# Searching for Key Topics around Artificial Intelligence and Machine Learning as a Process Optimization Driver

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## Abstract

The advancement of digital technology in the industry is making it possible for products and processes to connect people, materials, energy, plant, and equipment efficiently. More productive business processes will have an impact throughout the economy and the environment. Connected products generate data that is being seen as a key source of competitive advantage, and the management and processing of that data is generating new challenges in the industrial environment. The work to be presented looks into the framework of the adoption of Artificial Intelligence and Machine Learning in the Industrial sector under industry 4.0 or smart manufacturing framework. This work is focused on the discussion around Artificial Intelligence as a driver for Industrial Process optimization and looks into its link with process operators and people in the shop floor, and IIoT. The paper includes a bibliometric analysis of the key topics around Artificial Intelligence under Industry 4.0 or Smart Manufacturing paradigm. The main findings are related to the importance that the subject has adquired since 2017 in terms of published articles, and the complexity of the approach of the issue proposed by this work at the industrial environment.

## Keywords

Industry digitalization, Industry 4.0, IIoT (Industrial Internet of Things), AI/ML, Data driven culture.

## 1. Introduction

The fourth industrial revolution, commonly termed as industry 4.0, is not just about industry. It is about overall transformation of the industrial environment using digital integration and intelligent engineering. It is quoted as the next level of manufacturing where machines will redefine themselves in how they communicate and perform individual functions (Muhuri et al. 2019).

Another point of view about Industry 4.0 is given by Ibarra et al. (2017), according to this work the new model has been brought into the manufacturing world by the increasing fusion of Industrial Production and Information and Communication Technologies (ICT). This phenomenon is making possible to connect information, objects and people due to the convergence of the physical and the virtual worlds in the form of Cyber-Physical Systems (CPS). Therefore, it is enabling the transformation of factories into smart environments.

Ruiz-Sarmiento et al. (2020) observe that a key principle of the Industry 4.0 paradigm is that processes and machinery must be networked as a collaborating community for the collection, exchange and analysis of data in order to predict future behaviors and pursue optimal solutions to possible problems. In the paper the authors consider that nowadays, this principle is beginning to be achievable thanks to the development of a number of promising technologies. One of these technologies is the so-called CPS. These systems are enhanced with features from the Internet of Things (IoT) technology, providing them with the ability to continuously obtain information from sensors or processes across the factory, and securely forward it to (generally cloud-based) data centers. This massive data production implies the development of new tools based on Big Data techniques, for storing, managing, and processing it. This set of technologies is completed with the Internet of Services (IoS), which takes the processed information from Big Data tools and deploys it at the right place and in the right form.

Da Silva et al. (2019) gives an interesting approach to industrial process optimization and smart manufacturing. In this article it is said that opportunities for the development of smart industries have expanded. Besides production processes evolution is driven by the market demand for more efficient technologies and procedures, quality standards and cost reduction, and also by technological improvement. Furthermore, a large variety of issues are discussed on Industry 4.0, a concept pointed out by experts as the Fourth Industrial Revolution. The main focus of the new production paradigm is to bring into existing industries more intelligent and adaptable processes, with better use of production resources.

Moica et al. (2018) observes that the better way to digitalize production systems towards Industry 4.0 may be optimizing the internal and external processes due to new enabling technologies such as Big Data, Cloud Computing, Collaborative Robots, Additive Manufacturing, Artificial Vision or Augmented Reality. This will allow increasing efficiency and improving performance. The importance of some of the disciplines of Industry 4.0, like big data and analytics, are showing how data science can contribute to create value and business benefits for Industrial companies, through the development of analytical models to explain and predict process behaviors.

There are different works regarding issues of Artificial intelligence for the search of better operations processes which have motivated the research that it is being developed in this paper. One of them is the article “A fuzzy decision support system for managing maintenance activities of critical components in manufacturing systems” by İhsan Erozan (2019), another one that awake interest is “Machine learning applications in production lines: A systematic literature review” by Ziqiu Kang et al. (2020). These papers give excellent insights and concepts about IA/ML to optimize industrial operations. Like other works, these papers make focus in the analytics methodology and benefits of applying Artificial Intelligence and Machine Learning (AI/ML) in industrial processes. At this point there is no doubt about the value added and the feasibility of data analytics in manufacturing. What is aimed to study in this research is the state of the art of data science in the industrial environment and above all how to democratize the use AI/ML and reach a more massive deployment to search for the excellence in production processes.

This article pretends to go deeper into the concept of AI/ML as a solution to boost process optimization under the new manufacturing paradigm from previous work, Walas Mateo & Redchuk (2021). The discussion starts by proposing the conceptual framework, then it stablish the objectives and hypothesis of the research, then advances to the preliminary findings to go deeper into a bibliometric analysis around the idea of AI/ML as a tool for the optimization of processes within the framework of the Industry 4.0 model. Methodologically, a technological mapping was carried out through an exercise on Scopus indexed database, whose results was analyzed using bibliometric indicators. Through these indicators, information was obtained about the main authors, and evolution of the relevance of the issue. The analysis was completed through the use of the VOSviewer® 1.6.11 software tool (http://www.vosviewer.com/), to analyze results under the framework of this work, and make easier to reach the conclusions.

## 2 Conceptual Framework

Porter & Heppelmann (2014) stablish that the foundation for competitive advantage is operational effectiveness, and it requires embracing best practices across the value chain, including up-to-date product technologies, the latest production equipment, and state-of-the-art sales force methods, IT solutions, and supply chain management approaches.

In a later work, Porter & Heppelmann (2015) remark the value of data to improve design, operational efficiency, and maintenance among other benefit in the use of data. They pointed that the combination of monitoring data and remote-control capability through connected equipment and devices creates new opportunities for optimization. Algorithms could substantially improve product performance, utilization, and uptime, and how products work with related products in broader systems, such as smart buildings and smart farms. Then, the combination of monitoring data, remote control, and optimization algorithms allows autonomy. Products can learn, adapt to the environment and to user preferences, service themselves, and operate on their own.

Industrial Internet of Things (IIoT) makes possible to connect devices and obtain data from reading the devices. Porter & Heppelman (2015) explain that linking combinations of readings to the occurrence of problems can be useful, and even when the root cause of a problem is hard to deduce, those patterns can be acted on. Data from sensors that measure heat and vibration, for example, can predict an impending bearing failure days or weeks in advance. Capturing

such insights is the domain of big data analytics, which blend mathematics, computer science, and business analysis techniques.

An interesting article about the evolution of Artificial intelligence (AI) is brought by Tomas Davenport (2018). In this work he states that analytics 4.0 is the next step in analytical sophistication for organizations, and it is the era of artificial intelligence or cognitive technologies. It became widely adopted – with adoption rates, depending upon geography, of 20 to 30% across large enterprises in 2016 and 2017. It features not only the use of AI methods, but also greater use of autonomy in the execution of the methods, particularly automated machine learning (ML).

A recent article by Davenport (2020), which is based on a research by Deloitte on the use of AI tools in Industry highlights how barriers to the adoption of artificial intelligence tools have decreased. Based on a survey of more than 2727 global executives from nine countries, and their organizations have all adopted AI. The key facts that emerge from the article is that the respondents feel that AI is getting easier, and will continue to do so.

Then there are two interesting insights from the article of Davenport (2020). The first one, is the preference for buying ready-made AI technology over building it. Indeed, at some point it will be difficult not to buy. Another item points that 74% of these executives agreed that "AI will be integrated into all enterprise applications within three years." In terms of today's practice, 50% say they will either "buy all" of their AI capabilities. The second, is about the risks the adopter see about AI. Some of the specific risks that most concerned respondents were cybersecurity issues, AI failures that might affect business operations, misuse of personal data, and regulatory changes involving AI/ML.

Iansiti & Lakani (2020) conceptualize the Artificial Intelligence (AI) Factory as the core of the modern firm, where it is industrialized data gathering, analytics, and decision making. The AI factory is the scalable decision engine that powers the digital operating model, where value is created, of the twenty-first-century firm. Managerial decisions are increasingly embedded in software, which digitizes many processes that have traditionally been carried out by employees. Digital operating models can take various forms, AI factories are at the core of the model, guiding the most critical processes and operating decisions, while humans are moved to the edge, off the critical path of value delivery. From the concepts of these authors two points should be considered in this paper. The first one is transforming the industrial environment to an AI Factory environment, and the second one is the new role of the industrial operator or the industrial engineer.

A last issue to consider is what Ibarra et al. (2017) mention about the effects of the phenomenon considered as the Fourth Industrial Revolution. In the paper by this author is stablished that it will be the most powerful driver of innovation over the next few decades triggering the next wave of innovation. Thus, the main features related to the Industry 4.0 such as real-time capability, interoperability and the horizontal and vertical integration of production systems through ICT systems, are regarded to be the response to current challenges that companies must face to stay competitive in terms of globalization and intensification of competitiveness, the volatility of market demands, shortened innovation and product life-cycles and the increasing complexity around products and processes. The adoption of data models, especially when working with heavy industries where is not possible to change to last generation equipment and machines, and digitalization could help to improve the performance of assets with decades in use in industries like steel making, or energy generation.

## 3. Objective of the Work, Hypothesis of the Research

Having some evidence about the use and benefits of data analytics in the productive environment under the new industrial paradigm, this work is aimed to go deeper in the study of the use of Artificial Intelligence and Machine Learning in the industrial environment to improve industrial processes, in particular under Industry 4.0 framework.

There are many ways to improve processes, as examples it is possible to consider better process control to improve quality, optimizing processes to increase yield, improving energy efficiency to reduce carbon emissions, among other strategies.

To make clearer the hypothesis that drives this work, it is interesting to consider what Da Silva et al. (2019) observe about the implementation of the concept of Industry 4.0. This article points that in addition to technical knowledge, a diversity of other issues should be evaluated, such as (i) what are the advantages and challenges presented by this concept? (ii) What are the resources that companies need to dispose? (iii) What are the barriers inherent to the adoption

process? Understanding these issues is paramount for better direction with respect to the implementation and the development of the Industry 4.0.

Another observation that is object of this work is what is said by Muhuri et al. (2019) about studies that have shown that digitization of products and services has become a necessity for a sound industrial ecosystem. However, these requirements and advanced technologies have made the systems more complex and led to many other challenges such as cybersecurity, reliability, integrity, etc. These are the major bottlenecks which needs to be overcome for the successful design and deployment of Industry 4.0.

This paper aims to take in consideration the issues in the above paragraphs, in the framework of the adoption of AI/ML solutions. A key topic to explore is how process operators or industrial engineers can cope with the challenge that means the disruption that is produced in the industrial scenario when adopting data analytics models. Therefore the question is the way the shop floor will capture the value that generates the AI/ML, should the process operator or industrial engineer at the process level go further in the master of analytics tools, or the solutions that managers should buy according to Davenport (2020) will be tuned to the language and needs of the people that work in the process.

For industrial operations, AI/ML is a paradigm shift, in terms of Brun et al. (2019) AI/ML also represents a process upgrading, that means improving the process. Under this view some other things should be considered in this paper, like time and resources needed to deploy and capture value from AI/ML in the shop floor, costs and ROI, quality and quantity of data needed to feed the models, among other items. Another issue that awake curiosity regarding AI/ML as process optimization driver is the integration with IoT and its evolution from leading edge innovation mainstream technology, and potential to produce data to feed AI/ML models.

Furthermore, it is aimed to search for some evidence that could prove the feasibility of capturing process people knowledge and talent with the IA/ML tools.

## 4. Concepts on Bibliometric and Works Associated with Hypotheses

In the present work it will developed a bibliometric analysis on the topic of Artificial Intelligence, process optimization, and Industry 4.0 to address the hypotheses raised in the previous point.

Merediz-Solà & Bariviera (2019) establish that bibliometric studies has become an emergent and buoyant discipline, given the importance posed on the assessment of scientific production in recent times. They also say that scientific papers are now compiled and indexed in large databases, which allow to measure different aspects of such papers, such as number of authors, keywords, topic, citations, institutional collaboration, etc. The rationale for indexing articles is the following: authors cite other papers due to its connection with the core idea of his/her paper. Given that authors must select carefully which papers to cite, including only the most relevant and most closely related to his/her paper, most cited papers could reflect the importance of them within its discipline.

Bibliometric and Text mining is based on the search for statistically regular behaviours over time in the different elements related to the production and consumption of relevant scientific information. Thus, global explanations for the observed phenomena are achieved through the formulation of bibliometric laws: author productivity, bibliometric dispersion, exponential growth, scientific bibliographic obsolescence.

Based on this premise, the objective of this work is the exploratory study through a bibliometric analysis on the concept of Industry 4.0. As a basis for the analysis, the article entitled "Industry 4.0: a bibliometric analysis and detailed overview" by Muhuri et al. (2019). This work provided an interesting sample of the state of the art of technology around the concept under analysis, considering the bibliometric study. The authors summarized the evolution and growth in relevance of the industry 4.0 concept over the past few years, and provide concise background information and various areas of application.

The analysis task began with the definition of the search criteria. In this case, these are the keywords in English, artificial intelligence, process optimization, industry 4.0, and the alternatives industrie 4.0, smart manufacturing, and advanced manufacturing systems. It should be clarified that the search was carried out in English given the nature of the article database used. Below is the methodology used)

## 5. Methodology Used at Work

Once the keywords were established, the Scopus database was searched. Scopus was selected considering that is one of the broadest scientific data base. The search considers filtering the results prior to 2011, because this is the year that is considered the foundation of the concept of Industry 4.0.

On the other hand, to select the keywords within the search, the terms mentioned above were taken into account. The keywords included in the title, abstract and / or full text were combined using the Boolean operators "AND" and "OR".
The search query used was the following:

**ALL ("Artificial Intelligence" AND "process optimization" AND "industry 4.0"
OR "Smart Manufacturing" OR "smart factory " OR "industrie 4.0")**

Once the results were obtained, an analysis of main authors, evolution of the number of publications on the subject, and main countries of origin of the publications was carried out. Then the database was exported in a CSV file, to analyse the results in detail. The export was carried out in two formats, the first with the information related to the complete bibliographic data, and then another file that contains only the keywords and the abstracts of the papers found.

Subsequently, the analysis was completed by incorporating the database into the VOSviewer® 1.6.11 software tool to visualize the concentration of the most relevant authors and the clustering of keywords most associated with the concepts of interest. VOSviewer® is the most widely used information visualization software to select the topmost keywords used by the authors in their papers Muhuri et al. (2019).

## 6. Results and Discussion

The search using the methodology described in the previous section was performed on 22th December, 2020, and yielded 167 results. The first parameter to be analyzed is the evolution of the number of documents per year, which, as shown in Figure 1, has been growing since 2014 when the first articles appeared around the issue it is being considered in this article.

The first interesting insight from the search is that the topic is gaining interest, it can be seen by the exponential growing curve, taking into account the evolution of the first 2 articles in 2014, to a number of 74 published in 2020. One issue to consider for the exponential growth of the production in the last years, is that on May 2017, Sundar Pichai, Google's CEO, announced that Google's strategic focus, was shifting from mobile to "AI first". Iansiti & Lakani (2020) observes that from its beginning, the company's business and operating models had always been driven by data, networks, and software. At that moment the company had already invested heavily in AI, eclipsing most other firms and universities in the number of publications and patents.

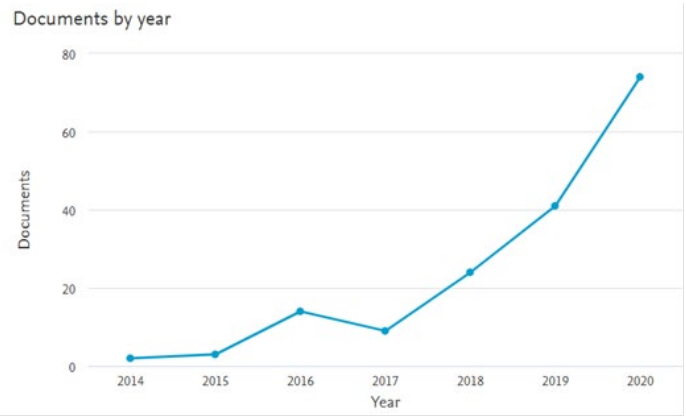


Figure 1. Evolution in the number of publications about AI and process optimization among Industry 4.0 model. From Scopus data base

The second item that was observed from the search at Scopus was the most prolific authors in the studied subject. To visualize the authors with more papers in the subject of interest for this paper is by using the tool VOSviewer. Then it was possible to see the concentration of authors in a more graphical way. Below in figure 2, it is shown the concentration of authors, based on the number of publications.

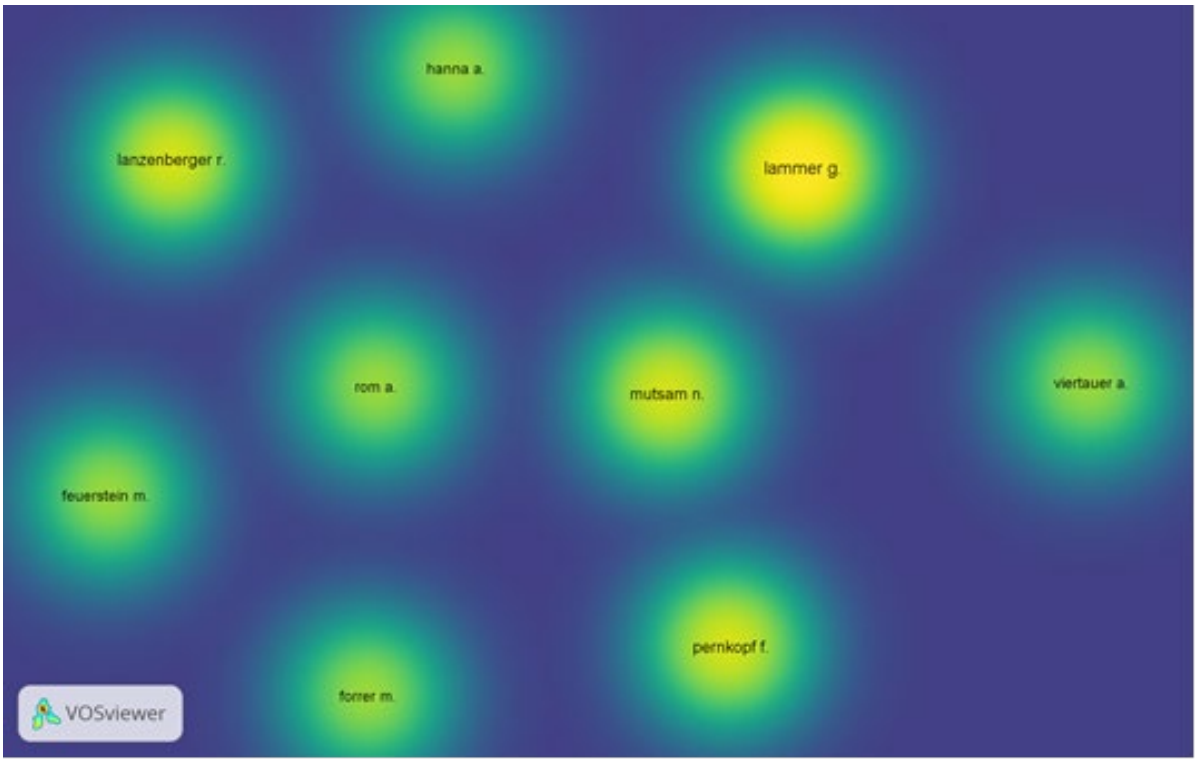


Figure 2. Concentration of relevant authors on Process Optimization, Artificial Intelligence under Industry 4.0 framework at SCOPUS, generated with VOSviewer.

Topmost keywords in the studied field at Scopus

Finally, the keywords were analyzed with the clustering generated by the VOSviewer® 1.6.11 software tool, from the CSV file generated by SCOPUS data base. The results are shown in figure 3, which allows to count the words which appear in the title, abstract and keywords to build all the relations which appear between different documents published in SCOPUS (Van Eck & Waltman, 2020).

Fig. 3 represents the cloud map with relevant words of the articles. This map shows the most relevant concepts, as they appear in the articles more than 8 times, and how related are between them. The cloud shows five clusters of words, and analyzing the nature of each one the cloud can be divided in two parts. The right side that shows less density, with the yellow and violet cluster related to knowledge and soft skills. The yellow related to strategy and maturity of the firm with words like management, knowledge, performance, among others; the violet cluster is related to research terms.

Then at the left, more dense in the links among words. There are three clusters, red, green, and light blue. The red is related to IA in the factory and the smart factory; the green is related to smart manufacturing, integration and control; then the third cluster in the right side shows the relationship among concepts like CPS, IoT, customer, demand and service.

It can be observed that IIoT and People or operator are not among the relevant words in the literature related to process optimization and IA under Industry 4.0 model.

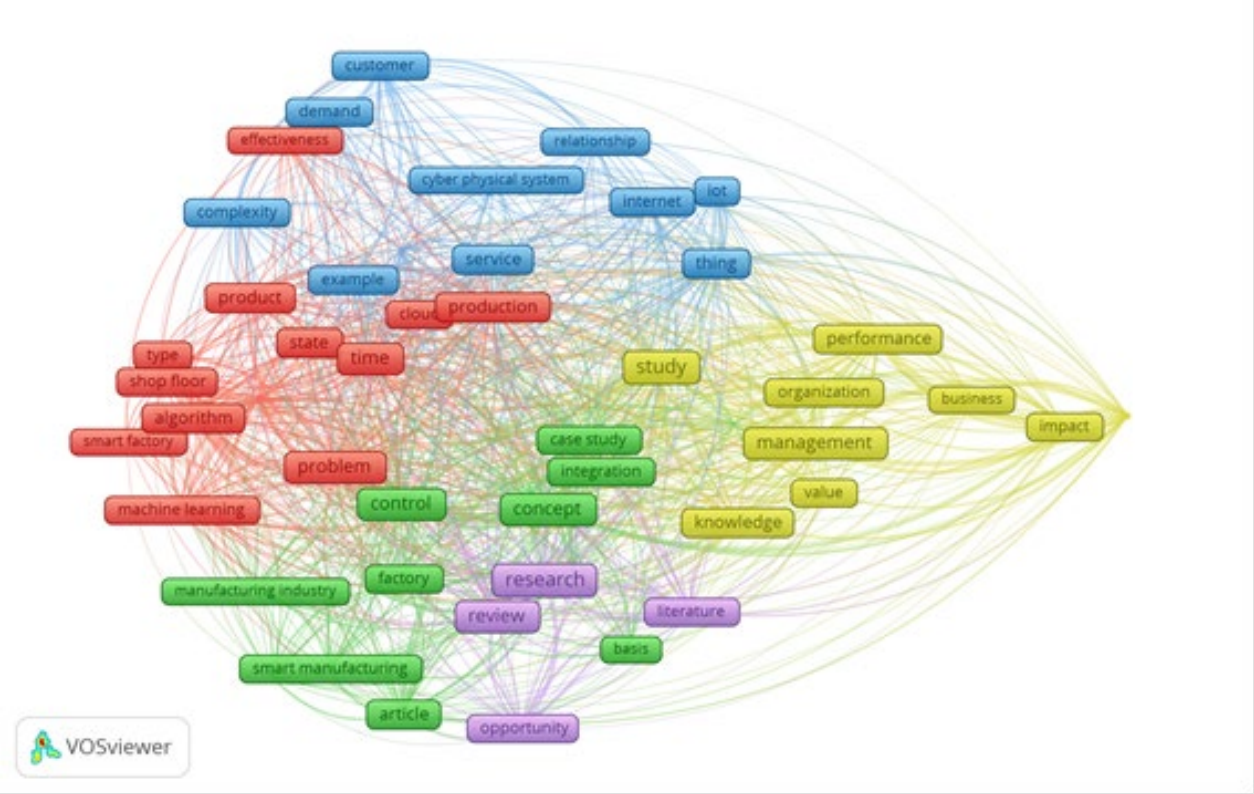


Figure 3. Cloud map of words in titles and abstracts (full counting), generated with VOSviewer.

## 7. Potential Research Lines

This work has been a good exercise to analyze the complexity that means involving IA/ML in industrial processes to optimize them. Some of the issues to continue looking into AI/ML in industrial processes are at first sight concepts like cybersecurity, complexity of deployment, and impact.

One of the next step in this line of research is to advance in the way data through analytics will be merged in the traditional practices of the industrial Organization.

Another item to continue exploring is the impact of AI/ML solutions on process operators or industrial engineers. The bibliometric analysis of this work has not given much clues about this issue, then it should be treated in future research.

Finally, to continue with this work can be studied deeper the implications to the whole organization and management changes or alterations that produce the adoption of AI/ML under the Industry 4.0 paradigm.

## 8. Conclusion

The first thing to mention as a conclusion is the vast amount of information and the potential the subject has in the future. It can see that the concept has a long road to walk to mature and adapt to capture the attention of the industrial world massively. It can be observed that more than 50% of the papers that were highlighted in the last section, 8 out of 15, were published in 2020.

On the other hand, it can be seen that the concept at the moment is well known and mastered by Researchers, Mathematicians, and engineers in software and operating research field, among others. A big doubt seems to appear regarding the knowledge of the concept and value that AI/ML can add in the shopfloor for the process operator. In this line, the work from Davenport (2020) gives some light about the knowledge of the subject by Managers.

Another finding from this work, is that both terms approached by this work regarding IA/ML and industrial processes optimization are not the most considered in the bibliometric analysis at SCOPUS Database, as it can be seen in the word cloud at figure 3.

The complexity and the diversity of issues that involves IA/ML under Industry 4.0 model as a Process optimization driver. This observation comes after analyzing the five clusters of key words showed in figure 3. I can be seen that involves the integration between soft and technical skills to transform the traditional plant into a smart manufacturing site.

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