

EXPLORING THE IMPACT OF EMERGING AND DISRUPTIVE TECHNOLOGIES DEVELOPMENT ON EVOLUTION OF INDUSTRY 5.0

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Abstract: *The last years depict a technological reality characterized by technological advance, innovations, or emerging and disruptive technologies which shape our society more rapidly than before. Artificial intelligence, virtual reality, internet of things, quantum computing, blockchain technology, or chatbots are just a few examples related to nowadays evolution of emerging technologies with a disruptive trend over time. Business processes, the day-by-day life of the citizens and the way in which many private or governmental institutions conduct and develop their activities are influenced and impacted by the rapid technological advance. In this context, the concept of Industry 4.0 with all its implications in the majority of activity fields seems to already reign absolute. The fast development of new innovations and emerging technologies contribute to the dawn of the so called - Industrial Revolution 5.0. This paper explores the impact of nowadays technological trends that could be linked over time to the evolution of the new Industry 5.0 concept.*

Keywords: emerging and disruptive technologies, Industry 5.0, artificial intelligence, technological trends, impact

1. Introduction

In today's fast-paced digital world, we are facing a rapid development of technology which greatly impacts all activity fields such as: economy, industry, the business models, academia, security and defense sector, government activities and even the daily life of citizens. Concepts like *Emerging and Disruptive Technologies* (EDTs) together with *Industry 5.0* are linked and used in almost all of the domains of activity. The time periods related to Industrial Revolutions (IRs), starting from Industry 1.0 till Industry 5.0, prove the rapid development of technical skills and technological knowledge and huge potential of humanity related to new innovations and advanced technology.

Industry 5.0 is described as a new phase of industrial development built upon the fourth industrial revolution (Industry 4.0) which encompasses more than just manufacturing enabled by the developments in IT that include facets such as artificial intelligence (AI), automation, big data analytics, the Internet of Things (IoT), machine learning, robotics, smart systems, and virtualisation [1].

Bringing both opportunities and challenges nowadays, EDTs and technology in general are considered the buzzword of today's geopolitical landscape and security architecture. There is a strong link between economic growth, security and technological evolution, all three part of the effort to build

resilience [2]. These new technologies such as big data, AI, novel materials and manufacturing, autonomous systems, next-generation communications networks or quantum technologies are changing our world, and the way it operates.

2. Conceptual Framework

Nowadays technological supremacy, as part of the national strategies, seems to be a normal fact and many countries have already planned to become the leading nation in this field. Indeed, the EDTs will have a great impact with specific effects and risks linked to new products and services that could appear and disrupt the markets and the ways in which the businesses will be adapted, transformed and run in accordance with new business models. Also, a shift of value's pools between producers or from producers to consumers could occur. In his blog "Emerging technologies vs. disruptive technologies" Dunn J. [3] argues that "emerging technologies are innovative technologies that have been recently developed, are under development or will be developed within the next few years. Disruptive technologies, however, are innovations that drastically change the way organizations and industries are functioning". Taking into consideration what was previously stated, EDTs could have a major impact on organizations by cumulating all of the above-mentioned features.

The rapid development, the implementation impact, and the dual-use features (technologies that are focused on commercial markets and uses but also have defence and security applications) of EDTs are worth considering over time. At the European Union level, the European Defence Agency (EDA) identifies six particularly disruptive technologies: quantum-based technologies, AI, robotics and autonomous weapons systems, big data analytics, hypersonic weapons systems and space technologies, and new advanced materials [4]. In comparison with EU perspective on EDTs, NATO's

innovation activities currently focus on nine priority technology areas [5]: AI, autonomous systems, quantum technologies, biotechnology and human enhancement technologies, space, hypersonic systems, novel materials and manufacturing, energy and propulsion, and next-generation communications networks. Based on new innovations and fast development and implementation of new technology the number of identified and considered EDTs is changing periodically. This trend of technological advance influences the daily life of citizen but also impacts the industrial evolution over time. Taking into account the industrial changes over time and rapid development of technology, the concepts starting from Industry 1.0 till Industry 5.0 (also linked to Society 5.0 concept) should be considered in following stages of progress:

- around the year 1800 - first industrial revolution/1IR (Industry 1.0) epoch is related to mechanization, water power and steam power - *mechanization*;
- around the year 1900 - second industrial revolution/2IR (Industry 2.0) epoch is related to mass production, assembly line, and electric power - *electrification*;
- around the year 2000 - third industrial revolution/3IR (Industry 3.0) epoch is related to computers, automated production, electronics – *automation*;
- around the year 2010 - fourth industrial revolution/4IR (Industry 4.0) epoch is related to cyber physical systems, IoT, networking, machine learning – *digitalization*;
- around the year 2020 - fifth industrial revolution/5IR (Industry 5.0) epoch is related to human-robot collaboration, cognitive systems, customization – *personalization/ humanization*.

Industry 5.0 will radically change how companies work in the next years. Beside the automation and optimizing processes as a basis of the 5IR, the focus will also be shifted to improving workers' lives using technology rather than replacing them with

robots [6]. Making activities and workflow processes more human-centric represents one of Industry 5.0 challenges. In this context, 5IR makes use of the concepts of cognitive computing, cyber-physical systems, and AI in order to ensure humans having a role in the digital transformation that is continuing to evolve. Promoted by the European commission and other governmental bodies, Industry 5.0 concept emphasizes a triple-bottom-line of economic, environmental, and societal impact, bringing ESG (Environment, Social and Governance) perspective and balance to what have often been technology-led and economic-driven choices [7]. In fact, 5IR is based on three main pillars: human-centric, sustainability, and resilience.

3. The Trend and Impact of EDTs Development on 5IR

The rapid development of EDTs in a sustainable and resilient way in order to ensure all necessary services to citizens, local administration, commercial or industrial fields, brings new opportunities, related to their implementation and use over time, in the majority activity fields.

This paper explores the impact of EDTs development closely link to the Industry 5.0 evolution and is focuses on the answers of at least following research questions:

- The extent to which the rapid development of EDTs will impact the

society, business models and industry over time;

- How the 5IR is affected by the fast implementation and use of EDTs over time;
- What could be the implications of AI in the evolution of 5IR.

In order to assess the likely EDTs impact and Industry 5.0 evolution, it is relevant to undergo a checking of Google Trends and a bibliometric analysis of scholarly publications related to our topic of interest. The figure no. 1 depicts the “interest over time” concerning EDTs and Industry 5.0 in the last ten year (2013-2023). It is noticeable that the interest in searching relevant information about 5IR (red color) on the internet had an increasing trend after 2020. The COVID-19 pandemic restrictions that were introduced for a period of time in the daily life of citizens and the widespread of AI technology (like ChatGPT from OpenAI) in many activity fields lead to an acceleration of digitalization and implementation of new technologies in order to provide continuity and support to social and government services without disruptions. In order to mitigate the negative effects of the COVID-19 pandemic, the industry and economic sectors were impacted by the adoption of new technologies, many of them having a strong disruptive feature.

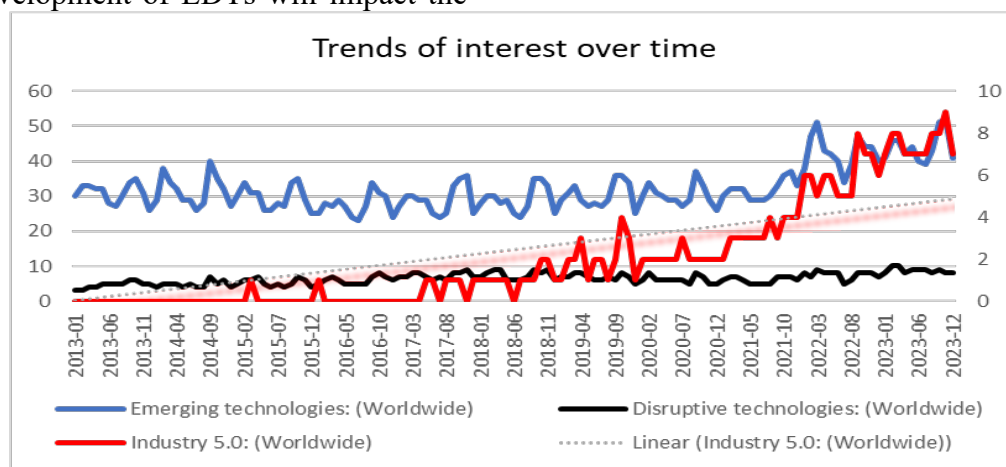


Figure 1: Trends of interest over time, EDTs vs Industry 5.0, 2013-2023

(Sources: Authors' computation, Google Trends, Microsoft Excel)

The bibliometric analysis of scholarly publications related to our topic of interest

reveals strong connections of EDT's implementation and Industry 5.0. The Web

of Science (WoS) database was selected as bibliometric analysis using the following interrogation attributes: “emerging disruptive technolog*” (All Fields) OR “emerging and disruptive technolog*” (All Fields) or “industry 5.0” (All Fields). After the interrogation of WoS database, the initial resulted bibliographic database was refined by searching the highly cited articles or proceeding papers in the last ten years (2013-2023). The final bibliographic database comprises 460 papers for the analysis and research by employing Biblioshiny as a bibliometric software.

Figure 2 shows the most relevant words used in the selected papers that are based on the authors’ keywords. One can remark that after “Industry 5.0” which is the central concept, having 117 occurrences, the following keywords are also used in many papers: *Industry 4.0, AI, sustainability, digital twin, blockchain, machine learning, smart manufacturing, human factors, IoT, human-robot collaboration, digital transformation, optimization, resilience.*

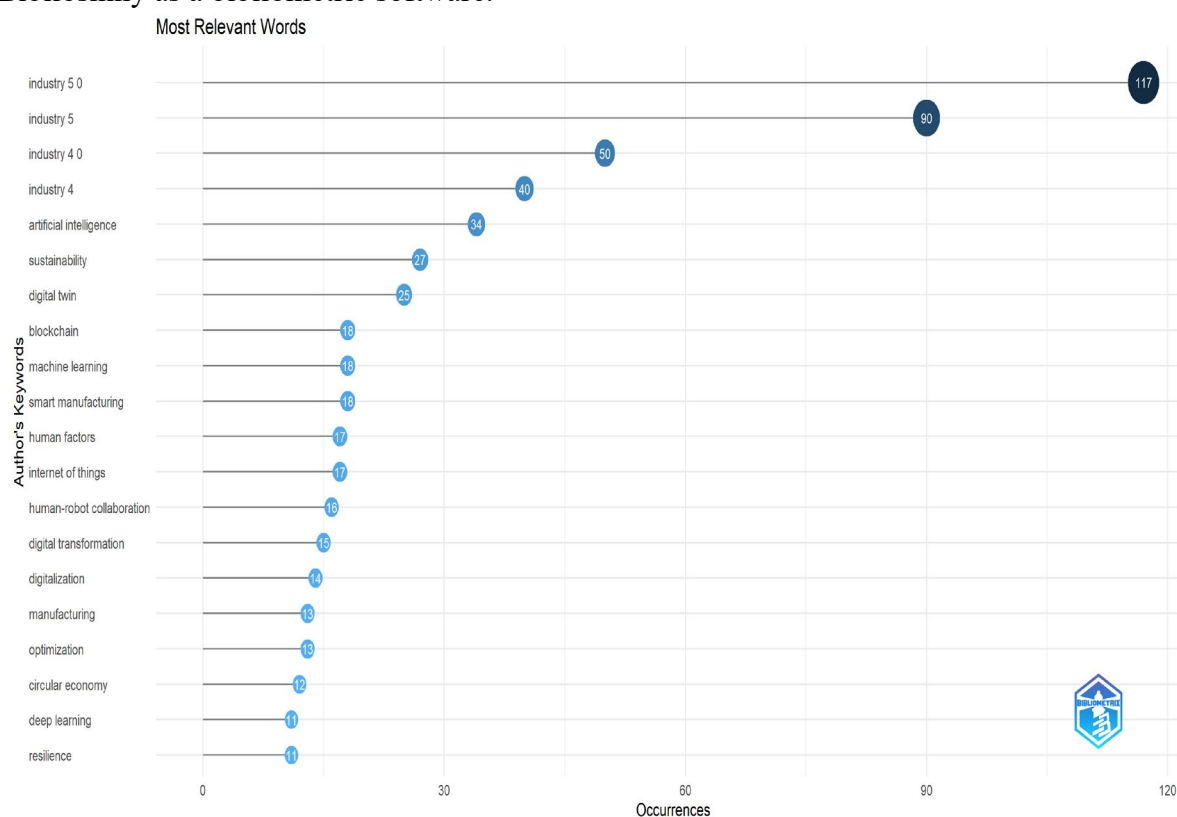


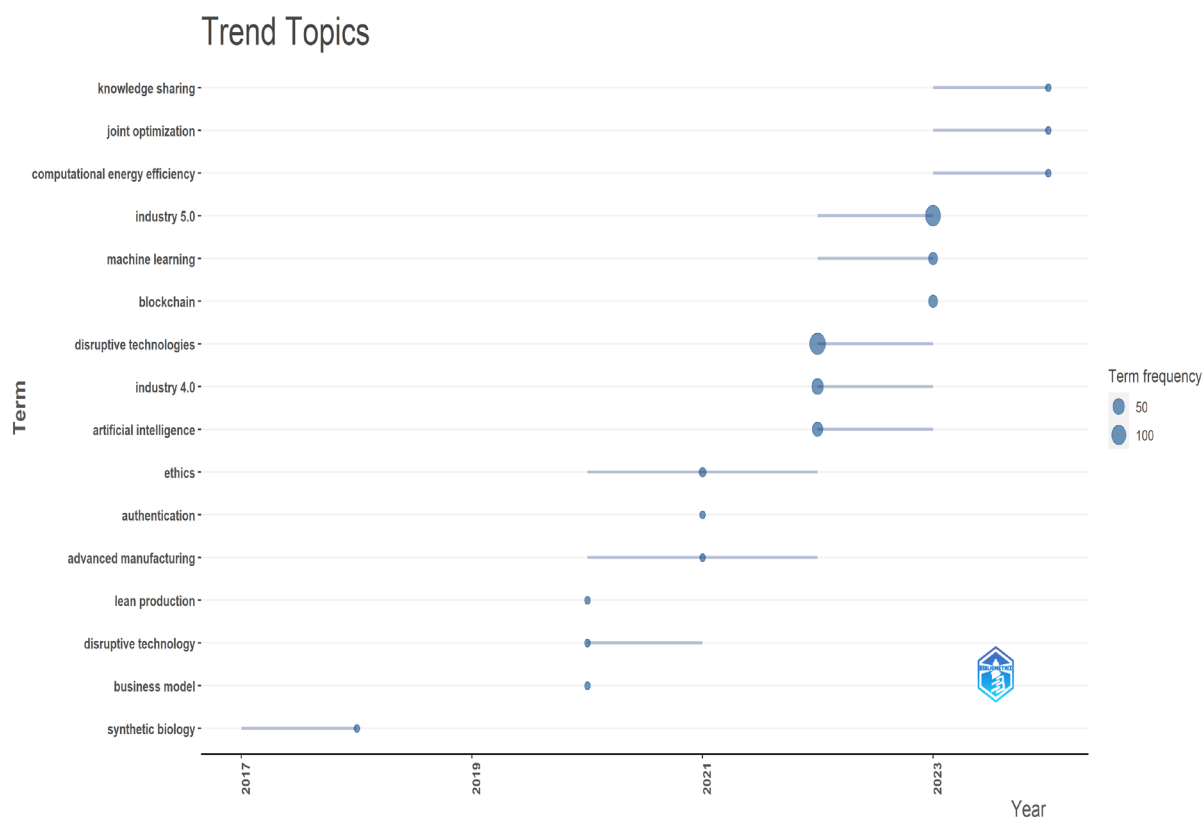
Figure 2: Most relevant keywords related to EDTs and Industry 5.0, 2013-2023
(Sources: Authors’ computation, Web of Science, Biblioshiny)

In addition to most relevant keywords, figure 3 presents how the EDTs and industrial revolution trend topics have changed over the last five years. The image was plotted on a two-dimensional scale representing logarithmic frequency values on the vertical axis and publishing years on the horizontal axis. Between 2020-2021, there were numerous technology-industry related interest topics with the frequency of terms counting between 5 and 20 such as:

business model, emerging technology, lean production, advanced manufacturing, authentication, or ethics. Starting with 2022, the central research topics, counting between 50-100 frequency of terms, were AI, Industry 4.0, and disruptive technologies. Then, in 2023 the topics trend shifted to blockchain technology, machine learning, and Industry 5.0. It seems that the current topic trend is related to computational energy efficiency, joint

optimization, and knowledge sharing. This last topic trend proves the linkage between EDTs and evolution of Industry 5.0 that is

related to a significant impact on business productivity and close collaboration between human and machine workers.



*Figure 3: Bibliometric Trend Topics based on the refined WoS database
(Sources: Authors' computation, Web of Science, Biblioshiny)*

The graph above shows that starting with 2021, the topic “ethics” had an increasing interest trend with its highest academic interest having the term frequency around 20 in the year 2022, probably as a consequence of the COVID-19 pandemic prolonged effects and the rapid implementation of digital technologies. Along with the ethics topic, the AI topic proves its highest study interest starting with 2020 during COVID-19 pandemic with its maximum score of 50 as a term frequency reached in the year 2022 when the famous ChatGPT was launched on the market. Also, at the same time with the AI topic one is notice the increasing interest in “disruptive technologies” topic, counting

around 100 frequencies of terms.

Table 1 presents a selection of promising 2024 technological trends related to EDTs that could have a real impact on the society and industry evolution over time. This kind of listings related to technology classification are revised yearly and published based on predicted future trends of emerging technologies that could influence and disrupt the life of citizens or the business models. These classification processes are also based on the predicted influences posed by actual used and implemented technologies on other technological trends that will emerge in the next 3-5 years.

Table 1 The emerging technologies and technological trends with potential disruptive effects in 2024

Top 10 technological predictions, trends and potential EDTs in 2024					
The EDTs/ technological trends were published in	<i>Top 10 Strategic Technology Trends for 2024</i>	<i>10 Breakthrough Technologies 2024</i>	<i>Top 10 Emerging Technologies 2024: How Tech Trends Shape 40+ Industries</i>	<i>Top Ten Technology Trends for 2024</i>	<i>Top 10: Technology trends for 2024</i>
Published by	<i>Gartner [8]</i>	<i>MIT Technology Review [9]</i>	<i>StartUs Insights [10]</i>	<i>The Digital Speaker [11]</i>	<i>Technology Magazine [12]</i>
Emerging technologies and their potential disruptive trends	AI Trust, Risk and Security Management (AI TRiSM)	AI for everything	Artificial Intelligence: the game-changer for future industries	Humanoids integrated with multimodal LLMs	Businesses will focus on creating guardrails to mitigate AI risks
	Continuous Threat Exposure Management (CTEM)	Super-efficient solar cells	AR & VR: use cases beyond entertainment	Intelligent applications that speak our language	AI advancements will drive even more energy usage
	Sustainable technology	Apple Vision Pro	Big Data & Analytics: transforming business insights & strategy	From the digital world to a fake reality	Continued rise of social engineering attacks
	Platform engineering	Weight-loss drugs	Blockchain: revolutionizing trust and transparency	The enterprise metaverse that will disrupt the future of work	Human skills will be essential for the uptake of AI
	AI-Augmented development	Enhanced geothermal systems	CleanTech: spearheading a sustainable business future	The convergence of AI and quantum computing	Quantum progress but not quantum leaps
	Industry cloud platforms	Chiplets	Internet of Things: connecting the world seamlessly	Significantly more advanced security threats due to Gen AI	IT spend will be focused on business outcomes more than ever
	Intelligent applications	The first gene-editing treatment	Advanced Robotics: advancing human capability	From the cloud to the edge (AI)	A renewed focus on zero trust models
	Democratized generative AI	Exascale computers	Additive Manufacturing/ 3D Printing: tailoring tomorrow's products, one layer at a time	Synthetic biology entering mainstream	Hyperscalers will drive a powerful, real-time ecosystem
	Augmented connected workforce	Heat pumps	Cloud Computing: redefining horizons through the internet	The military embracing autonomous weapons	A convergence of IT and security teams
	Machine customers	Twitter killers	Nanotechnology: harnessing the power of the minuscule	The second half of the chessboard	AI to take centre stage, moving from theory to practice

One can notice in the Table 1, beside many AI applications numerous emerging technologies are forecasted as future technological trends for 2024 and beyond, which could be implemented and widely used in the economic sectors and industrial fields, in accordance with Industry 5.0 human-centric industrial revolution, such as: sustainable technology, augmented connected workforce, intelligent

applications that speak our language, a convergence of IT and security teams, etc. Based on the real computation power of machine learning models and use of the generative AI and chatbots in the majority activity fields, two relevant tests were conducted in order to demonstrate how the AI implementation in the web-based platforms and applications could provide support in a suitable manner through very

fast answers linked to a topic of interest.

1. The first test was conducted using the Chatbot App, available at <https://chat.chatbotapp.ai>, that is based on ChatGPT software, and the following topic of interest was typed in the chat bar: “Industry 5.0”. An instantly subsequent answer was received: “*Industry 5.0 represents the next evolution in the industry where humans and machines work collaboratively in a shared space. This concept emphasizes the importance of human intelligence, creativity, and decision-making, while also leveraging the*

capabilities of advanced technologies such as AI, automation, and robotics to enhance productivity and efficiency. The focus is on creating a more human-centric approach to manufacturing and production processes, combining the strengths of both humans and machines for optimal results” [13].

2. The second test was conducted using the Research AI from Statista database platform and the following topic of interest was typed in the chat bar: “What are the key regulatory challenges associated with the adoption of Industry 5.0 technologies?” (Figure 4).

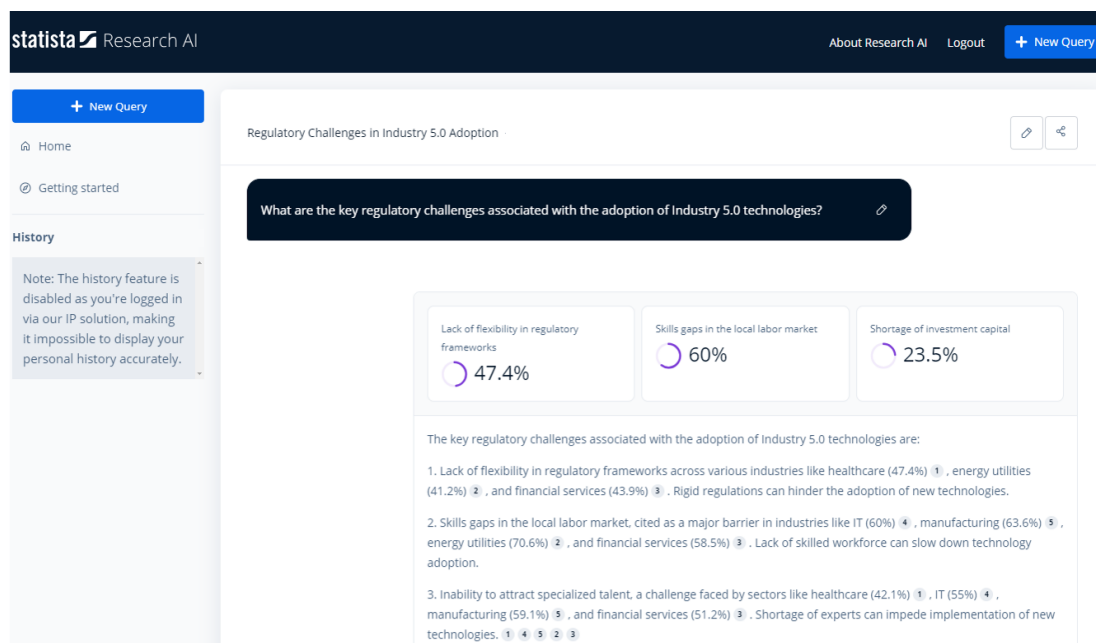


Figure 4: The use of Research AI from Statista [14]
(Source: Statista platform)

The Research AI provided following subsequent answers: “*The key regulatory challenges associated with the adoption of Industry 5.0 technologies are: A) Lack of flexibility in regulatory frameworks across various industries like healthcare (47.4%) [a], energy utilities (41.2%) [b], and financial services (43.9%) [c]. Rigid regulations can hinder the adoption of new technologies. B) Skills gaps in the local labor market, cited as a major barrier in industries like IT (60%) [d], manufacturing (63.6%) [e], energy utilities (70.6%) [b], and financial services (58.5%) [c]. Lack of skilled workforce can*

slow down technology adoption. C) Inability to attract specialized talent, a challenge faced by sectors like healthcare (42.1%) [a], IT (55%) [d], manufacturing (59.1%) [e], and financial services (51.2%) [c]. Shortage of experts can impede implementation of new technologies. [a][d][e][b][c] D) Shortage of investment capital, identified as a barrier in education (50%) [f] and agriculture, food & beverage (23.5%) [g] industries. Insufficient funding can restrict adoption of costly new technologies.”

The answers provided by Research AI from Statista were based on diverse

sources, such as: [a] Statistic: Perceived barriers to the adoption of new technologies in the health and healthcare sector worldwide in 2020; [b] Statistic: Perceived barriers to the adoption of new technologies in the energy utilities and technology industry worldwide in 2020; [c] Statistic: Perceived barriers to the adoption of new technologies in the financial services industry worldwide in 2020; [d] Statistic: Perceived barriers to the adoption of new technologies in the digital communications and information technology (IT) industry worldwide in 2020; [e] Statistic: Perceived barriers to the adoption of new technologies in the manufacturing industry worldwide in 2020; [f] Statistic: Perceived barriers to the adoption of new technologies in the education industry worldwide in 2020; [g] Statistic: Perceived barriers to the adoption of new technologies in the agriculture, food, and beverage industry worldwide in 2020.

4. Discussion and Conclusions

Our research focuses on exploring the landscape of the interconnections between emerging and disruptive technologies and Industry 5.0 concept. There are some research questions that were taken into consideration related to the implementation and impact of ETDs on society and industrial activities over time, and also the implications and effects of the AI implemented and used in the business models.

As a dual-use technology, the AI has emerged as a transformative force in the ever-evolving landscape of global security, economic sectors, academia and learning processes, or industry field by offering unprecedented opportunities and challenges. Taking into account the technological trends with potential disruptive effects in 2024 presented in table 1, one notices that there are numerous predictions linked to the implementation and use of AI (blue color) which could impact citizen life and most of the activity

fields, such as: AI Trust, Risk and Security Management (AI TRiSM); AI for everything; AI as a game-changer for future industries; Humanoids integrated with multimodal Large Language Models (LLMs); Businesses to focus on creating guardrails to mitigate AI risks; AI advancements to drive even more energy usage; Democratized generative AI, or significantly more advanced security threats due to Generative AI.

Today, the emerging and disruptive technologies are increasingly influencing all aspects of life – from electronics like phones and computers, to everyday activities like grocery shopping and banking [5]. The tech edge is concentrated in the hands of private companies and academia, while the government does not hold the grip on the advantage, as it used to in the past. Thus, technology extends the possibility and field of operation as they open a new chapter – the need for a “whole-of-society approach” [2].

Even if the principles of Industry 4.0 represent a big step further into automation, connected devices (like IoT), AI systems, robotics, and human-machine collaboration, the new Industry 5.0 concept shapes and changes the citizens' way of learning, working, and living. In addition, business processes, defense and security sectors, academia, and the way in which many private or governmental institutions conduct and develop their activities are impacted by new innovations and emerging technologies with a highly disruptive potential over time.

Both AI tests conducted with the purpose of getting the appropriate information based on specific topics proved, to a great extent, that the implementation and use of generative AI could be of real support as they providing in a very fast way the suitable information to researchers and those interested in various research topics. In this way, AI is an engine of change in many activity research fields due to the fact that it could analyze in a very short time large amounts of information in order

to provide the appropriate answers. Thus, the ethical issues related to the way in which the generative AI is used still require attention.

All the identified trend topics from the bibliometric analysis of scholarly publications related to our topic of interest as well as the technological trends depicted

in the table no. 1, prove and respond to our research questions. Undoubtedly, the rapid development of EDTs will impact our society, business models and industry over time, and the EDT's implementation, such as machine learning models besides generative AI, could have a greatly impact on the evolution of Industry 5.0.

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