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Sustainability: the main pillar of Industry 5.0

Hassane ZAOUI[a], Samia ZAOUI[a], Bernard KAMSU-FOGUEM[a], Dieudonné TCHUENTE[b]
[a]LGP-ENIT- UTTOP, INPT, Université de Toulouse, 47 Avenue Azereix, BP 1629, 65016 Tarbes, France
[b]TBS Business School, Information, Operations and Management Sciences Department, Place Alphonse Jourdain, 31068, Toulouse, France

ABSTRACT

The implementation of sustainability principles into Industry 5.0 is crucial in the face of climate change and rising global environmental issues. This study aims to analyze the interaction between Industry 5.0 and sustainability. The review of 464 papers extracted from the Scopus database demonstrates the increasing annual scientific production and illustrates the growing interest in the topic by researchers and scholars. The analysis of clusters provides scope on the dimensions of Industry 5.0 and sustainability with the domination of the environmental aspects like climate change, energy efficiency, environmental impact and sustainable development. The importance of the digital technology is also revealed.

Keywords: Sustainability, Industry 5.0.

I. INTRODUCTION

Industry plays a crucial role in the dynamics of the global economy. In 2022, industry contributed approximately 27.22 percent to the global gross domestic product (GDP). It is ranked second after the sector of services, which has contributed about 63.97 percent to the global gross domestic product (Statista, 2024). Since its beginning, the industry has undergone several revolutions that culminated with the industry 5.0 paradigm. To continue fostering prosperity, the industry must lead the digital and green transitions, prioritizing the well-being of workers and leveraging new technologies while being mindful of the planet's limits. This approach aims to create a sustainable, human-centered, and resilient industry (European Commission, 2024).

Furthermore, Industry 5.0 admits the ability to achieve societal objectives that extend beyond just creating jobs and economic growth. It aims to revolutionize production in a manner that considers the constraints of our planet and prioritizes the well-being of industry workers in the production process (Directorate-General for Research and Innovation, European Commission, 2021). According to Ivanov (2023), Industry 5.0 incorporates resilient, sustainable and human-centric technologies, organizational concepts, and management principles to design and manage cost-efficient, responsive, and adaptable systems. These systems protect the provision of products and services sustainably and humanly by rapidly reorganizing mechanisms and aptitudes (Ivanov, 2023).

Industry 5.0 prioritizes significant human contribution and interaction, pointing to combining the strengths of human workers with technological progress. This change is a leaving from the mainly technology-centric focus of Industry 4.0. On the other hand, sustainability is becoming a common word in the environmental strategy and research field. Sustainability is being seen as a goal to aim for in the realms of development and environmental management. This concept has been employed in many different fields and situations, from the idea of achieving the highest sustainable yield in the management of forests and fisheries to the aspiration of creating a stable society with a steady-state economy (Brown et al., 1987).

United Nations Brundtland Commission (1987) gives the most cited definition of sustainability. Sustainability refers to satisfying the current necessities while ensuring the potential for future generations to achieve their own needs (United Nations, 2024).

In 1994, the “triple bottom line” concept was coined by Elkington as a sustainability framework that studies a business’s social, environmental, and economic impact. According to Elkington (2018), accountants and consultants have diluted the Triple Bottom Line (TBL) concept. Although thousands of TBL reports are produced annually, it's unclear if the resulting data are effectively used to help decision-makers and policymakers understand and manage the systemic effects of human activity (Elkington, 2018).

Sustainability forms one of three pillars of Industry 5.0. It aims to establish an industrial landscape that is more focused on environmentally friendly. Essential points emphasizing its significance include optimizing resources and promoting adaptability and environmental responsibility.

II. BACKGROUND

The Global Goals, also known as the Sustainable Development Goals (SDGs), were globally adopted by the United Nations in

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2015 to rally efforts to eradicate poverty, safeguard the planet, and ensure universal peace and prosperity by 2030. With 17 SDGs in total, each focuses on a distinct facet of sustainable development. These goals are interlinked and attempt to harmonize social, economic, and environmental sustainability.

The framework for enhancing the well-being of global populations and reducing the harmful human-induced impacts of climate change is provided by the Sustainable Development Goals (United Nations, 2024).

The idea of sustainable development encompasses various aspects and aims to balance economic progress, justice in society and the protection of the environment. Its goal is to accomplish current needs without obstructing the capacity of future generations to fulfill their own needs. The concept of sustainable development emphasizes the fair treatment of both present and future generations, which is based on three distinct but interconnected aspects: the environment, the economy, and society (Mensah, 2019).

The concept of the circular economy involves a production and consumption model to prolong the lifespan of products, minimize waste, and encourage sustainable use of resources. This is achieved through strategies such as eliminating waste and pollution during the design phase of products. The focus is on utilizing materials that are both safe and sustainable, as well as designing products that can be easily taken apart and recycled. Additionally, the circular economy emphasizes the continued use of products and materials to maintain their value for as long as possible. This includes practices such as recycling, reusing, refurbishing, and remanufacturing.

Another principle involves revitalizing natural systems by reintroducing valuable nutrients to the soil and other ecosystems. This can be achieved through activities like composting organic waste and implementing regenerative agricultural methods. The transition to renewable energy sources is also essential for powering circular economy initiatives, reducing reliance on fossil fuels, and lowering greenhouse gas emissions. Furthermore, businesses are encouraged to adopt models that align with circular economy principles, such as offering products as services, where customers can lease or rent items instead of purchasing them outright. By integrating these principles, the circular economy aims to establish a more sustainable and resilient economic system (European Parliament, 2023).

III. FINDINGS

The search, on the 27th of august 2024, in the Scopus database about the topic Industry 5.0 and sustainability find 464 documents. Only results of the papers written in English language and related to Computer Science, Engineering, Business, Management and Accounting, Environmental Science, Economics, Econometrics and Finance and Decision Sciences was included after filtering. The documents found are from 2019 to 2024.

Figure 1 shows the annual scientific production from 2019 to 2024. Since 2019 the number of publications per year was increased significantly +354% in 2022 in comparison with 2021 and + 193% in 2023 compared to 2022.

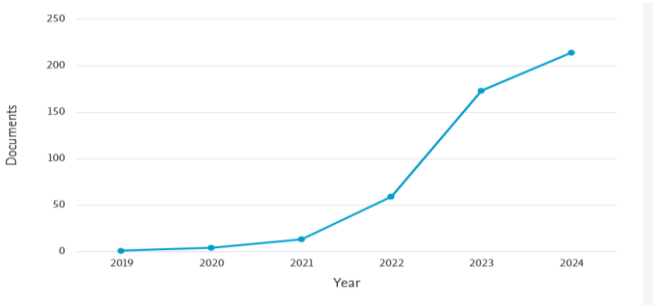

Figure 1. Annual scientific production.

Table 1 related to documents by source displays that Sustainability is in the first position with 34 papers followed by IFIP Advances in Information and Communication Technology with 19 documents and Lecture Notes in Mechanical Engineering with 15 papers.

Table 1. Documents by source.

Source	Documents
Sustainability Switzerland	34
IFIP Advances In Information And Communication Technology	19
Lecture Notes In Mechanical Engineering	15
Procedia Computer Science	10
Lecture Notes In Networks And Systems	9
IEEE Access	8
Computers And Industrial Engineering	7
Energies	7
Journal Of Cleaner Production	7
Sensors	7

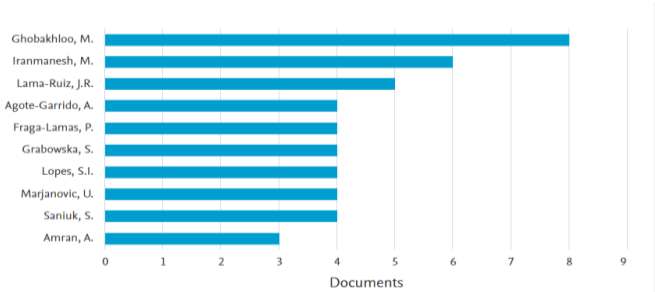

Figure 2 related to the Most relevant author shows that

Ghobakhloo with 8 papers is ranked first followed by Iranmanesh with 6 papers and Lama-Ruiz with 5 papers.

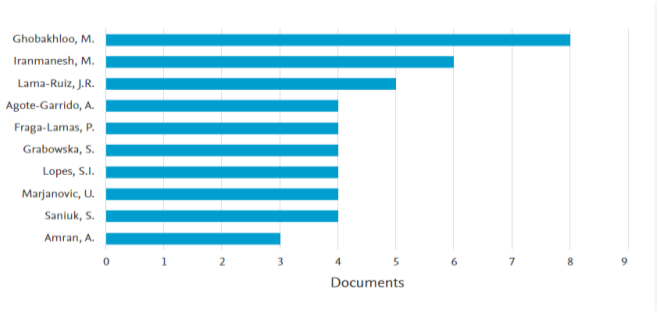

Figure 2. Most relevant author.

Figure 3 on documents by type displays that the article category is in the first position with 184 documents followed by conference paper with 132 documents and book chapter with 73 documents.

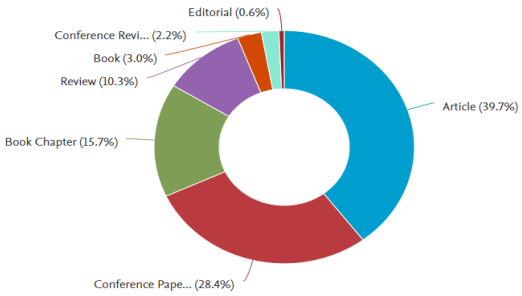

Figure 3. Documents by type.

Figure 4 presents co-occurrence. To understand the topics associated with literature related to sustainability and Industry 5.0 and identify the clusters associated with this topic, we used Vos Viewer software. 6 clusters encompassing 140 items was identified.

Cluster 1, with a red color, is composed of 43 items. The keywords encompassed by this cluster are related to industrial research, embedded systems, collaborative robots, cyberphysical systems, digital technologies and deep learning. Cluster 2, with a green color, comprised keywords regarding advanced technologies, the automotive industry, automation, big data and digital storage. Cluster 3, with a purple color, encompasses 25 items like industrial revolutions, the internet of things, decision-making, climate change and blochchain. Cluster 4, with an orange color, comprises 19 items like industry 5.0, sustainability, manufacturing, innovation and maintenance. Cluster 5, with a blue color, is composed of 18 items like sustainable development, digital transformation, supply chain, circular economy and human-centricity. Cluster 6, with an azure color, comprises 9 items like cost-effectiveness, production systems and technology.

The keywords distribution on clusters provides a wide scope on the dimensions of industry 5.0 and sustainability with the domination of the environmental aspects like climate change, energy efficiency, environmental impact and sustainable development Furthermore, the main tendency to be noted is related to digital technology group which comprises artificial intelligence, digital twin, deep learning, data analytics and blockchain.

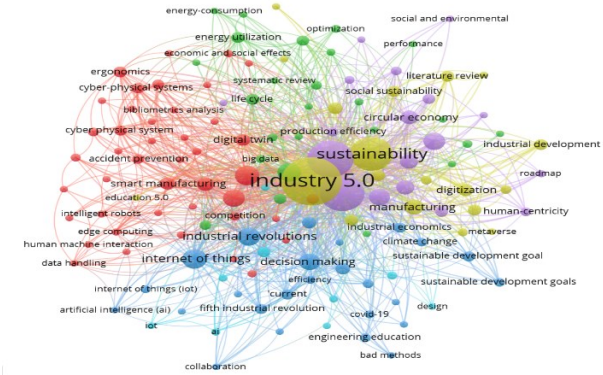

Figure 4. Co-occurrence

Sustainability: a main pillar of industry 5.0

Sustainability is connected with industry 5.0 by a strong link. The interplay between the two concepts is justified by the place of sustainability as a core of industry 5.0. The interplay of Industry 5.0 and sustainability represents a significant change towards a more human-centric and friendly environmental approach. It emphasizes worker well-being, prosperity through new technologies and respect for the limits of resources on the planet. Industry 5.0 aligns with the Sustainable Development Goals (SDGs) and can play a pivotal role in addressing various SDGs. Implementation of circular economy principles within industrial processes and product design is essential to the intersection of Industry 5.0 and sustainability for improving the contribution to sustainable production and consumption.

In the path traced by The European Commission on Industry 5.0, the subject matter was an area of significant interest for many researchers and scholars making it a captivating subject for exploration. However, the belief that Industry 5.0 has the potential to go beyond the profit-centered productivity of Industry 4.0 and promote sustainable development goals is in contrast to the insufficiency of studies to understand how this may deliver its intended sustainability values (Ghobakhloo et al., 2022). Furthermore, Industry 5.0 has led to the development of environmentally friendly projects, services, and products, but research on its sustainability is in its early stages (Baig & Yadegaridehkordi, 2024). On the other hand, there is still uncertainty about the definition of Industry 5.0, its scope, technological components, design principles, and intended values (Ghobakhloo et al., 2023).

Findings of studies focus on the concept's signification. The study revealed that Industry 5.0 has 16 functions that contribute to sustainable development values. These functions, such as circular intelligent products, employee technical assistance, and open sustainable innovation, should be developed in a specific order to maximize their synergies and contribution to sustainability. The roadmap developed in the study aims to provide a better understanding of Industry 5.0's role in sustainable development (Ghobakhloo et al., 2022).

Furthermore, the findings reveal that Industry 5.0 represents the future of industrial transformation, offering potential solutions to socioeconomic and environmental issues that were inadequately addressed or exacerbated by Industry 4.0. The study provides managers, industrialists, and policymakers with a comprehensive overview of Industry 5.0, including its technological constituents, design principles, and smart components (Ghobakhloo et al., 2023).

On the other hand, many authors emphasize the technology role. The research shows that Industry 5.0 technologies, such as the Internet of Things, artificial intelligence, and collaborative robots, are increasingly used for sustainability (Baig & Yadegaridehkordi, 2024). Another article emphasizes the potential of AI, IoT, and blockchain in creating a sustainable industrial future. These technologies enable operational efficiency, resource conservation, and adaptability to environmental and socioeconomic changes. Blockchain provides enhanced data transparency and security for accountable supply chains (Rame et al., 2024).

The main dimensions of industry are highlighted like technological principles which include collaboration, coordination, communication, automation, data analytics processing, and identification. Secondly, Industry 5.0 covers organization, management, technology, and performance assessment. Thirdly, it spans the society level, network level, and plant level. Finally, it frames a new triple bottom line: resilient value creation, human well-being, and sustainable society (Ghobakhloo et al., 2023).

IV. Conclusion

The interactions of Industry 5.0 and sustainability emphasize many dimensions like respect for planetary resources, a human-centric approach and worker well-being. The alignment with Sustainable Development Goals (SDGs) is the main challenge. Industry 5.0 promises to bring a new era to the industrial revolution by recommending the implementation of sustainability in industrial systems. However, the trajectory to achieving sustainability in Industry is hindered by many barriers that need to be addressed. Among them, we can enumerate the necessity to innovate and implement new production systems compatible with renewable energy. Another barrier is the technological dimension related to the choice of the most efficient digital technologies while taking into account their compatibility and interoperability.

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