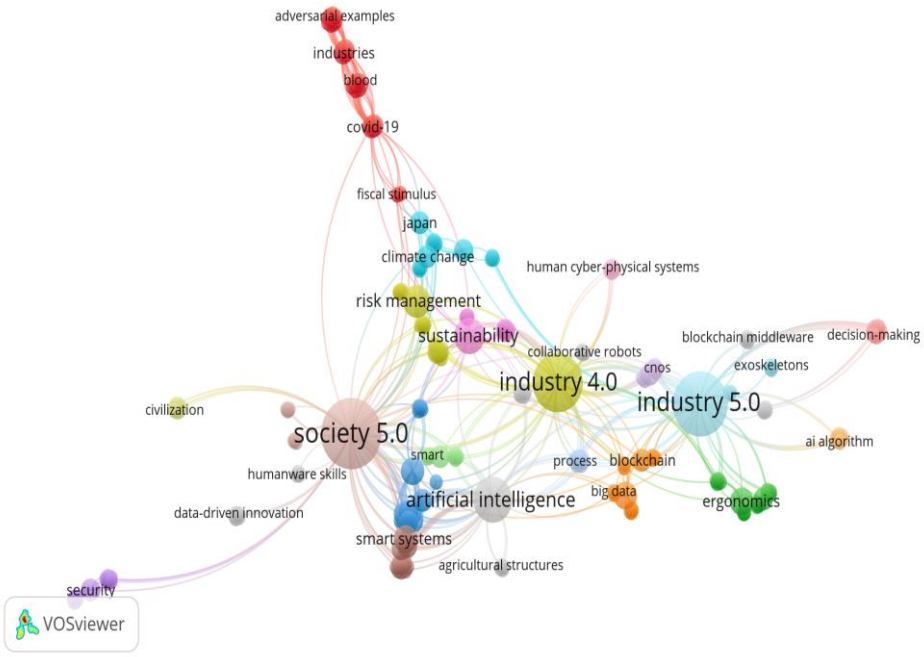

Fig. 7. Network Analysis of Keywords.

It can be observed from Figure 7 that the software identified 237 items subdivided into 25 different clusters, where the most found term is in line with the keywords used in the searches, which in this case were Industry 5.0 and Society 5.0, these terms being in the center of Figure 7, which shows that they have links to all other keywords. This proves that the keywords defined for this study were consistent.

It was also possible to identify the network built from the most cited authors. Therefore, Figure 8 aims to show which are these most cited authors.

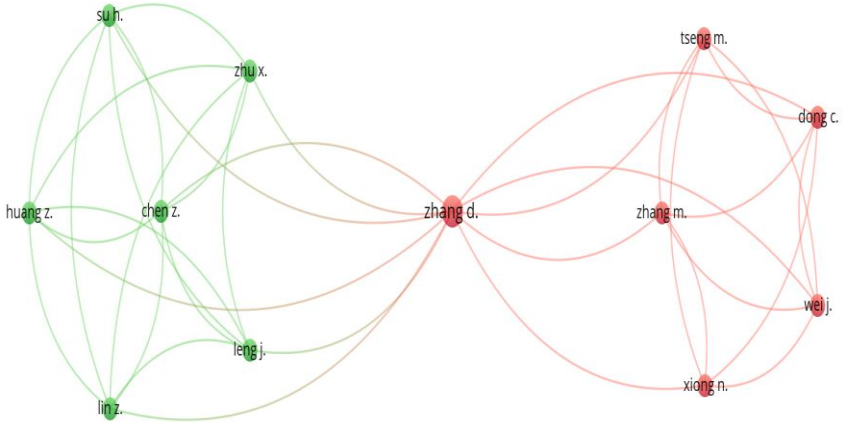

Fig. 8. Authors' Citation Analysis Network.

For portfolio analysis, a total of 47 articles were analyzed, and these articles were available for download. For the analyses performed, the NVIVO® version 12, software was used, which organizes, stores and analyzes the data of the selected scientific articles, allowing the achievement of robust results in less time. From the software it was possible to generate a word cloud, which allows a broad visualization of the trends of the portfolio, the generated word cloud can be checked in Figure 9.

Fig. 9: Word cloud.

The most mentioned words are digital (0.30%), insurance (0.53%), data (0.55%), risk (0.37%), industry (0.40%), and smart (0.30%), totaling 2.45% of the total analyzed.

The results show that risk has been researched along with Industry 5.0, so a deeper analysis of how these risks have influenced the theme of Industry 5.0 is needed.

From the definition of the authors, the analysis of the main themes present was performed, the graph generated by the program can be seen in Figure 10.

Fig. 10. Topic Hierarchy.

As observed, the nine themes mentioned above have a significant presence due to many citations; the themes information, development, work, analysis, manufacturing, research, and digital also stand out.

There is a strong presence of themes that refer to Industry 4.0, such as systems and data, which are taken to Industry 5.0 and improved. The theme "human," which refers to human interactions and their consequences, appears as one of the themes with the highest number of references, which is expected and essential since it is one of the studies focuses of Industry 5.0.

The second analysis performed was the sentiment analysis of the articles, which was conducted by analyzing the sentences in the papers. As a result, a total of 5117 positive references were found, with a total of 1196 being very positive and 3921 being moderate. The software also found 5306 negative references, with 3453 being moderate and 1853 very negative.

From this analysis, we perceive the predominance of themes such as system, data and process. The program also allows the analysis of each theme with its main subthemes. In this analysis, 9 themes that have more than 200 mentions in their total, the relationship of these 9 themes with their main subthemes (those with more than 10 mentions) can be seen in Table 2.

Table 2. Topic Analysis.

Themes	Main Sub themes (> 10 mentions)	Mentions
System	cyber-physical system; computing system; physical system	457
Data	big data; data collection	421
Technologies	Advanced technologies; emerging technologies; communication technologies; technological innovations. Digital technologies	317
Process	Production process	312
Risk	Risk assessment	298
Model	N.A	296
Production	Production line; production processes	278
Human	Human factors	214
Management	N.A	213

System: refers to the creation of organizational systems that assist in the transformation of production and the integration of the digital environment with the physical environment.

Date: encompasses the creation and use of the data created by the productive system, since its creation, storage, analysis and destination.

Technologies: it concerns the different technologies available and their applications, the theme of emerging technologies, which correspond to the use of innovative technologies, stands out in this category.

Process: encompasses the processes present in the production process, such as decision making, the manufacturing process itself and areas of data processing.

Risk: includes the risks present in the adoption of a new paradigm and the risks loaded with the old production models.

Model: the different models proposed by the literature to standardize and facilitate the transformational process.

Production: encompasses production steps and models, such as sustainable models and mass production, and includes product models such as digital, innovative products and essential products.

Human: encompasses human factors and all their interactions (interactions between people, interaction with the environment and human-machine interactions), as areas of well-being and interaction, which are the differential and focus of Industry 5.0.

Management: includes the management of the main areas of production and its entire production chain, in addition to including the management of knowledge and information generated by the company.

As noted, the 9 themes mentioned above have a large presence due to the large number of citations, also highlighting the themes information, development, work, analysis, manufacturing, research and digital.

This analysis highlights the strong presence of themes that refer to Industry 4.0, such as systems and data, which are taken to Industry 5.0 and improved. The theme "human", which refers to human interactions and their consequences appears as one of the themes with the highest number of references, which is expected and important, since it is one of the focuses of the Fifth Industrial Revolution.

There is a strong presence of themes that refer to Industry 4.0, such as systems and data, which are taken to Industry 5.0 and improved. According to [5], although Industry 4.0 brought great benefits to the efficiency of production means and their performance, it has also brought about a phenomenon of dehumanization, causing concerns from workers, government, and even society as a whole. With this in focus, Industry 5.0 seeks to focus on the interaction between humans and machines [11], bringing workers back into the production chain, further improving the human-machine interface, and countering the idea brought by Industry 4.0 that production means would be totally independent of human labor, reintroducing workers as an essential part of the production process [10].

The theme "human", which refers to human interaction and its consequences, appears as one of the themes with the highest number of references, reinforcing the discussion brought by Industry 5.0, placing the human being as the main focus.

The second analytical procedure undertaken involved conducting a sentiment analysis of the articles by scrutinizing the sentences contained therein. The findings of this analysis revealed a total of 5117 positive references, of which 1196 were categorized as highly positive, while 3921 were classified as moderately positive. Similarly, the software detected 5306 negative references, with 3453 falling under the category of moderately negative, and 1853 being classified as highly negative. These results serve to bolster the rigor and comprehensiveness of our analysis.

5 Conclusion

This study aimed to analyze the contents and metrics related to publications on Industry 5.0 and risk management. To achieve the objective, it was first necessary to conduct a search in the Scopus database to find the number of articles published in relation to Industry 5.0 and risk management.

The result of the search was 64 articles that were used for the analyses in the Scopus database and in the VOSviewer software. For the analyses performed using NVIVO, 47 articles that were available for download were considered.

It was identified that the publications over the years on Industry 5.0 and Risk Management have been growing and the countries that have published the most on the subject so far are the United States, Japan and China. With the help of the VOSviewer software, the network of keywords formed by the selected articles was identified and

later the most cited authors were identified from the citation network, highlighting Zhang.

Finally, content analysis was performed using NVIVO software, which allowed the identification of the coding of the themes that appear most in the selected articles, as follows: System, Data, Technologies, Risk, Model, Production, Human and Management. These themes were also presented in a hierarchical order chart. Finally, a word cloud was also generated. With this such results the objective of this study was achieved since it investigated the publications on Industry 5.0 added to Risk Management. It is known that the theme is still emerging, and that detailed studies must be developed, this being one of the pioneers in relation to the subject.

With the conclusion of the study, it can be seen that Industry 5.0 is considered as an extension of Industry 4.0 whose central focus is to provide better working conditions. The focus of Industry 5.0, unlike Industry 4.0, is the human being and not the implementation or development of technologies. This will change the entire work management as well as the technical and behavioral skills required of workers.

Furthermore, Risk Management in this Industry 5.0 scenario can help reduce uncertainties, in addition to providing a better analysis of what will change with the advent of Industry 5.0. It is understood that the theme of Industry 5.0 and Risk Management is still little explored, which confirms that new studies must be developed.

Based on the results obtained, it is suggested as future works: (i) conduct a bibliometric analysis in order to deepen the discussion of studies on Industry 5.0 and Risk Management; (ii) Map which are the main risks arising from Industry 5.0; (iii) Propose a study agenda to propagate the concepts of Industry 5.0 and its interfaces and (iv) Assess the risks arising from Industry 5.0 seeking to mitigate its effect on organizations.

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Appendix – Studies Uses

	ARTICLE NAME	AUTHORS
1	A Time-Sensitive Token-Based Anonymous Authentication and Dynamic Group Key Agreement Scheme for Industry 5.0	Xu *et al.*, (2021)
2	A Complex Hybrid Model for Evaluating Projects to Improve the Sustainability and Health of Regions and Cities	Kelemen; Gavurova; Polishchuk, (2022)
3	A Mixed Reality-Based Platform Towards Human-Cyber-Physical Systems with IoT Wearable Device for Occupational Safety and Health Training	Li *et al.*, (2022)
4	An Adaptive Enterprise Architecture Design for a Digital Healthcare Platform Toward Digitized Society – Industry 4.0, Society 5.0	Masuda *et al., (*2021)
5	An Adoption-Implementation Framework of Digital Green Knowledge to Improve the Performance of Digital Green Innovation Practices for Industry 5.0	Yin; Yu, (2022)
6	An Integrated Approach to Sustainable Development, National Resilience, and COVID-19 Responses: The case of Japan	Dewit; Shaw; Djalante, (2020)
7	An Intelligent Classification Diagnosis based on Blood Oxygen Saturation Signals for Medical Data Security Chain Including COVID-19 in Industry 5.0	Zhang *et al.*, (2022)
8	Applications of Artificial Intelligence in Fire Safety of Agricultural Structures	Maraveas *et al.*, (2021)
9	Architecture-Level Particular Risk Modeling and Analysis for a Cyber-Physical System with AADL	Xiao *et al.*, (2020)

10	A Scientometric Analysis of Studies on Risk Management in Construction Projects	Osei-Kyei; Narbaev; Ampratwum, (2022)
11	Benefit of Wearable blood Pressure Monitoring Device in Society 5.0	Kishi (2022)
12	Birth of Industry 5.0: Making Sense of Big Data with Artificial Intelligence, "The Internet of Things" and Next-Generation Technology Policy	Özdemir; Hekim, (2018)
13	Citizen Science in the Promotion of Sustainability: The Importance of Smart Education for Smart Societies	Sá; Serpa; Ferreira (2022)
14	Creating Quality-Based Smart Sustainable Public Parking Enterprises: A Methodology to Reframe Organizations into Smart Organizations	Todorović *et al.*, (2022)
15	Deep Fusion: Crafting Transferable Adversarial Examples and Improving Robustness of Industrial Artificial Intelligence of Things	Wang *et al.*, (2022)
16	Digitalizing Occupational Health, Safety and Productivity for the Operator 4.0	Romero *et al.*, (2018)
17	Disaster and Climate Change Issues in Japan's Society 5.0 - A Discussion	Mavrodieva; Shaw, (2020)
18	Enhancing the Decision-Making Process through Industry 4.0 Technologies	Rosin *et al.*, (2022)
19	Enterprise Architecture Resilience by Design - A Method and Case Study Demonstration	Aldea *et al.*, (2021)
20	Fundamental Theories and Key Technologies for Smart and Optimal Manufacturing in the Process Industry	Qian; Zhong; Du, (2017)
21	Future Security Challenges for Smart Societies: Overview from Technical and Societal Perspectives	Aldabbas *et al.*, (2020)
22	Governance of Collaborative Networked Organisations: Stakeholder Requirements	Tagarev (2020)
23	Harnessing Risk-Informed Data for Disaster and Climate Resilience	Fakhruddin *et al.*, (2022)
24	Impact of Cybersecurity on Operations and Supply Chain Management Emerging trends and Future Research Directions	Kumar; Mallipeddi, (2022)
25	Knowledge and Skills Development in the Context of The Fourth Industrial Revolution Technologies Interviews of Experts from Pennsylvania State of the USA	Saniuk; Grabowska; Grebski, (2022)
26	Known Unknowns in an Era of Technological and Viral Disruptions—Implications for Theory, Policy, and Practice	Carayanni *et al.*, (2022)
27	Lightweight Mutual Authentication and Privacy-Preservation Scheme for Intelligent Wearable Devices in Industrial-CPS	Jan *et al.*, (2020)
28	Microbial Exposure Assessment in Sawmill, Livestock Feed Industry, and Metal Working Fluids Handling Industry	Park; Park; Lee, (2010)
29	Modified Lampert Merkle Digital Signature Blockchain Framework for Authentication of Internet of Things Healthcare Data	Mehbodniya *et al.*, (2022)
30	Occupational Safety and Health 5.0 - A Model for Multilevel Strategic Deployment Aligned with the Sustainable Development Goals of Agenda 2030	Ávila-Gutiérrez; Miranda; Aguayo-González, (2022)
31	Preparation of Papers for IFAC Conferences & Symposia Computer Vision-enabled Human-Cyber-Physical Workstation for Proactive Ergonomic Risks Mitigation	Ling *et al.*, (2021)

32	Impact of Cybersecurity on Operations and Supply Chain Management: Emerging Trends and Future Research Directions	Kumar; Mallipeddi, (2022)
33	Re-engineering Process in a Food Factory an Overview of Technologies and Approaches for the Design of Pasta Production	Massaro; Galiano, (2020)
34	Resilience Learning through Self Adaptation in Digital Twins of Human Cyber Physical Systems	Bellini *et al.*, (2021)
35	Safety Assurance in Human Robot Collaborative Systems - A Survey in the Manufacturing Industry	Segura *et al.*, (2022)
36	Science, Technology and Innovation Ecosystem Transformation Toward	Fukuda (2020)
37	Secure Blockchain Middleware for Decentralized IIoT Towards Industry 5.0: A Review of Architecture Enablers Challenges and Directions	Leng *et al.*, (2022)
38	Smart Factory Floor Safety Monitoring Using UWB Sensor	Islam; Lee; Kim, (2022)
39	Smart Society and Artificial Intelligence: Big Data Scheduling and the Global Standard Method Applied to Smart Maintenance	Foresti *et al.*, (2020)
40	Smart Technology and Circular Economy for a Greener World and Resilient Society	Schoitsch (2022)
41	Society 5.0: A Self-Devouring System	Nurullin (2019)
42	Sustainable Development of the Intelligent Industry from Industry 4.0 to Industry 5.0	Majerník et al., (2022)
43	The role of digital technologies in supporting and improving fishery and aquaculture across the supply chain – Quo Vadis?	Rowan *et al.*, (2020)
44	Thirty Years of Science Technology and Academia in Disaster Risk Reduction and Emerging Responsibilities	Shaw (2020)
45	Towards Industry 5.0 A Multi Objective Job Rotation Model for an Inclusive Workforce	Battini et al., (2022)
46	Towards Forklift Safety in a Warehouse: An Approach Based on the Automatic Analysis of Resource Flows	Cantini; Carlo; Tucci, (2020)
47	Work Planning in Low-Volume Assembly Lines Under Ergonomic Constraints	Arkhipov (2020)