Challenges and Opportunities of Industry 4.0 – Spanish Experience

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***Abstract*—This article presents the study of the degree of implementation of the technologies of Industry 4.0 in Spain. We have seen that organizations in general are becoming aware of Industry 4.0 and have assumed that this revolution can help them to be more competitive, being key to their survival. However, although consciousness exists, it has not translated into the strategic plans of organizations. Although the Industry 4.0 measures are beginning to be implemented in Spain, it is still early to see the results and conclude if the model can be exported to other countries. Many industrial sectors, such as the automotive industry or the food industry, have targeted the new trend, but it remains to be seen whether this translates into a real increase in competitiveness.**

***Index Terms*—Industry 4.0, competitiveness, organizational strategy.**

I. Introduction

Without a doubt, many have heard of Industry 4.0. It has been the fast-growing trend in the recent years. Although, to see a real example is something else. Industry 4.0 presents itself as the salvation of many sectors that have been agonizing in Europe for decades. With the new technologies as enablers, this model promises an increase in competitiveness without sacrificing employment. How? With robots that collaborate with humans, machines that talk to each other, systems that are able to predict a failure before it happens or production chains that adapt to the demand, not the other way around.

Germany is the flagship of this digital transformation of the industry, but that does not mean that some Spanish companies are not already taking the lead. They are the pioneers of an adventure that has yet to be defined. Then the others will come.

The ongoing innovation process offers an opportunity to improve the current competitive position of factories based in Spain. The fourth industrial revolution is an opportunity for productive sectors to make use of the information they generate to optimize their processes, including logistics, energy efficiency and other resources such as raw materials or water.

II. Literature Review

The essence of every industrial revolution is to increase productivity [1]. Three previous industrial revolutions were triggered by technical innovations: utilization of water- and steam-powered mechanical manufacturing which took place at the end of the 18th century and allowed organizations to gain higher productivity; introduction of mass-production techniques by using electrical energy at the beginning of the 20th century; and the shift from analogue to digital technology in the 1970s [2], [3]. In the following decades the industrial technological advancements could only be seen as incremental ones, especially when compared with the breakthroughs that transformed e-commerce, mobile communications and information technologies (IT) [4]. Now, though, we are in the middle of the fourth wave of the technological advancements. The fourth industrial revolution is going to have more extensive impact triggered by Internet and allowing communication between humans and machines in Cyber-Physical-Systems (CPS) [5], [6] throughout large networks [3], [7]. Machines, sensors, IT systems and workpieces will all be connected along the value chain comprising a single enterprise. This means that the potential of productivity will reside especially in the improvements of decision-making processes and brainwork [2]. Industry 4.0 will make it possible to collect and analyze different data across machines, allowing faster, more efficient and more flexible processes to manufacture goods of higher quality at reduced costs [4]. This from its side will foster manufacturing productivity, shift economics and advance industrial growth modifying the profile of workers and changing the competitiveness of regions and organizations.

For Germany, for example, the transformation of the manufacturing industry has a great importance as it counts to over 25% of the country's GDP and creates more than 7 million working places [3].

The main ideas of Industry 4.0 were first published by Kagermann in 2011 and have created a foundation for of the manifesto of Industry 4.0 published in 2013 by the German National Academy of Science and Engineering [8]. The term "Industry 4.0" describes the expected digitalization of industrial value chains [9]. The idea lies in using emergent technologies to implement internet of things (IoT) and services in order different engineering and business processes being integrated allow production to operate in an efficient and flexible way with low costs and high quality. This strategic initiative with the leitmotiv "Securing the future of German Manufacturing Industry" [10] has built not only the landmark for Germany but for the international community as well in terms of establishing a vision, identifying technological opportunities and scientific challenges related to the appearance of the new generation of ICT technologies (Internet of things and services and CPS) in industrial

Manuscript received June 13, 2018; revised September 27, 2018.

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doi: 10.18178/ijimt.2018.9.5.814

production systems [11]. The concept CPS was actually coined by US in 2006-2008 by Lee [12] and readily adopted by Germany in the initiative of Industry 4.0 and later by the Horizon 2020 research framework program of the European Union [13]. CPS is meant to describe the convergence of two worlds: physical and digital (cyberspace) [14] and when applied to production CPS is then transformed into Cyber-Physical Production Systems (CPPS).

Due to the recent developments resulted in higher affordability and availability of sensors, computer networks and data acquisition systems, the competitive nature of today's industry makes the majority of the factories to go for the implementation of high-tech methodologies [15]. As the consequence, the growing use of networked machines and sensors has resulted in the high-volume data generation known as Dig Data [16], [17]. In this changing environment CPS can be further developed for Big Data management and leverage of machines' interconnectivity in order to produce resilient, intelligent and self-adaptable machines [18], [19]. Moreover, CPS integration within production services and logistics, would transform nowadays factories into Industry 4.0 ones with significant economic impact [20], [21].

The main aspects addressed by Industry 4.0 are the following:

1. The IT-enabled mass customization of manufacturing products, meaning that production should be adapted to the needs of the individuals [11], [22].
2. Production chain's adaptation in a flexible and automatic way to the requirements of the rapidly changing environment.
3. Tracking and self-awareness of different parts and products and their mutual communication with other products and machines [11].
4. Advanced human machine interaction paradigms, which includes new radical ways to interact and operate in the factories.
5. Production optimization thanks to Internet of Things enabled communication in the Smart Factories.
6. Appearance of completely new business models which will contribute to the radically new ways of interaction in the value chain.

Technological advancements on which Industry 4.0 relies can be summarized into nine following concepts: autonomous robots, the cloud, industrial Internet of Things, big data, cybersecurity, simulation, additive manufacturing, horizontal and vertical system integration, augmented reality [4].

A. Autonomous Robots

Even though manufacturers have been using robots for complex assignments for a long time, robots and their capabilities are evolving dramatically. They become more flexible and autonomous and eventually will interact with one another and work side by side with humans.

B. The Cloud

Within Industry 4.0 more organizations will start using cloud-based software allowing them to store and share data across organizational boundaries.

C. Industrial Internet of Things

The IoT comprises of enriching different devices with embedded computing and connecting them using standard technologies. This allows different devices to communicate and interact both with one another and with more centralized controllers.

D. Big Data

In the environment dominated by Internet of things and Internet of services new technologies will generate a huge amount of data. The internet of data will allow mass data transfer and storage as well as provide new and innovative analysis methods for mass data interpretation in the context of target application.

E. Cybersecurity

CPS equipped with internet technology require reliable concepts and technologies to make sure that safety, privacy, security and knowledge protection are taking place [7]. Therefore, reliable and secure communications together with sophisticated identity and access management of machines and users are crucial.

F. Simulation

Even though 3-D simulations are being used in the engineering phases nowadays, such simulations will also become widely used in plant operations in the future. They will use real-time data to mirror physical world in a virtual model, including products, machines and humans. As a consequence, the quality of products will increase dramatically.

G. Additive Manufacturing

With the arrival of Industry 4.0 additive-manufacturing methods (e.g., 3-D printing) will become widely used to produce small batched of customized products offering different construction advantages, among those lightweight and complex designs [15]. Such systems will also decrease stock on hand and transport distances.

H. Horizontal and Vertical System Integration

In order to successfully implement the concepts of Industry 4.0, the following three key features should be taken into account [10]: (1) horizontal integration through value networks in order inter-corporation collaboration is facilitated; (2) vertical integration of hierarchical subsystems inside the factory in order reconfigurable and flexible manufacturing system is created [23]; (3) end-to-end digital integration of engineering involving the whole value chain. The horizontal integration means cross-organizational and organizational-internal intelligent cross-linking and digitalization along the value chain of the life-cycle of the product and among value chains of adjoining life-cycles of the products [8]. Vertical integration is seen as the intelligent cross-linking and digitalization of different hierarchical levels of the value creation module. Finally, end-to-end digital integration of engineering covers intelligent cross-linking and digitalization throughout all phases of the product's life-cycle starting from the acquisition of raw materials and finishing with the product's end of life [10].

I. Augmented Reality

The organizations of the future will widely use augmented reality to provide employees with real-time information allowing better decision-making and improvement of work procedures.

In summary, Industry 4.0 tries to deal with personalized needs and global challenges in order to achieve competitive strength in the globalized markets. Therefore, emergent IT should be applied in every aspect of industry to implement integrations described. By doing these customized products of high quality can become available with improved efficiency of resources, low cost and productivity. It has also a huge world-wide impact mostly concentrated in 4 areas: revenue growth, productivity, investment and employment [4]. In general, Industry 4.0 is thought to have a great impact which is not limited to the industry itself but to the way the humanity works and rests [24].

III. Methodology

We can estimate the "degree of intelligence" of a particular organization by researching its website. We can build a ranking based on keywords or on the clues that each organization leaves on its website. It is about browsing the organizational website and filling out a questionnaire.

Our sample is made up of 98 companies based in Spain, which apply technologies of Industry 4.0 in their production processes.

We started from a previous analysis where we identified the concepts related to Industry 4.0 that are used by organization that implement it in their web pages (see Annex 1). From there we began to look for companies that used these technologies and noting, at the same time, those that visited and did not contain such concepts. All in all, we have analyzed 230 organizations.

Once we found an organization that adapted to the concepts of Industry 4.0, we classified it according to the CNAE (National Classification of Economic Activities) code, which classifies the various professional or business activities according to the activity they exercise within the Spanish market. Thus, we obtained a list with the name of the organization, its code CNAE and its sector of concrete activity.

Once we obtained this list of organization with the information of interest, we proceeded to analyze them one by one, justifying why we considered that they implemented aspects of Industry 4.0.

Next, we proceeded to calculate the penetration of the concept Industry 4.0, comparing the organizations analyzed as consulted, that is to say, both those that included concepts and those that did not. In addition, we established a list of words related to Industry 4.0 by classifying them according to the CNAE sector to which they belonged.

IV. Results

Below we show the results of the first phase of the research study on the communication strategies presented in organizations from different sectors, considered for their production process or the solutions they offer related to Industry 4.0.

To do this, we have researched 230 web pages of different organization and sectors to reach 98 that contain concepts typical of companies of this type. That is, 42.6% of the companies sought.

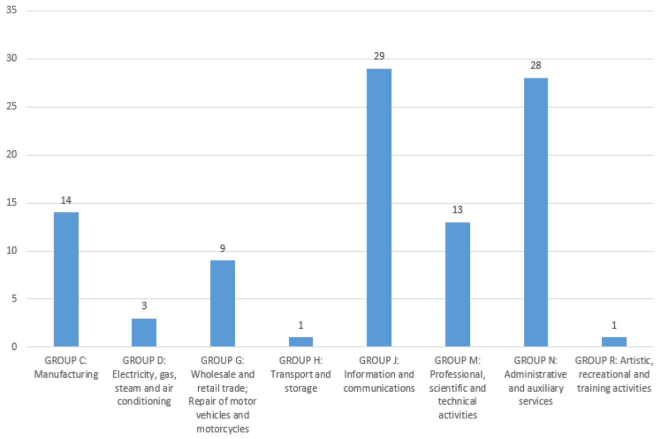

Fig. 1. Number of analysed organizations per sector.

Groups where the presence of Industry 4.0 was not found:

GROUP A: Agriculture, livestock, forestry and fisheries

GROUP B: Extractive industries

GROUP E: Water supply, sanitation activities, waste management and de-pollution

GROUP F: Construction

GROUP I: Hospitality

GROUP K: Financial and insurance activities

GRUPO L: Real estate activities

GROUP O: Public administration and defense; Compulsory social security

GROUP P: Education

GROUP Q: Health and social services activities

GROUP S: Other services

GROUP T: Household activities as employers of domestic staff; Activities of households as producers of goods and services for their own use

GROUP U: Activities of extraterritorial organizations and bodies

Fig. 2. Industry 4.0 concepts mentioned on organizational websites.

As seen from Fig. 2 the most repeated concepts on the webs are big data, digitization, internet of things and cloud computing, which are perhaps the most well-known among the general public.

We have also analysed organizations per link of the value chain. The results are presented in Fig. 3.

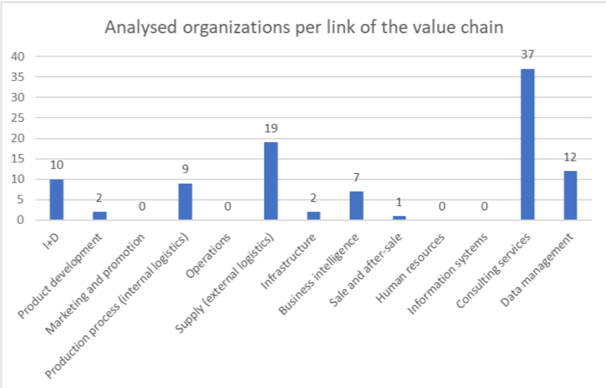

Fig. 3. Analysed organizations per link of the value chain.

V. Discussion

At first glance, we have not found any common characteristic regarding communication strategies in these organizations, so we consider that they still do not transmit much visually in this new facet of industrialization.

It should be noted that a large number of them have blogs, in which they comment on aspects related to the topic, share news and analysis of the latest tendencies that revolve around this new industrial revolution.

We have put more emphasis on the concepts used because we have seen that, in terms of communication and advertising, these are where we find a common link. They are concepts that denote that they are organizations that include technological processes and self-tinted in their production process and / or that offer solutions and services based in the digital world; where the ones that seem to repeat themselves are: digitization, automation, internet of things and cloud.

Apparently, the only sector of production that is not so present in this industrial revolution is the primary sector related to agriculture, livestock, hunting and fishing. Even so we imagine that they will be introduced in this new revolution through platforms (such as online supermarkets, Amazon, etc.) since there is enough "virtual disconnection" of a large part of the people dedicated to this sector due mainly to their age and lifestyle.

For all of this we have thought that the concept of Industry 4.0 still does not have much visibility or is not very clear in the online communication of most of the organizations analyzed, where the key indicators are the words associated with it that have stood out at what of this paper.

A. What is the Degree of Implementation of the Technologies of Industry 4.0 in Spain?

Although we have not completed the study, we know that organizations in general are becoming very aware and have assumed that this revolution can help them to be more competitive, being key to their survival. However, although consciousness exists, it has not translated into the strategic plans of organizations. Spain 4.0 study carried out by the consultant Roland Berger (http://www.elmundo.es/comunidad-valenciana/2017/05/22/592274d5268e3e4c538b4631.html) stated at the end of 2016 that only 10% of the industries and 15% of the infrastructure organizations really have a strategy in the field of digitization. For the most part, they are probably multinational organizations in the automotive and aerospace sectors and respective supplier parks, influenced by the strategic plans of their parent organizations. In other organizations you can implement trends, although it may be more due to a fashion, trend or timely initiative than by responding to an organizational strategy. At this point we should work more.

One of the major shortcomings of small and medium-sized enterprises is the lack of advice, to determine the priorities of the best project to begin with.

The biggest impediments to progress in the implementation of the Industry 4.0 are in general:

- Lack of qualified professionals. Factories are more dependent on these types of professionals.
- Higher requirements for cybersecurity required by this type of technology since, although more efficient factories also make them more vulnerable. Being highly automated factories controlled by computer algorithms, they are more likely to be victims of computer sabotage or leakage of information towards the competition.
- Lack of communication infrastructures: Many of these technologies require access to high-capacity broadband Internet, and in this sense, although broadband is coming more easily to Spanish households even in more remote villages, the same is not the case with many Spanish industrial estates (since it is not so profitable for telecommunications companies to bring optical fiber to hundreds of private homes than to wire an industrial estate for a small group of industries).

B. The Challenges and Opportunities

Spain and Europe play a lot in the transformation to increase the productivity of their industrial sector. It is an opportunity for the companies that relocated their production to carry out the route in reverse, as it is happening with companies from Germany, Austria or Switzerland where they relocated their production to countries of the Asian continent and are returning to their countries of origin or in countries closer to Eastern Europe. It is true that returning industries generate employment, but this will not be the same kind of employment that disappeared when the industry relocated, with the number of jobs being lower but at the same time more skilled.

If we do not invest in Industry 4.0 we will no longer be competitive in the manufacturing industry and we will have to focus on other activities such as tourism and services that imply generally less qualified jobs. In addition, we must take into account the drag effect of the industrial sector. When a factory moves, it drags all the SMEs that act as suppliers. That is to say, a lot of work of high added value is lost.

Small and medium-sized enterprises have fewer resources to handle their digitization and in this sense the government has begun to develop some programs such as Connected Industry Program 4.0. To foster Industry 4.0 in particular in small and medium-sized enterprises, both in the field of awareness-raising and training, as well as in the development of collaborative tools with different innovation clusters or in support of implementation, as well as providing A line of financing. However, from our point of view should be much more.

Although there are specific cases, Spain is not on the right track as far as Industry 4.0 is concerned and that, beyond specific examples, our productive organizations and institutions should seek to introduce mechanisms that will raise the competitiveness and profitability of Spanish organizations.

The Spanish industrial sector has the opportunity to make a big leap by adopting technological advances such as the exploitation of big data, the massive use of the Internet of things, robotics, additive manufacturing (3D printing), artificial intelligence or augmented reality. These new technologies and others allow industrial organizations to survive in an increasingly demanding environment, which requires more flexible and faster environments to produce more and more customized products, even going to single lots, and at the same time do not increase costs of manufacturing. All this in addition is coupled with the need to cut the launch cycle of a product from the idea is conceived until it reaches the market. For example, a very illustrative case in Germany is the German manufacturer Adidas that has created the intelligent factory Adidas Speedfactory that manufactures 500,000 shoes with a high degree of professionalization a year only using robots and supervised by 10 operators, making personalized wigs.

The possibilities of these technologies can change the paradigm of how the industrial sector we know today. The most important thing that companies must do is assess what needs the company has and what objectives can be achieved, to evaluate which technologies are more appropriate to implement and to make this part of their strategic plans.

A PwC report (https://ielektro.es/2016/08/11/informe-industria-4-0-pwc/) that conducted a survey of more than 2000 Spanish directors in 2016 mentions as main obstacles for Spanish organizations the lack of culture and training, the absence of a clear vision of digital operations and support as well as economic benefits of the application of confusing digital technologies (in many cases it is invested in Industry 4.0 more by fashion than otherwise), while high investment requirements or lack of talent were not considered as important obstacles.

It is also important in the long term to rethink the educational policies to give young people the technical skills to understand the digital world, as well as to foster an entrepreneurial spirit, so that they are more creative and thus generate innovation. In this sense, the entrepreneurial mentality of Spain compared to Anglo-Saxon or Asian countries is rather low, although this trend may change with the new generations. Measures must be taken to ensure that schools incorporate robotics as part of the subject matter or have 3D printers and encourage interest in programming at an early age. All this together foster as positive values the entrepreneurial spirit. That is to say that young people of now should choose to be entrepreneurs like Mark Zuckerberg, Elon Musk, Bill Gates, Warren Buffet and not soccer players.

Technology is evolving at a rapid pace and companies must adapt to change as soon as possible to generate a source of competitive advantage. The digitization of the industry is a revolution that will change (and is already doing) the paradigm of industrial manufacturing, and those companies that manage to catch the wave of Industry 4.0, will achieve success in their respective sectors.

Another major long-term challenge is a future where machines perform most of the production and a few humans with highly skilled knowledge oversee machines, leading to a shortage of employment. To this end, new measures will have to be applied to continue allowing the redistribution of income and that the economy flows (there is no point in manufacturing a product if there are no buyers). In fact, concepts such as creating a basic minimum income, reducing working hours or robots being traded to social security are already being discussed.

C. The Experience of the Spanish Industry 4.0 that can be Exported to Other Countries

Germany is pursuing a successful policy leading the transformation of the industrial sector to retain its model of exporting country. Germany has always been very jealous to defend its localized production and to retain its knowledge and know-how. This has allowed it to be flexible in the face of international market crises.

In Spain, on the other hand, the industrial sector has not been able to take off despite the fact that it has chosen to contain wages. In addition, there has been a huge flight of talent, although the Spaniards are not likely to emigrate. Mobility in the EU, although less than in the USA, for example, for cultural and language reasons, has not prevented a significant flight of talent from Spain to other EU countries.

Although the Industry 4.0 measures are beginning to be implemented in Spain, it is still early to see the results and conclude if the model can be exported to other countries. Many industrial sectors, such as the automotive industry or the food industry, have targeted the new trend, but it remains to be seen whether this translates into a real increase in competitiveness.

From our point of view Spain can be a reference in implementation of Industry 4.0 in those industries where it is a referent. Spain has for example an important production in the primary sector providing numerous fruits and vegetables to the rest of Europe and Spain can highlight with interesting innovations in this sector. For example, the existence of Spanish companies that have developed software in the cloud to control the evolution of the parasites in the fields according to meteorological variables and other parameters of the terrain, and thus to reduce the use of pesticides, The farmer and the production of a much greener product. The potential of the use of technologies in this sector is enormous and it is possible that in the future we will not only have Industries 4.0 but Farms 4.0 managed with artificial intelligence. The work in this sector is very automated and hard and condemning to disappear. However, there is enormous potential for improving productivity as little research has been done in this sector and given that the world population does not appear to be declining, it is necessary to find formulas that make farms and farms more productive. We also believe that there can be a revolution in this sector through platforms (such as online stores, Amazon, etc.) that can bring agricultural products to the final consumer.

VI. Conclusion

The concept of "Industry 4.0" and many of its technologies is not generally known among the general public (although it is in industrial and academic environments) so it is partly logical that it is not massively advertised on corporate websites. This is a limitation of our study since we know that there are organizations that are adopting incorporating Industry 4.0 to make factories smarter, but do not advertise on the web. We are considering the possibility of using in the future other indicators and systems to measure the degree of penetration of the industry 4.0.

In this sense, it would be very convenient, for example, for INE (National Statistical Institute) to incorporate questionnaires to companies in order to be able to measure the implementation of Industry 4.0, which is already done for example with the implementation of information technologies. Organizations should be asked if they do, for example, big data to improve their industrial processes, the use of autonomous robots, etc.

For all this we have found that the concept of Industry 4.0 still does not have much visibility or is not very clear in the online communication of most of the companies analyzed. In order to delve deeper, a questionnaire has been developed to interview the different companies analyzed in order to analyze the implementation and evolution of Industry 4.0 in Spain, which we will carry out at a later stage.

Appendix

SPECIFIC CONCEPTS INCLUDED IN INDUSTRY 4.0

1. Industry 4.0.
2. The Fourth Industrial Revolution.
3. Internet of Things (IoT).
4. Intelligent / connected factories / 4.0.
5. Autonomous intelligence.
6. Digital intelligence.
7. Digital future.
8. Digitization.
9. Mass customization.
10. Automation of the production chain.
11. Product communication - machines.
12. Man-machine interaction.
13. Optimization of production.
14. Robots or robotics.
15. The cloud or cloud.
16. The massive data (big data) and derivatives: data analytics, online data.
17. Cybersecurity.
18. The 3D simulation.
19. Augmented reality.
20. Sensors.
21. Connectivity.
22. Networks or network.
23. Wearable.
24. Virtual.
25. Smart product.
26. Technology 4.0.
27. Autonomous machine.
28. Custom manufacturing.
29. Monitoring.
30. analytical instrumentation.
31. "lab-on-a-chip".
32. Industrialization of products.
33. "I + D + i".
34. Technology management.
35. Home automation.
36. Security.
37. Mobile computing.
38. Information systems.
39. Virtual reality.
40. Ad Hoc Queries
41. Security analytics.
42. Real-time connection.
43. Business intelligence.

ACKNOWLEDGMENT

I would like to thank to all the members of SCOEM Group of the International University of La Rioja, Spain for data collection for this study. Especially, I would like to thank you to Jesús Perán Lopéz for organizing and supervising the study and to Irene Aliagas Ocaña for doing the initial data analysis.

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