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How the Industry 4.0 can overcome the Covid-19 pandemic: a systematic review

Botene P H R[1], Roel B M[2], Vieira Júnior M[3], Lima A[4]

Abstract Since the beginning of the industrial era, it has been necessary to innovate, both in technology and production models. The designation given to this transformation is Industrial Revolution which, besides changes in the industry and the economy, has also brought changes in people's lives. The last of them, the Fourth Industrial Revolution, or Industry 4.0, as it is better known, is still happening today. This means that this process is in progress and that, despite the expectations of success of its application, it is still susceptible to changes. In the current world context, a crisis has brought serious problems to all areas of life, with a significant impact on the industrial age. Within this scenario, this work aims to study and analyse how the 4.0 tools and methods can help in the struggle against the COVID-19 pandemic through a systematic review of the literature. The results showed that the nine technological pillars of Industry 4.0 have been used to combat the pandemic, mainly in the healthcare and public health areas. The improvements and difficulties were divided into categories in order to assist the identification of specific work for specific project goals for academics and professionals.

Keywords: Industry 4.0; Covid-19; Systematic Review

1 Introduction

Since the beginning of the industrial era, it has been essential to improve the means of production in order to develop new technologies and increase the competitiveness. The transformations of the industry come about through the Industrial Revolutions.

The First Industrial Revolution, is characterized by the increasing use of steam energy, also boosting the iron industry. The Second Industrial Revolution, includes the improvement of techniques and machines of the First Revolution, as well as the introduction of new means of production. The chemical and electrical industries, associated with the use of oil and electricity as sources of energy, and the introduction of mass production created by Ford stand out in this period. The Third Industrial Revolution, also known as the techno-scientific revolution, is marked by great technological development in the industrial environment and scientific advancement, ensuring integration between science, technology and production, and also by the introduction of biotechnology, robotics, genetics and telecommunications (Kagermann, Wahlster and Helbig, 2013; Schwab, 2019).

Finally, the Fourth Industrial Revolution, which emerged in Germany in 2011 and we are living today, better known as Industry 4.0, boils down to technologies that allow the fusion of physical, digital and biological environment. The cyber-physical systems will not be limited only to the physical environment,

[1]Pedro Henrique Ribeiro Botene (✉e-mail: phbotene@gmail.com)
School of Applied Sciences. State University of Campinas. Limeira, SP 13484-350, Brazil.

[2]Bruno Maroun Roel (e-mail: brunomroel@gmail.com)
Dept. of Industrial Engineering. Piracicaba Engineering School. Piracicaba, SP 13414-040, Brazil

[3]Milton Vieira Júnior (e-mail: buda.milton@gmail.com)
Dept. of Industrial Engineering. Methodist University of Piracicaba. Santa Bárbara D'Oeste, SP, 13450-310, Brazil

[4]Milton Vieira Júnior (e-mail: lima@eep.br)
Dept. of Industrial Engineering. Piracicaba Engineering School. Piracicaba, SP 13414-040, Brazil

but that integration will involve the entire supply chain (Venturelli, 2014). According to Fundação Dom Cabral (2016), the Boston Consulting Group Report lists the nine pillars of the fourth revolution, which are: automated robots; additive manufacturing; simulation; horizontal and vertical systems integration; internet of industrial things; big data and analytics; cloud; cyber security and augmented reality.

The Industrial Revolutions cannot be explained only by inventions and discoveries of new machines, energy sources, materials and methods. Factors such as human relations and the economy must also be considered (Dathein, 2003). This statement becomes even more real in the crisis the world has been experiencing. The COVID-19 pandemic has affected almost all countries and has had a significant effect on the lives of the population. Industries are facing challenges to reinvent themselves face of this new scenario and, on the other hand, people are facing changes in their lifestyle. For instance, in order to solve these challenges, some countries are adopting 4.0 technologies, such as Taiwan, which used Big Data to predict possible contamination, improving the assertiveness of the decision-making process in clinical consultations (Stanford FSI, 2020).

Several companies use tools from Industry 4.0, either in production, data analysis or decision making. Data from the Industry 2027 Project, points out that 21.8% of the Brazilian companies will acquire Industry 4.0 resources in the next 10 years (Época, 2017). However, this forecast was from 2017, and the reality we are living in 2020 is totally different. The current circumstances can accelerate the process of adoption the 4.0 in the quotidian of the population and industries all over the world. Simulation, big data, cloud servers are becoming increasingly common in the industrial environment. And in people´s routine, the IoT is gaining increasingly more strength.

Within this scenario, the objective of this study was to make a systematic analysis of the implementation and/or use of the enabling tools of the 4.0 industry applied in the struggle against the pandemic, in diverse segments. The proposal was to answer the following question: *What are the enabling tools and methods of I4.0 being applied to tackle the Covid-19 pandemic?*

This was investigated through the identification of the most applied or suggested tools and the analysis of the methods employed for their application through the systematic review of the literature.

2 Methodology

Based on the thematic question of this article (Q1), the method used for the development of the review was based on Levy and Ellis [13], which propose three stages for carrying out the activities. To ensure the understanding of the main steps and characteristics of the systematic review, the first stage was the development of a research protocol, proposed by the software StArt (an available software created by Ufscar), shown in Table.

Table 1 Full research protocol

Protocol	Parameter
Objectives	Systematic analysis of the implementation and/or use of the enabling tools of the industry 4.0 applied in facing the pandemic, in the most diverse segments
Source engine	Scopus and Science Direct
Studies languages	English and Portuguese
Filter	Article and Full text Access

The searches for these data were conducted in two periods in July 2020. The databases chosen were Scopus and Science Direct because they are important and recognized for their relevance to articles in the field of engineering III.

The first result showed a range of 339 documents found. Thereafter, the filters cited at the table were done. After that, a total of 81 documents were discarded and the final number of articles selected was 258. The second phase of the systematic review consisted of reviewing and filtering the data collected. With the list of articles, the results were exported to an auxiliary tool, the StArt. This application allows importing the data collected in the search engines and classifying them according to the relevance of the subject. The systematic flow followed can be seen in Figure 1.

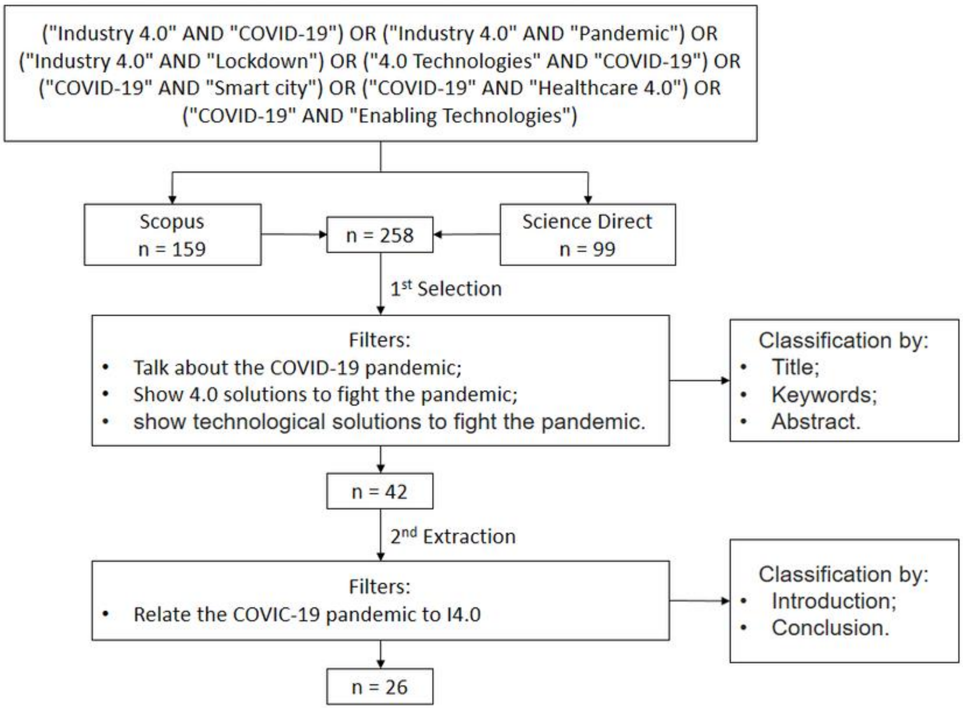

Fig. 1 Fluxogram of papers selection

In the selection step, the 258 selected papers from stage 1 were filtered regarding title, keywords and abstract. Those that met the inclusion criteria in this stage were considered approved. The approved papers were submitted to the extraction phase. In this second step, introductions and conclusions of each study were analyzed. At the final stage, the 26 articles that were approved in the previous filters were read in full. Simultaneously to the reading, a specific data survey.

3 Results and Discussions

3.1 Bibliometric analysis

Figure 2 presents an updated scenario of the number of journal articles published per month. It can be observed that the first articles were published at the beginning of 2020, period in which the pandemic started to gain more notoriety outside of China. The publications "boom" began in May, month in which the pandemic started to assume a global proportion, affecting almost all countries of the globe, as it has also been showed by Johns Hopkins University (2020). It is possible to observe that there was a growing trend of publications for the following months, as the covid-19 pandemic has led researchers from various fields of knowledge to work intensively. As the population gains more knowledge about the disease and about how to adapt to the "new normal", the use of the tools already available and the development of new ones becomes easier. In addition, both industries and other areas are maturing with respect to the applicability and adoption of Industry 4.0, increasing the range of options to combat the pandemic.

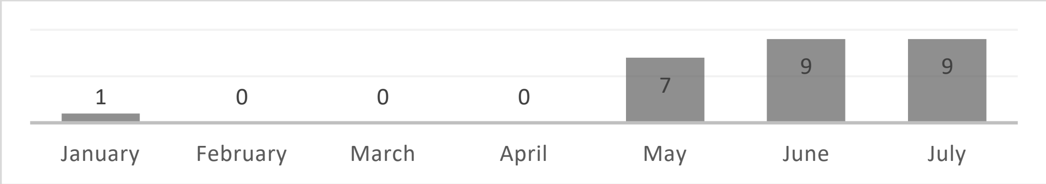

Fig. 2 Publications by month – Scopus and Science Direct databases

A total of 21 countries were identified (see Fig 3). India has the highest number of publications (16%) followed by the United States (14%), United Kingdom (12%), China (8%), Italy (6%), South Korea (6%) and Germany (4%). Together these countries represent 65% of the number of publications. This result confirms a trend similar to the studies which showed that India and the United States have the highest number of cases (WHO, 2020; ECDC, 2020).

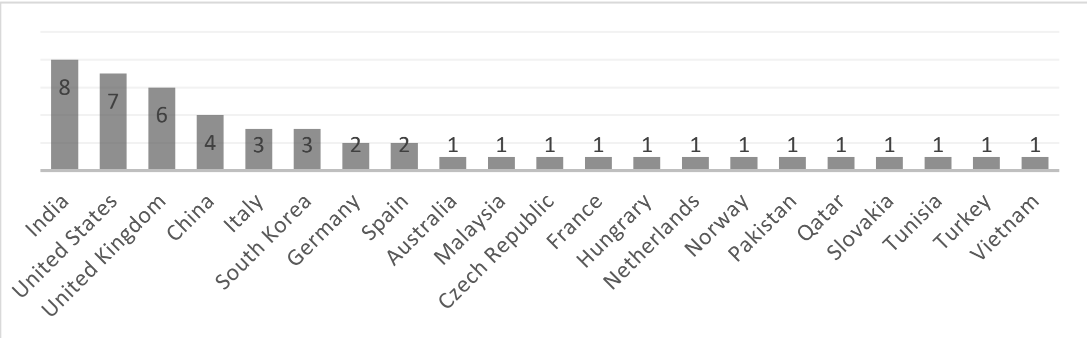

Fig. 3 Number of publications per country

The research fields observed in Figure 4 show the areas of concentration of the selected articles. Considering the three main areas, in the first place appears Medicine, indicating that, although Industry 4.0 is a subject very connected to the industrial area, it has extreme relevance in the health field, because it is related to the treatment of the pandemic. In the second position there is Engineering, due to the fact that Industry 4.0 is a concept that came from this field. Finally, the Social Sciences area shows that covid-19 and its forms of combat have a profound impact on the social life of individuals and human groups.

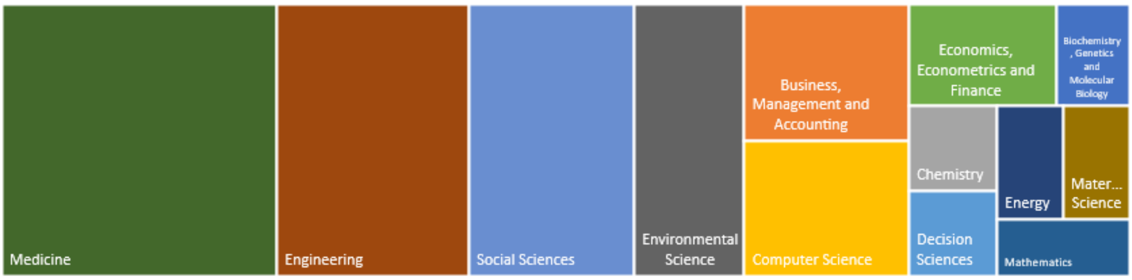

Fig. 4 Research concentration areas

3.2 *Studies classification*

The studies were classified by the research method extracted from each study. The categories were defined as Theoretical-conceptual (TC), Action Research (AR), Case study (CS), Survey (S) and Ethnography (E) (Costa and Godinho Filho, 2016).

The result shows that, from 26 studies, 50% were identified as TC. Those studies are based on theory, both literature reviews that discussed and analyzed the usefulness and applications of 4.0 technologies against COVID-19 in general (Javaid and Haleem, 2020; Madurai Elavarasan and Pugazhendhi, 2020), and reviews that focused on specific technologies (Khan, Siddique and Lee, 2020; Kumar, Gupta and Srivastava, 2020). That category also has studies that are a conceptual discussion, which addressed how concepts from the 4.0 can be applied, for example, in the water distribution sector (Barragán and Manero, 2020; Poch and Garrido-Baserba, 2020).

In the second place there is AR with 7 papers, a type of empirical study that approaches an action or resolution of a collective problem and involves the researcher and participants of the situation, as the study by Belfiore et. al (2020), that adopted artificial intelligence software to facilitate computed tomography diagnostics. The third place is represented by CS with 6 papers, an approach of multiple methods and tools from data collection that has no direct impact on the problem, but rather is a type of simulation, such as the studies by Gallego and Font (2020) and Rahman et. al (2020), who used data and tests to create methodologies and frameworks to predict areas of infection and propose solutions for better allocation of lockdown and for the reactivation of tourism markets.

According to the results presented, there are more theoretical studies than implementations, showing that there are still growth opportunities for AR. That may be due to the learning curve of the pandemic and could be a sign that there will be more implementation studies in the future.

3.3 *Main tools and methods*

Analyzing Figure 5, it is possible to observe that Artificial Intelligence was the enabling technology most referenced in the analyzed studies; it represents about 27% of all the tools mentioned. The use of Big Data and Analytics represents 14% of 4.0 enabling technologies being considered. Then Virtual Reality and the Internet of Things (IoT) represents 13% of the mentioned technologies. Thus, these 4 technologies represent about 66% of all 11 tools classified in this review.

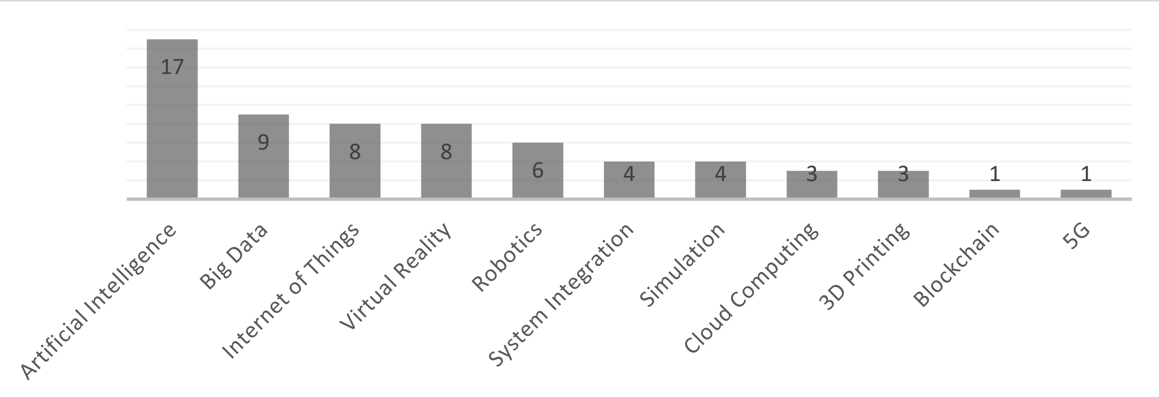

Fig. 5 Most used tool for implementations in pandemic

The technologies can be divided into two categories according to Madurai Elavarasan and Pugazhendhi (2020):

- Those used to support the society: help people to follow quarantine and keep social distancing effectively in order to reduce the spreading of the infection;
- Those used to control the pandemic: help in framing strategies to reduce the infection, to assist in health care facilities and to support society functioning as one.

Considering these two types of classification, it can be observed that Artificial Intelligence, Big Data, Internet of Things, Integration Systems, 3D Printers, among other technologies, can be classified as technologies “used to control the pandemic”, since they are rarely used for personal use. The main use of these technologies are for data control of infected, rapid processing to accelerate the system, interaction between machines avoiding the presence and contact of hospital staff and infected people, mainly in the treatment, as shown by Barragán and Manero (2020).

There are technologies that can be classified as “used to support society”, such as Virtual Reality (VR), which has a result that indirectly helps controlling the pandemic (Singh et al, 2020b). For instance, by allowing people to chat at a distance for personal or professional purposes, it avoids agglomeration, that can give greater prominence to the new virus.

However, VR can also be classified as “used for the pandemic control” since it could be used in hospital surgeries with augmented reality glasses. In this situation, in more severe cases of covid-19, a physician could operate the patient more accurately using the technology.

Therefore, it is possible to observe that the classifications are different, but not isolated, since both might provide solutions in similar contexts.

3.4 Main application areas

This section is completely related to the previous section, as both subjects are complementary. Analyzing any tool of scope 4.0, a change in the application area of those tools can be noticed. With the pandemic, many studies have emerged on how various sectors will cope with the current crisis, and considering the global context of connectivity and industrialization, 4.0 tools significantly interfered in this analysis.

Figure 6 shows the areas that were mentioned in the studies analyzed for this review. As it is a pandemic that is causing a global health crisis, the first two most mentioned areas were: Healthcare (39%) and Public Health (31%). Together, these two areas that symbolize the broad area of health represent about 69% of all 10 mentioned. In this long list of studies on health in the pandemic, it is predominant how the Artificial Intelligence (AI) tool stands out with a great growth potential. Moreover, they emphasize how 4.0 technologies can track infected people, help in surgical cases, and control the spread of the virus (Kumar and Gupta, 2020).

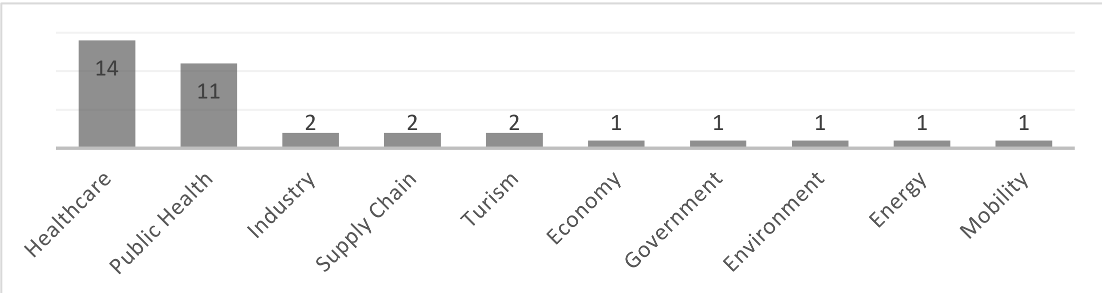

Fig. 7 Application areas

Other areas have also received studies related to the current pandemic and the innovative tools of generation 4.0. For example, the Tourism area, which represents about 6% of the reviewed studies, presents an analysis of the past and a perspective of the future of the sector, considering that the technology will be involved with tourism in the entire world. With that, Zeng, Chen and Lew (2020) conclude that the technology will mediate and even improve the experience for the sector.

Two other sectors that are also studied are: Supply Chain (6%) and Industry (6%). These two areas were also greatly impacted by the social isolation of covid-19. The studies analyzed and exposed suggestions for improvements using tools 4.0, like digital twins. The sectors Mobility, Energy, Environment, Government and Economy represent about 1% each and also make a co-relation between pandemic and 4.0 technologies.

4 Conclusions

According to the World Health Organization (2020) this pandemic has triggered a huge demand for digital technology for improving public health response to the COVID-19 pandemic. Since this crisis has impacted all spheres of life, science and technology is playing a vital role (Kumar and Gupta, 2020). In order to facilitate the understanding of the general framework of covid-19 and 4.0 research, this topic presents an aggregated analysis of the improvements and difficulties of the published studies.

The improvements results are listed above by categories:

- I1 - Real-time tracking, remote health monitoring, rapid case diagnosis, reduced professional workload and improved treatment;
- I2 - Improved distribution of lockdown areas, reduction of economic losses, reduction of contamination effects and reduction of resource use (water, military);
- I3 - Risk identification, improvement of emergency response, supply chain recovery plans and industrial information integration.

About the limitations of the studies observed, it is possible to group them into:

- L1 - Minimum computational requirements, data limitations (amount of information available), network availability (internet), vulnerability of security systems;
- L2 - Image identification problems in treatments;
- L3 - Countries with less technological advances.

The answer to the research question ("what are the enabling tools and methods of I4.0 have been applied in the face of the Covid-19 pandemic?") was also presented in this work, being divided into ten categories: artificial intelligence, big data, virtual reality, internet of things, robotics, simulation, system integration, 3D printing, cloud computing, 5G and blockchain. The areas with the highest number of applications of these tools were healthcare (hospitals, clinics) and public health, which can be justified by the fact that the most affected with the pandemic are the hospital systems and the population in general.

The limitation of this work is in its time window. In a quick preliminary survey three months after the date of this article, it was possible to notice a significant growth in research interest in this area, confirming the trend previously forecast. Other trend is that there will be more implementation work than theoretical work in the next months, evidencing the real impacts used by the tools that were proposed before. The updating of this data will be contemplated as a future research to be conducted.

In general, this article contributes to the understanding of academics and professionals about the main 4.0 tools that are effective in combating the COVID-19 pandemic, as well as its applications and difficulties.

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