

Digitalization and Sustainability: New Technologies, Challenges and Trends

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Abstract. *The purpose of the paper is to analyze the digitalization and sustainability. Political tensions, lack of natural resources, job market changes, socioeconomic outcomes that are now different from year to year are creating here the need for understanding the main problem and also opportunities that will appear if the digital-sustainable adoption is implemented correctly.*

The existence of new technology and projects such as the Digital Maturity Model or PROMES Systems project are just a few examples that validate the research in importance and relevance. A bibliometric research had been conducted, validating the importance of these two global directions by answering the following situations: observing the impact of the digitalization and sustainability concepts by comparing the numbers of articles about the subject to the ones written before Covid, presenting the actual and current trends from Digitalization and Sustainability in different industries, discovering if there are any challenges within the process of implementation of Digital and Sustainable methods.

The paper offers a complex overview of the global adoption to the new way of working and living by creating a clear view of the level of acceptance by years, countries, and industry level of adoption.

The researchers aimed to explore using bibliometric methods, the importance of new discoveries in each aspect. The hypotheses were validated using different programs and research platforms such as Vox viewer and Web of Science.

The research presents the new industry (created by the innovative synergy between digitalization and sustainability) in a new perspective where both challenges and opportunities are equal in importance if we want to understand the evolution in each industry, domain, or area.

Keywords: digitalization, sustainability, new technology, challenges, trends, digital transformation.

Introduction

The context of evolution in digitalization was extremely complex and was also affected by terms and methodology. The revolution of technology was always an important aspect that included computerization. Industry 4.0 was the name given to all technical activity of companies when it was discovered that a single computer could be connected to each activity and business process.

After this situation, most of the companies were impacted by the enormous change represented by high investments in technology as this was perceived as the future. The digitalization process started in the 1970s, when NASA created a program for Apollo where two machines were built to imitate the actions of each other. After this experiment occurred, it created

the code and materials to recreate this kind of activity on a smaller scale for companies. (Guzina et al., 2022)

Because of the new discoveries, all domains are impacted even if we are observing the market in general or just important industries. The most important step in observing the impact that Digital-Sustainable tools have in influencing the world is to present a balanced situation where challenges, trends and new discoveries implemented are used by individuals in a safe, clear, and creative environment.

The paper explored the gap that exists nowadays between the general knowledge of the global perspective in Technology and Sustainability and small but important details about the real adoption process that you can discover only if you take sufficient time to observe how these new methods are welcomed by society in each context where they are being used. Political contexts, economic wealth, and health stability are presented as vital for a better future, but it is important to understand that these are not the only ones that must be mentioned. By exploring the synergy between digital and sustainable knowledge instead of analyzing them individually, we can better observe if these emerging dynamics complement each other in solving current problems, or if their impact should rather be evaluated individually, as standalone constructs. This research offers a new perspective on The IT specialist crisis from a human resources perspective (a problem that must be taken into account because it influences stress levels globally within each company), an interest in sustainability, as well as new methods to scale the adoption of sustainability across companies.

Bibliometric research has been applied to answer if and how important observing the evolution of Digitalization and Sustainability really is. After the pandemic period, all aspects changed and opened a new era of behaviors and discoveries that must be observed in detail in order to conclude if society can adapt to the new hierarchy of factors that impact not only us but also future generations.

Literature review

1.1 Digitalisation and sustainability in the current market

The actual situation of the global market presents a context where the external factors such as digitalization, new technologies, sustainability are a must for any company or institution that wants to be considered as being impactful or modern. Digitalization has been considered an important pillar for each aspect, even for small or medium companies.

When it comes to understanding technological progress, the most important aspect that must be acknowledged is integration within other domains or methods. A good example in this case it's the integration of technology in sustainability. At this exact moment, each company or institution faces a challenge and also an opportunity to integrate the mix between these two concepts. Even if technology is considered an efficient tool of this century, we must consider that such a powerful tool drives the consumption of critical resources, such as energy. Due to this dependency on the availability of resources and the emerging global warming challenge, this problem of energy consumption must be thoughtfully tackled and balanced. There are different aspects that must be taken into consideration when referring to the digitized term. (Raihan A., 2024)

After the pandemic crisis pushed the boundaries and expectations with regard to new ways of working, it became clear that essential market needs were transformed according to new means of conducting business. Most of the problems were solved by integrating different types of technology that serve different functions. Because all activities were transitioned to an on-line

environment, the technological aspect became a vital tool with great influence over the quality of life of each individual - in the cultural, personal, or professional way. This new perspective also created the need for new sustainable ways to adapt one's life to the full online work environment.

This problem appeared because the usage of tech tools was high and the usage of hardware tools (which *are not sustainable at all*) was in high demand. Even if this argument is strongly taken into consideration, there were still more pro-technology arguments since the pandemic, than against it. According to (Polishchuk et al., 2022), in 2022, a new research paper named "Problems of Sustainable Development" presented the influence of adopting new technologies. To be more specific; Internet usage increased from approximately 20% of the global population in 2010 to over 50% in 2020 (only a decade), and that the mobile phone adoption had over 3 billion users by 2020. This ascending trend has reached its peak levels during the Covid pandemic crisis. This evolution had a positive overall impact over sustainability problems at a global level, due to the reduction of air pollution levels (a vocal indicator in the global warming situation) and due to the reduced necessity of daily use of automobiles, thus leading to less activity outside the house which was beneficial for each sustainability indicator (except electricity consumption).

The global market was indeed in a transforming era, where evolution was at its peak and models of working were forced to readapt, sometimes also due to new emerging markets, which were not needed beyond the pandemic.

According to (Seppänen et al., 2025), when it comes to defining the attributes that influence the integration of a new process in technology, every aspect counts. From the innovative openness of managers to the understanding of the skill gap of the employees, everything contributes to the adoption of digital instruments. Technological capabilities are only a small facet of the coin, while human openness to adopting those new capabilities is even more important.

As mentioned above, for this type of challenge, small and medium companies must focus on developing automation tools and technologies, while adapting their managerial and leadership style in order to stay ahead in the new digital era.

To understand the real state of technology today, we must analyze all the essential aspects that are related. This creates a complex problem in itself since in order to understand how efficient the mechanisms of digital adoption are truly performing, we have to rely on the data that companies are giving public access to. Since confidentiality is sometimes a competitive advantage for innovative companies, lack of information about new technologies becomes a challenge. Many businesses are interested in digitalization because it usually drives increased productivity, but due to the lack of transparency, the technologization process is being considered silent. Companies are not willing to provide early information on technological advancements they make to maintain a competitive edge in their markets. (Salvi et al., 2021) also acknowledges the fact that this might delay the innovative process and emphasises the fact that companies are quickly improving their business processes, even if they are not communicating it.

He also suggests observing some public tools that they have - a site or a platform - and comparing it to the previous versions, because it is being changed all the time. In addition, digitalization comes with high expectations from stakeholders, so technology means higher cash flow. This fact validates another indirect argument, which approves the theory that technology is the most important pillar for success nowadays.

Because it is essential to analyze all perspectives, even the timeline in order to have facts about a topic, the first thing that we must consider when thinking about the new automatization and technologization methods is the Covid period. Before this period, a wide range of industries and individuals were not even considering using a digital tool when solving a problem or a task.

After this period, many industries have been reshaped and new working patterns emerged, representing a turning point which sets the foundations for even more advancements. Financial support in R&D departments has evolved during the pandemic with an increase of more than 25% in digitalization and technological tools. Inventions also on a positive trend, with technology patents seeing an increase of over 5%.

Furthermore, another proven argument for the usage of new technology has increased the belief that institutions or companies investing in R&D departments have improved cost efficiency figures, better time efficiency in solving tasks, and more sustainable time management overall (Liu et al., 2024).

The transformational process of digitization includes new theories and processes that aim to assure a smooth transition the new automated and digitalized era. One of these processes is the Digital Maturity Model that is a part of the Maturity Model, a method in developing new informational structures that is utilized in IT and Management. The importance of this new methodology was researched by (Minh et al., 2022). According to these conclusions, the researchers presented the adoption of importance of the technology and proved that they created a new theoretical model that could improve the results. The process should change according to the market needs. After the change, the company should implement a personalized DMM. DMM is a diagnostic tool that improves problems in a company by comparing business results to the standard model that is being considered perfect, a model coded into the system.

Digital technologies improve sustainability in business processes by increasing efficiency, enabling data-driven decision-making, fostering innovation, ensuring transparency in the supply chain, engaging customers, and facilitating collaboration among stakeholders. By applying digital tools, companies can transform their operations towards sustainable business models, driving positive environmental and social impact while maintaining competitiveness in the market (Broccardo et al., 2022).

In the context of digital transformation, Sustainable Business Models (SBMs) are essential frameworks that not only prioritize long-term resilience but also integrate sustainability principles into their core operations. They should be able to adapt to changing market conditions and evolving consumer expectations while aiming to create value for multiple stakeholders, including customers and society. (Katsamakos, 2022)

Digital technology plays an essential role in creating sustainable business models by optimizing resource usage, improving operational efficiency, and enabling the development of innovative eco-friendly products and services. It facilitates efficient operations through data analytics and IoT, which reduce waste and emissions, while also creating new value propositions aligned with sustainability goals. In addition, digital platforms support circular economy initiatives by encouraging resource reuse and improving transparency regarding ecological impacts. By utilizing these technologies, companies can transform their traditional business models into sustainable ones, achieving both ecological and economic value simultaneously. (Böttcher et al., 2024)

But many authors (Broccardo et al., Böttcher et al., Caputo et al., Katsamakos) call for more research into the design and implementation of SBMs that effectively exploit digital strategies. Understanding how to create scalable and adaptive SBMs is crucial for firms looking to maximize the advantages of digital transformation while meeting sustainability goals, thus improving their social license to operate and contributing positively to broader social outcomes.

1.2 New technologies in digital and sustainable adoption

The concept of new technology has influenced each aspect of our lives, modifying how we work, think, and solve problems. Digital trends are evolving and are at this point presenting new opportunities for all businesses that will transform activity and will remain open to AI and new technology concepts. A trend that is now used by many businesses is characterized by tools that innovate the mechanism for organizing the processes in the company. PROMES Systems is one of the businesses that are upgrading methods by creating clear software methods that will improve management concepts, software integration, and applications. Automated processes are now helpful and desired by each company, not only because this type of activity will improve efficiency, but also because entire processes can be supervised by the managers by just one click.

Education also adopted some trends in technology, aspects that improve not only the quality but also the future of innovation. Multiple educational institutions are now in the middle of implementing a new style of learning in which students integrate technology so that they get used to what they will use at their jobs in the future. Courses, new classes, or even educational initiatives where students can learn about the new technologies are being included in the middle of the development process. In his research (Parviainen et al., 2017), agrees that technology has had a good influence in creating a better work environment for companies operating in a global market.

The adoption of digitalization is now a main topic because most of the jobs are shifting towards new working patterns or expanding their activity with the use of technology. Even industries that were not in the main spectrum of adoption are now implementing some processes and methods. Ship engineers are on the list of methods that need to be changed. Regarding the innovation methods, the engineers explained that now the daily activity is done by the computerized system. The patterns of interaction of work are also done by different programs and machines that help with the main tasks. Even in the ship industry, individuals are adapting to the new way of working and are also improving their work. Using technology at work is no longer a concern, but it needs guidance, training and a lot of informational upgrades, according to the opinions of the employees. (Pareliussen B., 2021)

According to (Zenya A., 2018) the new needs of the global market lacked a comprehensive method for completing the integration of sustainability and digital tools. As such, a new model of integration has been created, E-SET has been developed for companies in order to have a better understanding of how sustainability is applied within a company. The Enterprise Sustainability Evaluation Tool was the result of six sustainability indicators, a system that will use software (R programming language) to evaluate the key sustainability metrics within each company. Because of this tool, which creates clarity for each organization, managers are now able to understand how to improve their results and implement better ways of working.

Once the dots between the main aspects that a company must implement, the rest will be easier because managers will only need to follow the initial model to identify the metrics that can picture what is wrong and what is performing well. Some of the most important aspects that were considered pillars in creating the perfect model were: Climate Change Framework, Sustainability Reporting Guidelines, Inspector Expectation Report, Global Climate Change Survey and the International Integrated Reporting Framework. All the reports and surveys mentioned were the strongest points in creating E-SET. By combining digital tools and sustainability information, we can create a model of reference for the future, and also confirm that Digitalization and Sustainability need to merge so that most of the companies can have a wiser long-term objective that is strongly connected to the market needs.

1.3 Challenges and trends in the market regarding digitalization and sustainability

According to (Jain et al., 2024), if we are considering talking about challenges of digital adoption, we could consider what human resources experts are presenting. The lack of information, the absence of digital literacy and the constant need for an innovative perspective will make employees lose the will of adapting and integrate digitalization in the daily tasks. Even though this may be a difficult aspect to consider, humans are also the solution to this problem.

People are the common factor in each implementation, so in order to include the mass adoption of technology in each industry, the process must change the way that information is being displayed. Clearer, easier to read, more digestible and with focus on some use cases because practical examples are useful tools for learning.

Managers must also change and adapt to new types of leadership, because employees report that they are now more stressed by being affected by change and involved in the learning process for longer time than before. According to (MIKLOSIK et al., 2023), who researched the challenges of implementing new procedures in European countries with an interest in Germany; knowledge, depression and anxiety are some of the most common aspects that will become important blockers for the new Business Model. The constant learning process will require a lot of time spent working, an argument that will influence mental health. Also, it is hard to have compact knowledge if the subjects need to learn everything in a short amount of time, a fact that will also generate errors, frustration and depression. Another challenge will be the cost of energy in the actual political and social context. The increase of prices and economic factors will influence each aspect of the New Business Model.

Due to the influence of technology, many tools have become an actual trend. Each industry has been impacted by the digital transformation. The educational system is one of many that was influenced by technology. Processes, learning methods, teaching aspects and different courses were all evolving to keep pace with the rapid technological advancements. Depending on your personal situation, you are either confronting a challenge or enjoying an opportunity, but the most important fact which each individual must take into consideration is that this type of perspective creates a new way of thinking which drives evolution. Digital transformation has multiple angles that must be taken into consideration and is sometimes impacted by macroeconomic or political factors. Hong Kong is now in the middle of a brain drain crisis that also has a negative effect on the evolution of digitalization in the local market. The migration factor, the lack of experts and the political constraints that affect each and every aspect in the society will naturally affect the digitalization process.

This challenge also brings another important category of concerns: ethical and cultural. Phishing, scams, or hacking also benefiting from the lack of regulations and policies for new technologies. Ethics is now one of the key points in unifying digital communities. If ethics are not taken into account, the main purpose of digitalization is reduced because trust levels will decrease and level of adoption will naturally decrease. Data privacy is also an essential concern for new evolving technologies, as private information must be protected with priority. At this moment, most of the tech companies are in the middle of a difficult problem because of the connection between ethics and systems of the company data. (Sumbal et al., 2024)

According to Broccardo et al. (2022) and Valero- Gil et al. (2024), latest sustainability trends highlight the increased convergence of environmental, social and economic targets through digitalization. This is facilitated by its focus on circular economy practices such as reuse and recycling. Many companies employ digital tools to pursue and manage environmental impacts, improve resource efficiency, reduce waste and implement sustainable innovation that improves

overall performance. Despite these positive developments, there are considerable challenges. Companies often struggle with design implementation gaps and fight to integrate sustainability strategies into their daily operations. Guaranteed economic viability, compensation for various business goals, and alignment of interests of stakeholders remain important obstacles, particularly for small and medium-sized businesses with limited resources. Additionally, the lack of standardized metrics complicates the assessment of sustainability initiatives, with the majority of existing research focusing on developed countries, which lack traditional industries and developing countries. Finally, digitalization itself can introduce compromises such as: Increased energy consumption highlights the need for the introduction of responsible technologies. Integration of sustainability and digitalization is accelerating and a growing trend. To take advantage of the benefits of this convergence and address implementation challenges, a comprehensive, resource-efficient and integrated approach is essential.

Methodology

Researchers conducted bibliometric analysis in order to observe the impact of digitalization and sustainability. Trends, new technology, challenges and the actual market were the main preoccupations of this research paper. Keywords used to highlight the impact of sustainability and digitalization were digitalization, sustainability, new technology, challenges, trends, and digital transformation.

The database used had reliable sources such as ResearchGate, Web of Science and Elsevier. The results considered were only recently published articles in English. Our bibliometric research has as scope the impact and the importance of digitalization and sustainability by observing different implications in across industries, study cases and global changes that are now impacting the markets.

Each of the KPIs used had a personalized database such as: countries, citations, and years. Researchers conducted and created a set of procedures where they collected diversified information, so that the papers included as many perspectives as possible, to validate or invalidate the importance of digitalization and sustainability, or their intricate synergies.

As mentioned above, the procedures were focused on: opting for peer-reviewed articles that presented the current situation of the digitalization and sustainability market, a comprehensive research by using specific key-words and combinations of key-words and research of specialized terms used in our domain of interests.

Keyword combinations: Challenges-Trends-Digital-Transformation; New technology-Challenges-Digitalization; Digitalization-New-Technology-Trends; Sustainability-Digital-Transformation-Digitalization.

The current research has as objectives the validation of the following hypotheses:

H1: Observing the impact of the digitalization and sustainability concepts by comparing the numbers of articles on the subject to the ones written before Covid

Q1: How many articles have been written during the pandemic period about digitalization and Sustainability?

Q2: Is there any increase between the articles written during the pandemic and after?

H2: Are Digital and Sustainable Discoveries influencing industries globally?

Q1: Is there any affiliation between different industries/themes and the discoveries from Technology and Sustainability in the market?

Q2: If there are influences that impact the industries/themes (aspect reflected by the number of articles written about a subject), which are the most impacted?

H3: Discover if there are challenges within the process of implementing and adopting digital and Sustainable methods.

Q1: Has the concept of ‘challenge’ ever appeared in the written articles on the main concepts discussed in this research paper?

The Covid period prepared the market for a forced adoption of digital and sustainable activities. Because of this major change in a short time there are many implications that must be taken into account. The main objective of the paper is to validate the importance of these themes and also to present the effects of these complex domains in the actual global architecture.

Results and Discussion

The main objective of the paper was to observe the importance of the three aspects: new technologies, challenges and trends in the transformation of digitalization and sustainability. As we can observe even from the literature review, there are many initiatives that will also validate the importance of each point mentioned in the article.

In order to validate the first hypotheses, researchers performed a comparative analysis between 2021 and 2024 so that they could validate the evolution of interest in domains like Digitalization and Sustainability during and after the Covid pandemic. First, the detailed observation made in WoS presented the articles that included these concepts. In 2024 (1280 articles), the number of written articles has significantly increased with 66,6% compared to 2021 (768 articles) when the pandemic period started and the interest in these concepts was only at the beginning. In this situation, after reviewing the number of articles written, we can observe that the increasing interest in these subjects has been validated. (Fig1.1)

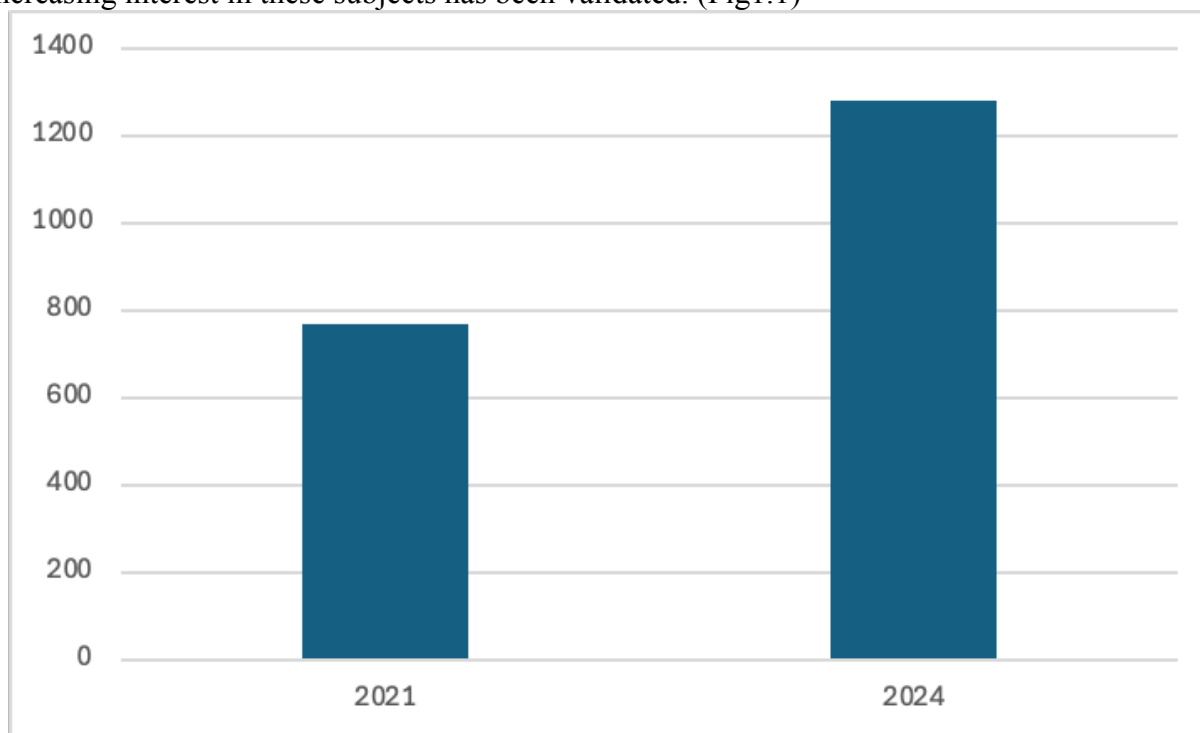


Figure 1.1 Digitalization interest during and after the pandemic periods

Source: Author's own research contribution.

Sustainability has also been a topic that brought a lot of interest both during and after the pandemic. The small number of resources that are now available represents an increasing dilemma at this moment. In 2021, 52,909 articles written about sustainability, which increased by 33,4%, to a total of 69,506 in 2024. (Fig1.2)

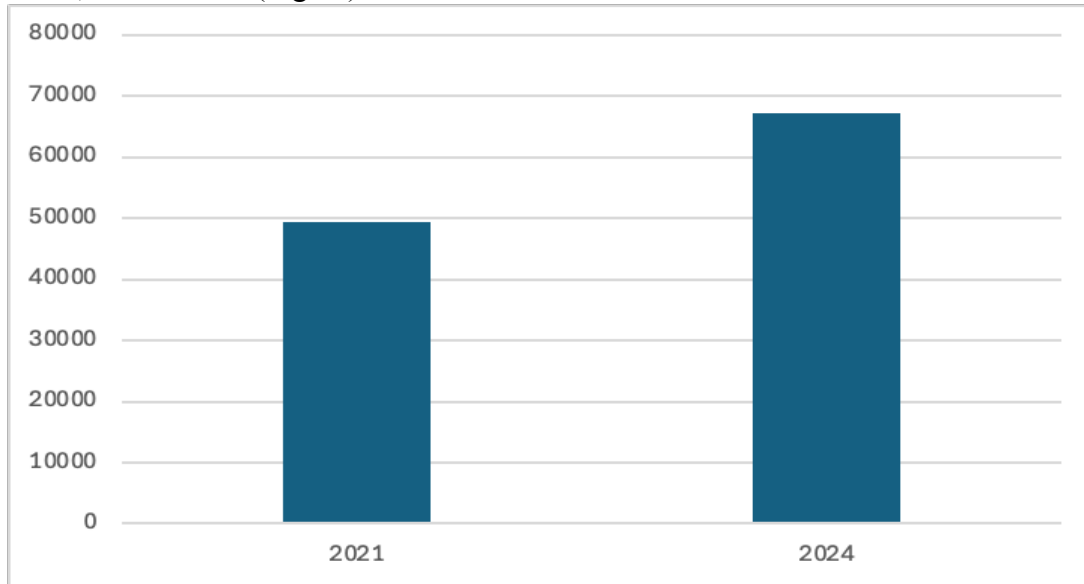


Figure 1.2 Written articles on sustainability

Source: Author's own research contribution.

The increased number of articles written about both subjects suggests that the overall interest in these domains and their relative importance in understanding the new problems of sustainability and digitalization have grown.

Table 1.1 Interest in digitalization and sustainability by country

Cluster	Country	Number of articles	Year
DIGITALISATION	GERMANY	180	2024
DIGITALISATION	ENGLAND	170	2024
DIGITALISATION	ITALY	121	2024
SUSTAINABILITY	CHINA	14896	2024
SUSTAINABILITY	USA	8756	2024
SUSTAINABILITY	INDIA	6261	2024

Source: Author's own research contribution.

The number of articles that contain detailed information on the actual progress of digitalization and sustainability has always been an important factor of interest for each market. Most of the articles published were from Germany and China, countries with large investments in green technology. The information was collected from WoS, and the filters applied were: country, year and domain.

The second hypothesis comes as a validation of the new industrial revolution. The figures below offer details about the most cited articles and present the main industries that adopted new and sustainable technology in 2024, source WoS. (Fig1.3, Fig1.4)



Figure 1.3 Adoption of digitalization in various industries

Source: Author's own research contribution.



Figure 1.4 Adoption of sustainability in various industries

Source: Author's own research contribution.

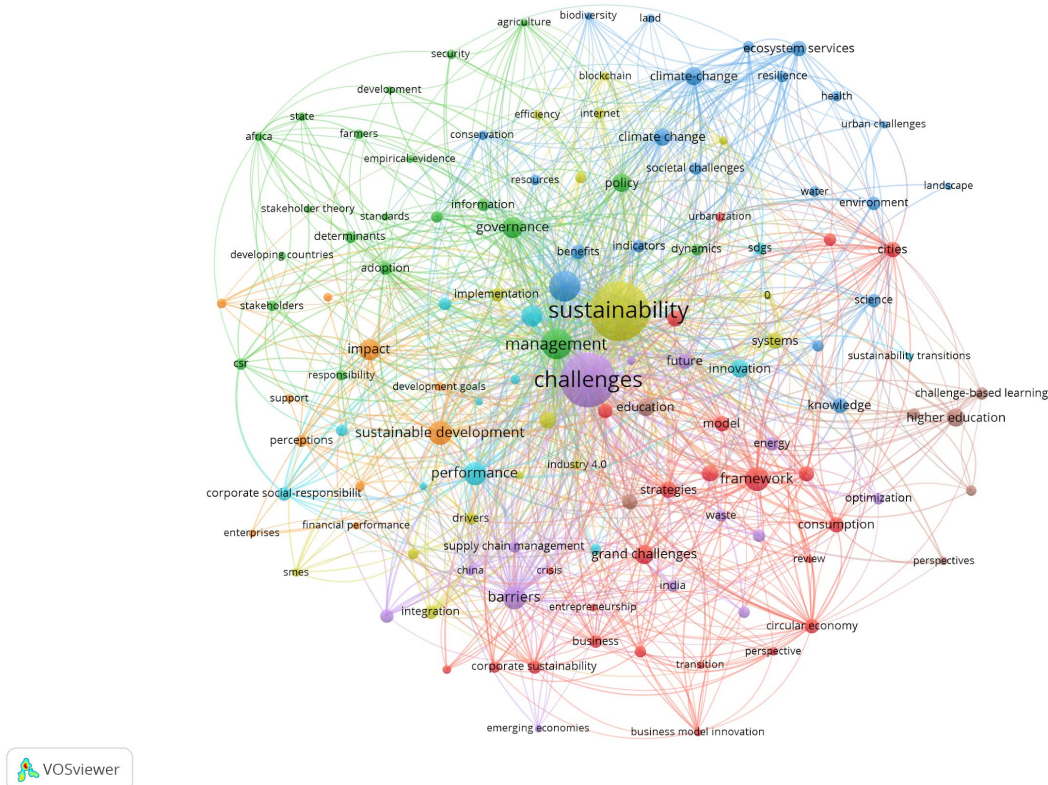
Management and Environmental Science are the themes of many written articles that included digitalization and sustainability in 2024, aspects that established a documented evolution of the interest in learning more about the conceptual knowledge of these terms.

After observing and confirming that there are modifications in the processes for most of the industries, challenges are also an important aspect that must be analyzed. The third hypothesis reviews whether the concept of challenge exists in both clusters of interest (Digitalization and Sustainability).

We can also conclude by observing the graphs made with VOSviewer that the concept of challenge is also an impactful term, analyzing how technology and sustainability are both integrated in research articles. The database was made up only of articles published in Web of Science. Filters applied to create the database: topic (digitalization and sustainability), keywords: challenge, year (2024).

The cocitation conclusions presented the high number of clusters that contain the term 'challenge' in each case. This can also validate the third objective of the paper: there are blocking points in implementing, adapting, and using technology and sustainable methods. (Fig1.5, Fig1.6)

Source: Author's own research contribution.



Source: Author's own research contribution.

Conclusion

Digitalization has become an important tool in developing new solutions that can drive sustainability at the same time. Within the paper research, we can observe the market's actual state. At this moment, we are in the middle of new discoveries and tools that could help us in the future to have better work conditions, less time spent in working spaces doing hard labor, or even a better sustainable life on our day-to-day conditions. Synergy between digitalization and sustainability is essential to better perspective for future generations. The research paper presented the starting point of innovation in technology and suitability during the pandemic period. After this period, most industries were forced to adapt to a new global factor that moved all the activities in the online world in a few months.

Because of these new needs, most of the tech tools were improved and introduced to daily routine without any training or preparation. This situation and the lack of training forced people to adapt as soon as possible to a new reality and to learn not from training or workshops (which would make the process easier for everyone), but from practice.

Health problems such as (depression or low immunity) were caused by lack of training and because of the fact that most companies are putting pressure on employees because they must adapt in seconds to a new tool just because it's on the market. If we are talking about technology, the most important point that must be discussed is the fact that experts who use the new technology are too rare. An example here would be AI that has already been used globally. It may seem normal to say that the process is easier because of this intelligent assistant, but the truth is that if you want to work with all tools to their full potential, you need experts and you cannot have experts if companies are not investing in their formation.

As we can observe from the hypotheses from the article, most of the questions addressed were validated by the progress made in this direction of innovation. Regarding the limitations of the research paper, we can discuss the fact that all the articles used were only scientific ones, excluding the ones that were present in a political, social, and public context. This aspect limited our discoveries and conclusions to the theoretical area.

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