INDUSTRY 4.0, SUSTAINABILITY AND INNOVATION AT THE CROSSROAD: A REVIEW ANALISYS

Florin PUCHEANU
Bucharest University of Economic Studies, Management Doctoral School, Romania
Florin_pucheanu@yahoo.com

Sofia-Elena COLESCA
Bucharest University of Economic Studies, Romania
sofia.colesca@man.ase.ro

Mihaela PACESILA
Bucharest University of Economic Studies, Romania
mihaela.pacesila@man.ase.ro

Stefan Gabriel BURCEA
Bucharest University of Economic Studies, Romania
stefan.burcea@amp.ase.ro

Abstract
The present article has the goal to provide an overview on the most relevant research publications placed at the intersection between the study of the Industry 4.0 and the concepts of innovation and sustainability. A review of the literature has been carried out and the most cited 80 publications identified in Scopus have been analyzed. The investigation pointed out that there is an exponential growth of the research activity in this field in recent years and that Europe is ahead of China and the United States as regards the number of scientific publications. The fundamental contribution of this article consists in highlighting the most important aspects related to the Industry 4.0 and the concepts of innovation and sustainability, by systematizing the findings of the publications studied.
Keywords: Industry 4; sustainalility; innovation.

1. INTRODUCTION

The starting point of the present research consists in investigating a research field incompletely covered in the literature, placed between the new emerging paradigm called by economists Industry 4.0 and the concepts of innovation and sustainability.

This new stage in the history of humanity called by some economists the 4th Industrial Revolution is of great interest due to its special and multidimensional importance worldwide.

First of all, the extent and speed of changes and innovation within the socio-economic system seems to be unprecedented in history, while its disruptive nature penetrates all economic sectors. Second, the complexity of interdependencies is heightened because this paradigm shift occurs at the peak of globalization, where value chains are deeply integrated and shared across states. Thirdly, the new paradigm has its origin in ecological pressures which humanity has dealt with superficially for a long time while now it is mandatory to solve them under the threat of irreversible imbalances and of an inexorably closing window of opportunity.

2. LITERATURE REVIEW

2.1. Industry 4.0

We are currently at the beginning of a new era, which some economists call the Fourth Industrial Revolution due to the scale, complexity and speed of technological transformations, unprecedented in history. In addition, there is also the possibility of fundamentally reforming the global economic and social system which could become a vector of exponential growth in productivity (Schwab, 2017).

ISSN 2067- 2462

Management Research and Practice
Volume 14, Issue 3 / September 2022

Although the generalized digitization of the economy and the promotion of innovative combinations of new technologies specific to the new paradigm received the economists' attention while generating consensus as regards the estimates for increasing the efficiency and economic performance, the new phenomenon has raised controversies.

According to Rifkin (2016) the speed of spread and the systemic impact are intrinsic attributes of economic digitization started 25 years ago at the dawn of the Third Industrial Revolution. Currently, the maturation of digital technologies leads to exponential growth curves and to the impressive reduction of marginal costs in very poorly developed industries, which only confirms the peak of the current economic paradigm, and in no way heralds the emergence of a new one.

For his part, in Nuvolari's view (2019), the name "Fourth Industrial Revolution" is not justified, because of lacking of clear technological or economic discontinuities that would support an important change. Moreover, the innovations of the current stage could be seen as incremental improvements in the field of information and communication technologies (ICT) and should not be considered the pillars of a new industrial revolution.

2.2. Innovation

Innovation is probably one of the oldest human activities contributing to the upward trajectory of humanity from the mists of prehistory to the modern era, while it is probably the only plausible response to demographic, environmental and later economic pressures. Over time, the strong evolutionary nature of innovation is widely mentioned and analyzed in the literature oscillating between the Darwinian and the Lamarckian approach. Thus, a general principle of "Evolutionary Epistemology" is outlined, considering innovation as a catalytic phenomenon contributing to the intellectual, social and material development of humanity in the logical and natural sequence of an organic evolution continuum (Ziman, 2000).

The evolutionary view is reiterated by many economists who make a clear distinction between innovation and invention, the latter referring to the first moment of conceptualizing a new idea, of presenting it publicly and protecting it by a patent, often in a way that cannot be implemented in reality. As regards innovation, it is a significantly improved variant due to continuous adjustments, resulting from interactions with the real economic environment and from consumers'opinion over long periods of time, meaning very often a drastic reconfiguration and a different economic significance compared to the initial variant (Kline & Rosenberg, 1986).

2.3. Sustainability

In their attempt to conceptualize the transition trajectories, Geels and Schot (2007) use the typology of Suarez and Oliva (2005), who analyzes the way companies react to changes in the business environment, by taking into account the higher-order changes, that is of the environment and climate. Geels and Schot deliberately exclude hyperturbulence between the influencing factors of their trajectories because this type of changes at the environment and climate is unlikely to appear in reality. However, the climatic evolutions tend to contradict the two authors only a decade later. The increasingly accentuated instability of climatic phenomena as well as the statistics in recent years shows a clear evolution towards hyperturbulence of the environment.

3. RESEARCH METHODOLOGY

The first part of the research includes a documentation providing a strong basis for the theoretical framework of the paper as well as a starting point in the epistemic approach. Thus, the main stages of the research are:

3.1. Identification of the study collection

The collection of studies was carried out on April 28 using data from Scopus dayabase. Scopus is one of the bigest scientometric database in the world, containing approximately 36,000 distinct titles from more than 10,000 publishers worldwide while covering various fields such as social sciences, life sciences or physical sciences (Anelis Plus, 2022). The initial search consisted of entering the keywords "*Industry 4.0 innovation*", "*Industry 4.0 sustainability*", "*Fourth Industrial Revolution innovation*", and "*Fourth Industrial Revolution sustainability*" in separate search fields linked by the logical operator "or" after selecting "*Article Title, Abstract, Keywords*" from the document search section of Scopus database (Figure 1). The search strategy deliberately excluded any other restrictions related to year of publication or region. In this regard, the search resulted in a number of 2455 scientific articles.

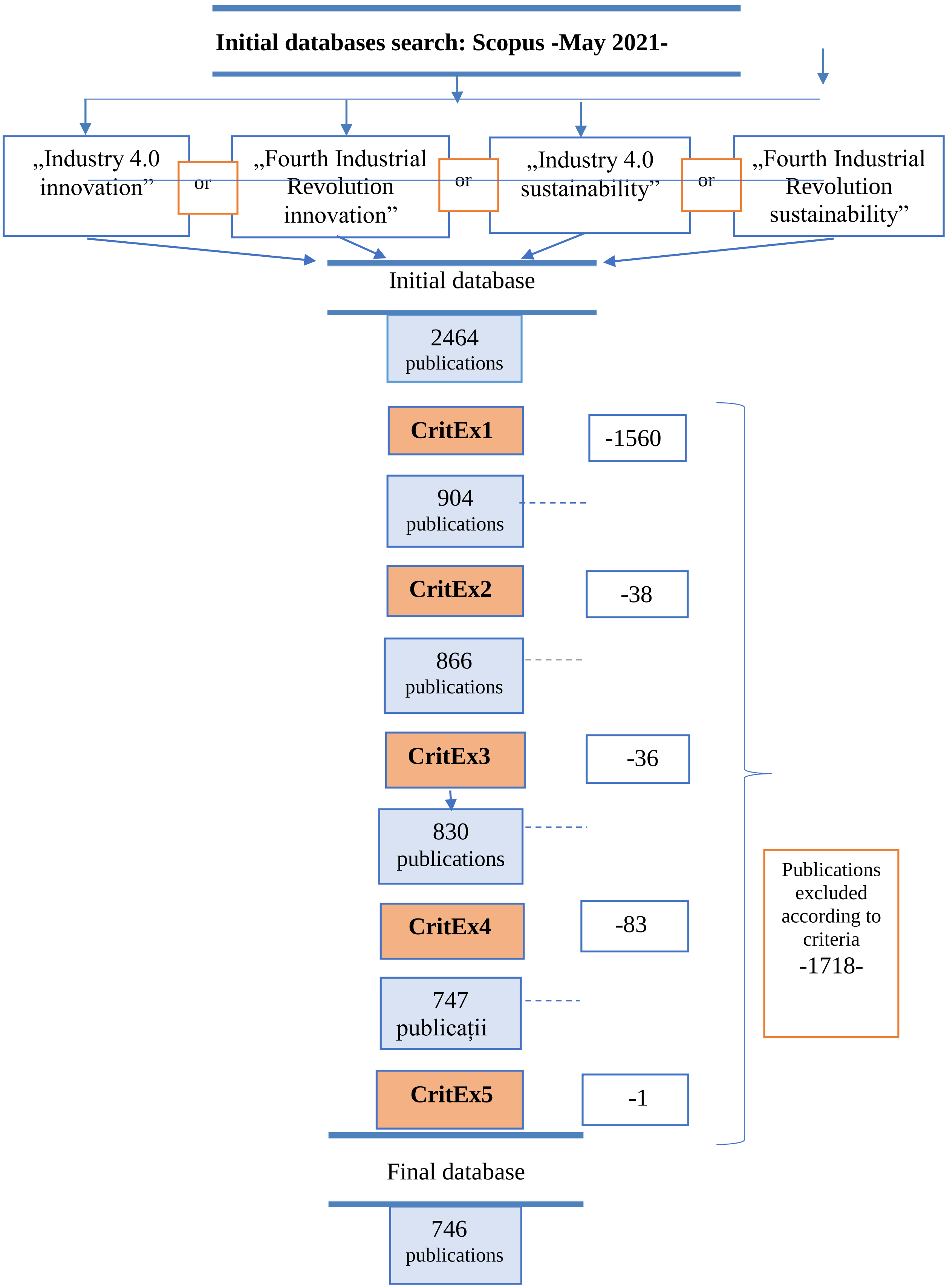


FIGURE 1 - ALGORITHM OF PAPERS' SELECTION

3.2. Selection of relevant studies

The next step was to define a list of exclusion criteria and build a sequential algorithm for their application. Each successive stage of exclusion led to creating a database of relevant articles for the research. The exclusion criteria used are shown in Table 1.

TABLE 1 -. EXCLUSION CRITERIA USED IN PROCESSING THE DATABASE OF ARTICLES UNDER ANALYSIS

Criterion number	Sequence code	Criterion description
1.	CritEx1	The paper is not open source, therefore the full analysis of the text is not possible.
2.	CritEx2	The paper is not written in english.
3.	CritEx3	The paper is not a review or an article published in a scientific journal or an article included in the conference proceedings
4.	CritEx4	The category "subject area" is irrelevant including less than 30 publications
5.	CritEx5	The year of publication generates discontinuities in the analysis

3.3. Statistical investigation selected studies

The final database containing the most relevant publications for the chosen topic was statistically analyzed (Figure 2). Out of the total number of 746 of papers, more than half are articles published in scientific journals, while 38.1% are papers presented at conferences. A smaller, but still consistent percentage (7%) is made up of reviews.

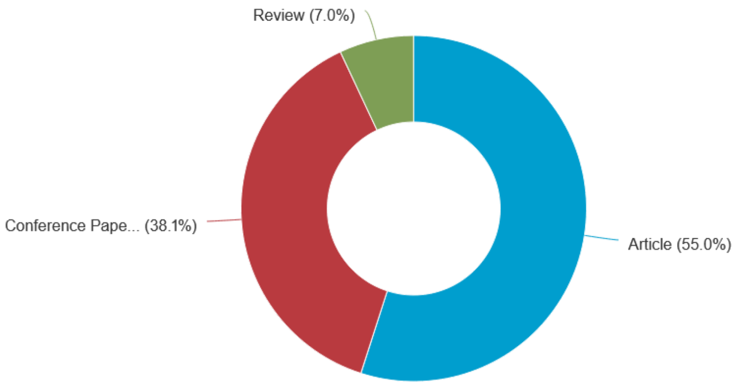
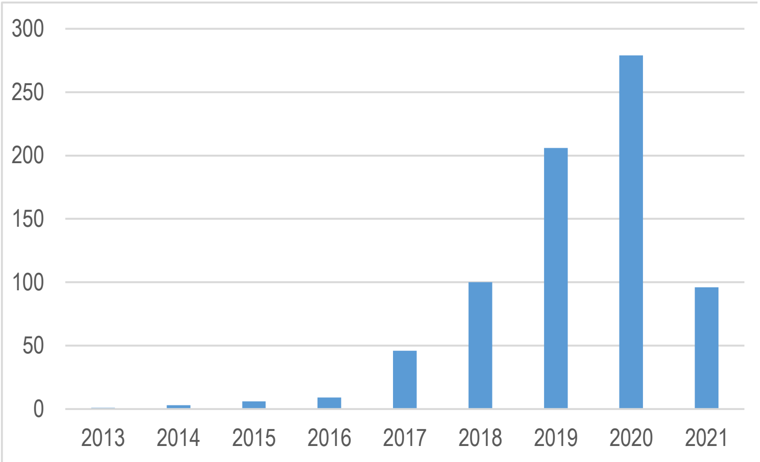


FIGURE 2 - DISTRIBUTION OF PAPERS ACCORDING TO CATEGORY

The analysis shows many interesting and revealing aspects for understanding the evolutionary dynamics of the Industry 4.0 phenomenon. On the one hand, the annual distribution of publications presented in Figure 3 reveals that the researchers' interests in this field have been recent, more precisely since 2013, leading to the conclusion that the field of research is in its infancy, thus providing exciting opportunities for experimentation and discovery.

On the other hand, after a relatively heavy and hesitant start with less than 20 articles published within 4 years, an exponential evolution in the number of annual publications has occured since 2017, which means an increase of 411% compared to the previous year. Each of the next three years brought consistent increases of 117%, 106%, and 35%. The growth trend has most likely continued in 2021, especially since the articles published in the first 4 months of the year exceeded by a third the number of the previous year. Therefore, in the context of the transition to the Fourth Industrial Revolution, the studies related to innovation and sustainability are experiencing an increase putting the research field on an upward trajectory.



Year	Document ↑
2021	96
2020	279
2019	206
2018	100
2017	46
2016	9
2015	6
2014	3
2013	1

FIGURE 3 - NUMBER OF PUBLICATIONS PER YEAR

Figure 4 provides a more suggestive picture about the exponential growth of the research activity in this sector in recent years, highlighting that the year 2020 and the first 4 months of the year 2021 (the time up to which the analysis was carried out) contain 50% of the entire volume of publications in the research field.

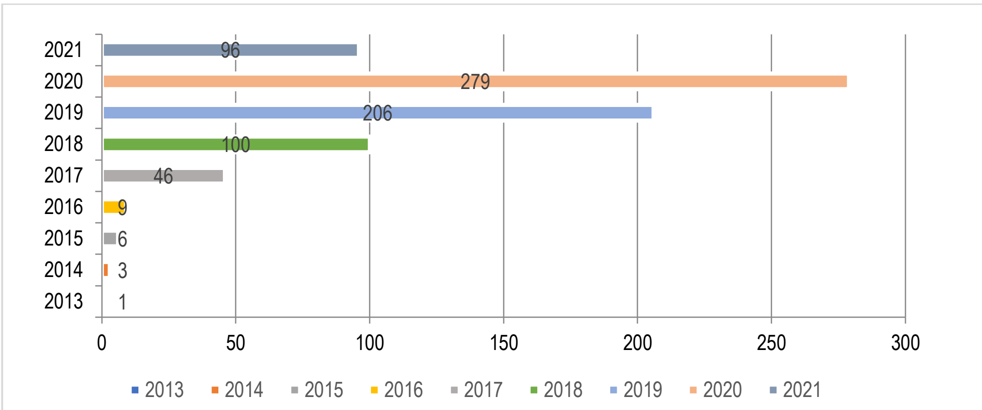


FIGURE 4 - PERCENTAGE DISTRIBUTION OF PUBLICATIONS PER YEAR

As regards the geographical distribution, a significant interest in this field of research could be found in Europe due to the higher number of scientific papers published, compared to the United States or China. Figure 5 presents the first 15 most prolific countries according to the academic interest in the Industry 4.0 analyzed by means of innovation and sustainability keywords. Thus, although they are two economic forces worldwide fiercely fighting for the top position in global leadership, the United States of America and China share the 11th and 12th rank, while they are behind Poland or South Korea as regards the ranking of relevant scientific publications.

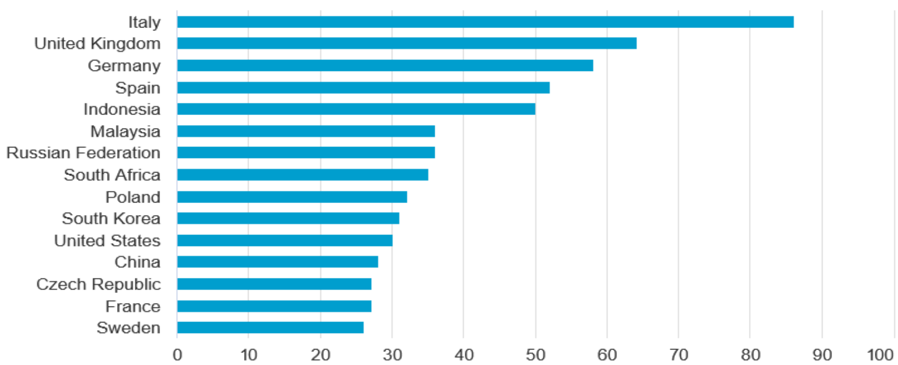


FIGURE 5 - TOP 15 STATES ACCORDING TO THE NUMBER OF RELEVANT PAPERS

Management Research and Practice
Volume 14, Issue 3 / September 2022

Figure 6 highlights the geographical distribution of papers. Out of the total of 746 publications under analysis, countries with less than 5 published articles were eliminated.

Thus, although Italy clearly stands out as regards the number of papers, Germany and Great Britain are chronologically better placed while having contributions in the field of study up to two years in advance. Moreover, both the United States and the cluster of China and South Korea are chronologically ahead of Italy, while quantitatively speaking, their aggregate contributions barely match the leader's individual performances. Last but not least, the Romanian scientific community is in its infancy in this field of scientific research, the contributions of researchers from our country taking shape after mid-2020.

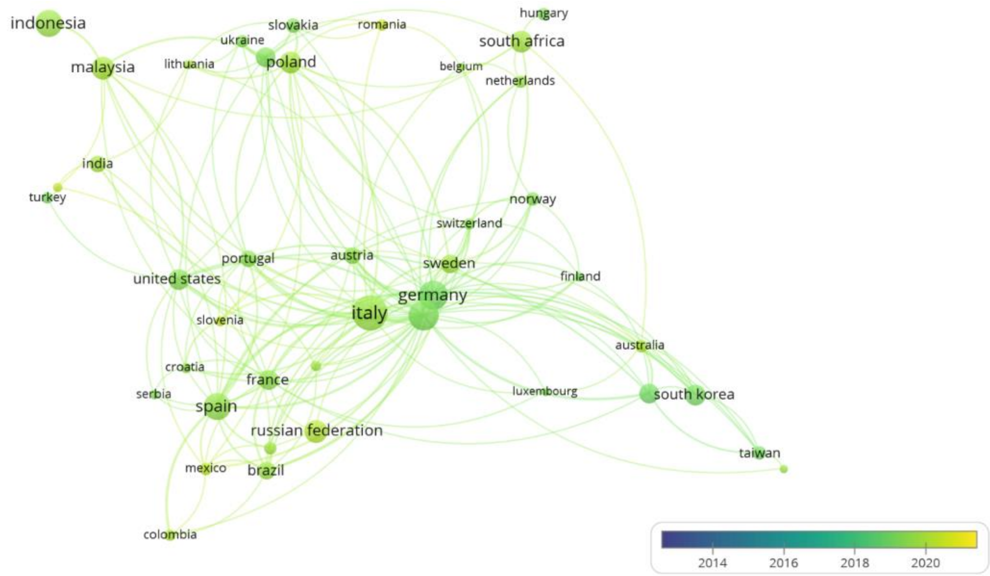


FIGURE 6 - GEOGRAPHICAL DISTRIBUTION OF PAPERS PER YEAR

Overviewing the distribution of scientific literature by continent, the absolute dominance of Europe stands out. As could be seen in Figure 7, Europe's contribution to the total of publications under analysis is 58%. Thus, with double the number of papers compared to Asia and North America combined, Europe is clearly a leader in the study of the innovative and sustainable nature of Industry 4.0.

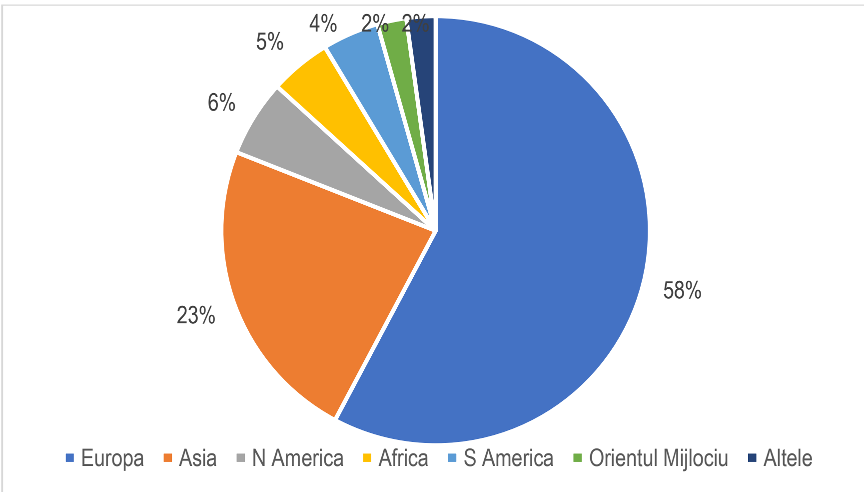


FIGURA 7 - PERCENTAGE DISTRIBUTION BY CONTINENT OF PAPERS

Taking further the analysis, the overall picture of the studied phenomenon takes shape by revealing the causes behind such a significant dominance of Europe in the field. Therefore, by investing and supporting the publication of scientific papers in this field, European Commission has a great contribution in highlighting

Europe's central leadership role in studying and implementing the Fourth Industrial Revolution by continuous innovation and the pursuit of long-term sustainability (Figure 8).

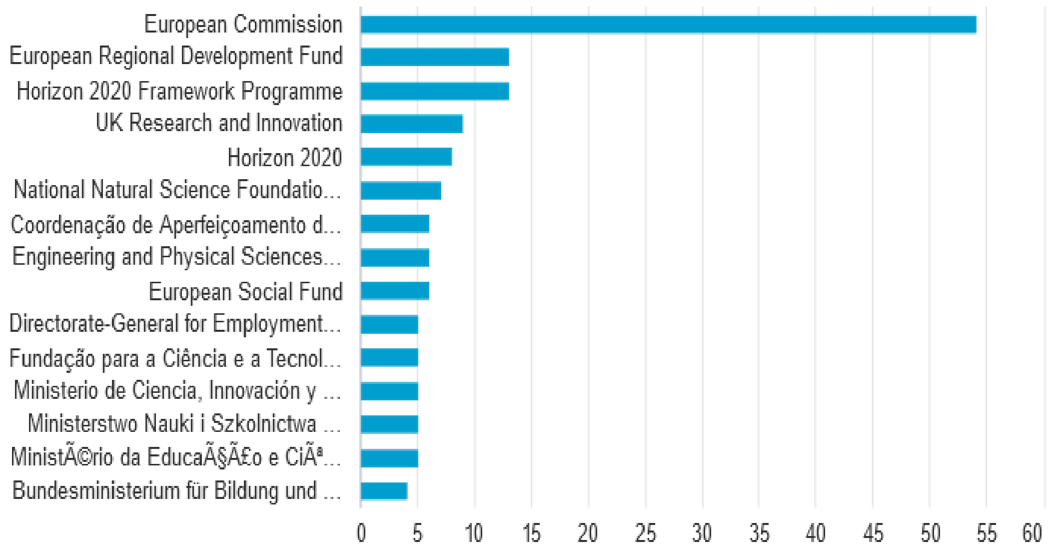


FIGURE 8 - CONTRIBUTING SPONSORS IN THE FIELD UNDER ANALYSIS

Extremely useful for understanding the multiple facets of the transition to the Fourth Industrial Revolution is the classification of the papers according to the field of study. Thus, as can be seen in Figure 9, the new emerging technologies seen as pillars of Industry 4.0 are mostly studied within the publications in the fields of Engineering and Computing Techniques, representing together 35.4% of the total number of scientific papers under analysis.

Social Sciences represents the next field of study, while the third most consistent field of interest, with a percentage of 11.6% of the papers, is that of Environmental Sciences.

Engineering	325
Computer Science	225
Social Sciences	216
Environmental Science	181
Energy	153
Business, Management and Accounting	124
Materials Science	76
Economics, Econometrics and Finance	61
Decision Sciences	45
Physics and Astronomy	45
Mathematics	38
Earth and Planetary Sciences	35
Chemical Engineering	30

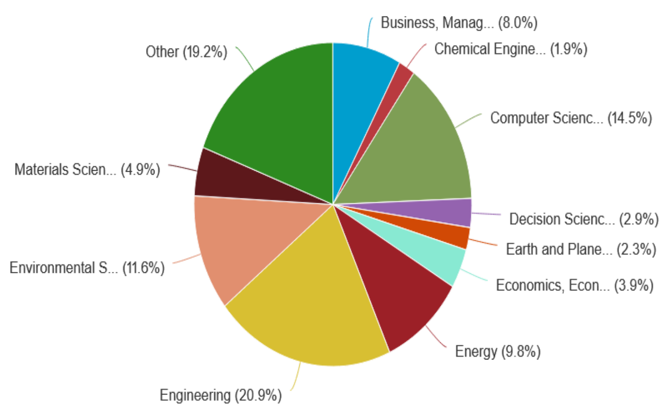


FIGURE 9 - DISTRIBUTION OF PAPERS UNDER ANALYSIS BY FIELDS

In order to analyze the keywords within the 746 papers, the VOSviewer software was used, which allows complex bibliographic analyzes on several dimensions. Thus, the software graphically highlights, as a map, the frequency of keywords used by authors, as well as the strength of the interdependencies between these words, by grouping them into specific clusters. Therefore, the software identified 2045 keywords. However, all the keywords with less than 10 mentions were eliminated, thus resulting 27 keywords, with the highest representativeness for the topic under analysis.

Figure 10 graphically shows how the 27 words were distributed using the software, as nodes in a network of connections made up of 5 clusters very different in size and composition. The key to deciphering the map lies in the correct interpretation of two essential parameters: the "bandwidth" or in simple terms, the extent of the connection between the two nodes, in other words the co-occurrence force between the words and the distance between the nodes describing the "degree of kinship" between the words.

Therefore, looking carrefully at the map in figure no. 12, the most obvious relationship is between Industry 4.0 and the concept of sustainability, which are not only in the same cluster. They have also developed the most significant co-occurrence connection and have been located at the minimum distance which means a strong relationship. Slightly surprising is the greater distance between Industry 4.0 and the concept of innovation, taking into account that the new paradigm is foreshadowed as the most innovative era in human history. However, the two concepts have important co-occurrences, while two other nodes in proximity, that of Digitization from the blue cluster and the Internet of Things from the red cluster, have strongly converging connotations with technological innovation.

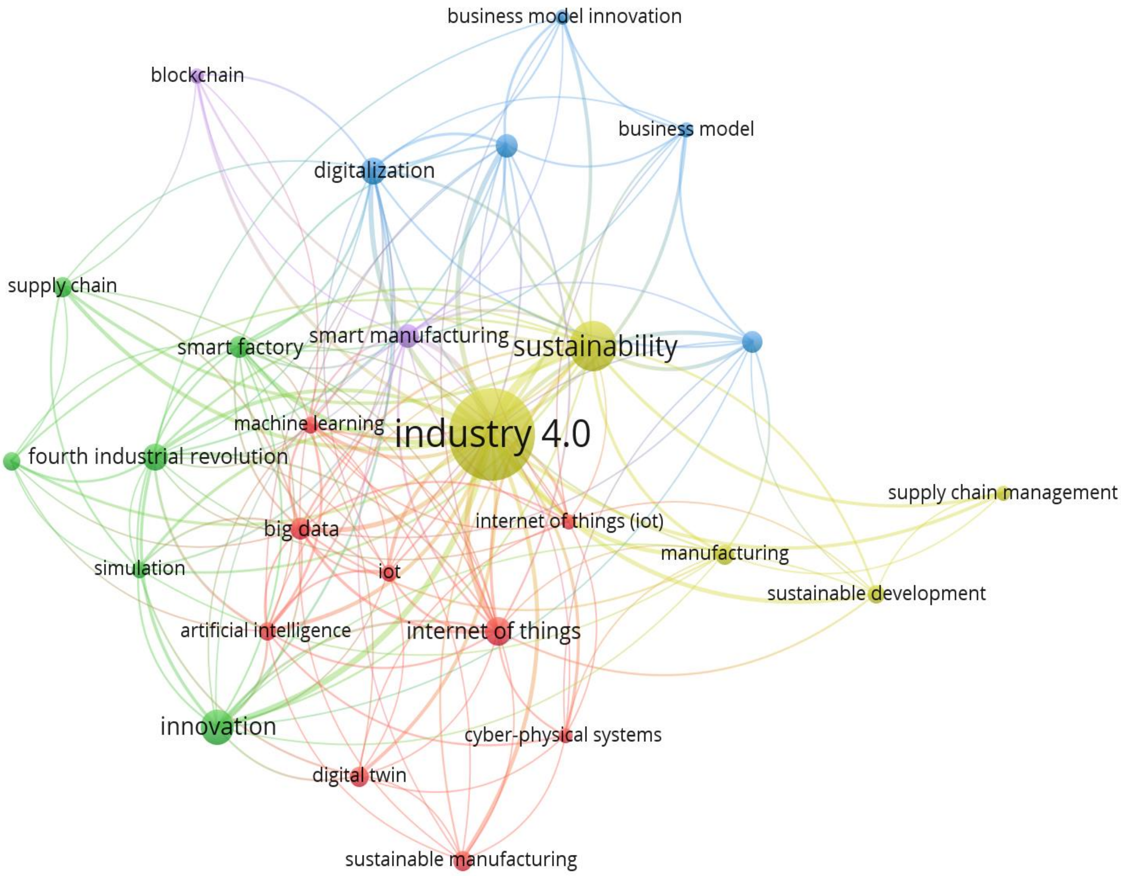


FIGURE 10 - PAPERS ANALYSIS ACCORDING TO KEYWORDS

Management Research and Practice
Volume 14, Issue 3 / September 2022

4. THEMATIC RESEARCH OF SELECTED PAPERS

In this stage, emphasis was on identifying the main topics linked to the concepts of innovation and sustainability in the context of Industry 4.0 in the literature. In this regard, the most cited 80 publications in the scientific literature were thoroughly analyzed from the content perspective. Essential information related to key concepts, recurring terms, converging viewpoints and categories of interest common to multiple authors were therefore manually extracted and sorted.

The fundamental topics of interest standing out from the analysis carried out are the following:

- Technological innovations of Industry 4.0
- Effects of generalized digitization on the socio-economic system
- Innovative/disruptive principles of Industry 4.0
- Catalytic factors for sustainability
- Discontinuities, opportunities and obstacles in the transition to Industry 4.0

4.1. Technological innovations of Industry 4.0

The technology has been widely considered the catalyst behind every industrial and economic boom in history. Therefore, it is no surprise that emerging technologies in the context of the transition to the Fourth Industrial Revolution have been the most intensively and complexly studied in the selected publications. Analyzing the content, two categories of approaches emerge, different in focus and reference system. On the one hand, there is the analysis of technologies having already reached a certain degree of maturity and classified by technical and commercial reliability, either on a national scale or in some industrial sectors. In this case, the analyzes focused mainly on their economic potential by increasing competitiveness and revenues of companies (Bonilla et al., 2018), by optimizing and streamlining processes (Liao et al., 2017), by reducing costs (Alami and ElMaraghy, 2021) or by creating network effects (Mulick et al., 2021).

On the other hand, early-stage innovations have been studied by means of their potential for evolution towards the higher level of extended adoption in the economy (Fromhold-Eisebith et al., 2021), or by the complementarities with already existing technologies (Ballestar, et al., 2020), either by completely replacing them (Rifkin, 2015) or by opening new markets (Silvestri, 2021).

Table 2 presents the main technologies analyzed in the literature considered important technological innovations for the new technical-economic paradigm.

TABLE 2 - TECHNOLOGICAL INNOVATIONS SPECIFIC TO INDUSTRY 4.0

No.	Technological innovation	Number of articles	% of the total
1.	Internet of Things (IoT)	36	45.00 %
2.	Big data algorithms	29	36.25 %
3.	Cyber-physical systems (CPS)	27	33.75 %
4.	Cloud	21	26.25 %
5.	Artificial Intelligence / Machine Learning	18	22.50 %
6.	Virtual reality/augmented reality	16	20.00 %
7.	Blockchain	13	16.25 %
8.	Digital twin	9	11.25 %
9.	Smart/ additive manufacturing	8	10.00 %
10.	Simulation	6	7.50 %

By far the most studied technology specific to Industry 4.0 is the so-called Internet of Things (IoT), an intelligent platform physically incorporating a whole plethora of sensors, actuators and autonomous machines communicating in real time with each other as well as with the platform and human decision-makers, where appropriate. All this vast information network provides efficiency level as regards the integration of processes both vertically and horizontally (Yang et al., 2017). This super-internet exceeds the boundaries of the traditional company, connecting the entire network of stakeholders in a flexible and agile ecosystem, which can respond much more quickly and efficiently to threats and opportunities from the business environment (Glova et al., 2014), or to dynamic customer needs (Fisher et al., 2018). The efficiency of collaboration and the optimization of information flows within the network are facilitated by the intensive use of algorithms performing complex data collection functions, as well as analysis and decision-making processes, all carried out in real time, using huge amounts of data collected by sensors attached to smart equipment (Herrmann, et al., 2014). Big-data algorithms are seen as an essential complementary technology of the Internet of Things providing huge opportunities for improving the productivity, efficiency and flexibility of economic processes (Li et al., 2017) by collecting and compiling data from the environment.

Therefore, in the new philosophy outlined by Industry 4.0, emerging technologies do not develop in isolation, but evolve towards a synergistic integration, in constellations of technologies that mutually self-enhance to generate positive leverage effects. In this regard, big-data algorithms are conceptualized in close connection with cloud technology providing distributed computational support in order to process enormous amounts of data in real time. The addition of the installed computing capacity is thus ensured, especially when the data flow exceeds the system capacity to provide a superior performance of gaining information and generating coherent and synchronized responses at the entire logistics chain (Ghobakhloo, 2018).

In complementarity with cloud technology, cyber-physical systems represent complex networks of interdependencies between various equipment, performing dynamic tasks and information processing units, interpreting incoming signals, rebuilding a virtual image of reality and sending commands factually adapted. At the intersection of cloud technology and cyber-physical systems, new areas of unexplored possibilities open up, such as the concept of control-as-a-service for industrial automation applications (Givehchi, et al., 2014), or the implementation of adaptive decision-making systems, based on multi-criteria (Mourtzis & Vlachou, 2018).

Not all innovations specific to Industry 4.0 benefit of similar developments as regards technological maturation, adaptation to the rigors of the market or degree of adoption in the real economy. If the innovations presented above have already largely become reference technologies, with solid applications and proven results, others, including virtual/augmented reality, digital twin technology or additive manufacturing, are still in the early stages of laboratory testing of their technical and economic viability (Oesterreich & Teuteberg, 2016).

Blockchain technology confirms its applicability and economic opportunity in the context of strong complementarity with the Internet of Things (IoT). From a wide range of Blockchain functions in contributing to Industry 4.0 ecosystems, in general and in the synergistic relationship developed with the Internet of Things, in particular, the most intensively studied are development and execution of smart contracts (Lone & Naaz, 2021), data security (Ge et al., 2020), third-party trust mediation (Kochovski, et al., 2019), automatic payments (Zhong et al., 2019), and solving IoT security issues (Khan & Salah, 2018). Beyond the possibility of solving problems specific to the various technologies of the Industry 4.0, the blockchain technology has a huge potential for complementarity with many of the emerging technologies, due to its role of decentralized infrastructure mediating information exchanges and value.

Another aspect intensively studied in the literature refers to the creative ways the innovations presented above interact with each other, in various configurations, generating economic and sustainability opportunities. In this regard, the most studied synergies are Internet of Things and Blockchain (Qian, et al., 2018; Villiers, et al., 2021), Blockchain and Artificial Intelligence (Kumari, et al., 2020; Gligor et al. , 2021) or Internet of Things and Artificial Intelligence (Mo & Sun, 2020; Hansen & Bøgh, 2021).

4.2. Effects of generalized digitization on the socio-economic system

The development of technologies, products and services with a high degree of digitization and their accelerated diffusion in the economy is an intrinsic characteristic of the transition to the Fourth Industrial Revolution. The new paradigm is the trigger of a complex multi-dimensional interactions between technological innovation, responses and accelerated dynamics of consumer expectations while companies make considerable efforts to reposition themselves in order to better deal with threats and opportunities provided by a hyper-competitive economic environment (Teece, 2018). In addition, there is also the regulatory dimension which is in a strong interdependent relationship with the above dimensions while the state is under pressure to respond coherently and quickly to developments in society by developing timely policies adapted to the new realities.

Emergence of new business models. The companies' focus on the innovation of business models which can prove to be more effective than the innovation of products or processes is one of the most intensively studied aspects in the literature (Geissdoerfer, et al., 2018).

The literature reveals success stories on the implementation of new business models, where leaders such as Amazon in the field of commerce (Aversa, et al., 2020), Uber in the field of mobility (Muller, 2020) or FoodPanda in food delivery (Yeo et al., 2021) stand out. On the other hand, companies such as Kodak (Koen et al., 2011) or Blockbuster (Raynor, 2016) failed in the attempt to develop business models adapted to the digital age and were doomed to bankruptcy.

Overviewing the literature, a lot of clear directions for structuring the research stand out. Quantitatively speaking, the most consistent of them revolves around the analysis of digitization by means of the changes generated within processes such as value proposition (Taylor et al., 2020), creation (Sjödin et al., 2020; Matarazzo et al., 2021), distribution (Beaulieu & Bentahar, 2021) and value capture (Kohtamäki et al., 2020).

Moreover, the configuration of business models in the context of increased digitization was analyzed in relation to emerging trends such as collaborative economy (Curtis, 2021), circular economy (Braun et al., 2021), servitization of the economy (Paiola & Gebauer, 2020), prosumer economics (Hwang et al., 2017) or innovation in the social economy (Tykkyläinen & Ritala, 2021).

Changes in labor relations in the context of the massive digitization of products, processes and business models is one of the basic concerns of both researchers and regulatory entities while generating wide controversies (Murillo et al., 2017), but also exploration opportunities (Lin et al., 2020). Many criticisms of digitization bring into focus the work relationships specific to the collaborative economy, while some authors state that workers can be exploited precisely because of the work relationships nature (Tran & Sokas, 2017). Seen as independent contractors (Carboni, 2016), short-term workers (Gleim et al., 2019) or "on-demand" workers (DeStefano, 2016) in the new work organization philosophy, the participants in collaborative models give platforms a significant advantage (Gonzalez-Padron, 2017), at the price of giving up social protection of employees (Steward & Stanford, 2017) and a long-term unfavorable status. On the other hand, some authors in the literature emphasize the positive aspects of this work model such as the flexibility of the work schedule (Hartono et al., 2021) and the opportunity to integrate low-skilled people into the labor market (Kelly, 2020).

Redefining the concept of "trust" is seen both as an effect and above all as an essential condition for a generalized adoption of digitization, in the new paradigm of Industry 4.0. In the new philosophy of open innovation, achieving a higher competitiveness by companies is conditional on the most effective integration of a wide range of external stakeholders (Schepis, et al., 2021), each of them with their unique specializations and knowledge, within a network generating value and innovation (Salampasis & Mention, 2019. Thus, in such a heterogeneous environment, dominated by cultural, technical and organizational value differences (Mubarak & Petraite, 2020), reaching an optimal level of trust within the network is the critical element for the success of a project (deOliveira & Rebechini, 2019) and for achieving a competitive advantage. In the context of Industry 4.0, trust evolves from the human level to direct integration in technological structures (Mubarak, et al., 2019), by the widespread use, especially of Blockchain technology, in various fields, starting from food traceability (Casino et al., 2019), securing medical data (Usman & Qamar, 2020) or financial transactions (Sangwan et al., 2020). Moreover, Internet of Things (IoT) (Narang & Kar, 2021) or Cyber-Physical Systems (CPS) are high potential technologies towards the automatic integration of trust in technological systems.

Another field intensively studied in relation to the concept of trust in the digital age is the collaborative economy. To guarantee trust and facilitate productive collaboration between complete strangers, the aggregator platforms play a decisive role in intermediating exchanges (Schor, 2016). Furthermore, implementing reputation mechanisms increases the trust between participants within platforms while facilitating an optimal level of socio-economic interaction (Stahl, 2013).

4.3. Innovative/disruptive principles of Industry 4.0

The literature provides a wide range of interpretations and conceptualizations of the organizing principles behind the disruptive nature of Industry 4.0. However on a closer look, a lack of conceptual homogeneity and a relative lack of rigor in defining the terms can be found, probably generated by the wide variety of specializations and disciplinary fields of the authors. In the current section, a brief classification of the defining principles behind the new paradigm is attempted, as they emerge from the content analysis of the relevant publications, accompanied by the broad definition of each concept, in order to contribute to epistemic homogenization.

Real-time integration involves the ability of Industry 4.0 platforms to ensure instant communication between intelligent components within ecosystem, to analyze data collected from different sub-systems of the logistics chain and to generate and send coherent decisions (Terziyan et al., 2018). For the first time, the new IT technologies allow a holistic approach by real-time dual integration, both vertically and horizontally. Vertical integration involves directly connecting all components and hierarchical levels of an organization in order to increase the overall profitability (Biancini & Ettinger, 2017) and to encourage innovation (Liu, 2016). On the other hand, horizontal integration involves the real-time coordination of many stakeholders, from suppliers to customers, within a flexible and dynamic network which can respond much more quickly to changes in the business environment (Strozzi et al. , 2017). In the literature, real-time integration has been studied by its potential benefits such as improving traffic congestion (Manseur et al., 2020), optimizing logistics routes (Bock, 2019), adjusting prices and energy consumption (Siano & Sarno , 2016), security monitoring of industrial processes (Yu et al., 2015) or dynamic planning of intelligent manufacturing processes (Rossit & Tohmé, 2018).

Reconfiguring the role of stakeholders. In theory, in any era or economic system, the fundamental role of any economic organization is to generate value for a wide range of stakeholders. In the new paradigm of Industry 4.0, this aspect remains valid, but there is a major reconfiguration of the interactions between the various categories of stakeholders as well as of the power relations between them (Martin, 2016). The organizational framework provided by the collaborative economy based on new emerging technologies and on aggregator platforms changes the roles and interactions within the value chains of companies while placing the customer in a central, privileged position (Frankenberger et al., 2013).

Whether becoming a micro-entrepreneur (Crittenden et al., 2019) or a prosumer (Moura & Brito, 2019), the customer has changed the role from passive consumer to generating and sharing value directly with strangers, in some cases completely eliminating intermediaries from the value chain (Rifkin, 2015). In response to the pressures or opportunities of the collaborative economy, other categories of stakeholders, including companies identified as market leaders in their fields (Ciulli & Kolk, 2019) or investors (Tao & Wei, 2019) have chosen to significantly reposition themselves.

Decentralization is the ability of an ecosystem components to self-coordinate without the intervention of a central authority or to manage their interactions and exchanges of value without an intermediary. It is studied in extremely diverse fields, starting from the decentralization of production control systems (Grassi et al., 2020), traceability within logistics chains (Chiacchio, et al., 2020), reconfiguration of waste management (González et al., 2020), decentralized energy generation systems (Schulz et al., 2020) up to decentralization of consensus among stakeholders (Liu et al., 2021), decentralization of taxation (Cheng et al. , 2021), payment processing (Lee, 2019), decentralization of auctions (Omar et al., 2021) or even car sharing (Saurabh, et al., 2021).

Generalized servicing represents the new trend which involves reinventing the philosophy of generating, monetizing and capturing value. By turning to new business models, customers are encouraged to give up costly investments in product acquisition in exchange for recurring payments for services complementary to products or value derived from their temporary use (Tukker, 2015). This trend initially started by implementing the so-called product-service system (PSS) (Hänsch-Beuren, et al., 2013) and mainly targeted the final consumers. Currently, by the convergence of Industry 4.0 technological innovations, this principle extends to the industrial sector, to the Internet of Things used in production (Rymaszewska et al., 2017) or the servitization of digital processes (Cimini et al., 2021). The benefits generated by servitization have been widely analyzed in the literature, especially as regards companies which could obtain long-term competitive advantages (Guo et

Management Research and Practice
Volume 14, Issue 3 / September 2022

al., 2015) by increasing and diversifying revenues (Salonen et al., 2017) as well as customer loyalty (Visnjic & Van Looy, 2013).

4.4. Catalytic factors for sustainability

The sustainability of Industry 4.0 is one of the main topic in the scientific literature together with the study of the new system economic benefits. More precisely, in this regard, the most popular topic is tripple bottom line, namely the analysis of economic, social and environmental aspects, seen as important elements in achieving a real long-term sustainability.

Economic dimension. The papers under analysis focus on the main aspects of the economic performance of companies while the authors identify a whole range of beneficial effects of the new technologies in the economy. *Increasing economic productivity* is identified as one of the main benefits of generalized digitization as regards the production (Jeske et al., 2021) and can be achieved by better process planning (Brecher, et al., 2019), by a superior level of monitoring and feedback transmission, the information aggregated through big data algorithms in real time providing an obvious competitive advantage (Sjåholm Knudsen et al., 2021). Even if the introduction of generalized digitization within company is not an easy process and could be accompanied by high costs and conflicts (Horvat et al., 2019), in the long run it generates undeniable positive effects, like the decrease in consumption of raw material (Brüggemann, et al., 2020). *Reducing costs* by optimizing supply chains based on collaborative models (Hu et al., 2019) or by reducing complexities of coordination and communication (Brito & Miguel, 2017) are other expected effects of technological innovations specific to Industry 4.0.

Last but not least, *increasing the flexibility and resilience of organizations*, an extremely current topic in the context of the multiple crises to which humanity is exposed, could be achieved by implementing decentralized models (Min, 2019) or by integrating real-time logistics chains based on the Internet of Things (Zhou & Piramuthu, 2018).

Increasing long-term economic competitiveness, an important element of sustainability, has been addressed in the literature by many authors interested in the obstacles to achieving economies of scale.

Social dimension. The social dimension of sustainability is addressed in the literature from several perspectives. One of them refers to *the empowerment of consumers*, by repositioning them in the economic ecosystem with the emergence of the prosumers category (Wilkinson, et al., 2020). In the new organizational paradigm, although the prosumers in the energy market face various cultural, geographical or legal barriers (Horstink et al., 2020), they gain both a greater bargaining power and a better distribution of costs and benefits (Hiteva & Sovacool, 2017). Moreover, the consumers enjoy the facilities of new technologies, which allow a *high degree of products and services customization* (Papazoglou et al., 2020), thus providing superior experiences to consumer at competitive prices.

From another perspective, Industry 4.0 technologies are analyzed by means of the benefits and efficiencies they generate on the labor market, while *increasing the flexibility of work processes* by integrating the Augmented Reality and Virtual Reality facilitates learning and reduces the execution times of various tasks (ValleEnrique et al., 2021). In the long run, workers assisted by technology can enjoy a better balance between professional and personal life (Dittes et al., 2019), although in certain cases there is a danger that professional activities facilitated by technology could invade private life.

Another area of analysis was the Artificial Intelligence and work automation by using software robots, which leads to *decreasing the share of repetitive tasks* (Ribeiro et al., 2021) while increasing the ease of professional life for many categories of employees. However, in the lomg run, the uncontrolled generalization of this technology may lead to loss of jobs in certain sectors (Nam, 2019), especially regarding unskilled workers (Frey & Osborne, 2017).

Dimension of environmental protection. The Industry 4.0 philosophy generates fundamental changes at the economic level as well as on business models, while integrating ecological sustainability into current economic practices (Stock, et al., 2018). Possibly the most pressing dimension of long-term sustainability because of the irreversible imbalances generated by human activities, the dimension of environmental protection is widely investigated in the context of the transition to the Fourth Industrial Revolution. One of the fundamental directions of study consists in analyzing the contribution of new technologies to promoting the circular economy (Moktadir et al, 2018) or the collaborative economy (Pouri, 2021), both having high potential as regards the sustainability. Therefore, *reducing the consumption of raw materials* is a major objective of Industry 4.0 (Amjad et al., 2021) and could be achieved by better planning and production flexibility (Novák et al., 2020), by integrating in real-time logistics and production processes (Pan et al., 2021), or by reducing production inefficiencies by using cloud technology and additive production processes (Simeone et al., 2020).

Furthermore, *reducing losses* could be achieved through the real-time integration of companies' value chains, an extremely useful approach, especially regarding perishable products (Lejarza & Baldea, 2020).

Another area of analysis refers to the possibilities of *reducing greenhouse gas emissions*, both in passenger transport by promoting car-sharing platforms (Yu et al., 2017) as well as in goods transport by optimizing transport routes (Guedria et al., 2017).

4.5. Discontinuities, opportunities and obstacles in the transition to Industry 4.0

As any major turning point in the evolution of socio-economic systems, the transition to Industry 4.0 brings a lot of transformations on all levels as well as significant discontinuities in some industries.

Major discontinuities are addressed in the literature, mainly by the emerging technologies, which either bring completely new capacities, or facilitate recombinations and complementarities of technologies and knowledge in new and creative ways (Grimpe & Sofka, 2016). All these are analyzed by means of social transformations they generate and fields where they appear more meaningfully. Significant discontinuities can be found in the semiconductor industry (Sydow & Müller-Seitz, 2020) influencing a wide range of fields such as production of green energy (Baker, 2021), information and communication technologies (ICT) (Hoisl et al., 2015), artificial intelligence and process robotization (Berg et al., 2018) or health (Hardeman & Kahn, 2020).

As regards social trends and transformations, there are studies on the connections between technological discontinuities and social media (Orlandi et al., 2020) representing the vector for the new trends and changes in consumption behaviors. The most important are collective ecological movements (Marshall, 2013) generating substantial changes both at the technological and organizational level (Kautish et al., 2019) and at the regulatory policies.

At the same time, major technological discontinuities are important opportunities for the companies that know how to take advantage of them, but also a danger of losing the dominant position, or even extinction for the hesitant companies (Hoisl et al., 2015).

Significant opportunities of the transition to Industry 4.0 stand out, starting from products and services to processes and economic systems (Enyoghasi & Badurdeen, 2021) for companies that are prepared to integrate the new technologies in their value chains.

As it emerges from the literature, the field providing the most opportunities for companies is that of *intelligent production* (Zenisek et al., 2021) by integrating modular and reconfigurable equipment allowing a rapid adaptation of production processes (Morgan et al. al, 2021), by the widespread use of cyber-physical production systems (Kim & Park, 2017) or by the real-time integration of labor, machines and materials in IoT-type operational platforms (Nabeel et al., 2020). Smart production, implemented and operationalized correctly, could provide superior competitive advantages (Lenz et al, 2020) and increased company profitability.

Another significant area of opportunity is that of *energy sustainability* (Ghobakhloo & Fathi, 2021), which companies can achieve both by supporting investment in research and developing more energy efficient technologies (Khalate et al., 2018) as well as by optimizing processes and streamlining value chains (Liu et al., 2018), based on decisions supported by real-time processing of information.

Analysis of threats/barriers emerging from the literature in relation to the transition to Industry 4.0. The analysis is clearly dominated by the topic of *cyber vulnerabilities* representing the "Achilles' heel" of the new era based on generalized digitization (Shahin et al., 2020). Due to the unprecedented integration facilitated by Industry 4.0 and the enormous amount of data underlying decision-making or production processes (Ren et al., 2019), the companies' information systems are exposed more than ever to the dangers of cyber-espionage (Pereira et al., 2017). Moreover, the intelligent platforms based on Internet of Things (IoT) technology have multiple vulnerabilities to various cyber attacks by the multitude of sensors, informational nodes and autonomous equipment communicating bi-directionally and in real time within the system (Burger et al., 2020). These vulnerabilities start from the simply deactivation of the system (denial-of-service) (Lawal et al., 2021) and conditioning its restart on a financial reward to complete destruction in the case of terrorist cyber attacks (Saidi et al., 2017).

The most targeted areas as regards the frequency of cyber attacks are energy systems, essential production processes, transport and communication networks (Kimani et al., 2019).

As regards the barriers and challenges of the transition to Industry 4.0, legal uncertainties (Kamble et al., 2018), substantial installation costs (Erol et al., 2016), lack of a strategic vision of companies (Basl, 2017), lack of qualification of the labor force (Kiel et al, 2017) or employees resistance to disruptions in labor relations (Horváth & Szabó, 2019) are among the most frequently stated and studied.

5. CONCLUSIONS

The purpose of this paper is to highlight the main findings regarding the concepts of innovation and sustainability in the context of Industry 4.0 in the literature. In this regard, the most cited 80 publications were analyzed, resulting in five topics of interest.

Analyzing the literature, the interdependencies between Industry 4.0 taking shape worldwide and the concepts of innovation and sustainability are clearly outlined. Innovation has always been the catalytic factor of progress, at the dawn of the new paradigm, while the information technologies and the generalized digitalization of systems and processes opened the path to a more efficient and sustainable future. Thus, in the context of increased ecological pressures, sustainability is a concern both within research activities and in the economic and social environment. Therefore, everyone seems to have understood that the only viable trajectory for the future of humanity is that of sustainability, this desire requiring the collaboration of all stakeholders by using digital technologies on a large scale.

The fundamental contribution of this article as regards the thematic investigation in searching the trends of research consists in identifying five research topics in the field. By systematizing the findings of the publications studied, this article shed light on a particularly important field of research outlining results which could be useful for university community, decision makers as well as professionals.

ACKNOWLEDGMENT

The paper was supported by the grant „Urban planning analysis of Bucharest Municipality from the perspective of sustainable development goals / Analiza planificării urbane la nivelul Municipiului București din perspectiva obiectivelor de dezvoltare durabilă (APUDD)”, funded by Bucharest University of Economic Studies.

REFERENCES

Alami, D. & ElMaraghy, W., 2021. A cost benefit analysis for industry 4.0 in a job shop environment using a mixed integer linear programming model. *Journal of Manufacturing Systems,* 59, pp. 81-97

Amjad, M., Rafique, M. & Khan, M., 2021. Leveraging Optimized and Cleaner Production through Industry 4.0. *Sustainable Production and Consumption,* 26, pp. 859-871

Anelis Plus. 2022. [Online] Available at: https://www.e-nformation.ro/profil-acces

Aversa, P., Haefliger, S., Hueller, F. & Reza, D., 2020. Customer complementarity in the digital space: Exploring Amazon’s business model diversification. *Long Range Planning*

Baker, L. H. S., 2021. Power struggles: Governing renewable electricity in a time of technological disruption. *Geoforum,* 118, pp. 93-105

Ballestar, M., Camiña, E., Díaz-Chao, A. & Torrent-Sellens, J., 2020. Productivity and employment effects of digital complementarities. *Journal of Innovation & Knowledge*

Basl, J., 2017. Pilot study of readiness of Czech companies to implement the principles of Industry 4.0. *Management and Production Engineering Review,* 8, pp. 3-8

Beaulieu, M. & Bentahar, O., 2021. Digitalization of the healthcare supply chain: A roadmap to generate benefits and effectively support healthcare delivery. *Technological Forecasting and Social Change,* 167

Berg, A., Buffie E.F. & Zanna, L., 2018. Should we fear the robot revolution? (The correct answer is yes). *Journal of Monetary Economics,* 97, pp. 117-148

Biancini, S. & Ettinger, D., 2017. Vertical integration and downstream collusion. *International Journal of Industrial Organization,* 53(7), pp. 99-113

Bock, S., 2019. Optimally solving a versatile traveling salesman problem on tree networks with soft due dates and multiple congestion scenarios. *European Journal of Operational Research,* 283(3), pp. 863-882

Bonilla, S. Silva H, Terra da Silva M., Gonçalves R.F., Sacomano J. 2018. Industry 4.0 and sustainability implications: a scenario-based analysis of theimpacts and challenges.. *Sustainability,* 10(10), p. 374

Braun, A., Schöllhammer, O. & Rosenkranz, B., 2021. Adaptation of the business model canvas template to develop business models for the circular economy. *Procedia CIRP,* 99, pp. 698-702

Brecher, C., Wiesch, M. & Wellmann, F., 2019. Productivity Increase – Model-based optimisation of NC-controlled milling processes to reduce machining time and improve process quality. *IFAC-PapersOnLine,* 52(13), pp. 1803-1807

Brito, R. & Miguel, L., 2017. Power, governance, and value in collaboration: differences between buyer and supplier perspectives. *Journal of Supply Chain Management,* 53(2), pp. 61-87

Brüggemann, H., Stempin, S. & lMeier, J., 2020. Consideration of digitalization for the purpose of resource efficiency in a learning factory. *Procedia Manufacturing,* 45, pp. 140-145

Burger, A., Cichiwskyj, C., Schmeißer, S. & Schiele, G., 2020. The Elastic Internet of Things - A platform for self-integrating and self-adaptive IoT-systems with support for embedded adaptive hardware. *Future Generation Computer Systems,* 113, pp. 607-619

Carboni, M., 2016. A new class of worker for the sharing economy. *Richmond Journal of Law & Technology,* 22(4), pp. 1-56

Casino, F., Kanakaris, V., Dasaklis, T., Moschuris, S., & Rachaniotis, N. (2019). Modeling food supply chain traceability based on blockchain technology. *IFAC-PapersOnLine, 52*(13), 2728-2733

Cheng, Y., Awan, U., Ahmad, S., & Tand, Z. (2021). How do technological innovation and fiscal decentralization affect the environment? A story of the fourth industrial revolution and sustainable growth. *Technological Forecasting and Social Change,* 162

Chiacchio, F., Compagno, L., D'Urso, D., Velardit, L., & Sandner, P. (2020). A decentralized application for the traceability process in the pharma industry. *Procedia Manufacturing, 42*, 362-369

Cimini, C., Adrodegarib, F., Paschou, T., Rondini, A., & Pezzotta, G. (2021). Digital servitization and competence development: A case-study research. *CIRP Journal of Manufacturing Science and Technology, 32*, 447-460

Ciulli, F., & Kolk, A. (2019). Incumbents and business model innovation for the sharing economy: Implications for sustainability. *Journal of Cleaner Production, 214*, 995-1010

Crittenden, V., Crittenden, W., & Ajjan, H. (2019). Empowering women micro-entrepreneurs in emerging economies: The role of information communications technology. *Journal of Business Research, 98*, 191-203

Curtis, S. (2021). Business model patterns in the sharing economy. *Sustainable Production and Consumption, 27*, 1650-1671

deOliveira, G., & Rebechini, R. (2019). Stakeholder management influence on trust in a project: A quantitative study. *International Journal of Project Management, 37*(1), 131-144

DeStefano, V. (2016). The rise of the just-in-time workforce: on-demand work, crowdwork, and labor protection in the gig-economy. *Comparative Labor Law & Policy Journal, 37*(3), 471-504

Dittes, S., Richter, S., Richter, A., & Smolnik, S. (2019). Toward the workplace of the future: How organizations can facilitate digital work. *Business Horizons, 62*(5), 649-661

Enyoghasi, C., & Badurdeen, F. (2021). Industry 4.0 for sustainable manufacturing: Opportunities at the product, process, and system levels. *Resources, Conservation and Recycling,* 166

Erol, S., Jäger, A., Hold, P., Ott, K., & Sihn, W. (2016). Tangible industry 4.0 : a scenario-based approach to learning for the future of production. *Procedia CIRP, 54*, 13-18

Fisher, O., Watson, N., Porcu, L., Bacon, D., Rigley, M., & Gomes, R. (2018). Cloudmanufacturing as a sustainable process manufacturing route. J. *Journal of Manufacturing Systems, 47*, 53-68

Frankenberger, K., Weiblen, T., & Gassmann, O. (2013). Network configuration, customer centricity, and performance of open business models: A solution provider perspective. *Industrial Marketing Management, 42*(5), 671-682

Frey, C., & Osborne, M. (2017). The future of employment: How susceptible are jobs to computerization? *Technological Forecasting and Social Change, 114*, 254-280

Fromhold-Eisebith, M., Marschall, P., Peters, R., & Thomes, P. (2021). Torn between digitized future and context dependent past – How implementing 'Industry 4.0' production technologies could transform the German textile industry. *166*

Ge, C., Liu, Z., & Fang, L. (2020). A blockchain based decentralized data security mechanism for the Internet of Things. *Journal of Parallel and Distributed Computing, 141*, 1-9

Geels, F., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research Policy, 36*(3), 399-417

Geissdoerfer, M., Vladimirova, D., VanFossen, K., & Evans, S. (2018). Product, service and business model innovation: A discussion. *Procedia Manufacturing, 21*, 165-172

Ghobakhloo, M. (2018). The future of manufacturing industry: a strategic roadmaptoward Industry 4.0. . *Journal of Manufacturing Technology Management, 29*(6), 910-936

Ghobakhloo, M., & Fathi, M. (2021). Industry 4.0 and opportunities for energy sustainability. *Journal of Cleaner Production, 295*

Givehchi, O., Imtiaz, J., Trsek, H., & Jasperneite, J. (2014). Control-as-a-service from the cloud: A case study for using virtualized plcs. 10th IEEE Workshop on Factory Communication Systems

Gleim, M., Johnson, C., & Lawson, S. (2019). Sharers and sellers: A multi-group examination of gig economy workers' perceptions. *Journal of Business Research, 98*, 142-152

Gligor, D., Pillai, K., & Golgeci, I. (2021). Theorizing the dark side of business-to-business relationships in the era of AI, big data, and blockchain. *Journal of Business Research, 133*

Glova, J., Sabol, T., & Vajda, V. (2014). Business Models for the Internet of Things Environment. *Procedia Economics and Finance, 15*, 1122-1129

González, R., Hernández, J., Gómez, X., Smith, R., Arias, J., Martínez, E., et al. (2020). Performance evaluation of a small-scale digester for achieving decentralised management of waste. *Waste Management, 118*, 99-109

Management Research and Practice
Volume 14, Issue 3 / September 2022

Gonzalez-Padron, T. (2017). Ethics in the Sharing Economy: Creating a Legitimate Marketing Channel. *Journal of Marketing Channels, 24*(1), 84-96

Grassi, A., Guizzi, G., Santillo, L., & Vespoli, S. (2020). On the modelling of a decentralized production control system in the Industry 4.0 environment. *IFAC-PapersOnLine, 53*(2), 10714-1071

Grimpe, C., & Sofka, W. (2016). Complementarities in the search for innovation—Managing markets and relationships. *Research Policy, 45*(10), 2036-2053

Guedria, M., Malhene, N., & Deschamps, J. (2016). Urban Freight Transport: From Optimized Routes to Robust Routes. *Transportation Research Procedia, 12*, 413-424

Guo, A., Li, Y., Zuo, Z., & Chen, G. (2015). Influence of organizational elements on manufacturing firms' service-enhancement: An empirical study based on Chinese ICT industry. *Technology in Society, 43*, 183-190

Hänsch-Beuren, F., Ferreira, M., & Miguel, P. (2013). Product-service systems: a literature review on integrated products and services. *Journal of Cleaner Production, 47*, 222-231

Hansen, E., & Bøgh, S. (2021). Artificial intelligence and internet of things in small and medium-sized enterprises: A survey. *Journal of Manufacturing Systems, 58*, 362-372

Hardeman, A., & Kahn, M. (2020). Technological Innovation in Healthcare: Disrupting Old Systems to Create More Value for African American Patients in Academic Medical Centers. *Journal of the National Medical Association, 112*(3), 289-293

Hartono, M., Raharjo, H., & Ronyastra, I. (2021). What difference does the gig mobility service make in the workers' human needs structure? *International Journal of Industrial Ergonomics, 82*.

Herrmann, C., Schmidt, C., Kurle, D., Blume, S., & Thiede, S. (2014). Sustainability inmanufacturing and factories of the future. *International Journal of Precision Engineering and Manufacturing - Green Technology, 1*(4), 283-292

Hiteva, R., & Sovacool, B. (2017). Harnessing social innovation for energy justice: a business model perspective. *Energy Policy, 107*, 631-639

Hoisl, K., Stelzer, T., & Biala, S. (2015). Forecasting technological discontinuities in the ICT industry. *Research Policy, 44*(2), 522-532

Horstink, L., Wittmayer, J., Ng, K., Luz, G., Marín-González, E., Gährs, S., et al. (2020). Collective renewable energy prosumers and the promises of the energy union: taking stock. *Energies, 13*(2), 1-30

Horvat, D., .Kroll, H., & .Jager, A. (2019). Researching the Effects of Automation and Digitalization on Manufacturing Companies' Productivity in the Early Stage of Industry 4.0. *Procedia Manufacturing, 39*, 886-893

Horváth, D., & Szabó, R. (2019). Driving forces and barriers of Industry 4.0: do multinational and small and medium-sized companies have equal opportunities? *Technological Forecasting and Social Change, 146*, 119-132

Hu, J., Hu, Q., & Xia, Y. (2019). Who should invest in cost reduction in supply chains? *International Journal of Production Economics, 207*, 1-18

Hwang, J., Choi, M., Lee, T., Jeon, S., Kim, S., Park, S., et al. (2017). Energy Prosumer Business Model Using Blockchain System to Ensure Transparency and Safety. *Energy Procedia, 141*, 194-198

Jeske, T., Wurfels, M., & Lennings, F. (2021). Development of Digitalization in Production Industry – Impact on Productivity, Management and Human Work. *Procedia Computer Science, 180*, 371-380

Kamble, S., Gunasekaran, A., & Sharma, R. (2018). Analysis of the driving and dependence power of barriers to adopt industry4.0 in Indian manufacturing industry. *Computers in Industry, 101*, 107-119

Kautish, P., Paul, J., & Sharma, R. (2019). The moderating influence of environmental consciousness and recycling intentions on green purchase behavior. *Journal of Cleaner Production, 228*, 1425-1436

Kelly, J. (2020). The low end of the gig economy. *Journal of Rural Studies, 75*, 229-236

Khalate, S., Kate, R., & Deokate, R. (2018). A review on energy economics and the recent research and development in energy and the Cu2ZnSnS4 (CZTS) solar cells: A focus towards efficiency. *Solar Energy, 169*, 616-633

Khan, M., & Salah, K. (2018). IoT security: Review,blockchain solutions, and open challenges. *FutureGenerationComputerSystems, 82*, 395-411

Kiel, D., Arnold, C., & Voigt, K. (2017). The influence of the industrial internet of things on business models of established manufacturing companies – a business level perspective. *Technovation, 68*, 4-19

Kim, S., & Park, S. (2017). CPS(Cyber Physical System) based Manufacturing System Optimization. *Procedia Computer Science, 122*, 518-524

Kimani, K., Oduol, V., & Langat, K. (2019). Cyber security challenges for IoT-based smart grid networks. *International Journal of Critical Infrastructure Protection, 25*, 36-49

Kline, S. J., & Rosenberg, N. (1986). An Overview of Innovation. In R. L. Rosenberg (Ed.), *The Positive Sum Strategy: Harnessing Technology for Economic Growth* (pp. 275-304). Washington DC: National Academy Press

Kochovski, P., Gec, S., Stankovski, V., Bajec, M., & Drobintsev, P. (2019). Trust management in a blockchain based fog computing platform with trustless smart oracles. *Future Generation Computer Systems, 101*, 747-759

Koen, P., Bertels, H., & Elsum, I. (2011). The Three Faces of Business Model Innovation: Challenges for Established Firms. *Research Technology Management, 54*(3), 52-59

Kohtamäki, M., Parida, V., Patel, P., & Gebauer, H. (2020). The relationship between digitalization and servitization: The role of servitization in capturing the financial potential of digitalization. *Technological Forecasting and Social Change, 151*

Kumari, A., Gupta, R., Tanwar, S., & Kumar, N. (2020). Blockchain and AI amalgamation for energy cloud management: Challenges, solutions, and future directions. *Journal of Parallel and Distributed Computing, 143*, 148-166

Lawal, M., Shaikh, R., & Hassan, S. (2021). A DDoS Attack Mitigation Framework for IoT Networks using Fog Computing. *Procedia Computer Science, 182*, 13-20

Lee, J. (2019). A decentralized token economy: How blockchain and cryptocurrency can revolutionize business. *Business Horizons, 62*(6), 773-784

Lejarza, F., & Baldea, M. (2020). Closed-loop real-time supply chain management for perishable products. *IFAC-PapersOnLine, 53*(2), 11458-11463

Lenz, J., MacDonald, E., Harik, R., & Wuest, T. (2020). Optimizing smart manufacturing systems by extending the smart products paradigm to the beginning of life. *Journal of Manufacturing Systems, 57*, 274-286

Li, D., Tang, H., Wang, S., & Liu, C. (2017). A big data enabled load-balancing control for smart manufacturing of Industry 4.0. *Computer Science, 20*, 1855-1864

Liao, Y., Deschamps, F., Loures, E., & Ramos, L. (2017). Past, present and future of Industry 4.0-a systematic literature review and research agenda proposal. *International Journal of Production Research, 55*(12), 609-3629

Lin, P., Au, W., Leung, V., & Peng, K. (2020). Exploring the meaning of work within the sharing economy: A case of food-delivery workers. *International Journal of Hospitality Management, 91*

Liu, A., Zhang, D., Wang, X., & Xu, X. (2021). Blockchain-based customization towards decentralized consensus on product requirement, quality, and price. *Manufacturing Letters, 27*, 18-25

Liu, H., Li, J., Long, H., Li, Z., & Le, C. (2018). Promoting energy and environmental efficiency within a positive feedback loop: Insights from global value chain. *Energy Policy, 121*, 175-184

Liu, X. (2016). Vertical integration and innovation. *International Journal of Industrial Organization, 47*(7), 88-120

Lone, A., & Naaz, R. (2021). Applicability of Blockchain smart contracts in securing Internet and IoT: A systematic literature review. *Computer Science Review, 39*

Manseur, F., Farhi, N., Nguyen Van Phu, C., Haj-Salem, H., & Lebacque, J. (2020). Robust routing, its price, and the tradeoff between routing robustness and travel time reliability in road networks. *European Journal of Operational Research, 285*, 159-171

Marshall, G. (2013). Transaction costs, collective action and adaptation in managing complex social–ecological systems. *Ecological Economics, 88*, 185-194

Martin, C. (2016). The sharing economy: a pathway to sustainability or a nightmarish form of neoliberal capitalism? *Ecological Economics, 121*, 149-159

Matarazzo, M., Penco, L., Profumo, G., & Quaglia, R. (2021). Digital transformation and customer value creation in Made in Italy SMEs: A dynamic capabilities perspective. *Journal of Business Research, 123*, 642-656

Min, H. (2019). Blockchain technology for enhancing supply chain resilience. *Business Horizons, 62*(1), 35-45

Mo, C., & Sun, W. (2020). Point-by-point feature extraction of artificial intelligence images based on the Internet of Things. *Computer Communications, 159*, 1-8

Moktadir, M., Rahman, T., Rahman, M., Ali, S., & Paul, S. (2018). Drivers to sustainable manufacturing practices and circular economy. *Journal of Cleaner Production, 174*, 1366-1380

Morgan, J., Halton, M., Qiao, Y., & Breslin, J. (2021). Industry 4.0 smart reconfigurable manufacturing machines. *Journal of Manufacturing Systems, 59*, 481-506

Moura, R., & Brito, M. (2019). Prosumer aggregation policies, country experience and business models. *Energy Policy, 132*, 820-830

Mourtzis, D., & Vlachou, E. (2018). A cloud-based cyber-physical system for adaptive shop-floor scheduling and condition-based maintenance. *Journal of Manufacturing Systems, 47*, 179-198

Mubarak, M., & Petraite, M. (2020). Industry 4.0 technologies, digital trust and technological orientation: What matters in open innovation? *TechnologicalForecasting&SocialChange, 161*, 120332

Mubarak, M., Shaikh, F., Mubarik, M., Samo, K., & Mastoi, S. (2019). The impact of digital transformation on business performance. *Engineering, Technology and Applied Science Research, 9*(6), 5056-5061

Muller, E. (2020). Delimiting disruption: Why Uber is disruptive, but Airbnb is not. *International Journal of Research in Marketing, 37*(1), 43-55

Mullick, S., Raassens, N., Haans, H., & Nijssen, E. (2021). Reducing food waste through digital platforms: A quantification of cross-side network effects. *Industrial Marketing Management, 93*, 533-544

Murillo, D., Buckland, H., & Val, E. (2017). When the sharing economy becomes neoliberalism on steroids: Unravelling the controversies. *Technological Forecasting and Social Change, 125*, 66-76

Nabeel, M., Srinivasan, M., Prince, E., & Padmanabhan, R. (2020). IoT architecture for advanced manufacturing technologies. *MaterialsToday Proceedings, 22*(4), 2359-2365

Nam, T. (2019). Citizen attitudes about job replacement by robotic automation. *Futures, 109*, 39-49

Narang, N., & Kar, S. (2021). A hybrid trust management framework for a multi-service social IoT network. *Computer Communications, 171*, 61-79

Novák, P., Vyskočil, J., & Wally, B. (2020). The Digital Twin as a Core Component for Industry 4.0 Smart Production Planning. *IFAC-PapersOnLine, 53*(2), 10803-10809

Nuvolari, A. (2019). Understanding successive industrial revolutions: A "development. *Environmental Innovation and Societal Transitions, 32*, 33-44

Oesterreich, T., & Teuteberg, F. (2016). Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. *Computers in Industry, 83*, 121-139

Omar, A., Hasan, H., Jayaraman, R., Salah, K., & Omar, M. (2021). Implementing decentralized auctions using blockchain smart contracts. *Technological Forecasting and Social Change, 168*

Orlandi, L., Zardini, A., & Rossignoli, C. (2020). Organizational technological opportunism and social media: The deployment of social media analytics to sense and respond to technological discontinuities. *Journal of Business Research, 112*, 385-395

Paiola, M., & Gebauer, H. (2020). Internet of things technologies, digital servitization and business model innovation in BtoB manufacturing firms. *Industrial Marketing Management, 89*, 245-264

Pan, Y., Qu, T., Wu, N., Khalgui, M., & Huang, G. (2021). Digital Twin Based Real-time Production Logistics Synchronization System in a Multi-level Computing Architecture. *Journal of Manufacturing Systems, 58*(B), 246-260

Papazoglou, M., Elgammal, A., & Krämer, B. (2020). Collaborative on-demand Product-Service Systems customization lifecycle. *CIRP Journal of Manufacturing Science and Technology, 29*, 205-219

Pereira, T., Barreto, L., & Amaral, A. (2017). Network and information security challenges within Industry 4.0 paradigm. *Procedia Manufacturing, 3*, 1253–1260

Pouri, M. (2021). Eight impacts of the digital sharing economy on resource consumption. *Resources, Conservation and Recycling, 168*

Qian, Y., Jiang, Y., Chen, J., Zhang, Y., Song, J., Zhou, M., et al. (2018). Towards decentralized IoT security enhancement: A blockchain approach. *ComputersandElectricalEngineering, 72*, 266-273

Raynor, M. (2016). Strategic Risk: The Risks "of" and "to" a Strategy: The Case of Blockbuster and the Need for Strategic Flexibility. *Enterprise Risk Management*, 219-230

Ren, S., Zhang, Y., Liu, Y., Sakao, T., Huisingh, D., & Almeida, C. (2019). A comprehensive review of big data analytics throughout product lifecycle to support sustainable smart manufacturing: A framework, challenges and future research directions. *Journal of Cleaner Production, 210*, 1343-1365

Ribeiro, J., Lima, R., Eckhardt, T., & Paiva, S. (2021). Robotic Process Automation and Artificial Intelligence in Industry 4.0 – A Literature review. *Procedia Computer Science, 181*, 51-58

Rifkin, J. (2015). *The Zero Marginal Cost Society.* New York: Griffin

Rifkin, J. (2016, 01 14). *The 2016 World Economic Forum Misfires With Its Fourth Industrial Revolution Theme*. Retrieved from Huffpost: https://www.huffpost.com/entry/the-2016-world-economic-f_b_8975326

Rossit, D., & Tohmé, F. (2018). Scheduling research contributions to smart manufacturing. *Manufacturing Letters, 15*, 111-114

Rymaszewska, A., Helo, P., & Gunasekaran, A. (2017). IoT powered servitization of manufacturing – an exploratory case study. *International Journal of Production Economics, 192*, 92-105

Saidi, F., Trabelsi, Z., Salah, K., & Ghezala, H. (2017). Approaches to analyze cyber terrorist communities: Survey and challenges. *Computers & Security, 66*, 66-80

Salampasis, D., & Mention, A. (2019). From a-value to value-multiplication: leveraging outbound open innovation practices for unrelated diversification in the sensor industry. *Technology Analysis and Strategic Management, 31*(11), 1327-1340

Salonen, A., Saglam, O., & Hacklin, F. (2017). Servitization as reinforcement, not transfor-mation. . *Journal of Service Management, 28*(4), 662-686

Sangwan, R., Kassab, M., & Capitolo, C. (2020). Architectural Considerations for Blockchain Based Systems for Financial Transactions. *Procedia Computer Science, 168*, 265-271

Saurabh, N., Rubia, C., Palanisamy, A., Koulouzis, S., Sefidanoski, M., Chakravorty, A., et al. (2021). The ARTICONF Approach to Decentralized Car-Sharing. *Blockchain: Research and Applications*

Schepis, D., Purchase, S., & Butler, B. (2021). Facilitating open innovation processes through network orchestration mechanisms. *Industrial Marketing Management, 93*, 270-280

Schor, J. (2016). Debating the sharing economy. *Journal of Self-Governance and Management Economics , 4*(3), 7-22

Schulz, J., Scharmer, V., & Zaeh, M. (2020). Energy self-sufficient manufacturing systems – integration of renewable and decentralized energy generation systems. *Procedia Manufacturing, 43*, 40-47

Schwab, K. (2017). *The Fourth Industrial Revolution.* New York: Crown Business

Shahin, M., Chen, F., Bouzary, H., & Zarreh, A. (2020). Frameworks Proposed to Address the Threat of Cyber-Physical Attacks to Lean 4.0 Systems. *Procedia Manufacturing, 51*, 1184-1191

Siano, P., & Sarno, D. (2016). Assessing the benefits of residential demand response in a real time distribution energy market. *Applied Energy, 161*, 533-551

Silvestri, L. (2021). CFD modeling in Industry 4.0: New perspectives for smart factories. *Procedia Computer Science, 180*, 381-387

Simeone, A., Caggiano, A., & Zeng, Y. (2020). Smart cloud manufacturing platform for resource efficiency improvement of additive manufacturing services. *Procedia CIRP, 88*, 387-392

Sjåholm Knudsen, E., Lien, L., Timmermans, B., Belik, I., & Pandey, S. (2021). Stability in turbulent times? The effect of digitalization on the sustainability of competitive advantage. *Journal of Business Research, 128*, 360-369

Sjödin, D., Parida, V., Kohtamäki, M., & Wincent, J. (2020). An agile co-creation process for digital servitization: A micro-service innovation approach. *Journal of Business Research, 112*, 478-491

Stahl, D. (2013). An experimental test of the efficacy of a simple reputation mechanism to solve social dilemmas. *Journal of Economic Behavior & Organization, 94*, 116-124

Steward, A., & Stanford, J. (2017). Regulating work in the gig economy: What are the options? *Economic and Labour Relations Review, 28*(3), 420-437

Stock, T., Obenaus, M., Kunz, S., & Kohl, H. (2018). Industry 4.0 as enabler for a sustainable development: A qualitative assessment of its ecological and social potential. *Process Safety and Environmental Protection, 118*, 254-267

Strozzi, F., Colicchia, C., Creazza, A., & Noè, C. (2017). Literature review on the 'Smart Factory' concept using bibliometric tools. *International Journal of Production Research, 55*(22), 1-20

Suarez, F., & Oliva, R. (2005). Environmental Change and Organizational Transformation. *Industrial and Corporate Change, 14*(6), 1017-1041

Sydow, J., & Müller-Seitz, G. (2020). Open innovation at the interorganizational network level – Stretching practices to face technological discontinuities in the semiconductor industry. *Technological Forecasting and Social Change, 155*

Tao, Y., & Wei, S. (2019). Funds sharing regulation in the context of the sharing economy: Understanding the logic of China's P2P lending regulation. *Computer Law & Security Review, 35*(1), 42-58

Taylor, S., Hunter, G., Zadeh, A., Delpechitre, D., & Lim, J. (2020). Value propositions in a digitally transformed world. *Industrial Marketing Management, 87*, 256-263

Teece, D. (2018). Business models and dynamic capabilities . *Long Range Planning, 51*(1), 40-49

Terziyan, V., Gryshko, S., & Golovianko, M. (2018). Patented intelligence: cloning hu-man decision models for Industry 4.0. *Journal of Manufacturing Systems, 48*, 204-217

Tran, M., & Sokas, R. (2017). The Gig Economy and Contingent Work: An Occupational Health Assessment. *Journal od Occupational and Environmental Medicine, 59*(4), 63-66

Tukker, A. (2015). Product services for a resource-efficient and circular economy - a review. *Journal of Cleaner Production, 97*, 76-91

Tykkyläinen, S., & Ritala, P. (2021). Business model innovation in social enterprises: An activity system perspective. *Journal of Business Research, 125*, 684-697

Usman, M., & Qamar, U. (2020). Secure Electronic Medical Records Storage and Sharing Using Blockchain Technology. *Procedia Computer Science, 174*, 321-327

ValleEnrique, D., Druczkoski, J., Lima, T., & Charrua-Santos, F. (2021). Advantages and difficulties of implementing Industry 4.0 technologies for labor flexibility. *Procedia Computer Science, 181*, 347-352

Villiers, C., Kuruppu, S., & Dissanayake, D. (2021). A (new) role for business – Promoting the United Nations' Sustainable Development Goals through the internet-of-things and blockchain technology. *Journal of Business Research, 131*, 598-609

Visnjic, I., & Van Looy, B. (2013). Servitization: disentangling the impact of service business model innovation on manufacturing firm performance. *Journal of Operations Management , 31*(4), 169-180

Wilkinson, S., Hojckova, K., Eon, K., Morrison, G., & Sandén, B. (2020). Is peer-to-peer electricity trading empowering users? Evidence on motivations and roles in a prosumer business model trial in Australia. *Energy Research & Social Science, 66*

Yang, C., Lan, S., Shen, W., Huang, G., Wang, X., & Lin, T. (2017). Towards product customization and personalization in IoT-enabled cloud manufacturing. *Cluster Computing, 20*, 1717-1730

Yeo, S., Tan, C., Teo, S., & Tan, K. (2021). The role of food apps servitization on repurchase intention: A study of FoodPanda. *International Journal of Production Economics, 234*

Yu, B., Ma, Y., Xue, M., Tang, B., Wang, B., Yan, J., et al. (2017). Environmental benefits from ridesharing: A case of Beijing. *Applied Energy, 191*, 141-152

Yu, H., Khan, F., & Garaniya, V. (2015). Risk-based fault detection using Self-Organizing Map. *Reliability Engineering and System Safety, 139*, 82-96

Zenisek, J., Wild, N., & Wolfartsberger, J. (2021). Investigating the Potential of Smart Manufacturing Technologies. *Procedia Computer Science, 180*, 507-516

Zhong, L., Wu, Q., Xie, J., Guan, Z., & Qin, B. (2019). A secure large-scale instant payment system based on blockchain. *Computers & Security, 84*, 349-364

Zhou, W., & Piramuthu, S. (2018). IoT security perspective of a flexible healthcare supply chain. *Information Technology and Management, 19*(3), 141-153

Ziman, J. (2000). *Technological Innovation as an Evolutionary Process.* Cambridge: Cambridge University Press