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INDUSTRY 4.0 AND SMES PERFORMANCE

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RESUMEN

La Industria 4.0 es un fenómeno reciente que ha cambiado la forma de producción en la industria teniendo como resultado una mejora en la calidad de vida de las personas. La literatura existente de la Industria 4.0 se ha centrado en grandes empresas sin considerar los efectos de las tecnologías de la Industria 4.0 en pequeñas y medianas empresas (PYMES). Este paper estudia el rendimiento de la Industria 4.0 en PYMES con una revisión bibliográfica del concepto y con su aplicación en una empresa real. El rendimiento en la empresa es medido utilizando un modelo de madurez. Los resultados muestran la importancia de implementar la Industria 4.0 en las PYMES y la necesidad de considerar factores externos a la propia empresa. Las tecnologías de la Industria 4.0 han cambiado el mundo de la empresa convirtiéndose en un nuevo paradigma con grandes oportunidades para la investigación futura.

Palabras clave: Industria 4.0, Cuarta Revolución Industrial, PYMES, Internet de las cosas, Internet de las cosas Industrial, rendimiento, innovación, oportunidades, riesgos, madurez

ABSTRACT

Industry 4.0 is a recent phenomenon that has changed productivity in the industry resulting in an improvement of the quality of life of people. Existing literature on Industry 4.0 has focused on large companies without considering the effects of Industry 4.0 technologies on small and medium-sized enterprises (SMEs). This paper studies Industry 4.0 performance on SMEs by conducting a literature review of the concept and analysing its application in a real company. Performance is measured in the company using a maturity model. Results have shown the importance of Industry 4.0 implementation in SMEs and the necessity of considering environmental factors. Industry 4.0 technologies have changed businesses becoming a new paradigm with high opportunities for future research.

Keywords: Industry 4.0, Fourth Industrial Revolution, SMEs, Industrial Internet of Things, performance, innovation, opportunities, challenges, maturity

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List of abbreviations

ADETs	Advanced Robotics and Integration Digital Enabling Technologies
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CPS	Cyber-Physical Systems
DESI	Digital Economy and Society Index
ERP	Enterprise Resource Planning
ICT	Information and Communication Technologies
IDETs	Information and Communication Digital Enabling Technologies
IIoT	Industrial Internet of Things
IoT	Internet of Things
IT	Information Technology
MES	Manufacturing Execution Systems
MES	Manufacturing Execution Systems
RFID	Radio Frequency Identification
SCADA	Supervisory Control and Data Acquisition
SMEs	Small and Medium-sized Enterprises

1. Introduction

Companies around the world are facing significant challenges due to the emergence of new technologies. The creation and development of these technologies have brought new opportunities for society. Previous industrial revolutions have led to new changes regarding productivity through history and as consequence an improvement of the quality of life of people. However, the Fourth Industrial Revolution or Industry 4.0 is understood as a new paradigm in the sector of industry. Industry 4.0. is changing companies´ strategies, products, business models and even their relationships with stakeholders (Dalenogare et al. 2018).

The Fourth Industrial Revolution consists of the integration between manufacturing systems and information and communication technologies (ICT). Industry 4.0 is composed of Cyber-Physical Systems (CPS), sensors, data processors and actuators to connect the real and the virtual world in real-time (Birkel et al. 2019). Therefore, the advantages and possibilities of Industry are endless, especially in this global world.

The intensity of digitalization of economy and society affects their welfare and their development but also productivity, competitivity and innovation, and as consequence an economic growth (Institut Valencià de Competitivitat Empresarial 2018). Industry 4.0 has brought new chances but also risks that managers and governments should consider influencing both business and society positively (Büchi, Cugno y Castagnoli 2020).

In the literature, many authors have examined the importance of Industry 4.0 among different countries including their industrial plans. Various disciplines, such as engineering, economics, or management, have studied the subject and analysed their applications. However, researchers have investigated Industry 4.0 focusing on large companies and marginalizing small and medium-sized enterprises (SMEs) (Müller, Buliga y Voigt 2018), as Figure 1 illustrates. For that reason, this paper studies the performance of SMEs regarding Industry 4.0 by a deep literature review and a case study.

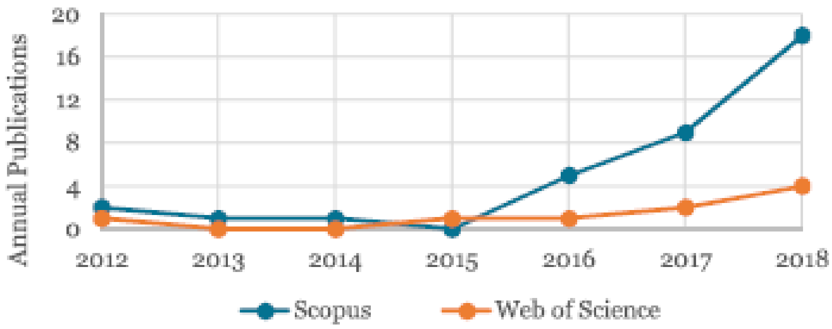

Figure 1. Annual publications of intersecting fields of Industry 4.0 and SMEs (Masood y Sonntag 2020)

The paper is structured as follows. In section 2, the objectives of the paper are presented with the methodology of the research. In section 3, the concept of Industry 4.0 is explained with some definitions and classifications of technologies. Followed by Section 4 where the relationship between Industry 4.0 and innovation is explored. Section 5 analyses Industry 4.0 performance including the implementation in the company, the benefits, the risks, and concluding with the case study. Finally, Section 6 shows the conclusions, limitations, and future research.

2. Methodology and objectives

This section indicates the utilised methodology in the research of this paper. First, the research topic was defined: Industry 4.0 and SMEs performance. After this definition, a literature review of the topic was conducted starting with a search in Scopus and Science Direct databases. The keywords used were *Industry 4.0, Fourth Industrial Revolution, SMEs, Industrial Internet of Things, performance, innovation, opportunities, challenges, maturity,* and different combinations of them. The search process consisted of a manual search of papers published in English since 2016. Books, reviews, and conference abstracts were excluded from the research.

After the data collection, papers were analysed, and irrelevant articles were deleted. The process of searching for information includes the selection but the evaluation of relevant articles. In addition, a backward search was conducted. This means the review of the references of the relevant articles due to the importance of the information. For that reason, the remaining papers used for the literature review are not limited to any specific time.

Regarding the case study, web pages of "*Secretaría General de Industria y de la PYME*" were consulted. "*Herramienta de Autodiagnóstico Digital Avanzada*" (HADA) was selected for the study of the maturity of Industry 4.0 in a real company. Answers to the questionary were introduced in the HADA software obtaining a benchmarking of the company. Results are explained in detail in Section 6.

As was above-mentioned, the focus of this paper is Industry 4.0 and SMEs performance. This scope presented in the paper has the following objectives:

1. To understand the concept of Industry 4.0 and Industry 4.0 technologies.

2. To recognise the importance of Industry 4.0 in small and medium-sized enterprises.

3. To apply the knowledge in a practical way.

3. Industry 4.0 concept

This section begins with the origins of Industry 4.0 and continues with the explication of the concept including definitions of the literature and classifications of the most important Industry 4.0 technologies.

3.1. Origins of Industry 4.0

The concept of the "*Fourth Industrial Revolution*" was created in 1988 to distinguish the procedures of developing technologies into innovation. The term was related to the development of technologies and their applications in the industry until 2013, when Henning (2013) denominated as Industry 4.0, after Germany´s "*Industrie 4.0*". The German program was an initiative of the federal government with universities and private companies to integrate physical objects and digital technologies (Frank, Dalenogare y Ayala 2019). The name of this revolution or "*Industry 4.0*" differs depending on the country. For example, EEUU named "*Industrial Internet*", "*Future of Manufacturing*" was established in the United Kingdom whereas China created "*Made in China 2025*" (Büchi, Cugno y Castagnoli 2020).

Industry 4.0 is understood as a new industrial stage consisting of integration between manufacturing operations systems and information and communication technologies (ICT), especially the Internet of Things (IoT) (Dalenogare et al. 2018). Indeed, the term Industry 4.0 derives from the introduction of the Internet of Things in the manufacturing sector. The concept of the Internet of Things was introduced by Kevin Ashton in 1998 as connecting things to the Internet. IoT includes a set of intelligent devices that facilitate communication between people and machines (Frank, Dalenogare y Ayala 2019).

In history, innovations have brought new opportunities and benefits for society. Three previous industrial revolutions provoked new changes regarding productivity (see Figure 2) improving thus the quality of life of the people. The Fourth Industrial Revolution or Industry 4.0 core is composed of Cyber-Physical Systems (CPS), sensors, data processors and actuators to connect the real and the virtual world by transferring data between people and objects in real-time (Birkel et al. 2019).

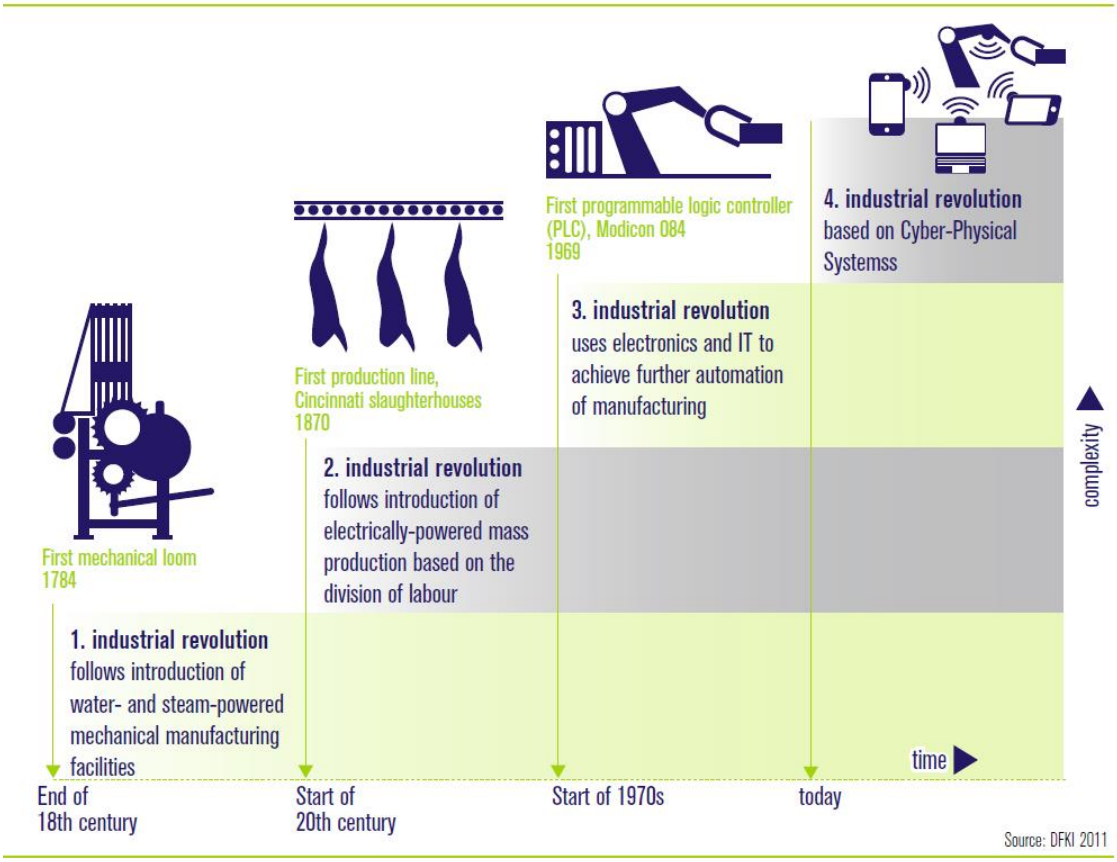

Figure 2. The four stages of the Industrial Revolution (Henning 2013)

3.2. Defining Industry 4.0

The aim of Industry 4.0 consists in the introduction and exploitation of Industry 4.0 technologies in the industry, transforming the company into a smart factory (Institut Valencià de Competitivitat Empresarial 2018). This transformation is only possible due to the enabling technologies that are technologies with the potential to digitalize the industry. In the literature, there is not a universally accepted definition of Industry 4.0 since is composed of more than 1200 enabling technologies and its innovations can become obsolete (Büchi, Cugno y Castagnoli 2020). Table 1 presents some definitions of Industry 4.0 found in the literature.

Table 1. Definitions of Industry 4.0

Definition	Author
"*Now, the introduction of the Internet of Things and Services into the manufacturing environment is ushering in a fourth industrial revolution. Businesses will establish global networks that incorporate their machinery, warehousing systems and production facilities in the shape of Cyber-Physical Systems (CPS). In the manufacturing environment, these Cyber-Physical Systems comprise smart machines, storage systems and production facilities capable of autonomously exchanging information, triggering actions and controlling each other independently*"	Henning (2013)
"Industry 4.0 is a large German initiative that emphasises the extension of traditional manufacturing systems to full integration of physical, embedded and IT systems including the Internet"	Wang et al. (2015)
"Industry 4.0 is the sum of all disruptive innovations derived and implemented in a value chain to address the trends of digitalization, autonomization, transparency, mobility, modularization, network collaboration and socializing of products and processes"	Pfohl et al. (2015)
"The term Industry 4.0 comprises a variety of technologies to enable the development of a digital and automated manufacturing environment as well as the digitisation of the value chain. This results in improvements in product quality and a decrease of time-to-market as well as improvements in enterprise performance"	Oesterreich & Teuteberg (2016)
"*Industry 4.0 is considered a new industrial stage in which vertical and horizontal manufacturing processes integration and product connectivity can help companies to achieve higher industrial performance*"	Dalenogare et al. (2018)
"The network of intelligent and highly connected industrial components that are deployed to achieve high production rate with reduced operational costs through real-time monitoring, efficient management and controlling of industrial processes, assets and operational time"	Khan et al. (2020)

Despite the unclear definition of Industry 4.0, four main or smart dimensions are fundamental to understand better the concept (Frank, Dalenogare y Ayala 2019):

- **Smart Manufacturing.** Industry 4.0 is rooted in advanced manufacturing or Smart Manufacturing that includes the adjustment of production processes automatically and as consequence improvements in quality, productivity, and flexibility. Smart Manufacturing is the core of Industry 4.0 (Frank, Dalenogare y Ayala 2019).

- **Smart Products.** Smart Products, another basic part of Industry 4.0, relates to these technologies embedded in the final products. In the literature, Smart Products are considered as the second main objective of Industry 4.0 since they enable new digital capabilities and business models (Frank, Dalenogare y Ayala 2019). In addition to Smart Manufacturing, Smart Products have the purpose of adding value to manufacturing and final products.

- **Smart Supply Chain**. The difference between these technologies and the previous dimensions is that Smart Products and Smart Manufacturing add value to final products whereas Smart Supply Chain provide efficiency to the complementary operational activities (Frank, Dalenogare y Ayala 2019). These technologies support horizontal integration with external suppliers outside the factory allowing companies to combine resources in collaborative manufacturing, share their capabilities, and focus on their core competencies (Frank, Dalenogare y Ayala 2019).

- **Smart Working.** This dimension, supplementary to Smart Supply Chain providing efficiency, supports workers tasks to be more productive and flexible. Smart Working includes remote monitoring of production, augmented reality for maintenance, virtual reality for workers training and product development, and collaborative robots (Frank, Dalenogare y Ayala 2019).

In their research, Frank et al. (2019) named these dimensions '*Front-end technologies*' because these technologies are concerned with operational and market needs. In contrast, Frank et al. (2019) included another group of technologies, '*Base technologies'*. These technologies aim to support and provide connectivity and intelligence for the front-end technologies, as illustrates in Figure 3. Base technologies have different capabilities in the company (Frank, Dalenogare y Ayala 2019):

- **Internet of Things**. IoT allows communication between objects and systems in a factory.

- **Cloud services**. These technologies enable access to information easily, whereas

- **Big data and analytics**. These Industry 4.0 technologies permit the management and analysis of a large amount of data.

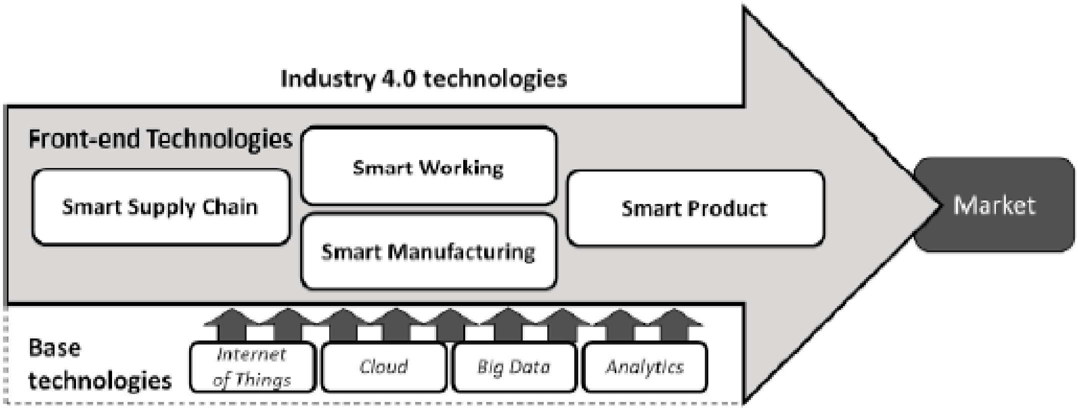

Figure 3. Industry 4.0 technologies (Frank, Dalenogare y Ayala 2019)

3.3. Classification of Industry 4.0 technologies

There are many classifications of Industry 4.0 technologies in the literature depends upon the objective of the author. For example, Somohano et al. (2020) classified enabling digital technologies into two groups according to their nature. The first group, "*Information and Communication Digital Enabling Technologies*" (IDETs) relate to the information technology for data processing and communications: big data, cloud computing and cybersecurity. The mainly general application of IDETs is software. In contrast, the second group, "*Advanced Robotics and Integration Digital Enabling Technologies*" (ADETs) refer to the information technology for data collection and transmission between devices: robotics and automation. Their general application includes software and hardware.

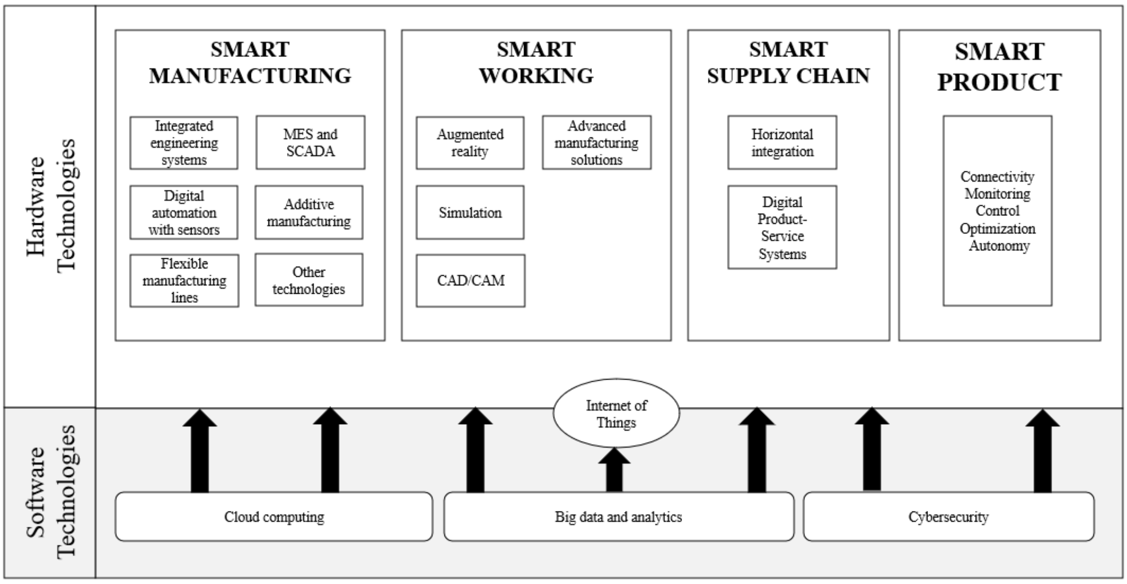

Figure 4. Industry 4.0 technologies framework

This paper establishes a classification of digital technologies into two groups according to their nature: Software technologies and Hardware technologies. The main difference with the model developed by Somohano et al. (2020) is the differentiation between the technology *Internet of Things*. In this case, the *Internet of Things* is located between both groups being a connector, since IoT allows communication between objects and systems (Dalenogare et al. 2018). The reason for this is to present a clear classification of Industry 4.0 technologies and integrate these technologies in the four above-mentioned dimensions. Figure 4 shows this classification including the most relevant Industry 4.0 technologies. In the following, definitions of Industry 4.0 technologies found in the literature are introduced.

3.4. Software Industry 4.0 technologies

Software technologies include Industry 4.0 technologies that support the Hardware technologies for the perfect functioning of the activities in the company. The most relevant Software technologies are *Cloud computing*, *Big data and analytics*, and *Cybersecurity*. Table 2 shows definitions of these technologies found in the literature.

Table 2. Software Industry 4.0 technologies

Technology	Definition	Authors
Cloud computing	This relates to the technologies that allow the archiving and managing large quantities of data with high performance. Cloud services consist of the storage of data in an internet server-provider allowing remote communications and the integration with different devices.	Buchi (2020); Dalenogare (2018), Frank et al. (2019)
Big data and analytics	This technology includes the obtention, analysis and dissemination of a large quantity of data derived from products, processes, machines, and people interconnected. The combination of IoT and Cloud services allows for the collection of a huge amount of data. Analytics allows managers to optimize the decision-making process of an industrial business.	Buchi (2020); Dalenogare (2018); Frank et al. (2019)
Cybersecurity	Cybersecurity refers to the measures created to protect the flow of information.	Buchi (2020)

3.5. Internet of Things

As was above-mentioned, *Internet of Things* technology has been located as a link between software and hardware technologies. The reason for this is that the Internet of Things is an Industry 4.0 technology that involves a set of intelligent devices that facilitate communication between people and machines (Dalenogare et al. 2018). Internet of Things offers a new vision in Industry 4.0 by the automation of smart objects and communication in real-time (Wang et al. 2016). The major objective of this technology in Industry 4.0 is to achieve high operational efficiency, increase productivity and manage better the assets of the company (Khan et al. 2020)

The concept of adding new components to machines and robots has always been part of the industry. The Third Industrial Revolution allowed the automatization of processes and many improvements in the sector of manufacturing. However, these machines worked interconnected autonomously but without human interaction (Institut Valencià de Competitivitat Empresarial 2018). Internet of Things is the integration of all these components of machines and computing "*in an internet environment through wireless communication*" (Frank, Dalenogare y Ayala 2019). Recent progress on the internet has allowed the communication between objects. For that reason, the Internet of Things is created to solve the problem of connection being a link between people and machines.

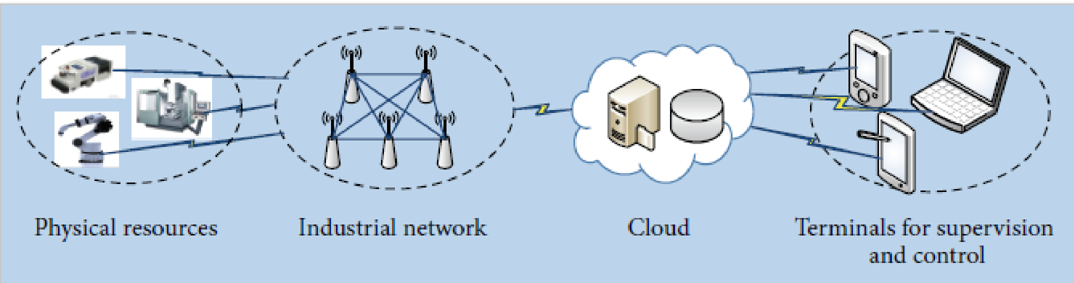

Figure 5. A brief framework of the smart factory of Industry 4.0 (Wang et al. 2016)

3.6. Hardware Industry 4.0 technologies

Hardware Industry 4.0 technologies refer to these technologies related to the physical components of the company. As it was mentioned, the proposed framework includes technologies into the four dimensions: Smart Manufacturing, Smart Working, Smart Supply Chain and Smart Products. The following tables show the definitions of Hardware Industry 4.0 technologies found in the literature.

Table 3. Hardware Industry 4. technologies: Smart Manufacturing technologies

Technology	Definition	Authors
Integrated engineering systems	Integration of IT in product development and manufacturing.	Dalenogare (2018), Frank et al. (2019)
Digital automation with sensors	Automation systems with sensors for monitoring.	Dalenogare (2018), Frank et al. (2019)
Flexible manufacturing lines	Manufacturing lines have automation systems with sensor technologies such as radio frequency identification (RFID) in a cost-efficient way. This allows the identification and traceability of raw materials and final products.	Dalenogare (2018), Frank et al. (2019)
Manufacturing Execution Systems (MES) and Supervisory control and data acquisition (SCADA)	Monitoring real-time data using SCADA and remote control of production.	Dalenogare (2018), Frank et al. (2019)
Additive manufacturing	Flexible manufacturing systems that enable transforming digital 3D models into physical products. This facilitates the production of complex products by creating layers of different types of materials. For example, 3-D printing	Dalenogare (2018), Buchi (2020)
Other technologies	These include technologies used for specific fields such as energy management, agri-food or reducing waste.	Buchi (2020), Frank et al. (2019)

Table 4. Hardware Industry 4.0 technologies: Smart Working technologies

Technology	Definition	Authors
Augmented reality	This refers to the technology that improves human sensory perception thanks to virtual environments.	Buchi (2020)
Simulation	This refers to the representation of the physical world in virtual models. Virtual models can simulate the properties of the implemented models.	Buchi (2020), Dalenogare (2018), Frank et al. (2019)
Computer-Aided Design and Manufacturing (CAD/CAM).	The development of projects and work plans based on computerized systems.	Dalenogare (2018)
Advanced manufacturing solutions	This technology relates to the creation of interconnected systems that support automated industrial plans including collaborative robots or automated vehicles.	Buchi (2020), Frank et al. (2019)

Table 5. Hardware Industry 4.0 technologies: Smart Supply Chain technologies

Technology	Definition	Authors
Horizontal integration	Horizontal integration represents the integration and exchange of information among the areas in the company.	Buchi (2020)
Digital Product-Service Systems	Incorporation of digital services in products.	Dalenogare (2018)

Table 6. Hardware Industry 4.0 technologies: Smart Product technologies

Technology	Definition	Authors
Product's connectivity Product's monitoring Product's control Product's optimization Product's autonomy	Smart Product encompasses the technologies that the product needs to create new product capabilities: connectivity, monitoring, control, and autonomy.	Porter and Heppelmann (2014)

Smart Product Technologies: How Smart Products are transforming companies

This part of the section has been included to explain better the meaning of Smart Products technologies and their importance in companies. Smart Products consist of *physical* components (mechanical and electrical parts), *smart* components (sensors, microprocessors, and software), and *connectivity* components that allow communication between the product and the cloud (Porter y Heppelmann 2014). Porter and Heppelmann (2014) explored the internal implications within the company: how Smart Products change the way of work virtually within the company. Connected products require a new technology infrastructure that facilitates new product capabilities: products can monitor, product operations can be controlled by the users creating new opportunities for optimization and as consequence allowing autonomy (Porter y Heppelmann 2014).

Porter (2014) indicated that manufacturing companies are being reshaped with new relationships in the way that companies interact with their customers. Traditional sources of data (research, surveys, interactions) are being changed by the product itself. In addition, new functional units appear creating a new organizational structure (Porter y Heppelmann 2014), as illustrates in Figure 6.

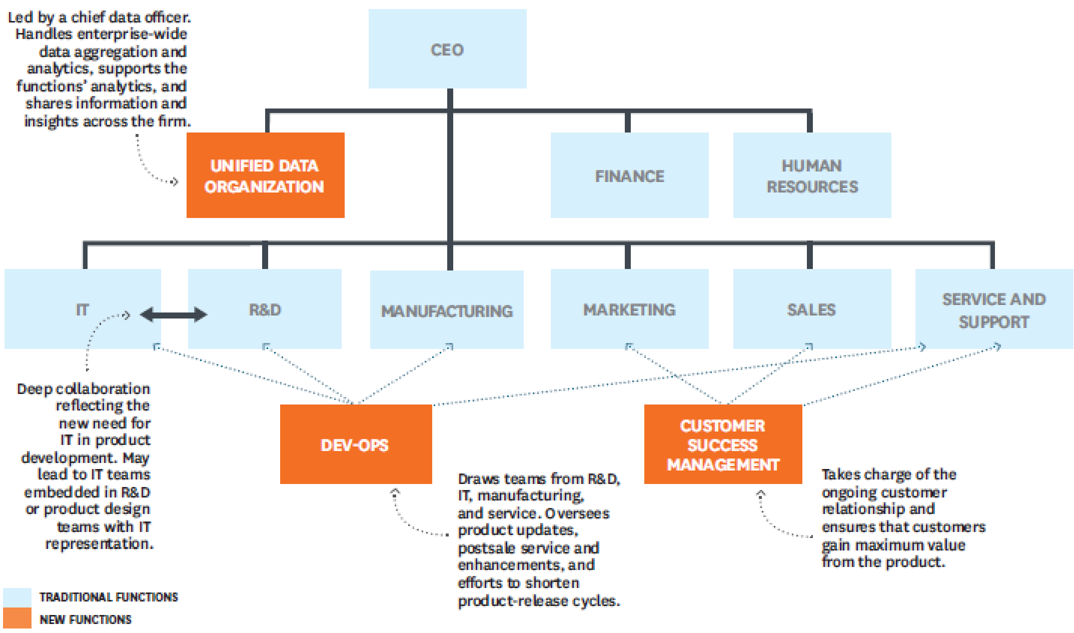

Figure 6. A new organizational structure (Porter y Heppelmann 2014)

Smart Product technologies have restructured the traditional functions of business transforming the value chain (Porter y Heppelmann 2014):

- Product development. This includes the rethinking of the design, from largely mechanical engineering to true disciplinary systems engineering (Porter y Heppelmann 2014). There are also differences with traditional product development techniques: low-cost variability, evergreen design, new user interfaces and augmented reality, ongoing quality management (monitor and identify design problems), connected service (remote), support for new business models (product-as-a-service models) and system interoperability (products are components of broader systems) (Porter y Heppelmann 2014).

- Manufacturing. Smart Products suppose a radical shift in manufacturing since they require a cloud-based system for operating (Porter y Heppelmann 2014). Smart factories are created with reconfigured assembly processes and continuous production operations (Porter y Heppelmann 2014). Figure 7 shows the contrast between the traditional production line and the smart factory production system (Wang et al. 2016). According to Pfohl et al. (2015), the most important impact from the Industry 4.0 technologies is for the production and distribution activities in the supply chain.

- Logistics. The development of current Smart Products and the creation of new technologies can revolutionize the field of logistics improving the delivery process and optimizing the movement of products (Porter y Heppelmann 2014).

- Marketing and sales. New ways to segment and customize customers, new customer relationships, new business models, and focus not discrete products but on systems (Porter y Heppelmann 2014). The interaction of people within the supply chain influences the department of sales, the customer can be integrated and in consequence eliminate organizational borders (Pfohl, Yahsi y Kurnaz 2015).

- After-sale service. Smart products improve service and enable a shift from reactive to preventive, proactive and remote service (Porter y Heppelmann 2014).

- Security. Smart products are exposed to cyberattacks, thus new risk models are created to protect data privacy (Porter y Heppelmann 2014).

- Human resources. Smart products are in high demand but short supply. Therefore, companies need to hire the right talent as their skill requirements shift from mechanical engineering to software engineering (Porter y Heppelmann 2014). Some manufacturers are establishing their facilities in hot spots (clusters), thus accelerating their learning and improve recruiting by being in the clusters (Porter y Heppelmann 2014).

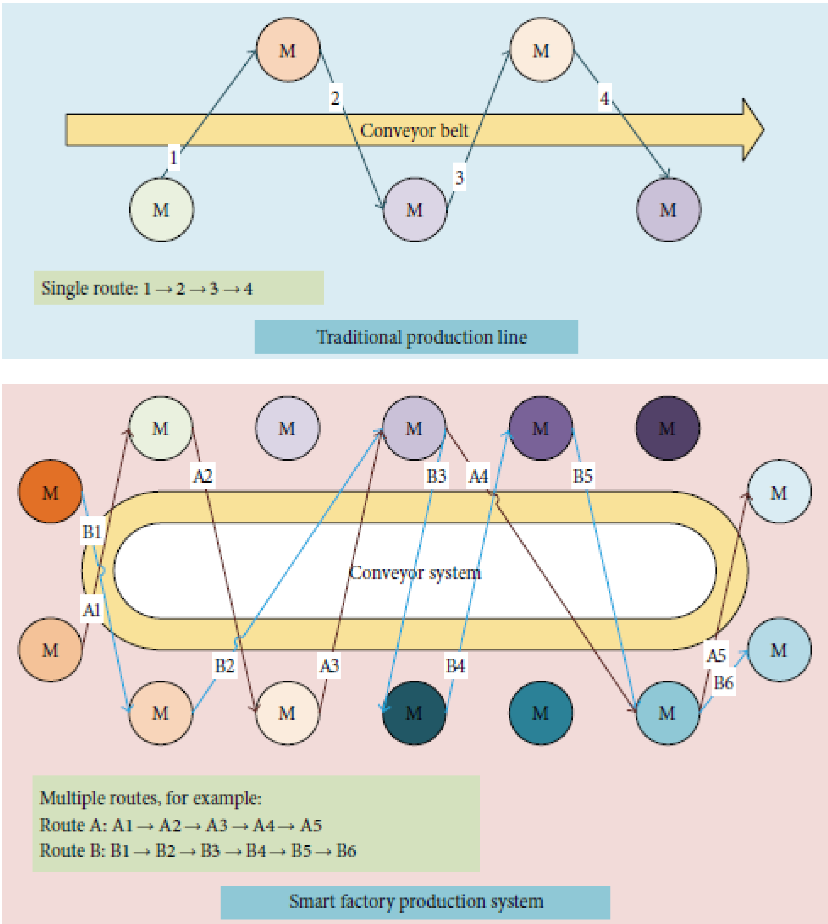

Figure 7. Traditional production line and smart factory production system (Wang et al. 2016)

4. Industry 4.0 and innovation

This section explains the relationship between innovation and Industry 4.0, the importance of developing an innovation strategy and the roles of capacities on innovation in the company.

4.1. The importance of innovation in Industry 4.0

In the literature, many authors have studied the applications of Industry 4.0 on innovation showing their positive effects as well as the influence between the company and society. However, Industry 4.0 is considered an emergent field that would entail being revolutionary in the management of companies. The reason for this is that firms can differentiate their innovation strategy to modify their business models regarding Industry 4.0 (Müller, Buliga y Voigt 2020). Industry 4.0 effects on SMEs innovation are positive and innovation increases firm growth and product quality, thus managers should think about changes in their business models (Somohano-Rodríguez, Madrid-Guijarro y López-Fernández 2020). However, SMEs do not know what to do and how to change their models in terms of digitalization (Sommer 2015).

The development and the implementation of new technologies are long-term strategic tasks; thus, managers must consider present and future technologies as well as customer needs (Somohano-Rodríguez, Madrid-Guijarro y López-Fernández 2020). SMEs have short-term perspectives thus Industry 4.0 is more reticent regarding implementation (Somohano-Rodríguez, Madrid-Guijarro y López-Fernández 2020). New investments are required to implement Industry 4.0 technologies; thus, companies cannot create benefits in a short-term period (Frank, Dalenogare y Ayala 2019). Large companies with high investments in a technological structure can invest in process and product innovation whereas small companies do not have the resources (Frank, Dalenogare y Ayala 2019).

The lack of an innovation strategy that integrates and align the actions of the company to the same goal could make resources inefficient and even counterproductive to the organization (Somohano-Rodríguez, Madrid-Guijarro y López-Fernández 2020). Therefore, how to use the resources is particularly important to SMEs, so the creation and development of innovation strategies is fundamental to the implementation of Industry 4.0 technologies (Somohano-Rodríguez, Madrid-Guijarro y López-Fernández 2020).

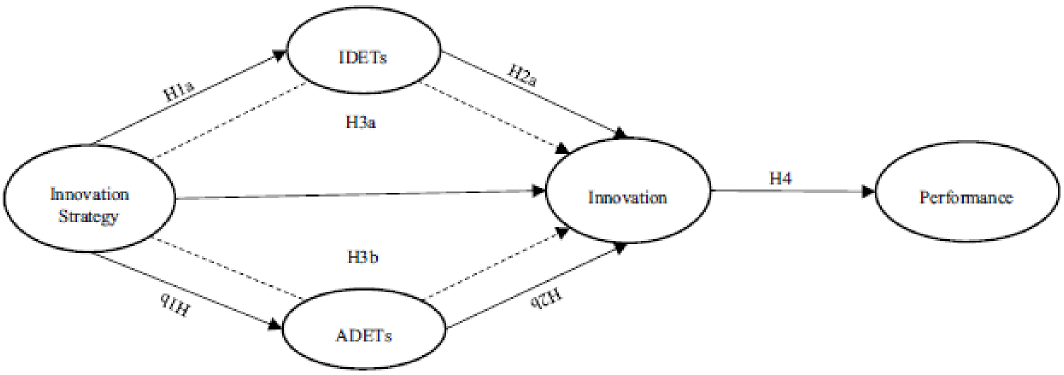

Figure 8. Structural model (Somohano-Rodríguez, Madrid-Guijarro y López-Fernández 2020)

Somohano et al. (2020) studied the role of the development of an innovation strategy in promoting Industry 4.0 in SMEs, the effects of innovation on SME performance and the SMEs abilities to expand innovation regarding digital enabling technologies, as shown in Figure 8. As was mentioned in the previous section, Somohano et al. (2020) classified enabling digital technologies into two groups according to their nature to show that play different roles in SME innovations: ADETs and IDETs. Somohano et al. (2020) explained that both IDET and ADET investments will transform business models as well as reshape manufacturing industries. However, the effects of these technologies in SMEs innovation are not equal.

ADETs promotes innovation but IDETs create innovation more effectively. When implementing ADETs, SMEs should consider how to implement these innovation strategies (Somohano-Rodríguez, Madrid-Guijarro y López-Fernández 2020). Somohano et al. (2020) indicated that IDETs are more relevant when promoting SME innovation since SMEs can search for data and use cybersecurity technologies easily. IDETs need fewer strategic innovation efforts and minor capabilities. The reason for this is because highly skilled employees are required for ADETs, although the costs of these technologies are higher than IDETs costs. Major innovation strategies with employees who are committed to innovative activities imply better innovation outcomes (Somohano-Rodríguez, Madrid-Guijarro y López-Fernández 2020).

Industry 4.0 facilitates the availability of information in management decisions and the interoperability between companies and people. In the case of SMEs, companies can obtain external knowledge, assimilate it, and find a commercial application (Somohano-Rodríguez, Madrid-Guijarro y López-Fernández 2020). There is a strong relationship between improving competitive advantage and innovation with the ability of the company to capture data, study and use it in the future (Müller, Buliga y Voigt 2020). In this context, *Big data and analytics* (IDETs) can be used to analyse customers as well as markets leading thus to better innovation.

In addition, digital systems, robotics and IoT (ADETs) promote also innovations in Industry 4.0 (Somohano-Rodríguez, Madrid-Guijarro y López-Fernández 2020). For example, their use could be a link between partners from different industries. Industry 4.0 practices include collaboration and data share with partners interconnecting value chains (Somohano-Rodríguez, Madrid-Guijarro y López-Fernández 2020). This is especially useful for SMEs because they have limited resources but also for large companies that can assume innovation risks when entering new markets (Somohano-Rodríguez, Madrid-Guijarro y López-Fernández 2020).

4.2. The role of absorptive capacity and innovation strategy

Some benefits or opportunities can become available for SMEs when they use Industry 4.0 technologies but also innovate their business models based on the advantages of Industry 4.0 (Müller, Buliga y Voigt 2020).

Knowledge is considered one of the most important resources of a company. Companies need to acquire knowledge through absorptive capacity; thus, they can enlarge their internal knowledge and transform it into innovations in R&D departments (Müller, Buliga y Voigt 2020).

Cohen & Levinthal (1990) defined absorptive capacity as the "*ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends".* Companies need to acquire and assimilate knowledge, but also transform and exploit it into an application. For that reason, Müller et al. (2020) represented absorptive capacity as two dimensions: potential (acquire and assimilate) and realized (transform and exploit), as Figure 9 illustrates.

Business models can be redesigned for efficiency and novelty (Müller, Buliga y Voigt 2020). Novelty means new and nontrivial changes to the three core elements of the business model of manufacturing SMEs: value creation, value offer, and value capture (Müller, Buliga y Voigt 2018).

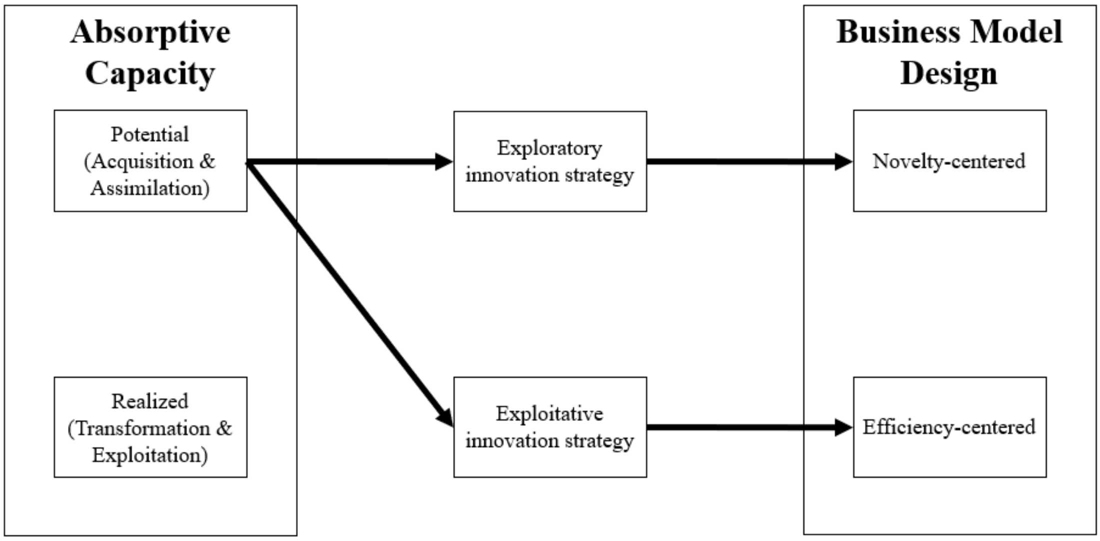

Figure 9. Absorptive capacity and business model relationship, adapted from (Müller, Buliga y Voigt 2020)

Exploratory innovation strategy is associated with the search for new information and ideas whereas *exploitative innovation strategy* is related to the optimization and implementation of new solutions in the extant business (Müller, Buliga y Voigt 2020). The assimilation of external knowledge includes the analysis, prosecution, interpretation and understanding of the external information. As consequence, SMEs can encourage both exploratory and exploitative strategies (Müller, Buliga y Voigt 2020). In contrast, the transformation and exploitation of external knowledge have a positive effect on exploratory and exploitative strategies only for large companies (Müller, Buliga y Voigt 2020). This is because SMEs are focus on acquiring external knowledge whereas the transformation and exploitation of this knowledge are still in their initial stages regarding Industry 4.0 (Müller, Buliga y Voigt 2020).

In the literature, authors have indicated that exploratory strategies imply the creation of knowledge regarding new demands from customers and new value offers for emerging customer groups (Müller, Buliga y Voigt 2020). Therefore, the result of the explorative search is the creation of new resources and as consequence, the creation of new business models, especially for SMEs (Müller, Buliga y Voigt 2020). However, due to the lack of resources, only some of the SMEs are exploring novel business models (Frank et al. 2019). In contrast, the objective of exploitative innovation strategy is the efficiency of organizational processes and activities. In Industry 4.0, the exploitative search leads to the application of Industry 4.0 technologies for improving existing processes and performance (Müller, Buliga y Voigt 2020).

5. Industry 4.0 performance

Many authors have studied Industry 4.0 in the literature from different perspectives. However, there is still a lack between the Industry 4.0 technologies and performance (Büchi, Cugno y Castagnoli 2020). This section approaches Industry 4.0 performance studying the implementation of Industry 4.0 technologies in the company and considering the potential benefits and risks focusing on SMEs. Finally, the maturity of Industry 4.0 is presented with a case study analysis.

5.1. Implementation of Industry 4.0

The concept of Industry 4.0 has a very complex technology architecture of the manufacturing systems, which is one of the main concerns. In the literature, there is a lack of research about the way that Industry 4.0 technologies are adopted in manufacturing companies (Frank, Dalenogare y Ayala 2019). Managers of manufacturing companies can focus on different needs when prioritizing the implementation of Industry 4.0 technologies (Frank, Dalenogare y Ayala 2019). In the literature some authors have indicated the benefits of these technologies are distinctive and companies should consider the implementation of Smart Manufacturing technologies to obtain a higher maturity level of Industry 4.0 (Frank, Dalenogare y Ayala 2019). Fort that reason, this part of the section explores how is the implementation starting with the value chain in the company regarding Industry 4.0.

5.2. How is the value chain regarding Industry 4.0?

Before the study of the implementation of Industry 4.0 is fundamental to know the value chain of a company regarding Industry 4.0. The Industry 4.0 value chain is composed of agents in the sector of TIC and industrialization that are required for the development of Industry 4.0 technologies (Institut Valencià de Competitivitat Empresarial 2018). As Figure 10 shows, these agents are:

- Competency centres and scientific-technological agents: institutes, universities and innovation and development units.
- Advanced services suppliers: engineering companies, TIC services and consultancy.
- Machinery and production systems suppliers: equipment, components, electronic devices.
- Materials, industrial products, and final products suppliers.

- Agents of territorial dynamization. These include the organizations that activate relations between companies and agents of knowledge and technology creation.

Figure 10. Industry 4.0 value chain (Institut Valencià de Competitivitat Empresarial 2018).

6.1.1 How to integrate Industry 4.0 technologies in the value chain?

There are three attributes to consider when implementing Industry 4.0 technologies: horizontal integration, vertical integration and end-to-end integration (Oesterreich y Teuteberg 2016). Figure 11 illustrates the relationships of the three kinds of integration:

- Horizontal integration (between the company and customers and suppliers) through value networks. There is a flow of information, finance and material between corporations (Wang et al. 2016).
- Vertical integration (between different departments within the company) and networked manufacturing systems. Thanks to this integration, smart machines compose an organized system that can be configured to adapt to different products (Wang et al. 2016).
- End-to-end digital integration of engineering across the entire value chain by using CPS, even after-sales. By this integration, the product model can be used at every stage (Wang et al. 2016).

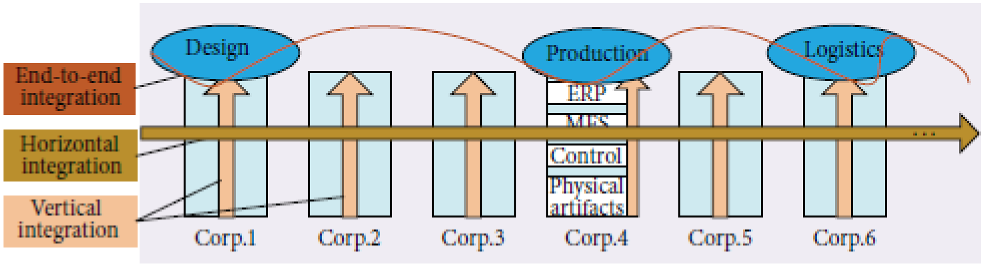

Figure 11. Kinds of integration and their relationship (Wang et al. 2016)

Oesterreich & Teuteberg (2016) represents these attributes illustrating the impact of the technologies on the value chain of a construction company, as Figure 12 shows.

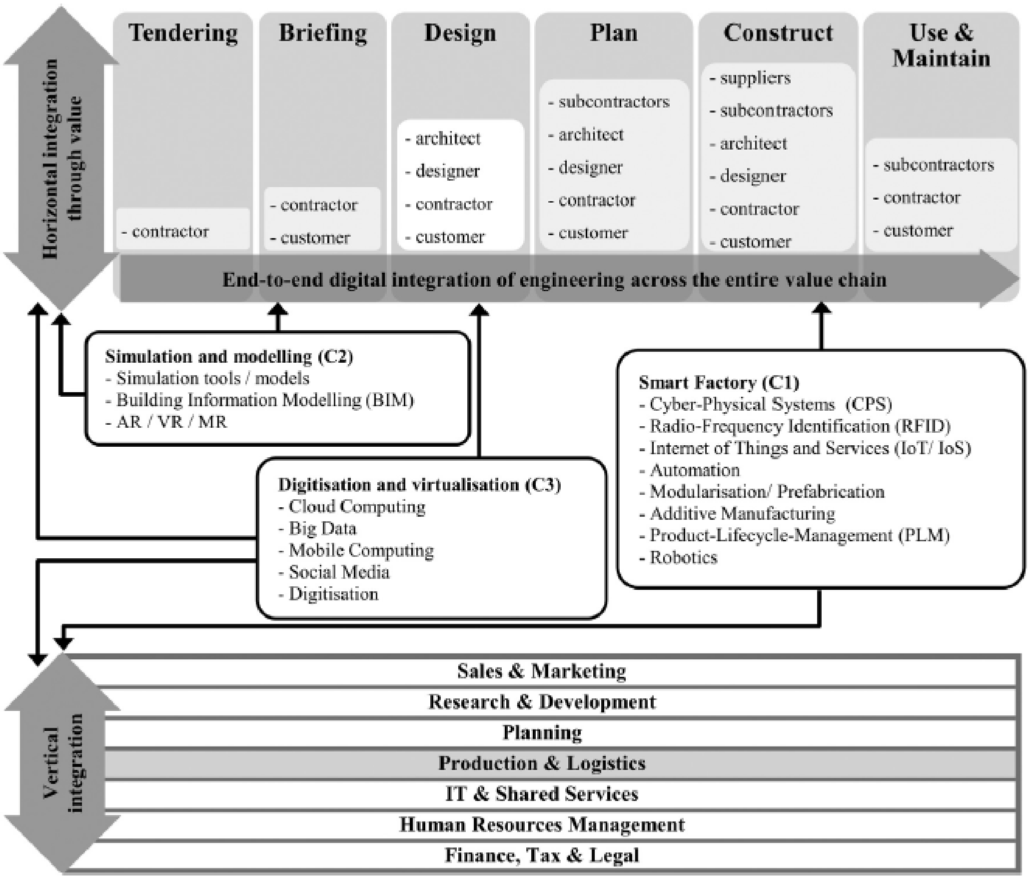

Figure 12. Impact of Industry 4.0 technologies on the construction value chain (Oesterreich y Teuteberg 2016)

5.2.2. How is Industry 4.0 implemented in the company?

Frank et al. (2019) showed that the level of implementation of Industry 4.0 depended on the size of the company. Large companies have the resources to invest in process and product innovation whereas SMEs cannot invest in a technological structure. Figure 13 shows the complexity level of implementation of Industry 4.0 technologies. In their research, companies only implemented "passive" Smart Products which means that are useful to monitor and control, but not to optimize and provide autonomy to the machines (Frank, Dalenogare y Ayala 2019). The reason for this is that supply chain integration is still immature in the development of the industrial sector (Frank, Dalenogare y Ayala 2019). Regarding Smart Working, *Augmented* and *Virtual Reality technologies* are still low implemented whereas *Advanced manufacturing solutions* (collaborative robots) are advanced adopters of the Smart Manufacturing technologies (Frank, Dalenogare y Ayala 2019).

Concerning Base Technologies, *Cloud services* are the first technology implemented to store remote data but not real-time data. Real-time data is represented as the combination of the *Internet of Things*, *Big Data* and *Analytics* and these technologies are still in the initial stages at an industry level (Frank, Dalenogare y Ayala 2019). *Flexible manufacturing lines* are the only technology that was not adopted in any company (Frank, Dalenogare y Ayala 2019).

Companies that want to implement Industry 4.0 technologies should think about their strategic goals before the implementation (Dalenogare et al. 2018). Therefore, companies with a focus on differentiation can focus on the prioritization of the implementation of technologies associated with *Product Development* technologies, such as *Additive manufacturing* or *Integrated engineering systems* (Dalenogare et al. 2018). In contrast, companies that want to differentiate in low cost, productivity or operational flexibility should focus on *Manufacturing technologies* (Dalenogare et al. 2018). Finally, it is also relevant to consider the implementation of Industry 4.0 from a socio-technical perspective. There are three complementary dimensions of the technologies of Industry 4.0 to consider the digitalization process towards the Industry 4.0 implementation (Frank, Ribeiro y Echeveste 2015):

1. Organization of work. New technologies are needed to rethink how the organization will operate.
2. Human factors: competencies and skills from the workers.
3. External environment or the maturity of the place where new technologies are implemented.

External environment: Types of countries

Industry 4.0 appeared as a natural growth of digitization of companies, being manufacturing a fundamental part of this development. For that reason, Industry 4.0 can be considered as a concern of technology diffusion and adoption (Dalenogare et al. 2018). Developed countries with emerging technologies are leading the process of diffusion to other countries interested in its adoption. However, the diffusion-adoption process is slow and usually in one direction, from developed to emerging countries (Dalenogare et al. 2018). According to diffusion-adoption theories, this directional flow could result in gaps between economies. There are barriers to the diffusion and the competition of suppliers and adopters contributes to the existence of differences. The consequence of this is that emerging countries could perceive diffused technologies differently. Dalenogare et al. (2018) studied the perception of industries in emerging countries focusing on the current adoption and its benefits. Dalenogare et al. (2018) indicated that emerging countries are more focused on the commercialization of commodities and not in terms of technology adoption. In the literature, some authors have shown the factors that could explain this adoption such as ICT infrastructure, culture, education, or economic and political instability.

When applying IoT, companies in emerging economies face challenges such as the availability of fixed and mobile internet, connectivity and cloud services (Haaker et al. 2021). These challenges are not only link to the use of technology but especially to the need for new business models. Haaker et al. (2021) identified and interpreted business model design options to better understand emerging IoT business models. In contrast, companies of emerging countries are more focused on investing in well-established technologies to improve their productivity instead of advanced technologies. Their economies are based on the low-cost workforce, especially manufacturing companies, thus investments are more expensive. (Dalenogare et al. 2018).

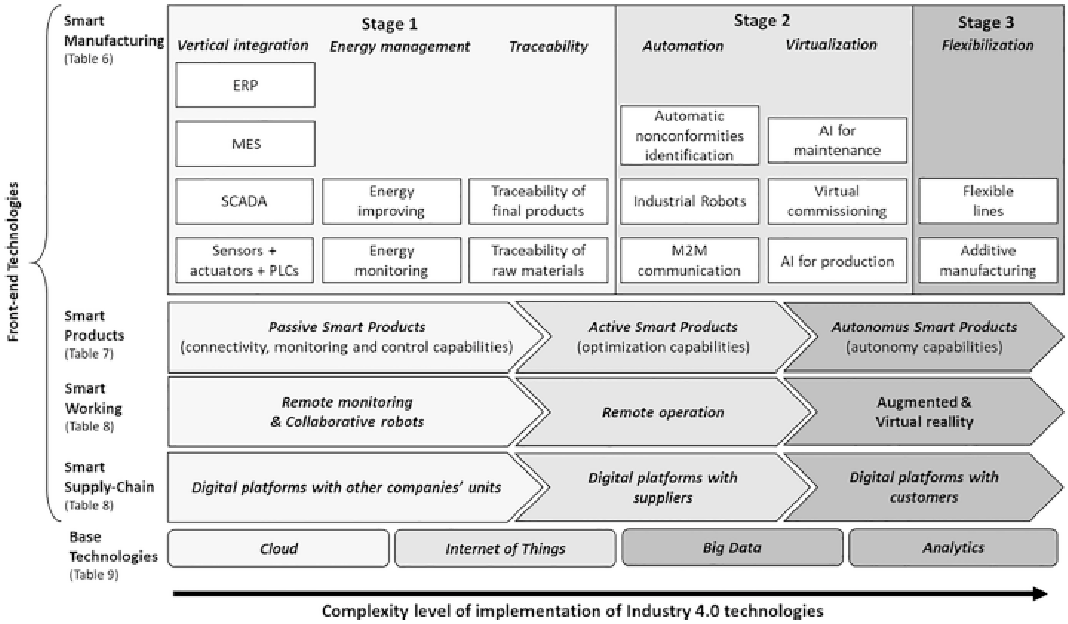

Figure 13. Adoption patterns of Industry 4.0 (Frank, Dalenogare y Ayala 2019)

5.3. Benefits of Industry 4.0

The integration achieved by digital technologies can benefit companies in the industry. There are different approaches to analyse the benefits of Industry 4.0 technologies in the company. Dalenogare (2018) analyzed the relationships between technologies and the expected benefits, as illustrates in Figure 14. Technologies´framework of Dalenogare (2018) divided technologies into two groups because the industrial sectors had different expectations for them. As consequence, the analysis was made by using two perspectives: product expected benefits and operational expected benefits, as is shown in Table 7.

Table 7. Industry 4.0 benefits – Industrial approach, adapted from Dalenogare (2018)

Perspective	Benefit
Product	Improvements in quality Improvements in customer relationship Reduction of set-up costs
Operational	Costs Productivity Flexibility

Table 8. Industry 4.0 benefits – PESTEL approach (Oesterreich y Teuteberg 2016)

Perspective	Benefit
Economic	Cost savings Time savings Improvements in on-time and on-budget delivery Improvements in quality Improvements in collaboration and communication Improvements in customer relationship
Social	Improvements in safety Improvements in the image of the industry
Environmental	Improvements in sustainability

Oesterreich & Teuteberg (2016) indicated the benefits of Industry 4.0 by using 6 perspectives of the PESTEL-framework: political (P), economic (E), social (S), technological (T), environmental (E) and legal (L). The PESTEL analysis has been used by many authors in the literature to study the factors of the environment that affect the company. For that reason, the section explores the benefits of Industry 4.0 technologies from the PESTEL perspective. Table 8 shows the benefits according to the PESTEL approach.

5.3.2. Economic Benefits

Regarding the economy of the company, the use of technologies that allow automatization such as *Digital automation with sensors* or *Flexible Manufacturing* can reduce labour and material costs (Oesterreich y Teuteberg 2016). Smart Working technologies such as *Augmented reality* or *CAD/CAM*, that aim supporting workers tasks to be more productive and flexible, permit the simulation of virtual models faster than conventional methods. In consequence, companies can save more time and decrease the project delivery time by adjusting their projects under the established budget (Oesterreich y Teuteberg 2016). These results coincide with literature since products can be digitally modified before their manufacture, thus optimizing resources and times (Dalenogare et al. 2018). Therefore, Smart Working technologies enable to increase the quality since simulation models can avoid errors in the early stages (Oesterreich y Teuteberg 2016).

Smart Working technologies can modify the projects and involve the customer to participate in the customization, thus, companies can focus on the details and improve the customer relationship (Oesterreich y Teuteberg 2016). The adaptation to changes in the market and new opportunities are created through horizontal integration, a collaboration between companies with information exchange and with customers (Wang et al. 2016). Therefore, sharing digital channels with other companies can improve the value of delivery to customers whereas enterprises can co-design products with customers increasing thus their perceived value (Dalenogare et al. 2018).

Regarding Smart Manufacturing technologies, Dalenogare et al (2018) found *Manufacturing Execution Systems (MES)* and *Supervisory control and data acquisition (SCADA)* was not associated with operational expected benefits because their adoption is in the early stage. In contrast, *Digital automation with sensors* had a significant association with operational benefits, being the main implemented technology of their study although is one of the less developed technologies in Industry 4.0 (Dalenogare et al. 2018). Also, *Additive manufacturing* showed a negative association with operational because it still has several restrictions for its application in manufacturing, such as the availability of materials (Dalenogare et al. 2018).

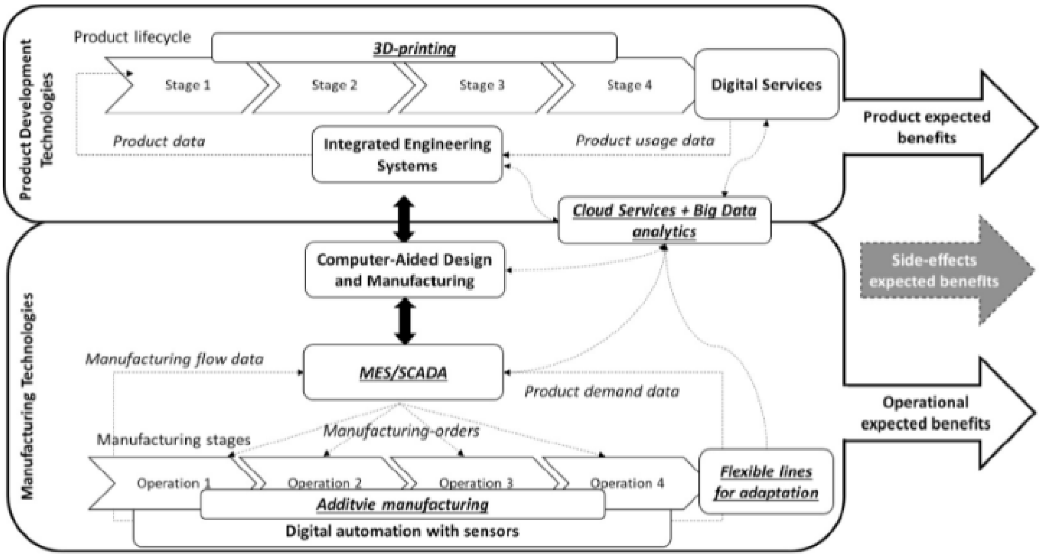

Figure 14. Technologies´framework of Dalenogare (2018)

Big Data and analytics are useful for managers to make decisions better (Dalenogare et al. 2018); thus, improve the quality of products (Oesterreich y Teuteberg 2016). In the literature, researchers have indicated that Industry 4.0 concepts allow companies to have flexible manufacturing processes and manage large quantities of data in real-time, thus managers can make strategic and operational decisions better (Dalenogare et al. 2018). However, Dalenogare (2018) found a negative association of *Big Data* to the benefits expected for product performance. This contrast with the findings of the literature that showed innovation, competition, and productivity in business processes. In contrast, *Cloud computing* indicated a positive relationship because the technologies of *the Internet of Things* are considered useful for real-time processing data but not for storage and analysis (Dalenogare et al. 2018). *Cloud computing* has several advantages because new functions and capabilities allow monitoring, controlling, and optimizing Smart Products (Dalenogare et al. 2018). *Cloud computing* improve collaboration and communication not only between the different departments of the company but even across company borders (Oesterreich y Teuteberg 2016). From a business operations perspective, communication between machines and products enables flexible manufacturing lines; thus, productivity can improve with better efficiency of resources (Wang et al. 2016).

Finally, it is important to mention that Dalenogare (2018) showed two complementary integration technologies: *Integrated engineering systems* associated with product benefits and *CAD/CAM* associated with operational expected benefits. *Integrated engineering systems* work with the integration of the product lifecycle and *CAD* can help to translate the product lifecycle data from end-to-end engineering into product design specifications (Dalenogare et al. 2018).

5.3.3. Social Benefits

Smart Working technologies such as *Simulation* enhance safety in companies (Oesterreich y Teuteberg 2016). Enterprises can develop safety training anticipating and avoiding work accidents. This is especially important for manufacturing and construction companies because safety is one of the most important concerns in the sector (Oesterreich y Teuteberg 2016).

Furthermore, the manufacturing sector has been considered a bad influence on the environment and companies often have difficulties attracting talented employees. Industry 4.0 and digitalization not only allow to improve the image of the company but also the image of the industry (Oesterreich y Teuteberg 2016).

5.3.4. Environmental Benefits

Regarding the environmental benefits, *Other technologies* are developed to handle the ecological problems. *Other technologies* that include energy management, agri-food or reducing waste are fundamental to create solutions and improve the sustainability of the environment (Büchi et al., 2020, Oesterreich & Teuteberg, 2016).

5.3.5. Summary of findings

The following tables summarize the findings of the benefits categorized by technologies using the Industry 4.0 technologies´ framework of this paper.

Benefits of Software Industry 4.0 technologies

Table 9. Benefits of Software Industry 4.0 technologies

Technology	Benefits	Author
Cloud computing	- Improvements in the quality of the product. - Improvements in the customer relationship. - Flexibility due to the potential of forecasting customers´ demand. - Improvements in collaboration and communication	Buchi (2020), Dalenogare (2018)
Big data and analytics	- Improvements in the quality of the product. - Improvements in the customer relationship. - Flexibility due to the potential of forecasting customers´ demand.	Lee et al. (2015), Wang et al. (2016)
Cybersecurity	- Reduction of risks associated with the flow of information.	Tuptuk (2018)

Benefits of Internet of Things

Table 10. Benefits of Internet of Things technology

Technology	Benefits	Author
Internet of Things	- Improvements in the quality of the product. - Improvements in the customer relationship. - Reduction of set-up costs and errors due to the interconnection.	Porter and Heppelmann (2014), Alqahtani et al. (2019)

Benefits of Hardware Industry 4.0 technologies

Table 11. Benefits of Hardware Industry 4. technologies: Smart Manufacturing technologies

Technology	Benefits	Authors
Integrated engineering systems	- Higher productivity. - Flexibility in production.	Dalenogare (2018)
Digital automation with sensors	- Higher productivity. - Flexibility in production.	Dalenogare (2018)
Flexible manufacturing lines	- Higher productivity.	Dalenogare (2018)
Manufacturing Execution Systems (MES) and Supervisory control and data acquisition (SCADA)	- Higher productivity. - Flexibility in production.	Dalenogare (2018)
Additive manufacturing	- Higher speed in the design of products. - Reduction of set-up costs and errors due to the development of customized production lots.	Buchi (2020)
Other technologies	- Improvements in the quality of the product. - Higher productivity. - Improvements in sustainability.	Buchi (2020), Oesterreich and Teuteberg (2016)

Table 12. Benefits of Hardware Industry 4.0 technologies: Smart Supply Chain technologies

Technology	Benefits	Authors
Horizontal integration	- Reduction of set-up costs and errors due to the ability to identify and solve problems.	Wang et al. (2016)
Digital Product-Service Systems	- Improvements in the quality of the product.	Dalenogare (2018)

Table 13. Benefits of Hardware Industry 4.0 technologies: Smart Working technologies

Technology	Benefits	Authors
Augmented reality	- Higher speed in the design of products. - Reduction of set-up costs and errors due to the development of virtual models.	Buchi (2020)
Simulation	- Higher speed in the design of products. - Reduction of set-up costs and errors due to the development of virtual models. - Improvements in safety	Buchi (2020), Dalenogare (2018), Oesterreich and Teuteberg (2016)
Computer-Aided Design and Manufacturing (CAD/CAM).	- Higher speed in the design of products. - Reduction of set-up costs and errors due to the development of virtual models.	Dalenogare (2018)
Advanced manufacturing solutions	- Reduction of set-up costs and errors due to the capacity of learning of the operator. - Flexibility in production. - Higher production capacity due to the potential of modifications.	Buchi (2020)

Table 14. Benefits of Hardware Industry 4.0 technologies: Smart Product technologies

Technology	Benefits	Authors
Product's connectivity Product's monitoring Product's control Product's optimization Product's autonomy	- Improvements in the quality of the product. - Improvements in the customer relationship.	Porter and Heppelmann (2014)

5.4. Risks of Industry 4.0

In the literature, many authors have examined the benefits of Industry 4.0 in industrial companies. However, there are also associated risks that should be considered when implementing. For that reason, Birkel (2019) made a research that contains economic, ecological, social, technical, legal and political risks. Birkel (2019) highlighted that companies need to consider the Triple Bottom Line of sustainability to benefit fully the concept of Industry 4.0. The Triple Bottom Line involves three dimensions: profit, planet, and people, which are represented by economic, environmental, and social aspects. However, there are uncertainty and contradictions when analysing the potential risks (Oesterreich y Teuteberg 2016). For example, Industry 4.0 risks are perceived differently by SMEs (Birkel et al. 2019). This section explores the risks of Industry 4.0 technologies using the PESTEL analysis but focusing on SMEs.

5.4.1. Political and Legal Risks

First, politicians should provide an appropriate infrastructure regarding the network. This is especially important for SMEs since their locations are often outside the urban areas where the infrastructure is not completely developed (Birkel et al. 2019). Companies in emerging economies have to deal with network problems such as the availability of mobile internet, connectivity and cloud services (Haaker et al. 2021).

There are laws and restrictions to be considered when implementing Industry 4.0 (Birkel et al. 2019). Therefore, companies need to check legal aspects to obey the law before the implementation of Industry 4.0 technologies (Oesterreich y Teuteberg 2016).

Intellectual property is one of the main resources of the company because competitive advantage can be lost if competitors obtain the information. Therefore, protecting the data from third parties is very important. This is particularly distinguished for SMEs because some of them are dependent on intellectual data for success (Birkel et al. 2019).

Digitization is leading to global networking creating differences regarding the standards. For that reason, the lack of standards is considered another legal risk since politicians need to find a solution to this problem (Birkel et al. 2019). In addition, politicians need to create programs for companies to incentive them to the adoption of new technologies (Oesterreich y Teuteberg 2016). This is because companies are hesitant to invest in Industry 4.0, the initial investments are large and the benefits are unclear (Oesterreich y Teuteberg 2016).

Table 15. Political and Legal Risks, adapted from Birkel (2019)

Risk	Subcode
Infrastructure	Broadband internet
Legal aspects	Regulatory compliance
	Data protection
	International standards differ
	Increasing legal complexity
	Hesitation to adopt

5.4.2. Economic Risks

Regarding the profitability in the long-term, processes are not clear to be economically positive (Birkel et al. 2019). This is due to Industry 4.0 needs large investments with uncertain duration for amortization and uncertain success (Oesterreich y Teuteberg 2016). In the short- and medium-term profitability, Industry 4.0 technologies can be negative because high investments are required in the beginning (complex machines and systems), benefits require time and cannot be measured in monetary terms (Birkel et al. 2019). Another relevant risk is the investment regarding experts and rare skills. This is especially important for SMEs because they are rare on the market thus are difficult to obtain and need huge investments (Birkel et al. 2019).

Managers concern the risk of false investments such as poor and often immature technologies (Birkel et al. 2019). This is especially relevant for SMEs because they have a limited resource base, therefore wrong investments could provoke negative consequences in the future (Birkel et al. 2019). It is also important to mention that managers face the risk of when to invest in certain Industry 4.0 technologies.

In this volatile environment of Industry 4.0, companies can change the way they work as well as the required skills (Birkel et al. 2019). The implementation of Industry 4.0 entails organizational and process changes (Oesterreich y Teuteberg 2016). Therefore, enterprises can lose their core competencies, market success or profitability (Birkel et al. 2019). Core competencies are fundamental for SMEs, thus losing them could make customers cease interest (Birkel et al. 2019). In contrast, Industry 4.0 promotes the creation of new business models with the consequence of the appearance of customers able to pay for these new technologies (Birkel et al. 2019).

The emergence of new technologies implies new competitors in the market who can appear unexpectedly. Therefore, traditional manufactures need to adapt their products to the entrance competitors' conditions (Birkel et al. 2019).

Table 16. Economic Risks, adapted from Birkel (2019)

Risk	Subcode
Financial	Long and uncertain amortization High investments Personnel costs
Time and manner of investments	Risk of false investments The decision in what to invest when Too late investments
Changing business models	Loss of core competencies Customer demands/acceptance Organizational and process changes Transformation of business models
Competition	New competitors Diminishing barriers to market entrance Competitive pressure Transparency of data can be misused

5.4.3. Social Risks

The implementation of Industry 4.0 can make activities and processes automated. Some employees can adapt to changes developing new competencies whereas others cannot assume new roles creating a problem in the company (Birkel et al. 2019).

Regarding the structure of the enterprise, structural changes are required when implementing Industry 4.0 (Birkel et al. 2019). These changes are organizational including giving more power to IT departments but respecting the personal interest of the stakeholders (Birkel et al. 2019). Communication within the company is fundamental, from management and leading personnel to employees (Birkel et al. 2019). The employee needs to be involved during the implementation process; thus, communication, as well as change management, is required for the future success of the company (Oesterreich y Teuteberg 2016).

Birkel (2019) indicated that employees should accept these changes to successfully transform the company. New IT or data-related business models cannot be implemented if new systems and processes are not accepted (Birkel et al. 2019). Therefore, companies should encourage employees to create new opportunities and in consequence improve their performance (Oesterreich y Teuteberg 2016). Training is a good tool for companies to be prepared for these changes. Training includes the job for existing employees but also the apprentices. For a company, this is an important risk since it is not able to retain its employees and hire new apprentices (Birkel et al. 2019). In the case of SMEs, this risk is more significant because they cannot offer the same monetary and non-monetary incentives as large companies (Birkel et al. 2019).

The main challenge of companies is to create and establish standards for knowledge management (Owen et al. 2010). This is one of the most important concerns of SMEs since knowledge is what differs them from competency. Companies need to create new competencies at the same time they optimize their current projects (Oesterreich y Teuteberg 2016). Some employees could be affected by the new changes of the organization creating overload and stress (Birkel et al. 2019). One of the concerns of the employees is the loss of their job since they could be changed by machines or robots (Oesterreich y Teuteberg 2016). Therefore, new functions could be becoming responsible for new tasks or even other employees. This is especially important for SMEs due to their family-like structure with strong relationships (Birkel et al. 2019).

Table 17. Social Risks, adapted from Birkel (2019)

Risk	Subcode
Job losses	Shifts of competencies Automation Reduction of process steps
Organizational structure and leadership	Organizational transformation Communication Awareness
Internal resistance and corporate culture	Older employees Resistance / Acceptance Error culture Knowledge management
New requirements for training	Training on the job Apprentices
Stress	Mental stress Missing social interaction Permanent availability
Lack of qualified personnel	Information technology (IT) Interdisciplinary thinking

5.4.4. Technological Risks

The implementation of Industry 4.0 technologies has also technical risks. As mentioned in the previous section, the integration is related to a high level of complexity to be implemented. For that reason, it is necessary to consider the technical complexity as risk itself. The machinery should be considered as well because the updating of existing machinery (retrofitting) can decrease the cost when implementing Industry 4.0 (Birkel et al. 2019). Sensors are needed in the machinery; thus, the software constitutes a technical risk. In addition, some projects depend on external factors so need higher requirements for computing equipment that must be considered as a technological risk (Oesterreich y Teuteberg 2016).

According to Birkel (2019), the dependency on technology is a technological risk because if there is a failure of the software or the system, the operational value chain could stop functioning. For that reason, managers need to use and establish the unification or the compatibility of the enterprise resource planning (ERP) and manufacturing execution systems (MES) (Birkel et al. 2019). The definition of interfaces and standards between systems and departments is fundamental within the company (Birkel et al. 2019). However, there is a lack of standards software incompatibilities for many Industry 4.0 technologies (Oesterreich y Teuteberg 2016).

Table 18. Technological Risks, adapted from Birkel (2019)

Risk	Subcode
Technical integration	Technical complexity Retrofitting Software Higher requirements for computing equipment
Dependency	System failure
Standards	Multitude of standards Definition of interfaces Lack of standards

5.4.5. IT Risks

Information in the company can suffer cyberattacks from the virtual world being an important IT risk. The management of the information and its sharing with external partners of the company need data protection (Oesterreich y Teuteberg 2016). Therefore, enterprises should be prepared for this with technical solutions or changes in the organizational structure (Birkel et al. 2019). Training courses for employees or the use of white hat hackers are measures to protect against cybercrime (Birkel et al. 2019).

Regarding the quantity of data, companies need to have an IT infrastructure capable of controlling and operating with large amounts of data. Thus, the consistency of the data across the supply chain of the company is included as a risk (Birkel et al. 2019). The quality of data is also important to consider across the multitude of data types, so it can be correctly used by the different departments. Furthermore, access to the connection of information and communication technologies is fundamental within the company (Oesterreich y Teuteberg 2016).

Despite *Cloud Computing* has been considered an Industry 4.0 technology, it is also associated with IT risks. Managers need to consider the overextension of cloud servers and the security of the data storage (Birkel et al. 2019).

Table 19. IT Risks, adapted from Birkel (2019)

Risk	Subcode
Cyberattacks	Technical solutions
	Awareness and organizational structure
Data handling	Data amount
	Data quality
	The multitude of data types
	Data consistency
Cloud computing	Overextension
	Data storage

5.4.6. Ecological Risks

The implementation of Industry 4.0 technologies and the application of digitization implicate ecological risk such as the consumption of raw materials (Birkel et al. 2019). Their extraction or movement can have negative consequences on the environment. Another ecological aspect is the consumption of energy. Their consumption due to the use of Industry 4.0 technologies is higher than the efficiency gains that would be created (Birkel et al. 2019). Birkel (2019) indicated that the implementation of Industry 4.0 involves waste generation and emissions.

Table 20. Ecological Risks, adapted from Birkel (2019)

Risk	Subcode
Consumption	Raw materials
	Energy
Pollution	Waste
	Emissions

5.5. Benefits vs Risks

Masood & Sonntag (2020) evaluate SME challenges against the benefits of Industry 4.0 technologies implemented. According to their findings, Figure 15 shows the technologies that have greater benefits for the potential risks that can provoke. Industry 4.0 technologies that have high benefits are *Predictive Maintenance*, *Simulation*, *Additive Manufacturing* and *Sensors*. *Internet of Things*, *Wireless Sensors Networks* and *Cloud Computing* have lower benefits but with low complexity. It is also important to mention that RFID (*Flexible manufacturing lines*) is a technology that managers should consider implementing due to its high complexity and low benefits. Therefore, the research of Masood & Sonntag (2020) is a good opportunity for managers of SMEs to examine Industry 4.0 in the implementation process.

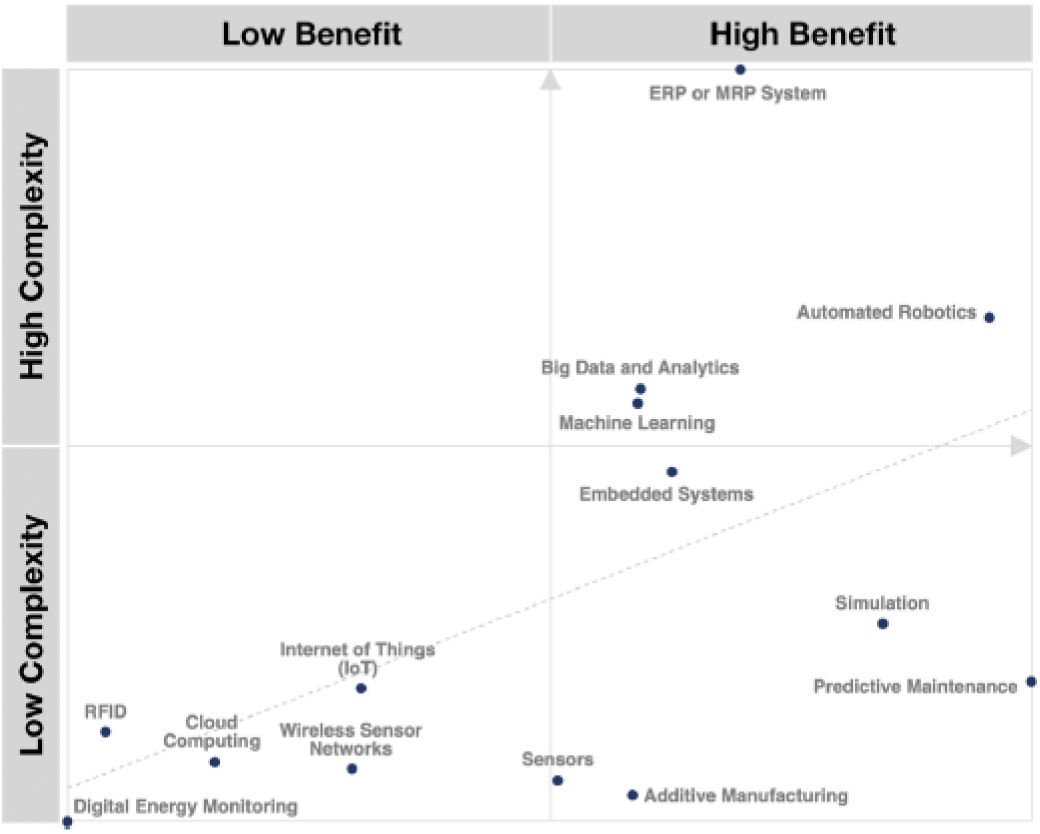

Figure 15. Benefits vs Risks (Masood y Sonntag 2020)

5.6. Maturity of Industry 4.0: A case study

This section explores how is the level of Industry 4.0 implementation in a company in the manufacturing sector in Valencia by studying maturity models. Maturity models are useful for identifying the current activities of an organization and managers can use the parameters of the model for business improvements (Angreani, Vijaya y Wicaksono 2020). The concept of maturity means the state of "*being complete, perfect or ready*"; thus, some progress is involved in the development of a system (Schumacher, Erol y Sihn 2016).

Maturity models are especially important in Industry 4.0 as they are useful to the diffusion of the concept and allow companies to understand better their implementation proposals (Amaral, Jorge y Peças 2019). In the literature, many models analyse the maturity of the company towards Industry 4.0 considering different dimensions regarding the location, the sector, and the size of the company. Pierin Ramos et al. (2020) summarized the most relevant maturity models raised in the literature of Industry 4.0. For example, Ganzarain and Errasti (2016) developed a model that can be directly applied in SMEs, Amaral et al. (2019) developed a methodology to assess SMEs and Schumacher et al. (2016) included organizational aspects (see Figure 16).

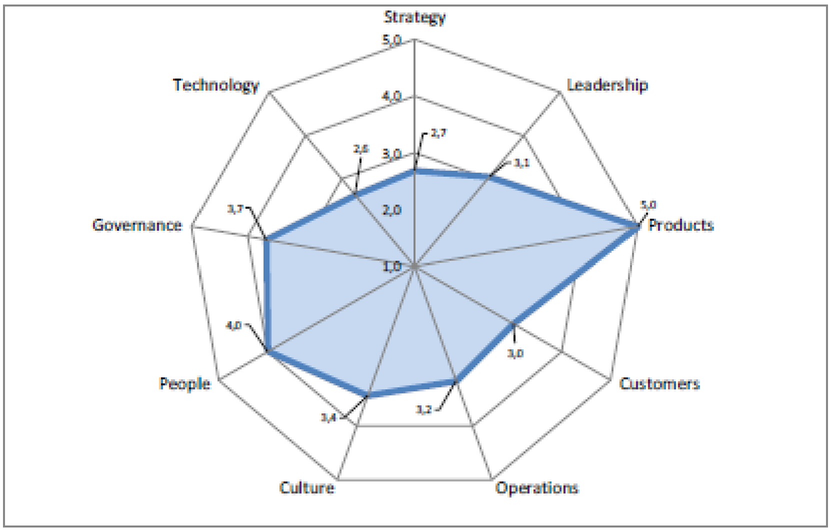

Figure 16. Radar chart visualizing Industry 4.0 maturity in nine dimensions (Schumacher, Erol y Sihn 2016)

5.6.1. Industry 4.0 current situation

As it was mentioned in the previous section, when implementing firstly it is necessary to consider the external environment or the maturity of the place where Industry 4.0 technologies are implemented (Frank, Ribeiro y Echeveste 2015). Globally, in 2018, one out of every five companies were high digitalized. However, only 17 % of the businesses were SMEs whereas 54 % of high-digitalized enterprises were large companies (Institut Valencià de Competitivitat Empresarial 2018). Regarding the sector, the most important companies were from TIC and aerospace and manufacturing (Institut Valencià de Competitivitat Empresarial 2018).

Industry 4.0 in Spain

The impact of Industry 4.0 technologies is different regarding the sector and the location. According to the Digital Economy and Society Index (DESI), Spain was in the 11th position in Europe in 2020 having low use of internet services and low integration of digital technology, as Figure 19 illustrates (European Comission, 2020). However, Spain is one of the European countries with the most significant progression, with Ireland, Netherlands, and Malta (see Figure 18). Figure 18 shows the progress of European countries as regards the overall level of digitalization of the economy and society over the last 5 years (European Comission, 2020). In Spain, the number of large companies represents 0,16 % of total businesses, as Table 21 shows (Secretaría general de Industria y de la PYME, 2021).

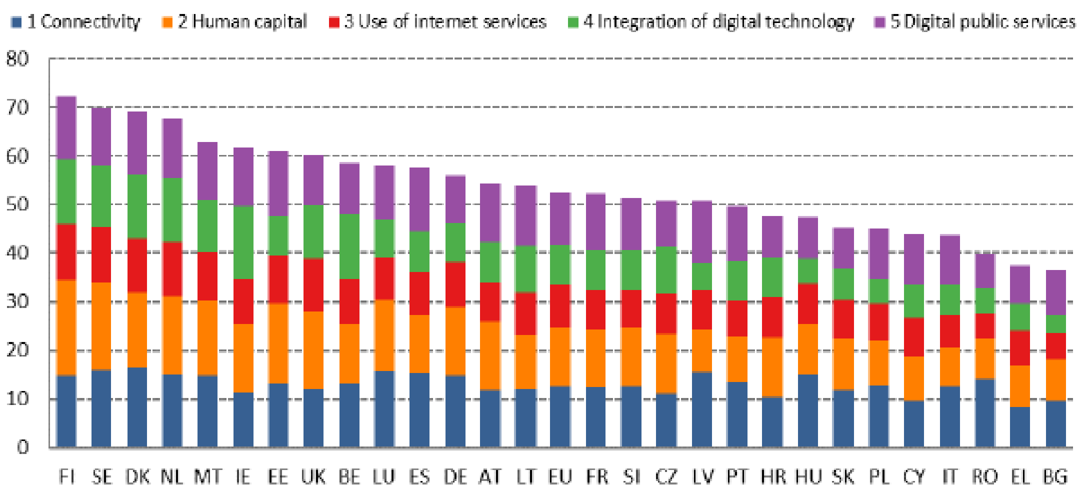

Figure 17. Digital Economy and Society Index (European Comission, 2020)

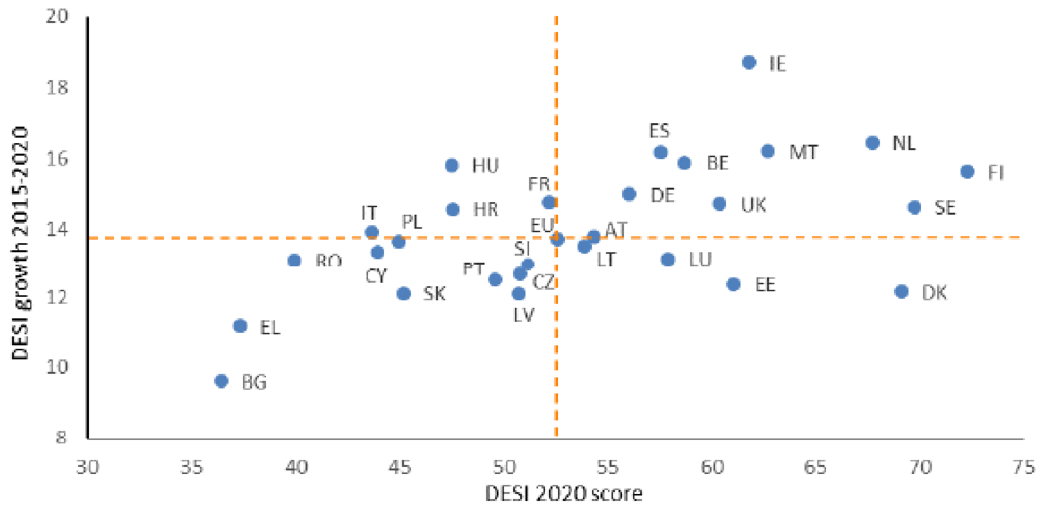

Figure 18. Digital Economy and Society Index – European countries' progress, 2015-2020 (European Comission, 2020)

Table 21. Number of companies by size in Spain (Secretaría general de Industria y de la PYME, 2021)

Size	Number	% Monthly variation	% Annual variation
SMEs	2.910.160	0,28	2,13
Large companies	4.779	-2,05	4,12
Total	2.914.939	0,28	2,14

Sectores	Empresas	Tasa de variación % Mensual	Tasa de variación % Anual
Agrario	274.864	-1,47	-2,15
Industria	174.577	0,17	0,75
Construcción	330.404	0,35	3,72
Servicios	2.135.094	0,51	2,59
Total Empresas	**2.914.939**	**0,28**	**2,14**

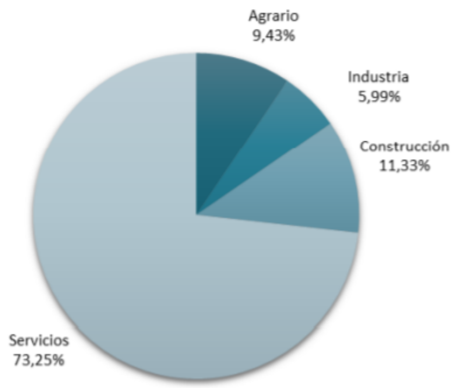

Figure 19. Sector distribution of companies in Spain (Secretaría general de Industria y de la PYME, 2021)

Regarding the sector, there are differences with the rest of the world. The most important sector is not manufacturing but services, as Figure 19 illustrates. Manufacturing only represents 5,99 % of the total companies in Spain.

Industry 4.0 in Comunitat Valenciana

In the region, Comunitat Valenciana is close to the European average regarding Industry 4.0 Readiness Index, as Figure 20. Industry 4.0 Readiness Index (Institut Valencià de Competitivitat Empresarial 2018) illustrates. This index measures the capacity of a region to leverage the opportunities of Industry 4.0 transformation.

Regarding the sector, the percentage of SMEs in the industry in Comunitat Valenciana is slightly superior to Spain (Secretaría general de Industria y de la PYME, 2020). However, the difference is not significant with only 0,64 %. Table 22 shows SMEs by sector in Comunitat Valenciana categorizing by the number of employees. Like Spain, the most important sector, services, possess 58 % (see Figure 21). Table 23 shows in detail the rest of the services. In Comunitat Valenciana, Information, communication, and business services are the main sector with 43 % of total services, as Figure 22 illustrates.

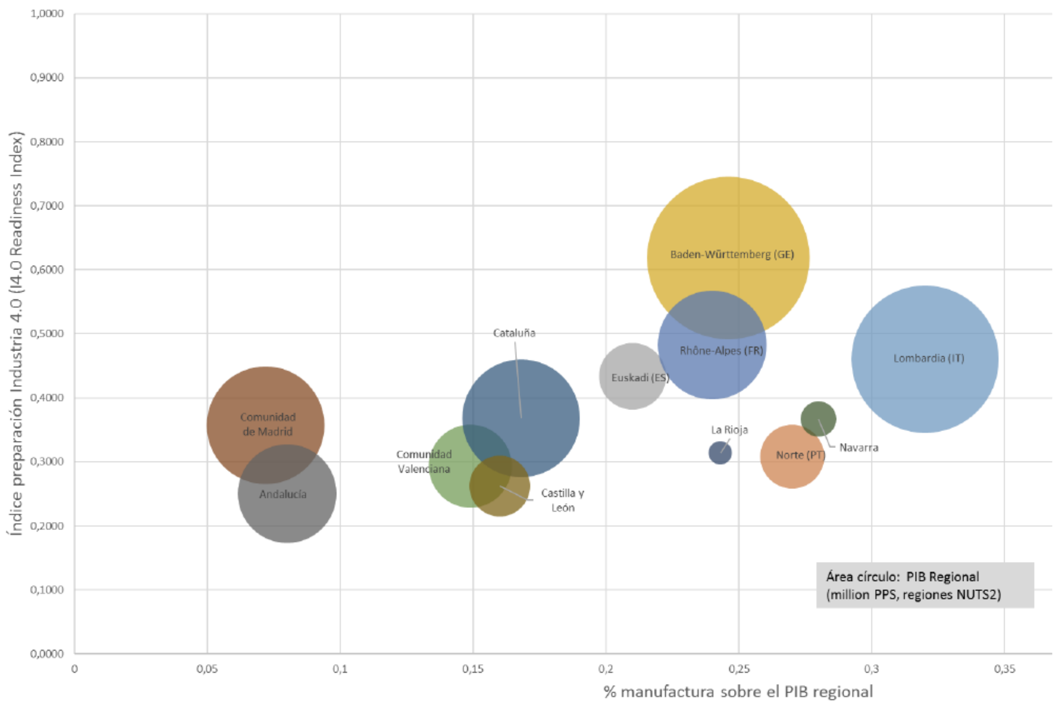

Figure 20. Industry 4.0 Readiness Index (Institut Valencià de Competitivitat Empresarial 2018)

Table 22. SMEs by sector in Comunitat Valenciana (Secretaría general de Industria y de la PYME, 2020)

Sector	Micro (0-9)	Small (10-49)	Medium (50-249)	Total SME (0-250)	Percentage %
Industry	20192	3707	661	24560	6,63
Construction	43585	1798	128	45511	12,29
Commerce	81466	2408	444	84318	22,77
Rest of services	208449	6351	1033	215833	58,30
Total	353692	14264	2266	370222	100

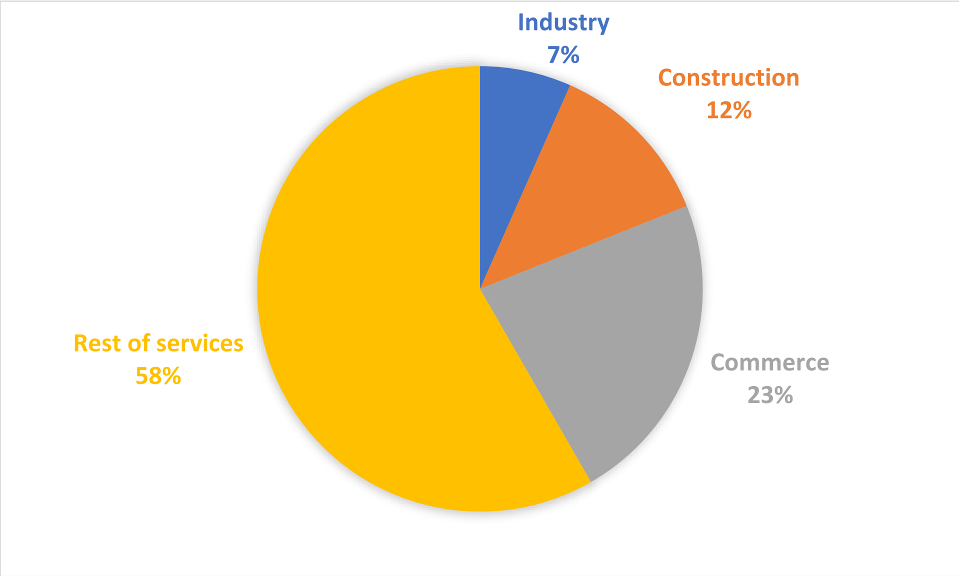

Figure 21. Sector distribution of SMEs in Comunitat Valenciana (Secretaría general de Industria y de la PYME, 2020)

Table 23. SMEs by sector in Comunitat Valenciana: Rest of services (Secretaría general de Industria y de la PYME, 2020)

Rest of services	Micro (0-9)	Small (10-49)	Medium (50-249)	Total SME (0-250)	Percentage %
Hotel industry	30208	1204	151	31563	14,62
Logistics	17014	911	130	18055	8,37
Financial intermediary	8700	66	9	8775	4,07
Information, communication, and business services	91223	2010	277	93510	43,33
Education	10741	690	202	11633	5,39
Social services	50563	1470	264	52297	24,23
Total	208449	6351	1033	215833	100

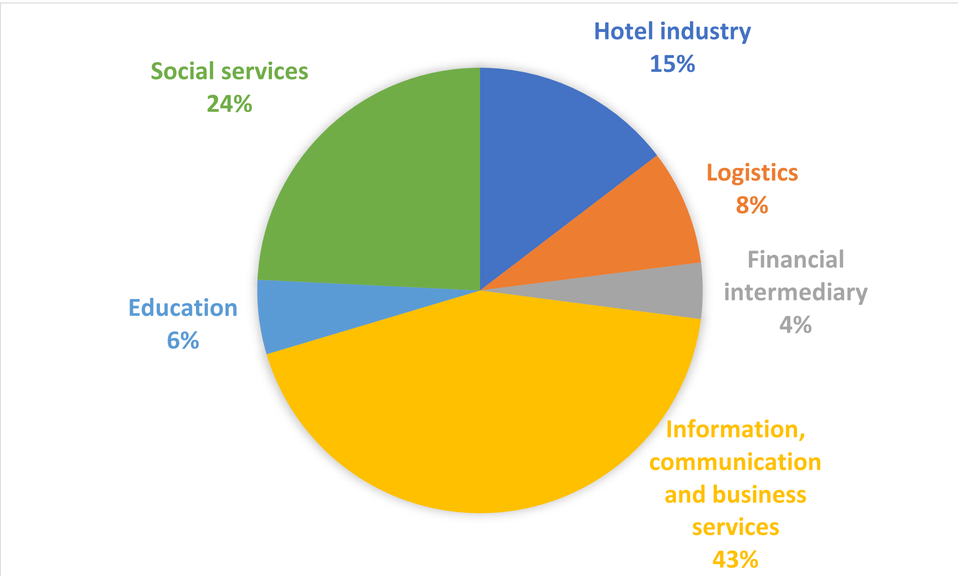

Figure 22. Rest of services distribution of SMEs in Comunitat Valenciana (Secretaría general de Industria y de la PYME, 2020)

5.6.2. Industry 4.0 Maturity Model: HADA

The next step after the analysis of the literature is the selection of the most adequate model for the SMEs (Amaral, Jorge y Peças 2019). This case study uses the "*Herramienta de Autodiagnóstico Digital Avanzada*" (HADA) that is an online application that allows companies to evaluate their digital maturity. HADA is part of a major strategic, "*Industria Conectada 4.0*" designed by "*Secretaría General de Industria y de la PYME*". Industria Conectada has the objective of incrementing the value of the industry by giving favourable conditions for the future of the Spanish digital industry (Escuela de Organización Industrial). HADA considers organizational and strategic dimensions in the maturity model. Dimensions are "*the amount of areas within the company that the model is assessing*" and change regarding the objective of the model (Amaral, Jorge y Peças 2019). In this case, HADA is composed of 5 organizational and strategic dimensions:

- Strategy and business model, studying how is the ability of the company to adapt to the environment and their competitors.
- Processes, analysing the digital competencies of the enterprise.
- Organization and employees, identifying the organizational model and their relationship with external agents.
- Infrastructures, evaluating the potential of transformation of the cyber-physical infrastructure.
- Products and services, studying the technological level of the products and services as well as their potential of digitalization.

In the tool, 16 work areas of the company are evaluated to show the intensity of Industry 4.0 implantation, as Table 24 indicates; thus, companies can understand their digital transformation process better. The objective of HADA is not only to offer a vision of the company regarding Industry 4.0 but establish a model to guide a company to the digital transformation (see Figure 23).

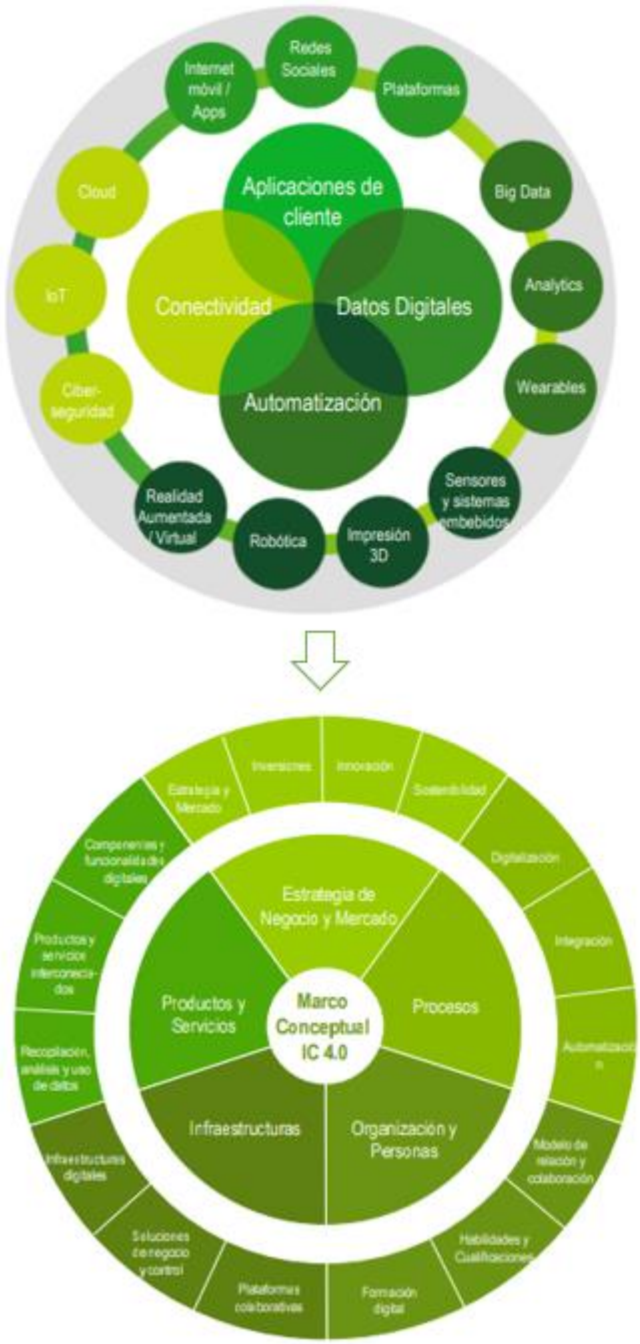

Figure 23. Digital transformation model of the industry (Industria conectada, 2021)

Table 24. Dimensions and maturity items of Industry 4.0 Maturity Model (Industria conectada, 2021)

Dimension	Maturity item
Strategy and business model	Strategy and market
	Investments
	Innovation
	Sustainability
Processes	Digitalization
	Integration
	Automatization
Organization and employees	Organization model and collaboration
	Skills and coalification
	Digital training
Infrastructures	Digital infrastructure
	Business solutions and control
	Collaborative platforms
Products and services	Components and digital functions
	Products and interconnected services
	Collection, analysis, and data use

After the election of the model, the following step is the creation of a survey to evaluate the performance of the company in Industry 4.0 (Amaral, Jorge y Peças 2019). It is important to mention that the questions should be close-ended and the answers should use the same scale (Schumacher, Erol y Sihn 2016). The survey of HADA has 68 questions grouped by the 5 organizational and strategic dimensions. In this case study, the evaluation of the questionnaire of the HADA model has a scale from 0 to 10, with 0 being the lowest score and 10 being the highest score.

5.6.3. Case study analysis

In the following, results are obtained from a manufacturing company with 45 employees in the metal-mechanical sector in Valencia. To make the correct analysis and test the validity of the results, the chosen organization has extensive knowledge of Industry 4.0 and its concepts. Answers to the questionnaire can be found in the Annexes of this paper. Figure 24 is an exemplary question to evaluate the "*digitalization*" maturity item. Finally, to assess correctly the Industry 4.0 implementation, a real application in a company is required (Amaral, Jorge y Peças 2019).

After the questionnaire, the answers were introduced in the HADA application to evaluate the maturity of the company. Figure 25 shows the digital performance of the company regarding the five above-mentioned dimensions. The graph illustrates the level of maturity of the company concerning the maturity model developed by "Secretaría General de Industria y de la PYME".

Digitalización		
14	¿Cuál considera que es el nivel de digitalización de sus procesos? Compras, Logística, Producción, Ventas, Otros	6.0

Figure 24. Exemplary question

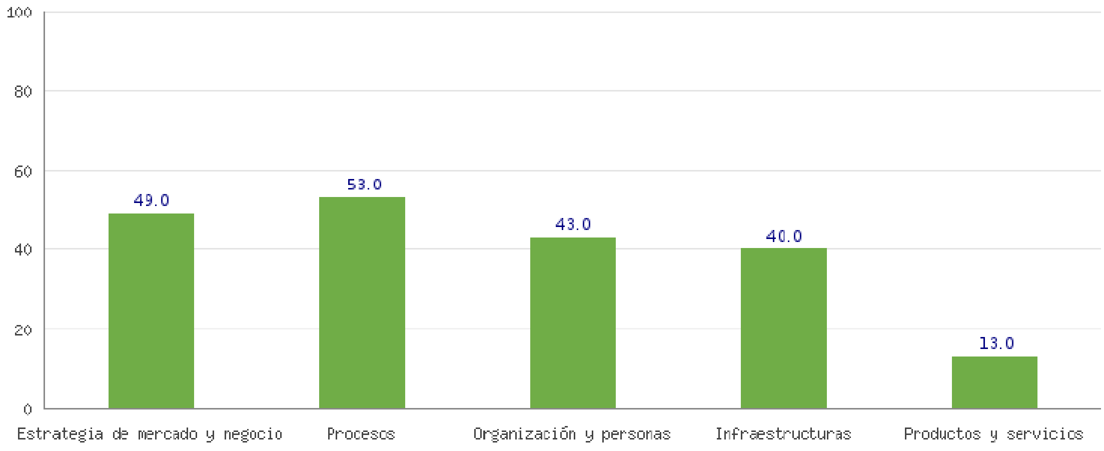

Figure 25. Industry 4.0 maturity of the company

According to the results, the lowest dimension is "*products and services*". The measured maturity items were the "*components and digital functions*", "*products and interconnected services*", and "*collection, analysis and data use*". Most of the answers of this dimension have a rating of 2, being the digitalization intensity of the products offered the highest value with 4. The low maturity level of the dimension "*products and services*" is explained by the activity of the organization since the metal-mechanical components present low maturity regarding Industry 4.0. The industry of Comunitat Valenciana stands out for its traditional characteristics in manufacturing sectors as ceramic, footwear, toys, wood or metal (Institut Valencià de Competitivitat Empresarial 2018).

In contrast, there are high maturity levels in "*processes*" that analysed the digital competencies of the company. The reason for this is the extensive understanding of the company in Industry 4.0 technologies. Furthermore, the development of competencies is one of the main concerns of SMEs due to allowing them to differentiate from competitors.

Benchmarking

To make a better understanding of the maturity of the company, a comparative analysis of the maturity of the organization with other companies is presented. This comparison is done between the company and the average of the companies registered in the HADA database. Figure 26 shows a comparison between the company and the average of all the SMEs in Spain, Figure 27 compares the results with companies of the same sector (manufacturing), Figure 28 illustrates the maturity of the companies in Comunitat Valenciana and Figure 29 shows the results in the province of Valencia.

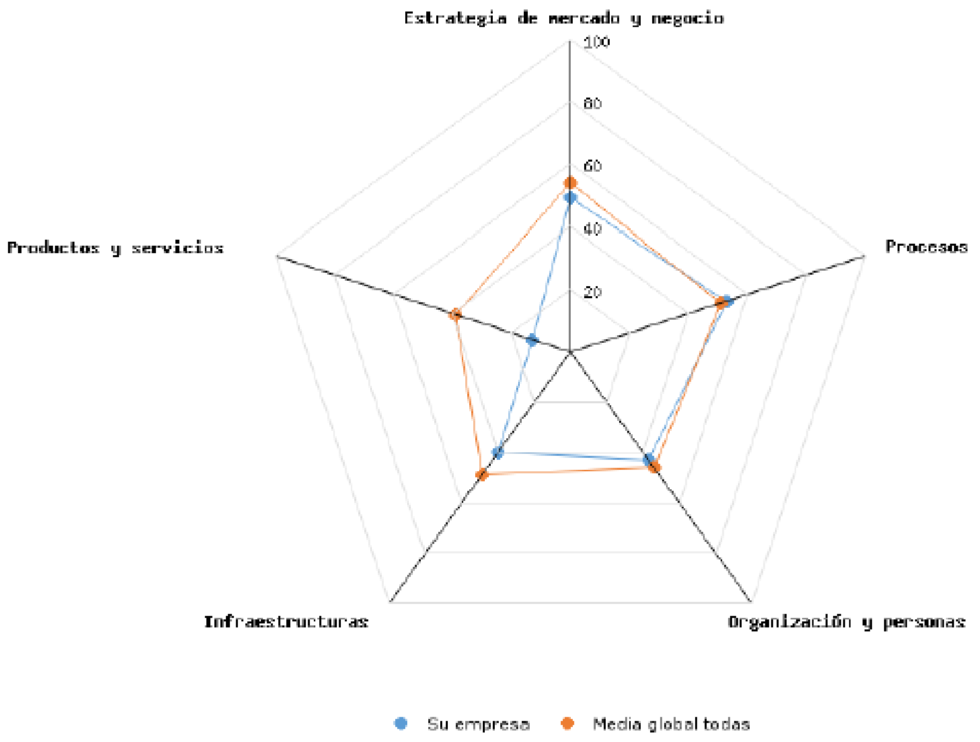

Figure 26. Maturity performance vs SMEs in Spain

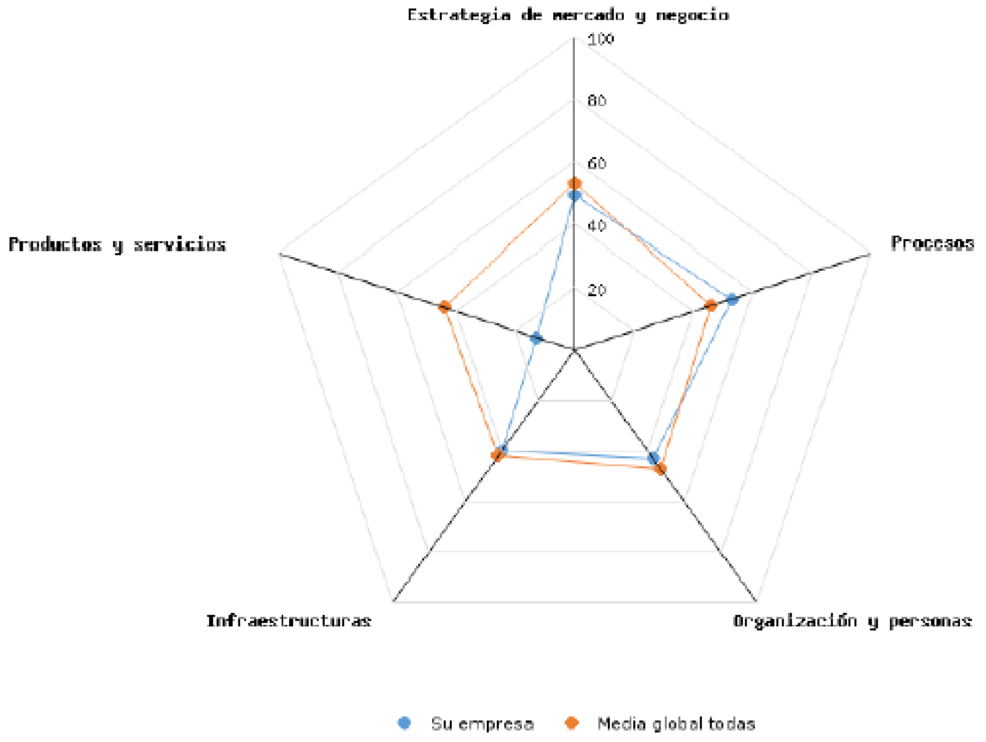

Figure 27. Maturity performance vs manufacturing companies in Spain

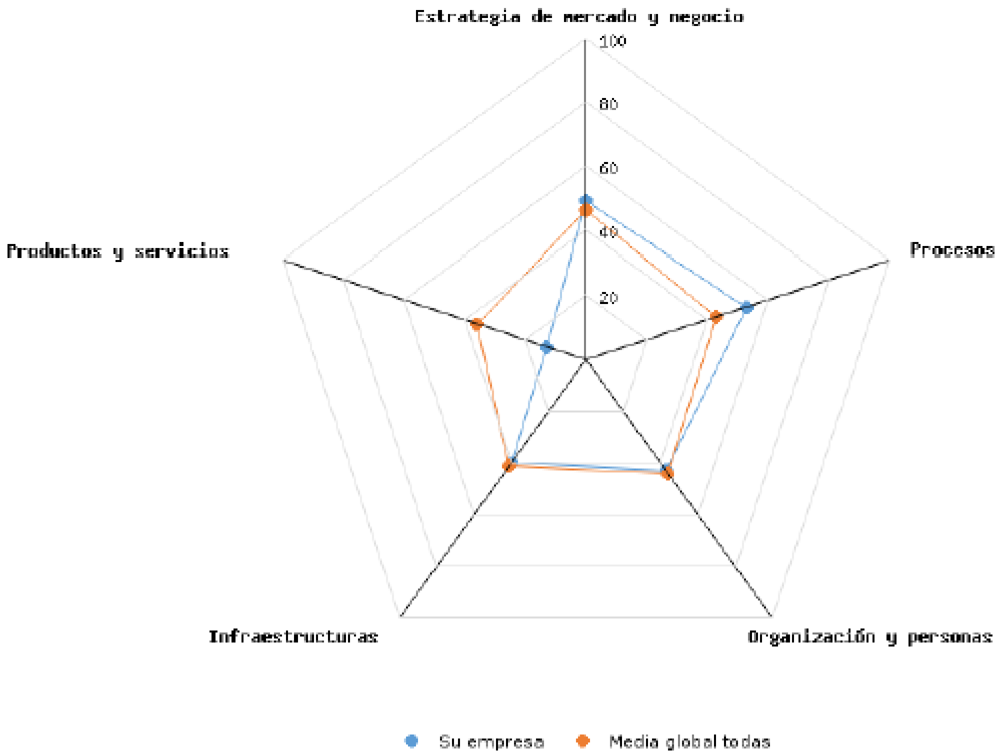

Figure 28. Maturity performance vs companies in Comunitat Valenciana

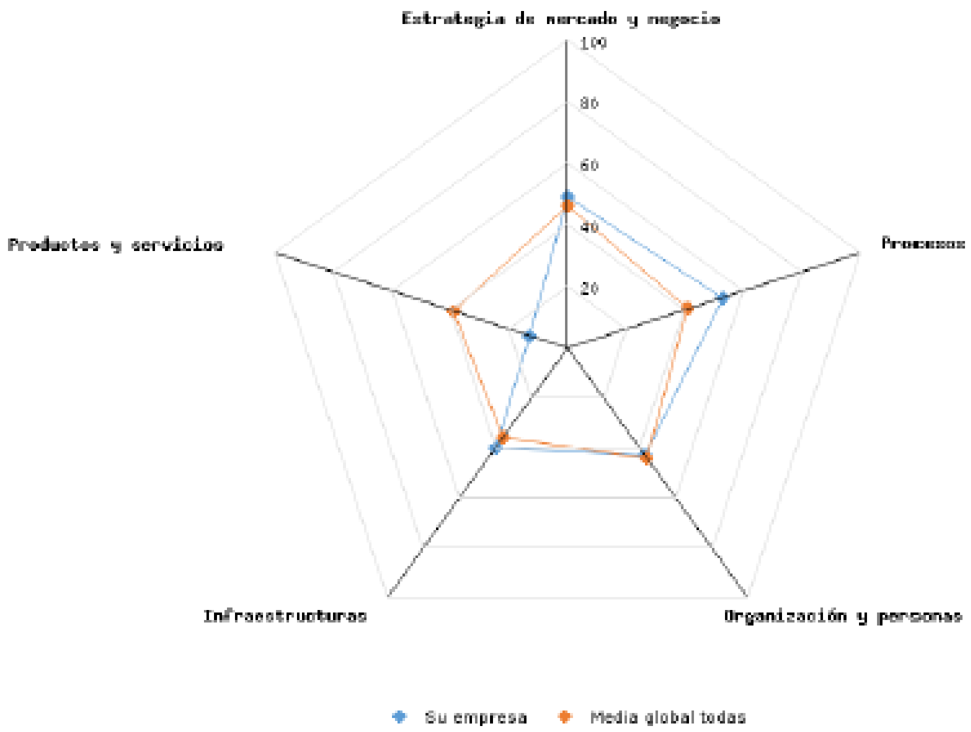

Figure 29. Maturity performance vs companies in the province of Valencia

Analysing the graphs, there are remarkable differences regarding the dimension "*processes*". This differentiation between the company and other manufacturing enterprises can be seen in Figure 27 and between other companies in Comunitat Valenciana in Figure 28. As it was above mentioned, this is one of the distinctive attributes of the company due to its understanding of Industry 4.0.

Also, it should be pointed out that the rating of the "*infrastructures*" dimension of the company is lower than the average of SMEs in Spain (see Figure 26). This dimension studies the potential of digital transformation of the company including business solutions and collaborative platforms. One possible reason is that most manufacturing companies in Comunitat Valenciana are micro-companies, as Table 22 indicates. This size allows them more flexibility but reducing synergies as well as not attracting the needed expertise for the digital transformation (Institut Valencià de Competitivitat Empresarial 2018).

A general assessment of the results can be done regarding the tool developed by "*Secretaría General de Industria y de la PYME". *Industria conectada (2021) establishes a rating maturity scale with different levels of performance, as Figure 30 illustrates. According to the results, the maturity of the company is *competent* in Industry 4.0 regarding the Industria conectada scale (2021). This means:

- *The company has Industry 4.0 initiatives in their strategy.*
- *The company is making investments in Industry 4.0 in some areas.*
- *The company is collecting data automatically, but their exploitation is limited.*
- *There is a flow of information within the company and the integration of the information with suppliers and clients outside the company is in the early stages.*

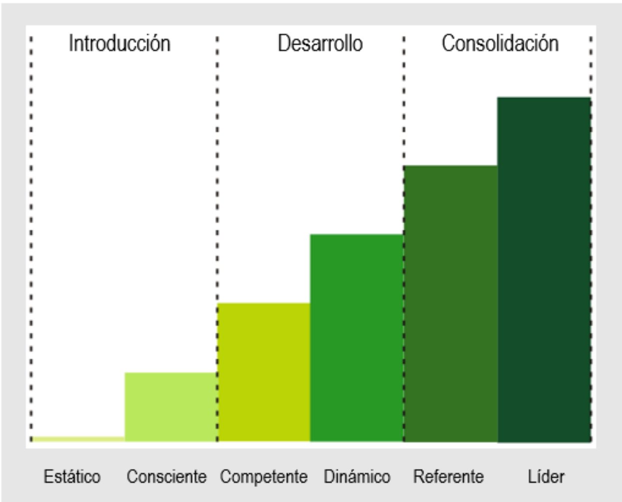

Figure 30. Rating Industry 4.0 Maturity scale (Industria conectada, 2021)

Figure 31 is a summary of the PEST Industry 4.0 analysis in Comunitat Valenciana. The PEST analysis identifies the most important factors that affect the company regarding Industry 4.0. The benchmarking is useful to show the situation of the company in each dimension, but these factors are relevant to explain the differences in the results regarding the maturity of Industry 4.0.

With both the PEST analysis and the benchmarking, attainable improvements should be done by managers of the company if they consider appropriate. Also, external auditors are useful to support critical assessment (Schumacher, Erol y Sihn 2016). Institut Valencià de Competitivitat Empresarial (2018) researched the industry in Comunitat Valenciana showing the strengths, weaknesses, opportunities and threats (see Table 25); thus, the company can contemplate all these considerations to take actions in the process of Industry 4.0 implementation. Another external organism, "*Secretaría General de Industria y de la PYME"*, has a personalized program to continue the digitalization plan named "*Activa Industria 4.0*". The objective is to identify the opportunities for the adoption of Industry 4.0 technologies as well as new opportunities for technological and sustainable businesses (Industria conectada, 2021). Furthermore, this program helps companies in this process of implementation with funding.

Figure 31. Summary of the PEST Industry 4.0 analysis in Comunitat Valenciana (Institut Valencià de Competitivitat Empresarial 2018).

Table 25. SWOT Industry 4.0 analysis in Comunitat Valenciana, based on Institut Valencià de Competitivitat Empresarial (2018).

Strengths	Weaknesses
- Powerful industrial clusters. - Specialized sectors with high technological components (machinery, transport materials). - Traditional exporter region. - Development of a political industry. - Excellent innovation regional system led by universities and technological centres.	- Limited size company. Most of the companies are SMEs and familiar businesses. - Excessive orientation to traditional sectors (low technological level). - Low productivity. - Low investment in innovation and development. - Financial autonomous government.
Opportunities	**Threats**
- Improvements in productivity. - Strengthening of the manufacturing industry. - Increase in highly specialized markets. - Development of new markets for products and services. - Increase in satisfaction client levels. - High flexibility and control of production processes. - Strengthening of TIC sector. - Reduction of entrance barriers for SMEs.	- Cybersecurity, loss of privacy and intellectual property. - Loss of competitiveness for those SMEs that cannot adapt to Industry 4.0. - Adoption of Industry 4.0 from foreign competitors that can neutralize national companies. - Costs of development and implementation, especially in traditional sectors. - Problems with the loss of employment and the loss of the training of unqualified workers. - Need to import highly skilled workers.

6. Conclusions

This paper studies the performance of Industry 4.0 in small and medium-sized enterprises by conducting a literature review of the topic and an analysis of a case study. Many authors have studied Industry 4.0 focusing on large companies thus marginalizing SMEs (Müller, Buliga y Voigt 2018).

The theoretical contribution of this paper is the understanding of the concept of Industry 4.0. The literature review has demonstrated the importance of Industry 4.0 in small and medium-sized companies. Findings of the literature have explored Industry 4.0 technologies, the relationship between Industry 4.0 and innovation, and the performance of Industry 4.0 in SMEs. For the analysis of performance, this paper has studied the implementation in the company including potential benefits and risks of Industry 4.0 technologies.

The practical contribution of this paper is the study of Industry 4.0 performance in a real company. This performance has been analysed using a maturity model. Maturity models can help to show the Industry 4.0 capabilities of a company; thus, managers can take better strategic decisions for the future success of the business. The case study includes the analysis of the current situation of Industry 4.0 as well as an evaluation of a benchmarking of the company. Results have shown that environmental factors of the company need to be considered in the process of Industry 4.0 implementation. Therefore, the digitalization of a company is a difficult task (Schumacher, Erol y Sihn 2016) and having a maturity model is not the only one for the adoption of Industry 4.0 technologies, more efforts of the company are required to ease this adoption (Angreani, Vijaya y Wicaksono 2020).

This research has limitations that offer opportunities for future research. The case study focuses on a small company in the metal-mechanical sector in Valencia. Therefore, it is important to mention that the case study is not representative of the whole industry. Authors in their future research are invited to validate the obtained results by the study of other regions or sectors. Furthermore. it is relevant to point out that the literature review includes only articles over the last five years. As mentioned in the introduction, Industry 4.0 is a recent phenomenon with exponential growth and, as consequence, the quantity of information will increase considerably in the next few years.

7. References

ALQAHTANI, A.Y., GUPTA, S.M. y NAKASHIMA, K., 2019. Warranty and maintenance analysis of sensor embedded products using internet of things in industry 4.0. *International Journal of Production Economics*, vol. 208, pp. 483-499. ISSN 0925-5273. DOI 10.1016/j.ijpe.2018.12.022. Scopus

AMARAL, A., JORGE, D. y PEÇAS, P., 2019. SMALL MEDIUM ENTERPRISES AND INDUSTRY 4.0: CURRENT MODELS' INEPTITUDE AND THE PROPOSAL OF A METHODOLOGY TO SUCCESSFULLY IMPLEMENT INDUSTRY 4.0 IN SMALL MEDIUM ENTERPRISES. *Procedia Manufacturing*, vol. 41, pp. 1103-1110. ISSN 2351-9789. DOI 10.1016/j.promfg.2019.10.039.

ANGREANI, L.S., VIJAYA, A. y WICAKSONO, H., 2020. Systematic Literature Review of Industry 4.0 Maturity Model for Manufacturing and Logistics Sectors. *Procedia Manufacturing*, vol. 52, pp. 337-343. ISSN 2351-9789. DOI 10.1016/j.promfg.2020.11.056.

BIRKEL, H., VEILE, J., MÜLLER, J., HARTMANN, E. y VOIGT, K.-I., 2019. Development of a Risk Framework for Industry 4.0 in the Context of Sustainability for Established Manufacturers. *Sustainability*, vol. 11, no. 2, pp. 384. ISSN 2071-1050. DOI 10.3390/su11020384.

BÜCHI, G., CUGNO, M. y CASTAGNOLI, R., 2020. Smart factory performance and Industry 4.0. *Technological Forecasting and Social Change*, vol. 150, pp. 119790. ISSN 00401625. DOI 10.1016/j.techfore.2019.119790.

COHEN, W.M. y LEVINTHAL, D.A., 1990. ABSORPTIVE CAPACITY: A NEW PERSPECTIVE ON LEARNING AND INNOVATION. , DOI 10.2307/2393553.

DALENOGARE, L.S., BENITEZ, G.B., AYALA, N.F. y FRANK, A.G., 2018. The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics*, vol. 204, pp. 383-394. ISSN 09255273. DOI 10.1016/j.ijpe.2018.08.019.

ESCUELA DE ORGANIZACIÓN INDUSTRIAL. Activa Industria 4.0. [En línea] https://www.eoi.es/es/empresas/programas-activa/activa-industria-40.

EUROPEAN COMISSION. 2020. The Digital Economy and Society Index. *European Comission.* [En línea] 2020. [Citado el:] https://digital-strategy.ec.europa.eu/en/policies/desi.

FRANK, A.G., DALENOGARE, L.S. y AYALA, N.F., 2019. Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, vol. 210, pp. 15-26. ISSN 09255273. DOI 10.1016/j.ijpe.2019.01.004.

FRANK, A.G., MENDES, G.H.S., AYALA, N.F. y GHEZZI, A., 2019. Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. *Technological Forecasting and Social Change*, vol. 141, pp. 341-351. ISSN 0040-1625. DOI 10.1016/j.techfore.2019.01.014.

FRANK, A.G., RIBEIRO, J.L.D. y ECHEVESTE, M.E., 2015. Factors influencing knowledge transfer between NPD teams: a taxonomic analysis based on a sociotechnical approach. *R&D Management*, vol. 45, no. 1, pp. 1-22. ISSN 1467-9310. DOI https://doi.org/10.1111/radm.12046.

GANZARAIN, J. y ERRASTI, N., 2016. Three stage maturity model in SME's toward industry 4.0. *Journal of Industrial Engineering and Management*, vol. 9, pp. 1119. DOI 10.3926/jiem.2073.

HAAKER, T., LY, P.T.M., NGUYEN-THANH, N. y NGUYEN, H.T.H., 2021. Business model innovation through the application of the Internet-of-Things: A comparative analysis. *Journal of Business Research*, vol. 126, pp. 126-136. ISSN 0148-2963. DOI 10.1016/j.jbusres.2020.12.034.

HENNING, K., 2013. Recommendations for implementing the strategic initiative INDUSTRIE 4.0. [en línea]. [Consulta: 3 marzo 2021]. Disponible en: /paper/Recommendations-for-implementing-the-strategic-4.0-Henning/80d4b3eccd6951cf6dba61f1b33889a0edbf0407.

INDUSTRIA CONECTADA. 2021**.** Herramienta de Autodiagnóstico Digital Avanzada (HADA). *Ministerio de Industria, Comercio y Turismo. Gobierno de España.* [En línea] 2021. https://www.industriaconectada40.gob.es/programas-apoyo/Paginas/HADA.aspx.

INSTITUT VALENCIÀ DE COMPETITIVITAT EMPRESARIAL, 2018. Agenda Industria 4.0 de la Comunitat Valenciana. Ejes, retos y líneas estratégicas. , pp. 100.

KHAN, W.Z., REHMAN, M.H., ZANGOTI, H.M., AFZAL, M.K., ARMI, N. y SALAH, K., 2020. Industrial internet of things: Recent advances, enabling technologies and open challenges. *Computers & Electrical Engineering*, vol. 81, pp. 106522. ISSN 0045-7906. DOI 10.1016/j.compeleceng.2019.106522.

LEE, J., BAGHERI, B. y KAO, H.-A., 2015. A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems. *Manufacturing Letters*, vol. 3, pp. 18-23. ISSN 2213-8463. DOI 10.1016/j.mfglet.2014.12.001.

MASOOD, T. y SONNTAG, P., 2020. Industry 4.0: Adoption challenges and benefits for SMEs. *Computers in Industry*, vol. 121, pp. 103261. ISSN 0166-3615. DOI 10.1016/j.compind.2020.103261.

MÜLLER, J.M., BULIGA, O. y VOIGT, K.-I., 2018. Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting and Social Change*, vol. 132, pp. 2-17. ISSN 0040-1625. DOI 10.1016/j.techfore.2017.12.019.

MÜLLER, J.M., BULIGA, O. y VOIGT, K.-I., 2020. The role of absorptive capacity and innovation strategy in the design of industry 4.0 business Models-A comparison between SMEs and large enterprises. *European Management Journal* [en línea], [Consulta: 4 marzo 2021]. ISSN 0263-2373. DOI 10.1016/j.emj.2020.01.002. Disponible en: https://www.sciencedirect.com/science/article/pii/S0263237320300190.

OESTERREICH, T.D. y TEUTEBERG, F., 2016. Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. *Computers in Industry*, vol. 83, pp. 121-139. ISSN 0166-3615. DOI 10.1016/j.compind.2016.09.006.

OWEN, R., AMOR, R., PALMER, M., DICKINSON, J., TATUM, C., KAZI, A.S., PRINS, M., KIVINIEMI, A. y EAST, B., 2010. Challenges for Integrated Design and Delivery Solutions. *Architectural Engineering and Design Management*, vol. 6. DOI 10.3763/aedm.2010.IDDS1.

PFOHL, H.-C., YAHSI, B. y KURNAZ, T., 2015. The Impact of Industry 4.0 on the Supply Chain. . S.l.: s.n., DOI 10.13140/RG.2.1.4906.2484.

PIERIN RAMOS, L.F., ROCHA LOURES, E. de F. y DESCHAMPS, F., 2020. An Analysis of Maturity Models and Current State Assessment of Organizations for Industry 4.0 Implementation. *Procedia Manufacturing*, vol. 51, pp. 1098-1105. ISSN 2351-9789. DOI 10.1016/j.promfg.2020.10.154.

PORTER, M. y HEPPELMANN, J.E., 2014. How Smart, Connected Products Are Transforming Competition. *undefined* [en línea]. [Consulta: 3 marzo 2021]. Disponible en: /paper/How-Smart%2C-Connected-Products-Are-Transforming-Porter-Heppelmann/8119a80c6059bfda198e1f6e5b52cf7351b0962d.

SCHUMACHER, A., EROL, S. y SIHN, W., 2016. A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises. *Procedia CIRP*, vol. 52, pp. 161-166. ISSN 2212-8271. DOI 10.1016/j.procir.2016.07.040.

SECRETARÍA GENERAL DE INDUSTRIA Y DE LA PYME. 2020. Estructura y dinámica empresarial en España. *Ministerio de Industria, Comercio y Turismo. Gobierno de España.* [En línea] 2020. https://industria.gob.es/es-es/estadisticas/Estadisticas_Territoriales/Estructura-Dinamica-Empresarial-2020.pdf.

SECRETARÍA GENERAL DE INDUSTRIA Y DE LA PYME. 2021. Cifras PyME. *Ministerio de Industria, Comercio y Turismo. Gobierno de España.* [En línea] 2021. https://industria.gob.es/es-es/estadisticas/Cifras_PYME/CifrasPYME-junio2021.pdf.

SOMMER, L., 2015. Industrial revolution - Industry 4.0: Are German manufacturing SMEs the first victims of this revolution? *Journal of Industrial Engineering and Management*, vol. 8. DOI 10.3926/jiem.1470.

SOMOHANO-RODRÍGUEZ, F.M., MADRID-GUIJARRO, A. y LÓPEZ-FERNÁNDEZ, J.M., 2020. Does Industry 4.0 really matter for SME innovation? *Journal of Small Business Management*, pp. 1-28. ISSN 0047-2778, 1540-627X. DOI 10.1080/00472778.2020.1780728.

TUPTUK, N. y HAILES, S., 2018. Security of smart manufacturing systems. *Journal of Manufacturing Systems*, vol. 47, pp. 93-106. ISSN 0278-6125. DOI 10.1016/j.jmsy.2018.04.007.

WANG, L., TÖRNGREN, M. y ONORI, M., 2015. Current status and advancement of cyber-physical systems in manufacturing. *Journal of Manufacturing Systems*, vol. 37, pp. 517-527. ISSN 0278-6125. DOI 10.1016/j.jmsy.2015.04.008.

WANG, S., WAN, J., LI, D. y ZHANG, C., 2016. Implementing Smart Factory of Industrie 4.0: An Outlook. *International Journal of Distributed Sensor Networks*, vol. 2016, pp. 1-10. DOI 10.1155/2016/3159805.

8. Annexes

7.1. Estrategia de mercado y negocio

Estrategia y mercado		
1	¿En qué medida está alineada la estrategia de su organización a la Industria 4.0? ¿Dispone de una estrategia de transformación a la industria 4.0?	5.0
2	¿Cuál es el grado de implantación de soluciones de transformación a la Industria 4.0 en su organización?	5.0
3	¿Qué nivel de importancia tiene la Industria 4.0 como elemento diferenciador con respecto a sus competidores?	7.0
4	¿Cuál es el nivel de interiorización de los principios de la Industria 4.0 en la cultura directiva de su organización?	3.0
Comentarios		

Inversiones		
5	¿Dispone de un plan de inversiones con un apartado específico para la implantación de soluciones digitales de Industria 4.0?	5.0
6	¿Cómo valoraría el nivel de inversión de su organización para el desarrollo de soluciones de Industria 4.0 con respecto a la inversión del resto de sus competidores?	8.0
7	¿Cuál es el grado de madurez de la metodología utilizada para la valoración financiera y del impacto de sus inversiones en soluciones de Industria 4.0?	3.0
8	¿Cuál ha sido su nivel de inversión en soluciones digitales de Industria 4.0 durante los últimos 2 años? Describa si lo considera oportuno por cada área: I+D+i; Producción; Compras; Logística; Ventas; Finanzas; Servicios Postventa; IT; Otra (describir).	5.0

Inversiones		
9	¿Cuáles será su nivel de inversión durante los próximos 5 años? Describa si lo considera oportuno por cada área: I+D+i; Producción; Compras; Logística; Ventas; Finanzas; Servicios Postventa; IT; Otra (describir).	7.0
10	¿Qué importancia tiene para su organización la existencia de ayudas (exenciones fiscales, subvenciones, préstamos bonificados, etc.) para implantar soluciones de Industria 4.0?	6.0
Comentarios		

Innovación		
11	¿Qué grado de aportación presentan sus proyectos de I+D+i para la puesta en marcha de soluciones de industria 4.0?	7.0
12	¿En qué grado han identificado, valorado y priorizado iniciativas innovadoras orientadas a soluciones de industria 4.0?	7.0
Comentarios		

Sostenibilidad		
13	¿En que medida cuentan con soluciones digitales que ayudan a mejorar la sostenibilidad de su organización? Ej.: control del consumo, apagado automático de luces, máquinas…	5.0
Comentarios		

7.2. Procesos

Digitalización		
14	¿Cuál considera que es el nivel de digitalización de sus procesos? Compras, Logística, Producción, Ventas, Otros	6.0
15	¿Cuál es el nivel de uso de habilitadores digitales de industria 4.0 en su cadena de valor? Ejemplos de habilitadores digitales: -Conectividad: Cloud, IoT, Ciberseguridad -Aplicaciones: Movilidad, Apps, redes sociales, plataformas colaborativas -Datos digitales: Big Data, Analytics, Wereables -Automatización: Realidad Virtual, Realidad Aumentada, Robótica, Impresión 3D, Sensores y sistemas embebidos	4.0
16	¿En qué medida cuenta con herramientas digitales que le permiten generar flexibilidad y eficiencia en los procesos productivos?	7.0
17	Valore la capacidad de la infraestructura tecnológica actual de su empresa para acometer un proceso de transformación a la industria 4.0.	8.0
18	¿En qué medida los sistemas de información de su organización generan datos en tiempo real a lo largo de la cadena de valor (información proveniente de la maquinaria o de los procesos)?	6.0
19	¿Cuál es el grado de trazabilidad de la información durante el proceso productivo de su empresa?	5.0
20	¿Cuál es el nivel de calidad de la información generada por los sistemas de información de su organización?	6.0

Comentarios

Integración		
21	¿En qué medida se comparten y utilizan los datos generados por los sistemas de información entre las diferentes áreas de la empresa?	9.0
22	¿En qué medida se comparten y utilizan los datos generados por los sistemas de información con sus clientes?	3.0
23	¿Cuál es el nivel de integración e inteligencia digital con sus clientes (procesos digitales orientados al cliente)?	5.0
24	¿En qué medida tiene digitalizados y adaptados sus canales de distribución a las necesidades de sus clientes (gestión omnicanal)?	7.0
25	¿En qué medida se comparten y utilizan los datos generados por los sistemas de información con sus proveedores?	3.0
26	¿Cuál es el nivel de integración digital con sus proveedores?	3.0
27	¿Cuál es el nivel de integración e inteligencia digital de su logística de aprovisionamiento?	4.0
28	¿Cuál es el nivel de integración e inteligencia digital de su logística de distribución?	7.0
Comentarios		

Automatización		
29	¿Cuál es el grado de automatización actual de los procesos productivos de su organización?	9.0
30	¿Cuál es la capacidad actual de su organización para manejar tiempos de producción más cortos?	8.0
31	¿Cuál es la capacidad actual de su organización para manejar tamaños de series de producción más cortas?	7.0
32	¿Cuál es la capacidad actual de su organización para llevar a cabo una personalización masiva de sus productos y servicios?	5.0
Comentarios		

7.3. Organización y personas

Modelo de relación y colaboración		
33	¿Cuál es el grado de motivación de los empleados de su organización para impulsar de forma proactiva un proceso de transformación a la industria 4.0?	6.0
34	¿En qué medida se favorece la colaboración entre departamentos, para generar un escenario de industria 4.0 en su organización, identificando oportunidades para la implantación de soluciones digitales de industria 4.0? ¿Existe una cultura de innovación y del conocimiento?	6.0
35	¿En qué medida su organización colabora con otros agentes (proveedores, clientes, entidades financieras, universidades, centros de investigación, clúster…) para el desarrollo de soluciones de industria 4.0?	5.0

Modelo de relación y colaboración		
36	Valore el grado de implantación y distribución en su empresa de los siguientes roles digitales claves para la industria 4.0: CEO – Chief Exectuvie Officer CDO - Chief Digital Officer CMO – Chief Marketing Officer CCEO – Chief Customer Experience Officer CIO – Chief Information Officer CPO - Chief People Officer CCO – Chief Culture Officer	3.0
Comentarios		
Habilidades y cualificaciones		
37	¿En qué medida tienen detectadas las habilidades y cualificaciones necesarias en sus empleados para la transformación a la industria 4.0?	6.0
38	¿En qué medida cuenta su organización con las habilidades y cualificaciones digitales necesarias en relación a las necesidades de la industria 4.0? Ejemplos: - Infraestructura digital - Tecnologías de automatización - Análisis de datos - Seguridad de los datos - Tecnologías Cloud - Software colaborativo - Habilidades no técnicas como la comprensión del proceso tecnológico - Otras (describir)	5.0
39	¿En qué medida se han detectado los gaps existentes de sus empleados con respecto a las habilidades y cualificaciones digitales, en cada una de las áreas de su organización? Ejemplos: - I+D+i - Producción - Compras - Logística - Ventas - Finanzas - Servicios Postventa - IT	5.0
Comentarios		
Formación digital		
40	¿En qué medida se ha incluido la formación digital sobre Industria 4.0 en el Plan de formación de su organización?	6.0

Formación digital		
41	¿Cuál es el grado formación actual de sus empleados en cada uno de los procesos, en relación a las necesidades futuras de la Industria 4.0? Ejemplos: - I+D+i - Producción - Compras - Logística - Ventas - Finanzas - Servicios Postventa - IT	5.0
42	¿En qué medida su organización invierte en formación digital continua relacionada con la Industria 4.0?	5.0
Comentarios		

7.4. Infraestructuras

Infraestructuras digitales		
43	¿En qué medida su empresa dispone de la capacidad tecnológica (infraestructuras digitales) para implantar soluciones de industria 4.0?	8.0
44	¿Cuál es el grado de implantación de soluciones de industria 4.0 en su organización?	5.0
45	¿Cuál es el grado de flexibilidad e interoperabilidad de la infraestructura de TI de su organización para la integración de soluciones de industria 4.0?	7.0
46	¿Cuál es el grado de inteligencia de sus infraestructuras digitales?	7.0
Comentarios		

Soluciones de negocio y control		
47	Valore el grado de utilización de las siguientes soluciones en su empresa: MES – Manufacturing execution system ERP – Enterprise resource planning CRM – Customer relationship management PLM – Product lifecicle management PDM – Product data management PPS – Production planning system PDA – Production data acquisition MDC – Machine data collection CAD – Computed-aided design SCM – Supply chain management FCM – Financial chain management HRM – Human resources management	6.0

Soluciones de negocio y control		
48	Valore el grado de interconexión e interoperabilidad de las siguientes soluciones con el sistema principal de su empresa: MES – Manufacturing execution system ERP – Enterprise resource planning CRM – Customer relationship management PLM – Product lifecicle management PDM – Product data management PPS – Production planning system PDA – Production data acquisition MDC – Machine data collection CAD – Computed-aided design SCM – Supply chain management FCM – Financial chain management HRM – Human resources management	7.0
49	Valore el grado de utilización de información en tiempo real en las siguientes soluciones: MES – Manufacturing execution system ERP – Enterprise resource planning CRM – Customer relationship management PLM – Product lifecicle management PDM – Product data management PPS – Production planning system PDA – Production data acquisition MDC – Machine data collection CAD – Computed-aided design SCM – Supply chain management FCM – Financial chain management HRM – Human resources management	6.0
50	¿En qué medida se encuentran implantadas herramientas de ciberseguridad y protección de datos en su organización?	4.0
51	¿En qué medida se encuentran implantadas herramientas de Big Data o Análisis de datos en su organización?	3.0
52	¿En qué medida se encuentran implantadas soluciones Cloud en su organización?	3.0
Comentarios		

Plataformas colaborativas		
53	¿En qué medida se pueden conectar sus procesos funcionales a través de soluciones en la nube con los siguientes agentes del ecosistema industrial de valor? - Proveedores - Clientes - Entidades financieras - Universidades - Centros de investigación - Clúster	3.0

Plataformas colaborativas		
54	¿Cuál es el grado de conexión e intercambio de datos a través de sistemas digitales con los siguientes agentes del ecosistema industrial de valor? - Proveedores - Clientes - Entidades financieras - Universidades - Centros de investigación - Clúster	3.0
55	¿En qué medida su empresa está promoviendo acciones de innovación colaborativa con los siguientes agentes del ecosistema industrial de valor?Proveedores Clientes Entidades financieras Universidades Centros de investigación Clúster Otros (describir)	4.0
Comentarios		

7.5. Productos y servicios

Componentes y funcionalidades digitales		
56	Valore el grado de digitalización del portfolio de productos y servicios que ofrece su empresa	4.0
57	Valore el grado de implantación de los siguientes componentes y funcionalidades en sus productos y servicios, convirtiéndolos en productos y servicios inteligentes: - Sensores - Memoria - Integración - Localización - Monitorización	2.0
58	¿En qué medida el uso de productos y servicios inteligentes le ha permitido la obtención de nuevos clientes y/o ingresos?	2.0
59	Valore el impacto en la optimización de los costes con el uso de productos y servicios inteligentes en su empresa	3.0
Comentarios		

Productos y servicios interconectados		
60	¿En qué medida sus productos y servicios son interoperables y se pueden interconectar a productos y servicios externos?	2.0
61	¿En qué medida la hiperconectividad de sus productos y servicios le permiten disponer de información exhaustiva con valor para su empresa?	2.0
62	¿En qué medida la interconexión de productos y servicios le han permitido generar nuevos productos y servicios, así como nuevas necesidades y mercados?	2.0

Productos y servicios interconectados		
63	¿En qué medida los productos y servicios interconectados han transformado su modelo de negocio?	2.0
Comentarios		

Recopilación, análisis y uso de datos		
64	¿En qué medida los productos y servicios de su empresa permiten la recogida de información durante su uso?	2.0
65	Valore el grado de análisis y uso de los datos que recopila desde la fase de uso de sus productos y servicios	2.0
66	¿En qué medida los productos y servicios de su empresa permiten el análisis y el uso de la información de manera automática (nivel de inteligencia artificial de los productos y servicios)?	2.0
67	¿En qué medida utiliza las siguientes tecnologías para captar y/o analizar la información? - Sensores - Aplicaciones móviles - Big Data / Analytics - Social Media	2.0
68	¿En qué grado su empresa realiza un análisis predictivo de las necesidades de sus clientes?	4.0
Comentarios		