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Maker Movement as Part of Industry 4.0

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Abstract The paper investigates the participation of the Maker Movement in Industry 4.0. The paradigm of Industry 4.0 is analysed from the technological, business model and sustainability perspectives and is correlated to the characteristics found in the production of the Maker Movement. Firstly, a literature review was conducted in order to characterize Industry 4.0 as a productive paradigm and to setting up which are the characteristics of the production of Maker Movement. The literature review was also used to elaborate a mental map and to establish from which perspectives the work would be built. As a result, the paper presents the correlations made between Industry 4.0 and the Maker Movement from the proposed perspectives. In conclusion, was found the Maker Movement can be considered part of Industry 4.0 – although it does not follow the orthodox industrial model – and can mainly contribute to the sustainable impact of Industry 4.0.

Keywords: Industry 4.0, Fourth Industrial Revolution, Maker Movement.

1 Introduction

Industrial revolutions have been driving major changes in the socioeconomic model of capitalism and, also, in the environment. There are efforts in the literature to understand which aspects lead to an industrial revolution.

The transformations resulting from the First Revolution were not only industrial, but also social and intellectual, motivated by monetization and knowledge [1, 2]. The First Industrial Revolution is characterized by the transition from rural production to a first industrial and urban model and increased production capacity due to innovations and machines, especially within textile and iron manufacturing.

The Second Industrial Revolution is due to the expansion of industrialization to other countries and is characterized technologically by the insertion of new driving forces and improvements and the use of electric energy and oil [3], reaching its fullness only in the 20th century [4]. The auto industry actively participates in the creation of a new productive paradigm: mass production. To meet the demand of the time, mass production has a high volume of production, standardization of products and work and interchangeable parts; contributing to the drastic reduction of costs [5].

With the advent of information technology and automation, the Third Industrial Revolution was marked during the 1970s. This new revolution reduced the workload of workers and generated an increase in productive capacity through the accelerated diffusion of digitization mechanisms. The computer begins to guide the machine system, completely or partially [6]. From that moment on, the demand for specialized and flexible labor began to increase more and more [3]. The demand for customized products has also started to grow. Japan collaborated to reduce costs through the creation of "lean manufacturing" with the computer technologies of the time.

“Fourth Industrial Revolution” is the name that came up in response to the integration of physical and cyber systems in manufacturing [7]. From then on, the term “Industry 4.0” originated - a classification for factories that adhere to manufacturing models framed in the technologies proposed by this revolution, such as Internet of Things (Internet of Things, or IoT, as it is also called) and additive manufacturing. This is the revolution that promises drastic changes for sustainability and foresees a series of risks and challenges to

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be overcome [8]. Industry 4.0 is also a response to the increasingly personalized demand that requires differentiation by value and has the client's participation in the design [9].

Dale Dougherty, who envisioned the combined use of the virtual and the physical as a means of production, was a catalyst for the formation of the Maker community. According to Chris Anderson [10] and other recent authors, this movement would be part of a new industrial revolution, working in a sustainable and personalized way.

Although there is still no consensus on which aspects characterize an industrial revolution, in all of them it is possible to notice changes in previous productive paradigms through: application of technological innovations, impact on the ability to produce more and more with less and an increasing demand for flexibility.

Therefore, the study presented here has the stated objective of characterizing Industry 4.0 as a productive paradigm and correlating it with the emerging Maker Movement phenomenon.

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2 Methodology

For this paper, a literature review was conducted according to the aspects suggested by Rowley and Slack [11], which contemplate four essential steps to "face the confused nature of knowledge": (I) Evaluating information sources; (II) Searching and locating information resources; (III) Developing Conceptual Framework and Mind Mapping and, finally, (IV) Writing the literature review.

Articles are good sources for research when conducting literature reviews, as they bring various topics and discussions on the topic of interest, in addition to offering updated and reliable views from researchers in the area [11]. Therefore, in step (I) Evaluating information sources, the platform chosen to carry out the research in this work was Scopus. The Scopus platform has one of the largest collections, a careful selection of publications and research tools to perform the filtering - which is so necessary during a review in order to stay focused and not take on the same scope as a textbook [11].

For step (II) Searching and locating information resources, an advanced search was performed in English using the words industry 4.0 and maker movement. For "industry 4.0" it was limited to those publications that had the word in their titles; for "maker movement" the scope was greater, including keyword and abstract research, due to the smaller number of relevant publications related to manufacturing. Filters were also used to separate articles in the final stage and that were in the Engineering area (see Table 1).

Table 1. Search criteria

	Industry 4.0	Maker Movement
Database	Scopus	Scopus
Word in	TITLE	TITLE-ABS-KEY
Language	LIMIT-TO (LANGUAGE , "English")	LIMIT-TO (LANGUAGE , "English")
Publication stage	LIMIT-TO (PUBSTAGE , "final")	LIMIT-TO (PUBSTAGE , "final")
Subject area	LIMIT-TO (SUBJAREA , "ENGI")	LIMIT-TO (SUBJAREA , "ENGI")
Document results	1911	579

After stipulating the population (total document results), a non-random selection was used to select a feasible sample for reading and analysis [12]. Therefore, for prioritization, a convenience criterion was adopted. The ordering of Industry 4.0 results was made by the most cited articles and for Maker Movement, the ordering by number of citations and also by relevance was used - in order to obtain more results to compose the sample (see Table 2 and Table 3) .

Table 2. Stipulating the sample size

	Industry 4.0 (%)	Maker Movement (%)
Margin of error	10	7
Reliability	90	95

Table 3. Quantity of documents for reading

	Industry 4.0	Maker Movement
Population	1911	582
Sample size	66	140

For the step (III) Developing conceptual framework and mind mapping, was developed a concept map based on the authors understanding. The aim was to clarify thinking about the structure of the literature review in preparation for the writing review and understand theory, concepts and the relationships between them [11]. The final map contains the common criteria for defining Industry 4.0 and Maker Movement (see Fig. 1).

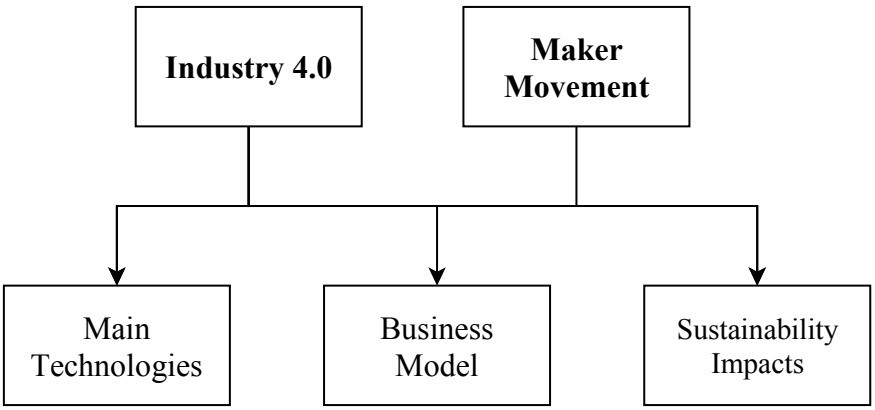

Fig. 1. Common criteria for defining Industry 4.0 and Movement Maker.

For the step (IV) Writing the literature review, the abstracts of the 206 documents were carried out to determine which would be the most adherent to the study. Texts with a focus on development of new technologies, education and research aimed at only one sector (e.g., logistics, communication) were excluded. At the end, fourteen works on Industry 4.0 and eight on the Maker Movement were read in full to effectively compose the review. The attention fell on documents of a conceptual nature or other apparently contributions to the aims of this paper.

3 Results

Results cover the presentation of literature review about Industry 4.0 and Maker Movement and the content analysis – setting up the characteristics found from the point of view: technological, business model and sustainable.

3.1 Literature review

Industry 4.0. Industry 4.0 first emerged in Germany in 2011 as a high-tech government strategy for 2020, a few years later, after the term was disseminated through a fair in the country, the subject became widely discussed as a call for a new industrial revolution [13].

According to Pereira and Romero [14], at the core of each revolution is a significant increase in the productive capacity of the industries. The increase in productivity in Industry 4.0 is due to the technologies and new production practices that the concept brings with it. CPS, IoT, Big Data, modeling, virtualization, cloud computing, semantics, data mining, machine learning and 3d printing (or additive manufacturing) are some of the technological resources that have been related to Industry 4.0 [7][13] [15][16][17]. In this way, Industry 4.0 is characterized by the application of these new technologies, being mainly linked to the use of IoT, Cyber-Physical Systems (CPS) [18] and cloud computing [19].

Industry 4.0 is a new paradigm for manufacturing [14][20][21]. Bringing the promise of making production more flexible and allowing for more customization, quantity and quality, in order to meet a growing demand for increasingly individualized products and with shorter terms [17][22][23], without leaving aside the effectiveness of the process and reasonable prices [17].

The technologies of the smart factory (synonym for Industry 4.0) should be used based on the need for information agility, data flexibility, guarantee of communication between equipment and semantic and learning skills [24]. A prior preparation of the company is necessary to use the technologies of Industry 4.0 effectively and to be successful in the transition [7], as the transition will include the integration of its entire value chain [15].

Industry 4.0 is also linked to other aspects, such as management, economy and society [14]. This is still a field of research in formation and there are few studies that discuss, for example, the sustainability of Industry 4.0 [21]. Corporate environmental and social responsibility are relevant topics, as this revolution offers countless opportunities for improving sustainable manufacturing and, on the other hand, may act as a job inhibitor. The magnitude of this new impact will depend on the levels of labor, and may have a negative social consequence [7]. Therefore, the creation of value in Industry 4.0 must be related to the triple bottom line in order to guarantee sustainable development [25].

One of the main physical technologies of the Fourth Industrial Revolution is additive manufacturing (or 3d printing). Additive manufacturing has the capacity to massively produce products in a customized way and has a significant role in sustainability by collaborating with the reduction of waste. In addition, additive manufacturing is also linked to increased accuracy and productive speed. Hybrid systems between additive and subtractive manufacturing have been a solution for more complex productions where only 3d printing is not enough. As a future expectation, additive manufacturing is also expected to have a social impact in two instances: (1) redefining the role of employees and (2) involving users themselves as manufacturers, through initiatives such as the Maker Movement and the "DIY" (Do It Yourself) [20].

Maker Movement. Besides being used by large companies, AM (additive manufacturing) is also important because it paved the way for ordinary people to produce. It is one of the key technologies in the development of the Maker Movement [26][27]. As a result, several tools and practices that were previously exclusive to engineers and other specialists, have become part of the daily life of regular citizens. The greatest attraction of AM as a creative tool and for solving problems is its simplicity and the low cost necessary to invest, facilitating the transformation of the user into a manufacturer [28], but the capacity of this powerful tool still has knowledge as a limitation of the user who operates it [27]. Some of the unique capabilities of AM are flexibility in product formats and design, no additional cost to produce different and more complex shapes, greater accuracy and product quality and the possibility of business models by order [26].

In a process for using AM, it starts with the digitization of the product in a CAD file based on the internet [26], the printing occurs through a machine that can be used privately or shared – as in the case of the makerspace initiatives, FabLabs, hackerspaces and makerspaces, they are open-source production environments, technologically equipped and fertile to share knowledge and lengthen discussions in the Maker community [29][30]. One of the main open source technologies used by Makers is Arduino [29] and, in addition to 3D printing machines, laser cutters are quite common in creative spaces [31].

Promoters of the Maker Movement argue that these technologies are disruptive in the flow of manufacturing history. In the physical context, they occupy less space and have more affordable prices and there is a community appeal due to the rapid exchange of information over the internet, making this type of production much more democratic [31]. The possibility of collaboration provided made Maker production one of the focuses of sustainability and social manufacturing [32] and topic for shared economy and SCP (Sustainable Consumption and Production) [33]. Some other characteristics found in Maker production are modularization, flexibility, production orientation by order and digitization [32].

3.2 Content analysis

During the literature review, it was possible to identify several similarities between Industry 4.0 and the Maker Movement. In order to visualize this occurrence, the main notions of characterization of Industry 4.0 and the Maker Movement were extracted, within the three axes previously established: Technological, business model and sustainable impact (see Fig. 2-4).

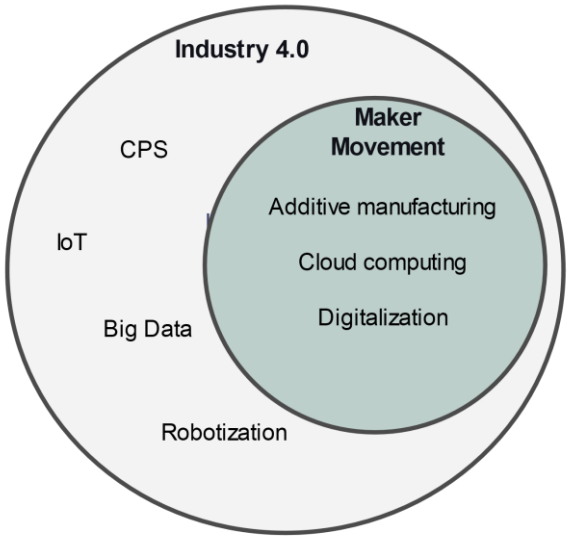

Fig. 2. Main technologies in common between Industry 4.0 and the Maker Movement.

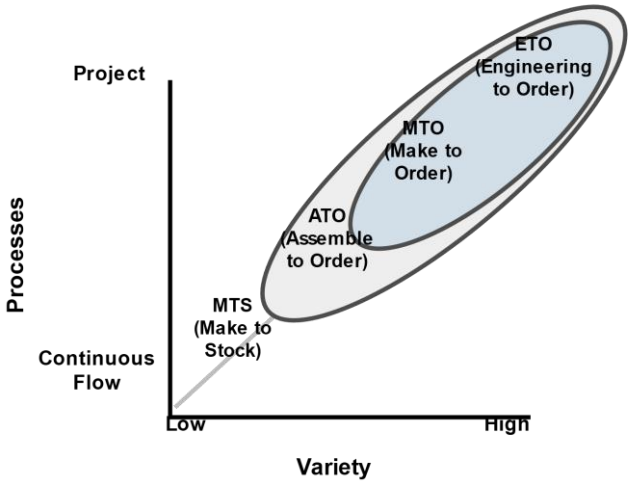

Fig. 3. Business models in common between Industry 4.0 and the Maker Movement.

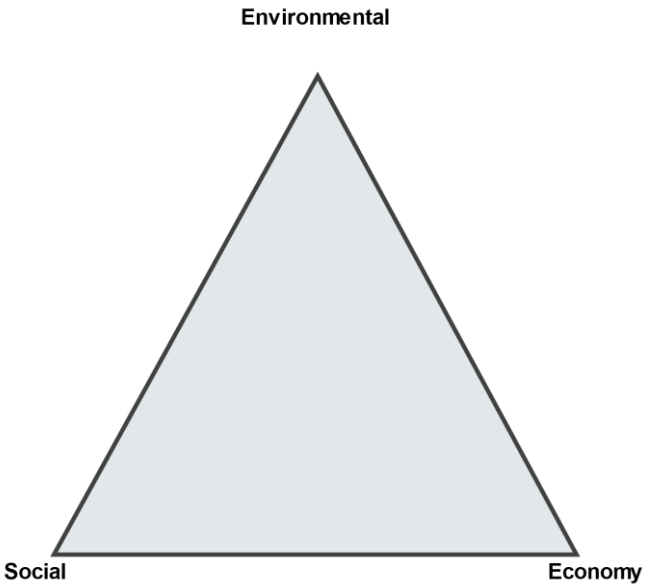

Fig. 4. Triple bottom line. The three axes of sustainability can be impacted by the development of the Maker Movement and Industry 4.0.

4 Conclusion

The Maker Movement, as far as it is possible to analyze in this work, is not an exact and absolute representation of all the details that can be identified in Industry 4.0 - just as it is suggested that many of the companies, although traditional, will use the 4.0 paradigm until where it fits, that is, partially. However, it is possible to see that the main characteristics identified in the Maker Movement are within the guiding aspects of the Fourth Industrial Revolution, making it an arm of Industry 4.0 and an important engine for the sustainable development of manufacturing – especially on the social axis of triple bottom line, where literature emphasizes the contributions of the maker movement.

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