VALORES DE LA INDUSTRIA 5.0. UN ANÁLISIS BIBLIOMÉTRICO DEL NUEVO PARADIGMA INDUSTRIAL DESDE EL ENFOQUE SOCIAL.

INDUSTRY 5.0 VALUES. A BIBLIOMETRIC ANALYSIS OF THE NEW INDUSTRIAL PARADIGM FROM THE SOCIAL APPROACH

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ABSTRACT:

Over the years, different technological breakthrough such as electricity or automation have marked a before and after in the industry, giving rise to the various industrial revolutions. Studies on technological implementation within Industry 4.0 reflect how the development of increasingly advanced and innovative technologies is generating new ethical challenges in industrial environments.

Know the origin and give answers to the effects of these challenges is an incentive for the European Commission in presenting a new industry model. This new model, called Industry 5.0, arises to promote principles of social justice and sustainability. It provides a change of focus to serve humanity in the long term, take care of the environment and guarantee the business structure.

In this paper, a bibliometric analysis of the Industry 5.0 concept is carried out in order to present its main characteristics and learn about the different lines of research that are guiding its development. In addition, it delves into their main objectives and how they seek to be satisfied by including a series of values. After the analysis, a non-exhaustive list of values is presented to show in detail the change of approach, as well as the benefits for the interested parties.

Finally, a series of conclusions about the concept of Industry 5.0 is obtained. These conclusions, because of the established search criteria, delve into the expected role of the human factor within the new industrial paradigm. A proposal of possible future lines of research is resented in the search to lay the foundations of the new industry model.

Keywords: *Industry 5.0, Society 5.0, Social-smart Environment, Ethics, Values, Human factor, Industrial Safety, Value Sensitive Design.*

1.- INTRODUCTION

The successive industrial revolutions that have taken place throughout history have been a turning point for humanity. They have changed aspects of daily life and have had a powerful impact on areas such as society and the economy [1]. From the first industrial revolution, in which mechanical production was driven by steam power [2], to the fourth, which was based on the integration of physical and cybernetic technologies [3], each of the industrial revolutions was characterised by the development of new forms of production and technological drives [4]. This phenomenon of technological development in the last two industrial revolutions, the age of automation (Industry 3.0) and the digital age (Industry 4.0), has meant that the prosperity of industry is based on the promotion of increasingly advanced and innovative technologies aimed at increasing production efficiency [5].

Due to the rapid introduction of new communication and information technologies, on the one hand, various challenges are identified in relation to workers due to their interaction with these technologies. For example, in some factories working with collaborative robots, there are psychological problems due to lack of social interaction or competition between robots and humans [6]. On the other hand, there is growing concern about the consumption of existing resources by the development of an industrial model like the current one, due to the laws and regulations that sometimes need to be put in place [7]. All this leads some researchers to question whether the overall result of the impact of the new technology is really positive [8], and so the need to give new meaning to the concept of industry begins to be addressed.

One of the reasons for the emergence of the new Industry 5.0 approach is the pursuit of industrial processes that are guided by the principles of social justice and sustainability and serve humanity in the long term [9]. These principles have been sought as corporate

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goals by various companies for years through the development of management strategies such as Corporate Social Responsibility (CSR) [10], but they seem to have taken a back seat in this era of digitalisation. Therefore, the purpose of Industrie 5.0 to ensure these goals is based on the idea that technologies need to be shaped according to values to ensure that technological change is shaped in accordance with the needs of society and not vice versa [11]. Industry 5.0 is focused on the development and implementation of innovative models and processes for a more socially, environmentally and economically sustainable industrial development [12].

The analysis carried out in this paper provides an in-depth understanding of the emergence of the concept of Industry 5.0, the main lines of research developed to lay the foundations for this new industrial model, and the main objectives. A bibliometric network analysis, following the search methodology described in section 2, will be used to analyse the characteristics, relationships and implications of Industry 5.0. The analysis also allows us to discover the relationship of the co-occurrence of keywords among the documents that make up the sample, thus revealing the possible currents of thought or research groups. After presenting the search results, Section 3 discusses the concept of Industry 5.0 and the values on which this new approach should be based. Finally, section 4 draws the conclusions from the research conducted and discusses possible future research directions.

2.- METHODOLOGY

Based on the information available in bibliographic databases, obtaining a complete and accurate sample and understanding the results derived from their analysis is a broad area for research [13]. Moreover, both the concept of Industry 5.0 and its impact on the planet and society are currently under constant research and development [12]. For this reason, it is considered essential to create a methodological structure to manage the process, from the selection of the database to the final analysis of the results obtained. From the multitude of options that can be considered for bibliometric studies [14], [15], we have opted for the structure proposed by authors such as Zhao and Strotmann [16] for this study. This is divided into four phases: Keyword and database definition, data cleaning and refinement, initial data analysis and in-depth analysis.

Having established the objective of working with as complete a sample of scientific production as possible and taking into account the multidimensionality of the Industry 5.0 concept, the bibliometric analysis is carried out using several databases, in particular Scopus and Elsevier's Web of Science. After defining the databases, the review of the literature on the concept of Industrie 5.0 begins with a search for terms such as "human factor", "sustainability" and "values", as these are considered the most important terms used to conceptualise Industrie 5.0 due to their greater scientific consensus [9], [11]. All searches were conducted in English, first in the "all fields" field and then in the "title, abstract, keywords" field to obtain more precise results. No philtres were applied by date or type of document, so as a first approximation all mentions available for these terms in the databases are included. The result of this first search yields a wide range of documents, including scientific articles, books, book chapters, etc. from 2016, when the first mention of the term Industry 5.0 was recorded, to March 2023, when this review was conducted.

After each search, the results are post-processed. For this purpose, the software VOSviewer version 1.6.18 is used. This software displays all the terms collected around a concept, allowing the deletion of terms that are repeated or named differently. It also allows filtering out terms that are not considered relevant to the research and standardising the nomenclature of authors so that they are not interpreted as different authors. The most interesting use, however, is that it also allows the construction and visualisation of bibliometric networks [17]. These are maps that show relationships such as co-authorship, co-citations or co-occurrence of terms, etc. based on the search results. The approach used by VOSviewer to visualise these bibliometric networks is based on distance and strength of association. VOSviewer approximates the concepts that are most closely related, displays the most relevant concepts in a larger format, and displays the concepts collected under the same research line in the same colour [18].

3.- RESULTS

Table 1 shows the results of the main search equations according to the above criteria. It shows the number of documents collected in the established fields and identifies the main authors, countries and areas of knowledge where the topic of interest is being developed. It becomes clear that Industry 5.0 is a concept that is mainly located in the field of engineering and computer science. However, as shown in Figure 1, the development of the new industrial paradigm affects a wide range of knowledge areas. Under the category "Other", categories such as neuroscience, medicine or planetary sciences can be found. In addition, it can be observed that countries such as India are placing more emphasis on the Industry 5.0 approach, which relates to people and the protection of workers in the industrial environment [19]. However, other countries such as the United States and China are evaluating the new industrial wave in terms of its impact on society and corporate social responsibility.

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Search equation	Nº of documents		Main area (nº doc.)	Author (nº doc.)	Country (nº doc.)
	All fields	Title, abstract, keywords			
Industry 5.0	1960	576	Computer Science (1.073)	Javaid, M (50)	India (325)
Industry 5.0 AND *Human Factor*	280	33	Engineering (175)	Javaid, M (5)	Italy (48)
Industry 5.0 AND *Sustainability*	1016	88	Engineering (561)	Javaid, M (29) Haleem (25)	India (154)
Industry 5.0 AND *Society 5.0*	264	42	Engineering (132)	Carayannis, E. G. (9) Mourtzis, D. (8)	United States (27)
Industry 5.0 AND *Corporate Social Responsibility*	87	1	Engineering (35)	Javaid, M (50) Singh, R. P. (3)	China (17)
Industry 5.0 AND *Safety*	558	49	Engineering (333)	Javaid, M (22)	India (92)
Industry 5.0 AND *Industrial Safety*	10	1	Engineering (7)	Fraga-Lamas, P. (2)	Spain (3) Portugal (3)
Industry 5.0 AND *Sustainability* AND *Accident*	63	4	Engineering (38)	Chew, K. W. (2) Fraga-Lamas, P. (2)	India (15)
Industry 5.0 AND *Society 5.0* AND *Values*	158	3	Engineering (81)	Mourtzis, D. (6)	India (18)
Industry 5.0 AND *Value Sensitive Design*	5	1	Computer Science (5)	Umbrello, S (4)	Italy (5)

Table 1. Main search equations and research results. Own elaboration

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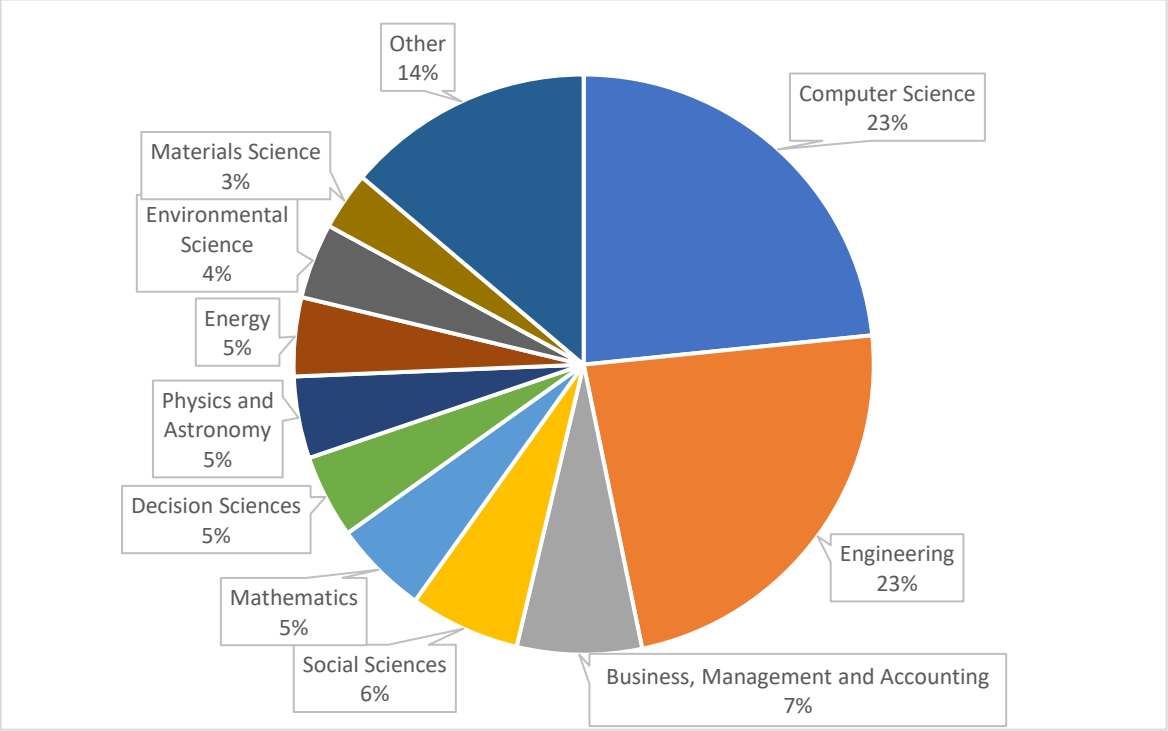

Fig. 1. Frequency analysis of thematic categories. Source: Scopus. Own elaboration

In addition, the development of the scientific interest that the concept of Industry 5.0 had and has was reviewed. For this purpose, the volume of annual publications on this concept was evaluated. Figure 2 shows how research interest in the new industrial paradigm has increased exponentially over the last 7 years since it was first mentioned in 2016. By March 2023, the searches conducted identified a total of 289 articles dealing with the new industrial concept. If the trend continues, it is expected that more than 1,600 research papers will be published on this topic by the end of this year. The publications collected are mainly articles, reviews, book chapters and essays.

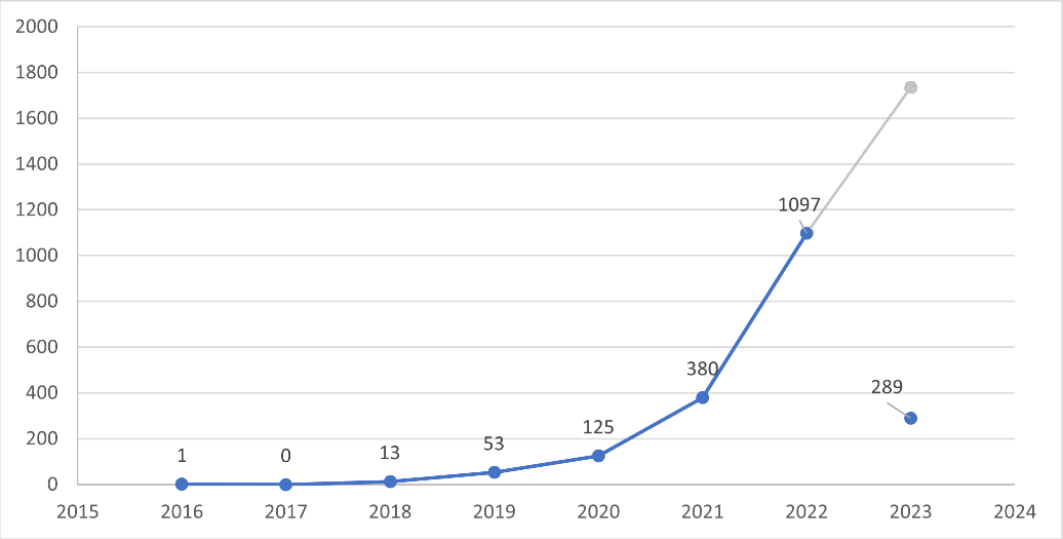

Fig. 2. Historical development of publications. Source: Scopus. Own elaboration

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3.1.- BIBLIOMETRIC ANALYSIS

Keyword analysis using VOSviewer allows us to identify the concepts that are most frequently repeated in the publications collected on the topic of the study and to show the strength of the link between these concepts [17]. Figure 3 shows the co-occurrence map of the keywords resulting from the search for the concept "Industry 5.0". This first sample identifies a total of 4,283 keywords. With a correlation level between the documents of at least 10 keywords, this results in a network with 78 nodes.

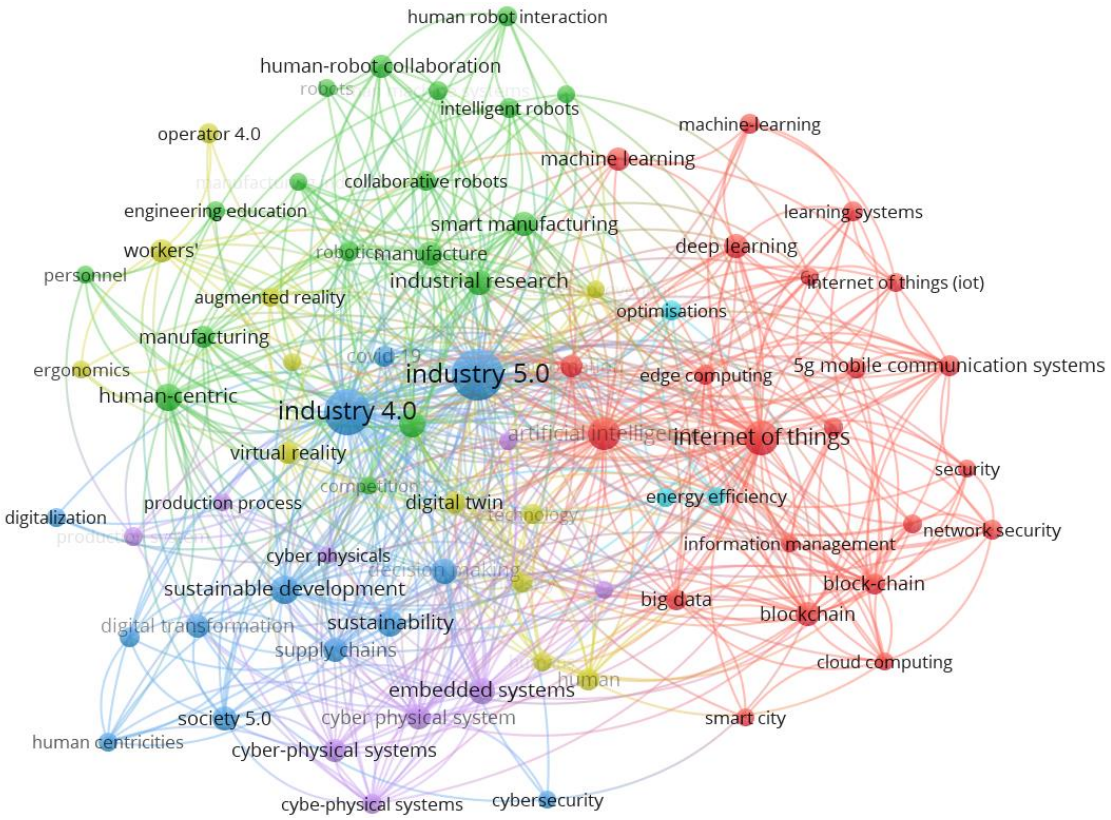

Fig. 3. Cooccurrence map of the Industry 5.0 concept. Source: VOSviewer. Own elaboration

Table 2 shows the co-occurrence classification of the main keywords represented in the bibliometric map in Figure 3. It can be seen that without taking into account the concept of Industry 5.0 itself, Industry 4.0 is the one with the strongest connection to the first place in the table. This is followed by terms related to technological advances, such as artificial intelligence or the Internet of Things. However, the most prominent term among those with the strongest bonding power is the term “people-centric”. This is due to the character that Industry 5.0 brings with it, trying to eliminate, through occupational safety, the limitations and risks that production can have for the people directly or indirectly involved in the process.

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Position	Keyword	Occurrences	Link strength	Position	Keyword	Occurrences	Link strength
1	Industry 4.0	230	1.162	8	Sustainability	35	138
2	Internet of things	90	932	9	Society 5.0	28	104
3	Artificial intelligence	72	461	10	Smart manufacturing	27	181
4	Sustainable development	46	343	11	Blockchain	27	154
5	Human-centric	41	238	12	Deep learning	27	105
6	Embedded systems	36	215	13	Cyber physical system	26	182
7	Industrial revolutions	35	223	14	Workers	25	114

Table 2. Classification of the main keywords under the concept of Industry 5.0. Own elaboration

Figure 4 shows the relationship between the Industry 5.0 concept and the human factor. A total of 2,153 keywords were identified in this sample. The filtering process leads to a network of 58 nodes in which the following lines of research can be identified. First, the research in green is grouped around the development of robotics in industry, the incorporation of collaborative robots and the related impact on the economy and society. The concepts of safety, ergonomics and accident prevention appear in this line. Second, research related to the technology itself is presented in blue, including augmented reality, artificial intelligence, and virtual reality. In this context, the question of their "human-centred" implementation is raised. Third, in yellow, the literature on the worker's experience of production processes through interaction with machines. Fourth, in purple, research oriented towards the concept of Society 5.0 is presented. These are discussed in more detail later in this paper, with their direct relationship to the concept of Industry 5.0 shown in Figure 5.

The fifth and final line of research, shown in red, contains documents dealing with the direct relationship between the worker and technological development. Two key concepts can be identified: Operator 4.0 and Ethics. We wanted to highlight the latter by putting the cursor on the concept to see how ethics will be the element that enables the transition from Industry 4.0 to Industry 5.0, with the development of technology in line with the needs of human beings[20].

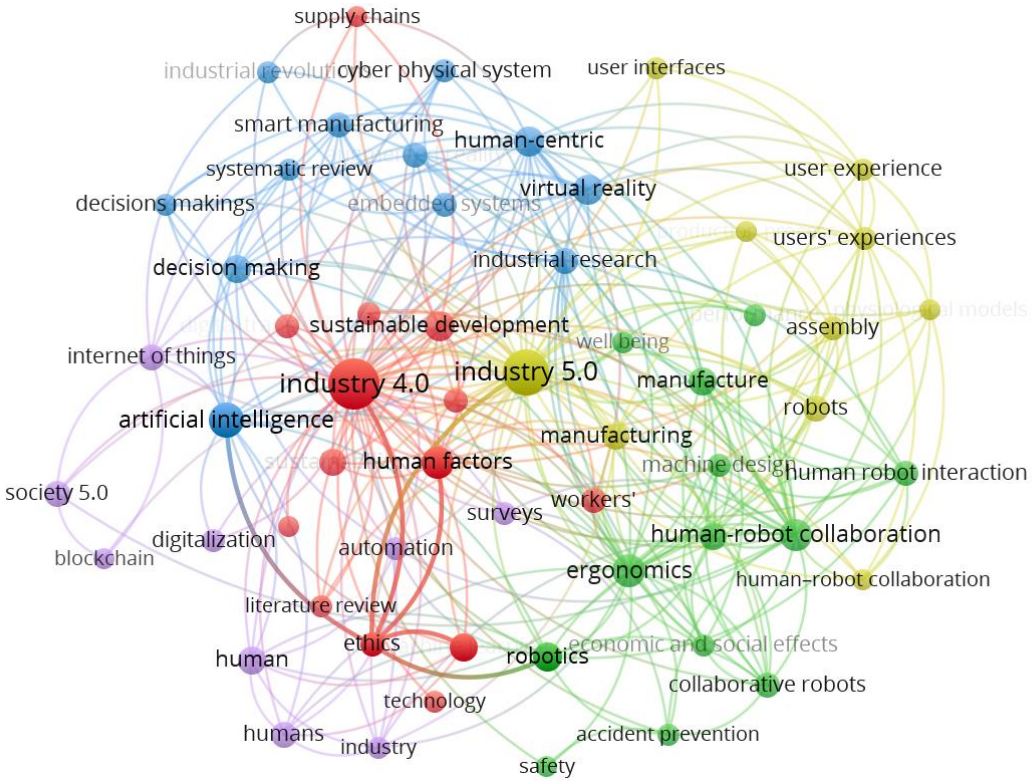

Fig. 4. Map of co-occurrences of the Industry 5.0 concept and Human Factor. Source: VOSviewer. Own elaboration

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In the field of Industry 4.0, the Operator 4.0 is the worker who comes into contact with new and advanced communication and information technologies and is defined as a hybrid actor, a product of the symbiotic relationship between man and machine. Moreover, he is considered as an industrial worker whose physical, sensing and cognitive capabilities are linked to the various emerging cyber-physical technologies of Industry 4.0 [21]. Regarding the concept of the operator 4.0, the following conflicts can be noted: On the one hand, the definition of Operator 4.0 is still evolving and there are no clear guidelines for the implementation of this concept in companies [20]. On the other hand, the definition of the concept operator 4.0 does not refer to human values, so that a reorientation of this concept is likely to be necessary in the emerging industry 5.0. These conflicts reflect the fact that while research claims that the application of new technologies is aimed at improving the capabilities of the worker in the industrial environment, the actual focus is on rapid technological progress and the needs of the worker take a back seat [22].

Figure 5 shows the relationship between the concept of Industry 5.0 and Society 5.0, with a total of 1,908 keywords identified, resulting in a network with 60 nodes and 6 main lines of research. It follows that the concept of Society 5.0 was introduced in 2016 to give a name to the society that will experience the changes brought about by the new industrial paradigm. It establishes a set of sustainable development goals aimed at ending poverty, protecting the planet, and ensuring human prosperity [23]. Figure 5 also shows the emergence of the concept of value creation. The European Commission [9] states that the new approach to industry must take into account a set of values to guide its development. These must be present at all levels, from the conception of the organisation to the development of the new technology, to ensure that ethical, moral and also other aspects, such as environmental sustainability, are the basis for Industry 5.0 [20].

The interest in ensuring these values arises from three main challenges that arise in the course of Industry 4.0. First, because of the operator health and safety issues that raise scepticism about technological growth [24]. Second, because of the rapid consumption of resources caused by the current industrial paradigm [7]. Third, because of the response of the current corporate structure to a situation such as the Covid-19 health crisis [25]. All of this makes it possible to establish an initial basis for how the new industrial paradigm, Industry 5.0, will emerge, where it will start, and where it should go.

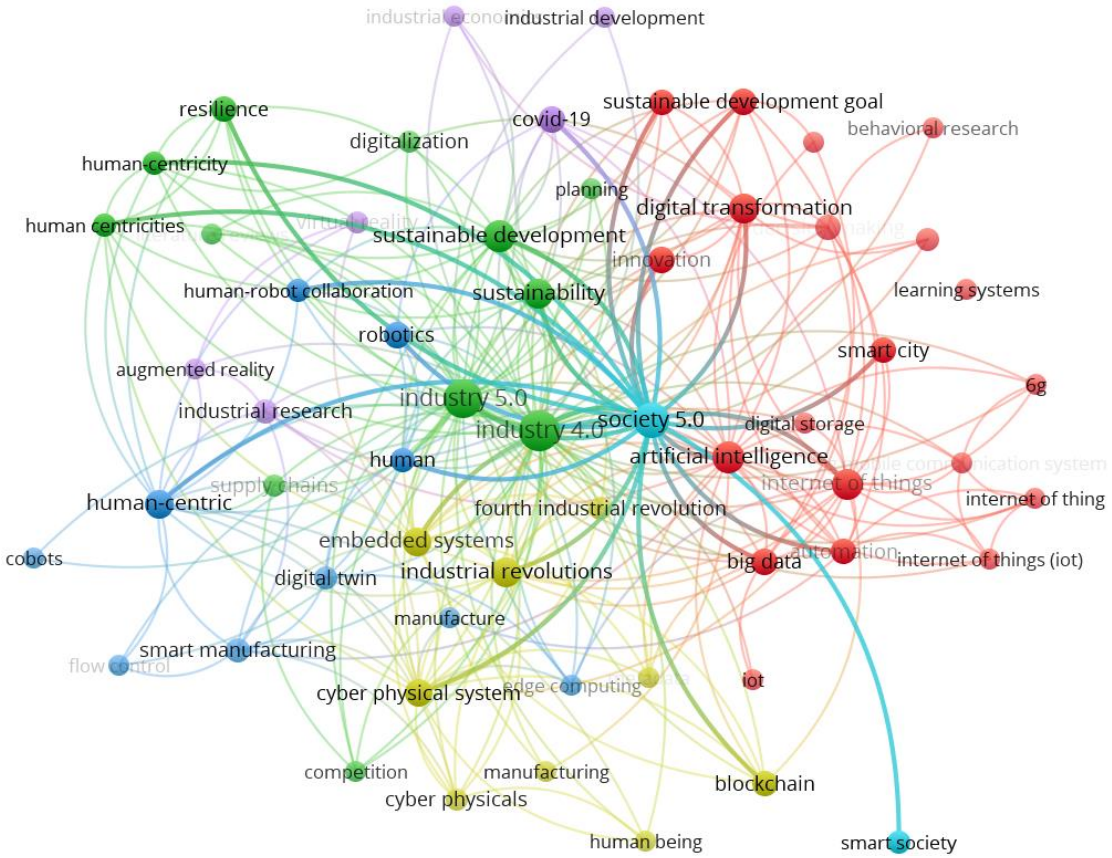

Fig. 5. Cooccurrence map of the Industry 5.0 concept and Society 5.0. Source: VOSviewer. Own elaboration

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3.2.- INDUSTRY 5.0. CLASSIFICATION OF VALUES

The conducted research resulted in several definitions of the concept of Industry 5.0. This new paradigm is seen as an incremental evolution of Industry 4.0 that extends rather than displaces the current concept of industry [26]. It is also seen as a revolutionary new wave that aims to align people and machines to create synergistic factories [27]. However, most definitions focus on putting the worker at the centre of the production process, developing strategies that preserve environmental resources, and creating an infrastructure that ensures the prosperity of industrial systems [9].

Industry 5.0 uses its main objectives as areas to collect and classify the values to be respected during the process. The three objectives are defined as follows: Human, Sustainability, and Resilience [11]. Figure 6 shows a set of values associated with each of these goals. These values can be specific to the technology being evaluated or derived from the strategic management of the company [28]. The values shown in Figure 6 are the result of the scientific review conducted and are not an exhaustive list, as there is no framework that provides such a list. However, they provide an important starting point for research in this area.

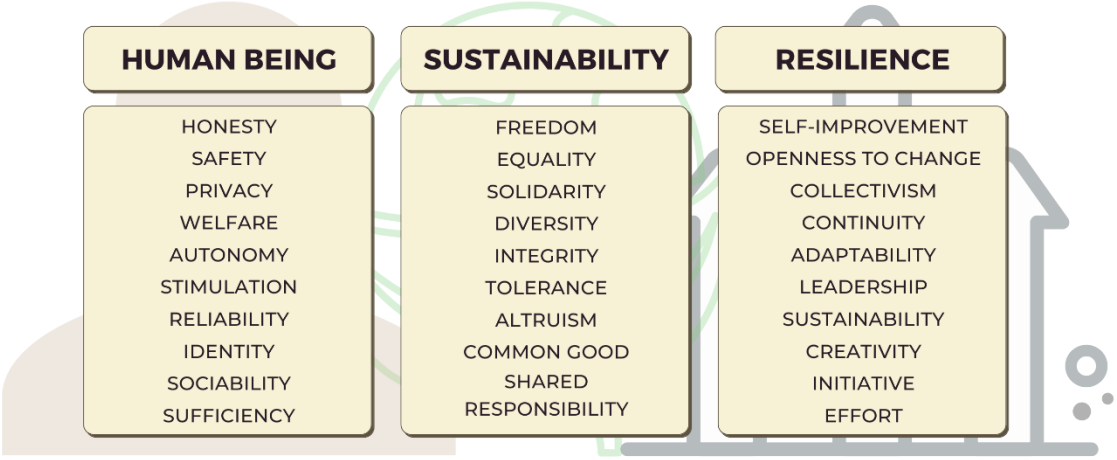

Fig. 6. Industry 5.0 value classification. Own elaboration

Referring to the human-centred approach, values related to industrial safety are presented to protect the worker in his position, both physically and psychologically [24]. These values are characterised by an attitude of concern for people and their being, and include values such as identity, trust, and well-being [29], [30]. In terms of the sustainability approach, values such as co-responsibility or respect for nature are valued [7]. In sustainability issues, multiple values need to be considered to increase citizen participation and social legitimacy [31], [32]. Finally, in the resilience concept, values are intended to guide how best to remedy or introduce recovery measures in the face of emerging problems in the development of industry and its processes [25]. In addition, a review of values-based resilience can provide insight into where the industrial environment is heading and what it might become, especially in an era of constant evolution [33], [34].

4.- CONCLUSIONS

The results of the analysis of the initial literature on Industry 5.0 show some uncertainty about what it will bring and how it will affect different sectors, as well as about the potential of this new industrial paradigm to overcome the boundaries between the real and virtual worlds. The current concept of Industry 5.0 is emerging as a response to the social and sustainability aspects that were neglected during the development of Industry 4.0. According to the review conducted, Industry 5.0 can be defined as a broad and renewed industry that goes beyond the production of goods and services, with the premise underlying this new purpose based on three key objectives: people, sustainability and resilience. These three areas frame the main lines of research of the new industrial paradigm.

Research addressing the relationship between humans and Industry 5.0 represents about 25% of the total work collected on the new industrial model. The results focus on putting basic human needs and interests at the centre of the production process. So instead of adapting the worker to the industrial environment and its technology, the aim is to use that technology to adapt the production process to the needs of the worker. This shift also aims to ensure that the use of new technologies does not violate the fundamental rights of workers [35]. On the other hand, research on the concept of industrial sustainability accounts for about 45% of the documents received.

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In these documents, the search for circular production processes continues, using new technologies to optimise resource efficiency and reduce energy consumption and emissions. Finally, it is worth highlighting an aspect whose publications have been collected mainly in China under the term Industry 5.0 and Resilience. These aim to achieve a higher level of resilience in industrial production through initiatives that consolidate the current globalised production structure. This is particularly true for the satisfaction of basic human needs such as safety and health [36].

Technologies already used in industrial settings, such as virtual reality or augmented reality, can be useful for workers to perform more specialised tasks that would otherwise require more expertise. However, the lack of consideration of ethical issues in the development of these technologies can lead to problems of various kinds. Problems such as stress due to information overload or visual fatigue from interacting with data screens. Therefore, the European Commission specifies that a set of values must be taken into account to guide this technological development. The consideration of ethical aspects in the industrial environment allows the development of new concepts such as "human-centred factories" or "socially intelligent industry", which can be used to define the new industrial model.

The importance of ethical considerations in this new industrial paradigm and the drive to involve multiple stakeholders in the design of new technologies and environments means that designers need tools to help them translate the abstract values of Industry 5.0 into concrete design requirements. Thus, this premise represents a future research direction within the social approach of Industrie 5.0. Researchers [27], [37] are already focusing on developing models that allow translating the above values into design situations at the different levels of industry: Plant level (macro), production line (meso) and workplace (micro).

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