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SME's INNOVATION TOWARDS THE INDUSTRY 4.0

A method to compare companies' approaches

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A la mujer que ha sido mi roca y mis alas durante toda mi vida — mi madre y a mi padre, cuyo amoroso espíritu aún me sostiene en esta aventura

To the woman who has been my rock and my wings all my life — my mother, and my father, whose loving spirit still sustains me in this adventure.

ABSTRACT

The core of this document is the *Industry 4.0* and how it is being developed and supported by both private and public initiatives worldwide, prioritizing the analysis of nine cases of success in the implementation of *4.0 technologies* in Italian companies, with the objective of develop a meaningful (*qualitative and quantitative*) comparison between them and then be able to identify and establish the key elements (which also includes the things that should be avoided) that Companies should consider when implementing innovative technologies.

Industry 4.0 technologies are defined, explained and categorized, stressing on the relationship between the physical and the digital world, in which they are taking place. It is also emphasized the interaction and application of new processes on industry, especially in the small and medium enterprises (*called SMEs*). In order to classify companies, is defined an *SME* by establishing the differences between this concept among different regions, considering the economic and social factors that make the difference between one place and other.

ABSTRACT (*Italiano*)

Il nucleo di questo documento è l'*Industria 4.0* e come viene sviluppata e supportata da iniziative private e pubbliche in tutto il mondo, dando priorità all'analisi di nove casi di successo nell'implementazione di *Tecnologie 4.0* in aziende italiane, con l'obiettivo di di sviluppare un significativo confronto (*qualitativo e quantitativo*) tra loro e poi essere in grado di identificare e stabilire gli elementi chiave (che comprende anche le cose che dovrebbero essere evitate) che le aziende dovrebbero considerare quando implementano tecnologie innovative.

Le tecnologie di *Industria 4.0* sono definite, spiegate e categorizzate, sottolineando la relazione tra il mondo fisico e quello digitale in cui si stanno svolgendo. Viene inoltre sottolineata l'interazione e l'applicazione di nuovi processi sull'industria, in particolare nelle piccole e medie imprese (*chiamati PMI*). Per classificare le aziende, viene definita una *PMI* stabilendo le differenze tra questo concetto tra le diverse regioni, tenendo conto dei fattori economici e sociali che fanno la differenza tra un luogo e l'altro.

EXECUTIVE SUMMARY

The world is constantly changing in every imaginable way; These changes can be perceived individually by each one of us, but also by society. They can be cultural, social, personal, religious, technological and industrial, but they are intertwined among themselves, constituting the basis of the actual transformation of our society and the way in which we live on it. This transformation is totally gradual, affecting also people's needs, consequently forcing both the market and people to adapt to it.

Industry is one of the pillars of what we call "*modern society*", since for hundreds of years it has allowed the development of systems for the exchange of goods and services, and in this way a society based mainly on trade and economy has been stablished.

This industry is a living entity that adapts to culture and society and has suffered different dramatic changes on its productive dynamics, called "*industrial revolutions*". These revolutions have allowed firms to adopt and develop new technologies becoming avant-garde, acquiring different competitive advantages over their competitors and thus (generally) climbing positions in their field.

Such is the importance of the inclusion of new technologies on industrial processes that, thanks to them we can use in our daily life electric machines, vehicles with combustion engines, production chains (which allow the production of low prices items, for example), automatic machines that make productive processes much faster, effective and safe for workers and operators as well as for the final customer.

The fourth industrial revolution shapes this document, since we are currently living its development and so, we are able to actively interact with it. This revolution is sculpted using technologies based mainly on information that nowadays can be easily accessible, and its integration with the dynamics and operations within a factory. This integration is determined by the establishment of two types of realities that coexist and work together: the physical and the virtual world.

The physical world is determined by tangible and measurable facts, which are easily monitored and modifiable, but which have restrictions on their management (*for example, a mechanical machine allows the monitoring of its operation through its production but, because of its structure and its form, it is difficult to monitor its internal performances, components and maintenance*). In one way or another, the physical world allows the visualization and access to a superficial layer but restricts the access to more advanced levels.

On the other hand, the creation and implementation of digital technologies have allowed the generation of a totally different reality: the digital world. By means of the digitization of processes and especially, the acquisition of information through sensor elements, a giant possibilities panorama was opened; the fact of being able to obtain information of a productive process in real time makes possible its in-depth monitoring (*something that the physical world does not allow in an easy way*) and thus permitting the control of every detail and leading to improvements on efficiency, use of materials, quality of products, and reducing times creating more repeatable operations. In other words, achieving a better service and getting more advantages for both the client and the organization.

It can be seen that both realities operate in different ways (*can be said that in different dimensions)* but they are related to each other in a special and very tightly way, allowing industry to revolutionize and become a generating entity of goods that contribute to the improvement of the quality of peoples' life and thus, to an advance in our society.

Industry 4.0 is basically the implementation of advanced technologies in industrial processes with the sole objective of improving the conditions for all the actors involved. It is not simply about achieving the connection between machines; it is about generating a joint operation between physical and digital sides, which includes communication, obtainment and analysis of key information for making intelligent decisions about the process under consideration. It can be summarized as the "*marriage between the digital and the physical world*".

Getting deeper into this subject, there are several types of *4.0 technologies*, some related to digital world (*information technologies or IT*) and others with physical world (*operational technologies or OT*).

We must bear in mind that this differentiation is not definitive, since technologies have the ability to move in both worlds, making their analysis much more interesting. There are technologies that allow the transfer of information from the physical to the digital world (*called P2D*) and others that also allow the transfer of information but in the opposite direction, that is, from the digital to the physical world (*called D2P*). Some examples would be the sensor elements, augmented reality, which allow the obtainment of information in the physical world and its translation into digital signals, and the collaborative robots that allow to translate information and commands generated in the digital world into tangible and observable actions in our physical world.

The technologies related to *IT* are: **Industrial Internet (of Things), Industrial Analytics** and **Cloud Manufacturing**. The technologies related to *OT* are **Advanced Automation**, **Additive Manufacturing** and **Advanced Human-Machine Interface (Advanced HMI)**.

Smart technologies are applied in practically all the processes of an industrial and manufacturing company. To better frame this discourse, it is useful to resort to a scheme divided into **three areas**. The first one, **Smart Lifecycle**, includes the process of developing a new product, managing its life cycle and managing the suppliers involved in these phases. The second, **Smart Supply Chain**, includes the planning of physical and financial flows in the enlarged logistics-production system. Finally, the third area, **Smart Factory**, including the processes that represent the heart of manufacturing: production, internal and external logistics, maintenance, quality, safety and compliance with standards.

The IT technologies mainly allow (as already mentioned above) the interconnection of the machines and the possible joint operation among systems; allowing obtaining, organization and analysis of information inherent to the process and also to be able to optimize it (*Industrial Analytics e.g.*). These processes can be developed and centrally managed in the digital world using Cloud Technologies, allowing then the virtualization of almost any process and the facilitation of its control (*also remotely*).

On other hand, OT technologies allow the use of digital to obtain tangible results; technologies such as Advanced Automation (*for example, collaborative robots or co-bots, drones or AGVs*) and the use of Advanced Human-Machine Interfaces (*tablets, mobile devices, smart glasses e.g.*) help workers to carry out their tasks in a more secure, clear and efficient way (having the ability to receive orders and interacting with the outside), making processes much easier, faster and more efficient, increasing load capacity, the standardization of products and finally, reducing costs.

It is very important to mention that the advantages of the use of i4.0 technologies are not limited by factors related to production and costs only, they are also extended to the proper use of raw materials, the reduction or elimination of unnecessary processes and thus, reducing electricity and other resources consumption, producing a positive environmental impact. In social terms, these technologies facilitate (or make more comfortable) tasks, prompting a better work environment and more friendly and safer conditions for people. This facilitates the management and organization of a firm, and substantially improves it.

The perspective of this document is not only focused on the description of this new industrial revolution, but it delves into the way these technologies are being implemented and supported (by public and private entities) worldwide, trying to understand in which ways the businesses are interacting and adopting these advances and also the barriers that exist around this.

To make this analysis, *SMEs* (small and medium enterprises) were taken as a focus group. *SMEs* generate more than half of the total added value created by companies in the European Union, covering almost 98% of the total number of companies and employing more than 50% of the working force in Asia and constituting 27.7% of Australian workforce. The definition of an *SME* changes depending on the geographical region in which it is located, being susceptible to variations in the currency, political and economic situation; This document mentions the context in Asia, America, Australia and the Middle East, but focuses on the European context, specifically in Italy.

Bearing in mind that the modernization of processes contributes to the improvement of a country's production, some governments are interested in supporting and promoting this type of initiatives, creating programs that benefit the firms that have already implemented them and creating programs that contributes economically or intellectually to companies that are willing to do it. Almost 30% of European countries have created one or several initiatives that mainly seek the promotion of development of new products, improvement of processes, increase of investments and research in innovation and thus, ensuring the economic and environmental sustainability of industry. In regions like South America, initiatives are more focused towards the creation of spaces and means for diffusing knowledge about the industrialization of processes and training of people within it. By other hand, countries like China seek the standardization of their processes, the capturing of value and the strengthening of exports through company's growth.

As mentioned several times, the focus taken was on Italian context. The Italian industry is interesting to be analyzed because among the developed European countries (like Germany, France and the United Kingdom), for approximately 15 years has presented the lowest growth rate of the region, but in the past few years has been possible to see the reduction in interest rates and then, the increase in banking activity, being an indicator of the acceleration of the industrial production. The main barriers face by the country's industries are focused on the difficulty to adapt the public/governmental administration and the industrial and productive structure to the new challenges that globalization brings, and it is therefore essential to understand the way in which the Italian industries are adopting these innovative technologies and interacting with them.

In order to carry out this analysis, with the help of "*Osservatorio Industria 4.0"* of *Politecnico Di Milano*, 9 success cases were identified among companies that have implemented (or that are in the process of being implemented) *I4.0 projects*. As expected, the companies comply with a series of requirements related to their size, amount of annual revenues and number of workers (*which places them among SMEs*). These companies are located mainly in the regions of *Lombardia* (Bergamo and Milano), *Puglia* (Bari area), *Veneto* (Padova) and *Friuli-Venezia Giulia* (Pordenone) and they have similar characteristics regarding the work sector (most of them work in the metalworking sector) but also, they are very different in terms of size (revenues of €65 million compared to €3.2 million and 400 workers compared to 40 *e.g.*). These differences turn their comparison interesting and valuable since it allows to understand how *SMEs* with different characteristics are developing this topic and thus determine, for example, if the size of a company is an influential factor in the implementation of this technologies.

Personal and telephone interviews were conducted with the representatives of the enterprises. The main characteristics of these companies were identified and subsequently also the level of progress of the innovative projects they are implementing, emphasizing on their motivations, objectives and their possible expected results.

Having obtained this information, the next step was the organization and analysis of it, in order to make the subsequent comparison. By having a certain amount of information, both quantitative and qualitative, a **numerical indicator** was developed that allowed for more focused and meaningful comparisons, giving a quantitative (accounting) value to the company's progress in terms of implementation of 4.0 technologies, and thanks to it obtaining important conclusions in this regard. This index, called **TIP indicator (*Technology Implementation Progress indicator*)** was developed taking into account the number of projects implemented, the level of implementation progress of each of them and the number and proportion of people who are qualified to use this technology. Its value depends on the number of companies compared and the characteristics of their projects; for this reason, in the moment of doing comparisons and having results two perspectives were taken: first, a general comparison among all 9 companies and second, a comparison considering only companies with similar sizes (that is, comparing small ones with small ones and medium ones with medium ones *e.g.*). The TIP indicator has a maximum value of 1 and a minimum value of 0; the higher the value, the better the firm is in the implementation of 4.0 projects compared to the other ones.

An important result of the analysis is that, **the size of the companies (*the number of workers and/or the amount of money billed*) is not a determining factor in the successful implementation of I4.0 projects**, although is decisive the amount of money that is determining or that they are willing to invest for the improvement of their processes, the training of personnel and in the research and development of new products; then, in conclusion, a factor of success is the **willingness of firms to invest and update their processes, rather than their size**. This conclusion is very important since it shows that it is not necessary to have a too strong capital structure to invest in new technologies, it is enough to identify the needs of the company and clients and translate them into *innovative projects* whose size is determined by the firms' investment capacity and the volume of required production.

Another important factor is related to the internal organization of firms. It was possible to identify that a key factor for a 4.0 project to succeed is to **establish an internal organization, in terms of specific roles in charge of the topic and a defined action plan that allows to create clear goals and objectives, development times and standing for possible next projects**. This conclusion was developed considering that companies which establish clear objectives and create one or several figures or roles within them whose objective is the coordination of other units around the fulfillment of these objectives, manage to implement initiatives more quickly and in greater quantity, taking better results, regardless of their size.

This is the case of *Intermek*, which despite of being a small company in comparison with the others (for example with *Palazzetti*), manages to have a high TIP value by stating clearly that, despite the lack of large amount of resources, they have developed a strategic plan based on the change in their whole organizational structure and thus, being able to have better processes. By other hand, *Palazzetti* is focused on the improvement on their customer service and the maintenance of a product that has worked well for years, but they have not developed a mentality around the improvement of processes. Therefore, with the lack of strategic roles and plans, they have not achieved great advances in 4.0 technologies, which is reflected in their poor value of TIP.

Finally, suffice to say that, as mentioned at the beginning of this text, we are currently living in the midst of the boom of these new technologies and we have the opportunity to interact with these changes in real time, it is certain that as time passes and as companies start to understand that the future of their organizations is the adaptation to new trends, advances and innovations in terms of production processes, their dynamics will change and we will experience the generation of greater number of private and governmental initiatives, more quantity of projects and bigger progress in terms of process optimization and systems efficiency in general, of course benefiting firms, workers, government and end user, who will experience a dramatic enhancement on services, products prices and quality.

At the level of Italy, companies are making efforts to improve themselves, improving their processes and their products, which has shown with real facts that the industrial production is currently accelerating and demand for goods is constantly increasing.

1. OBJECTIVES & METHODOLOGY

Industry 4.0 is the term used to describe the new wave of digitization of the industry, the usage of new technologies and the pursuit of a bigger optimization rate and efficiency into the industrial processes. Since it was established in Germany some years ago, have been adopted by several productive sectors worldwide, turning the workforces into stronger ones and giving the people the tools to make a better and more precise work into a renewed and comfortable working environment.

The rise of the new digital industrial technology is a transformation that makes possible to gather and analyze *data across machines*, enabling faster, more flexible, and more efficient processes to *produce higher-quality goods at reduced costs*. According to *Oliver Scalabre* (BCG – Boston Consulting Group) [1], this manufacturing revolution will *increase productivity*, *shift economics*, *foster industrial growth*, and mo*dify the profile of the workforce* itself.

Despite of this adoption of new technologies, we are still in the process of apprenticing, knowing and finally developing those processes in certain sectors or countries in which the most traditional production alternatives still predominate in the panorama. Companies face formidable challenges in the adoption of these new technologies, those challenges can be defined by certain barriers like monetary investment needed, the lack of facilities to obtain (*or import*) certain technologies or the inability of the sector to implement them in their own processes, deficit or inadequacy of government and private support into those initiatives or basically the shortage of desire of the companies avoiding leaving their comfort zone.

To build and sustain a lead in the race to full implementation, the companies need to broaden and deepen their practical knowledge about digital technologies and the related use cases—and then develop and implement tailored digital manufacturing strategies [1].

The companies that composes an industry can be defined (*organized or divided*) according to their specific features, related with income, productivity and number of workers that establish a measure of their size and their capacity to compete with similar ones (*firms can be Big, Medium, Small and Micro*).

The Small and Medium enterprises (barely called: *"SMEs'"*) represents almost the 99,8% of the total businesses on the whole European Union (EU) (European Commission) [2], specifically 92,8% Micro companies, 6% Small Companies and 1% Medium ones; *SME's* are often referred to as the *backbone of the European economy*, providing a potential source for jobs and economic growth [3], bringing the 57,4% of the added value and represent the 66,8% of the total European workforce (7th International Conference on Information Society and Technology ICIST) [4]. According to Eurostat [3], the SMEs also account 59% of the workforce in the *manufacturing sector* and provides 44% of the added value in this sector.

Considering this information, is totally reasonable and important to understand how the *SMEs* are adopting *industry 4.0* technologies and which are the strong and weak points of this process. Several roadmaps have been done into this topic, but the challenges are still there; each specific context is completely different than the others, and it is difficult to establish a single checklist that fits to every environment.

The principal objectives of this investigation are related with the description, definition and analysis of the relationships between the topics mentioned before and the establishment of the basis for drawing (or complementing) a roadmap that fits for the *Italian market* at this specific time. For the establishment of these bases, success stories of Italian companies are analyzed, and **a methodology of qualitative and quantitative analysis will be designed** that will allow to identify and conclude the key points that could lead these companies to success in the implementation of industry 4.0 projects.

1.1. GENERAL OBJECTIVES

- Describe and define the characteristics of the *industry 4.0* and the technologies that compose it and establish the importance of this new industrial revolution (*worldwide*) and specifically, at the Italian level.
- Establish a correct classification of the enterprises according to the legal and economic frameworks established by each country (*or region*) in order to explain the differences between each continent.
- Identify and number the importance of *SMEs* in the global production area.
- Identify and describe the initiatives focused on industrial production with *4.0 technologies* for *SMEs* at public (*government*) and private level worldwide.
- Describe success Cases of Italian companies that have implemented *4.0 technologies* in their productive processes.
- Create a formal methodology for analyzing and comparing the success Cases.
- Propose specific actions that nurture a roadmap about the implementation of *4.0 technologies* in the Italian context.

SPECIFIC OBJECTIVES

- Define the term "*industry 4.0*" and its relationship with the new industrial revolution.
- Describe the evolution of *industrial revolutions* at a general level.
- Describe the technologies that are part of the *industry 4.0.*
- Identify and number the advantages and possible disadvantages of the application of *technologies 4.0* in the industry.
- Identify the barriers that the industry faces when applying technologies 4.0.
- Define the characteristics of an *SME* in different economic and geographical contexts.

- Identify and describe relevant data about *SMEs* worldwide and their importance in the industrial sector.
- Define the importance of *SMEs* in relation to the implementation of *4.0 technologies*.
- Identify and describe the *policies*, *initiatives* and/or *government or private programs* that encourage the implementation of *4.0 systems*, the renewal of technologies related to production processes (or management) and/or the training of personnel (*workforce*) around this issue.
- List some Italian companies and describe the internal programs that include the implementation of *4.0 technologies* on them.
- Schematize the methodology used for the identification and analysis of these Italian success cases (principally interviews).
- Propose specific actions that nurture a roadmap for the implementation of *4.0 technologies* in the Italian context.

1.2. METHODOLOGY

The methodology of development of this research is determined by the objectives of the project and more specifically by the challenges that have to be faced, primarily related to the definition and description of *industry 4.0*, *SME* and the relationship that exists between them.

The investigation starts from the obtaining of the information and its subsequent analysis and concatenation in an understandable format according to the objectives of the project. Different secondary sources are used as papers, mainly obtained from specialized databases such as SCOPUS (editors such as *Springer Nature*, Institute of Electrical and Electronics Engineers - *IEEE*, *Journal of Intelligent Manufacturing*), business reports (*Deloitte University Press, Siemens*), internet pages specialized in this type of topics (*Boston Consulting Group, European Standards Organization*) and university reports (*Osservatorio Digital Innovacion of Politecnico Di Milano*).

On the other hand, to describe the initiatives regarding the use of *4.0 technologies*, the researched sources are different: government reports, internet pages of institutes that promote innovation in each country (*generally the information is in the native language of the country investigated*) and especially the reports of the "*Digital transformation Monitor*" of the "*European Commission*" of the year 2017, where the most reliable information is found about the European initiatives (which are the most documented).

With respect to the initiatives of other areas, such as the *Middle East* or *Latin America*, the information is in some way vaguer and less concentrated, having to access to it through articles published in local magazines and newspapers in which the improvement of the local industry is boasted. Some of these informative sources are: *Ministry of Information and Communications Technologies of Colombia* (MINTIC), *La Nación Newspaper* (Argentina), *El Economista newspaper* (Mexico) and the "*Economic and Commercial Office of the Spanish Embassy on Pekin*", among others.
The methodology related to the collection of information related to the specific success cases of applications of *4.0 technologies* in Italian companies (*See chapter 4)* and industries, is a little different from the aforementioned. The construction of each one of the cases is carried out based on the realization of a series of **interviews with managers and representatives of these companies**.

The process begins with the obtaining or identification of the appropriate companies; It is necessary to look for in secondary sources (such as *journalistic reports*, various *news or specialized portals)* companies that belongs to the productive sector and that implement one or several technologies that enrich or improve their processes (*both productive and managerial*). These companies have to be small or medium - *SME* (with respect to the standard adopted in Italy) complying with the restrictions of income and number of employees (*the explanation around SMEs companies is done in chapter 3.1.).*

When those companies are identified and has been verified that the implemented projects will serve as a real example for this research, a personal contact work is carried out with the managers of the company; in this case, the "*Osservatorio Digital Innovation*" of *Politecnico Di Milano* has identified some companies and has established direct contact with them, while I have found and, with the help of them, have contacted and fixed some appointments.

Personal and phone interviews were carried out, in which, information related to generalities of the company was extracted *(size, number of workers, specific tasks, productive sector, internal organization, products and services rendered)* and the details of the innovations 4.0, as the way that are applied and the barriers or problems that the company had to overcome for its implementation, were identified.

The interviews duration is approximately *1 hour - 1:30h*; These interviews are transcribed and then analyzed with the objective of extract and organize the information said previously.

Having all this information extracted from the interviews, the next step was the organization and analysis of this information to make a later comparison. At this point, some problems arose, related to the quantity and the characteristics of the qualitative data that had to be compared; To solve this, was developed a numerical indicator that allowed to do more focused and meaningful comparisons and thus to have important conclusions about this. This indicator was designed in several stages, arising from the identification of the factors that influence the implementation of *4.0 projects* in a company and ensuring that it is mathematically correct and able to provide the information for what was developed.

Finally, the conclusions were made based mainly on the information extracted from the analysis and the comparison of the different cases of study at Italian level and thus be able to contribute with the construction of a roadmap for the companies that want to implement similar projects or processes.

2. INDUSTRY 4.0

The particular interest of this research is driven by relationships between the *SMEs'* and the implementation of new technological solutions into their processes. So, it's crucial to establish the concept of "*industry 4.0*" and highlight its panorama.

Industry 4.0 is basically based into the *adaptation of new digital technologies* (digitization) *into the existing factories* (specifically into manufacturing ones). It has been called "*the fourth industrial revolution*", after the invention of the engine, then the chain production and finally the automation of industrial processes [5]. This revolution is related with some important aspects: the information technology, the internet connection (the ease of accessing anywhere), the open source and the maker culture.

Manufacturing systems nowadays go beyond simple connection, to also communicate, analyze and use collected information to drive further intelligent actions. It represents an integration of *IoT*, *Analytics*, *Additive Manufacturing*, *robotics*, *artificial intelligence*, *advanced materials*, and *augmented reality* [6].

The widespread diffusion of Information and Communication technologies gives the chance to develop smart processes into the factories and then, provide new tools for a predictive manufacturing approach. According to *7th International Conference on Information Society and Technology ICIST 2017* (*Kopaonik, Serbia*) [3] the potential key goal of *I4.0* is to ensure a better *flexibility* and *scalability* of manufacturing systems through information technologies and industrial automation. This is the reason why a number of Governments all around the world are funding *I4.0* solutions implementation with middle/long term investment.

Digitization have influenced life in several aspects, starting from people's communication, relationships, movement and work; highlighting in this aspect the way that existing business models are driven, and new ones are born [7]. This fact is increasing the pressure on the industry, but at the same time is encouraging the opening of new business opportunities [5]. Companies are slowly adopting *industry 4.0* parameters, driven with the needs to *improve flexibility* in relation with product mix, *reduce time to market*, increase quality, ensure *security of data* and the reduction of possible *data spill-overs* to undesirable actors, maintaining at the same time policies of energy reduction and resource consumption.

Industry 4.0 government programs and international initiatives aims to transform the industrial workforce and their work capabilities in the near future; the integration of manufacturing progress and the strengthening of autonomous capability in production systems ***change the framework of human works***. The service-oriented, customer-centric and demand-driven production is pushing forward the progress of industrial automation. This progress is totally correlated with the ***fail rate of the production systems***, also related with the *failure rate* of the human, so its key to achieve the seamless integration between human and machines/robots and harness human's full potential [8].

According to *Deloitte* [9], apart from the advances and advantages related to the implementation of new technologies and the creation of new products, the *I4.0* allows a *more transparent interaction between the object and the user*, being an advantage for both the user and company. The impacts can be summarized:

- ***Market and sell products and services more intelligently***, where the information collected from the users and their behavior is used to establish a payment policy adapted to each one (as in the *Uber* example with the "*dynamic prices*", where, depending on the demand of users, prices are stablished, and this prices at the same time control the demand, controlling the service itself).

- ***Improve the aftermarket experience***: where are implemented technologies that allows the monitoring of the state of the elements, their failures and possible need for maintenance, or the possible patterns of use of the users.

- ***Optimize performance and distribution***: depending on the information tracked from the users, their wishes and needs, it is possible to assign products, quantities, distributors, locations and even means of transport in order to ensure more efficient market dynamics and a better service for clients.

2.1. BASIC DEFINITION

The term *Industry 4.0* was originally introduced in 2011 at the *Hannover Messe* trade fair (*and was the subject of an Industry 4.0 working group established by the German federal government*) by the **integration of information technology (*IT or IoT)* and operational technology (*OT*) to the industrial automation** *(for more detailed information about this topic, refer to section 2.4)* domain to create factory and process automation with the objective of bringing products faster to the market in a very efficient way, creating what has been called a *''smart factory''*[10].

The term "*Industry 4.0*" lacks a generally accepted definition. According to *Drath & Koziolek* [11], the meaning of the neologism is divides into two different parts: **Industry**, reflects the common definition of the industrial process and **4.0** that refers to the fourth stage of the industrialization process.

In this sense, Industry 4.0 is the continuation or the evolution given from the productivity gained through the implementation of mechanized production systems driven by water and steam power (*mechanization*), the division of labor and mass production using electricity (*electrification*) and finally, the computerization of industrial manufacturing by the using of programmable, novel and innovative technologies (*digitization*), being this one the explanation of the so called "*fourth industrial revolution*".

As was said before, the definition of *I4.0* is diffuse and can be confused with concepts as the "*digitization*", "*modernization of production processes*" and "*computer-integrated manufacturing".*

Digitization of processes is a mandatory step into the 4.0 transformation but is not the only component; the **digitization** is limited to the monitoring, controlling and adjustment of a production process functions (in this case), but lacks other important features as the real time control and the networking connectivity. By other hand, **computer-integrated manufacturing** proposes the vision of a *completely automated factory that operates without any human intervention* because of technological or/and economic reasons (*Hirsch-Kreinsen*) [12], while the *I4.0* leverage on the human–machine interaction (human-centered perspective) based on the new generation of collaborative/assistance industrial technologies and the interconnection of the system and the person.

In a general way, an *Industry 4.0 system* allows the **networking/connection** of *products*, *means of production* (*machines, work pieces or production modules*), *people* (individuals such as operators or customers in the *B2C sector*) and *partners* (institutions such as suppliers, strategic partners or customers in the *B2B sector*) as entities participating in a unique value creation chain, with the aim of optimize the performance of the particular process into which the system is integrated. Networking is not limited to the entity means of production (not only machines, but also products and people) is gathered towards an **inter-organizational integration and process unification**, allowing to bridge the gap between digital/virtual world with the physical, analogue/real world, fostering the collaboration on micro-level (*between people and machines*), mid-level (across systems or vendors) and macro levels (across factories or companies).

Industry 4.0 is a state in which manufacturing systems and the objects they create **are not simply connected**, drawing physical information into the digital realm, but also communicate, analyze, and use that information to drive further intelligent action back in the physical world to execute a **physical-to-digital-to-physical transition** [10] [10].

According to GTAI (“*Wirtschaftsförderungsgesellschaft der Bundesrepublik Deutschland*”, in English “*Germany, Trade and Invest*”) the concept of Industry 4.0 is born in base of the concept of *Cyber Physical Systems* (*CPS*): technologies that **marry the digital and physical worlds**, typically via sensors affixed to physical devices and networking technologies that collect the resulting data [13].

According to this, an *Industry 4.0 system* must be able to **capture and analyze physical data** by means like sensors, use actuators to **impact on physical processes**, leverage globally **real-time data** (*monitor physical processes*), interact and **synchronize with the other machines**, offer multimodal interfaces for an **effective human–machine collaboration**, create a virtual copy of the physical world and make decentralized decisions.

Industry 4.0 is based on **Cyber-Physical system integration** through the conjunction of the internet of things (*IOT*) with manufacturing techniques to enable systems to share information, analyze it and use it to guide intelligent actions. It also incorporates cutting-edge technologies including additive manufacturing, robotics, artificial intelligence and other cognitive technologies, advanced materials, and augmented reality [7].

According to Siemens [7], the overall objectives/benefits of this industrial revolution are:

- Increase productivity and save costs.
- Bringing together advances of machines, networks and facilities, automating the operation of the Industries with embedded computers, real-time monitoring and control.
- Connect factories with globally interconnected value chains (*networks*) linking global suppliers, customers and business partners. Enables people, machines, sensors and devices to connect and communicate with one another.
- Creation of cyber-physical environment that enables systems to instantly share and analyze data in real-time.

- Be capable to offer (more) customized products which will be profitable and helps to expand business.
- Building a system that can support humans in decision making and problem-solving, especially focused on the generation of safe work environments (providing systems that operates on dangerous places/tasks).

In resume, *I4.0 systems* are characterized by:

- Human dimension/ Machine networking.
- Ecosystem behavior.
- Ability to monitor and interact with every production step.

2.1.1. Evolution of the industrial revolutions (*Industry x.0)*

As was said in several times, the industry 4.0 is known as the fourth industrial revolution and entails several changes into the general production mentality worldwide. The evolution of the "*industrial revolutions*" starts with the introduction of water and steam powered mechanical manufacturing systems during end of 18th century/beginning of 19th century ***(Industry 1.0)***. Water and steam-powered machines were developed to help workers. As production capabilities increased, business also grew from individual cottage owners taking care of their own and maybe others need to organizations with owners, managers and employees serving customers [7].

In 20th century, the ***Industry 2.0*** started with the introduction of electrically powered mass production (*electricity became the primary source of power*) based on the division of labor (*increasing of productivity*.). The most important advantage is related with the fact that the electrical systems were easier to use than the other ones and enabled businesses to concentrate power sources to individual machines, giving way to the development of machines with their own power sources, leading into the portability of systems. This second industrial

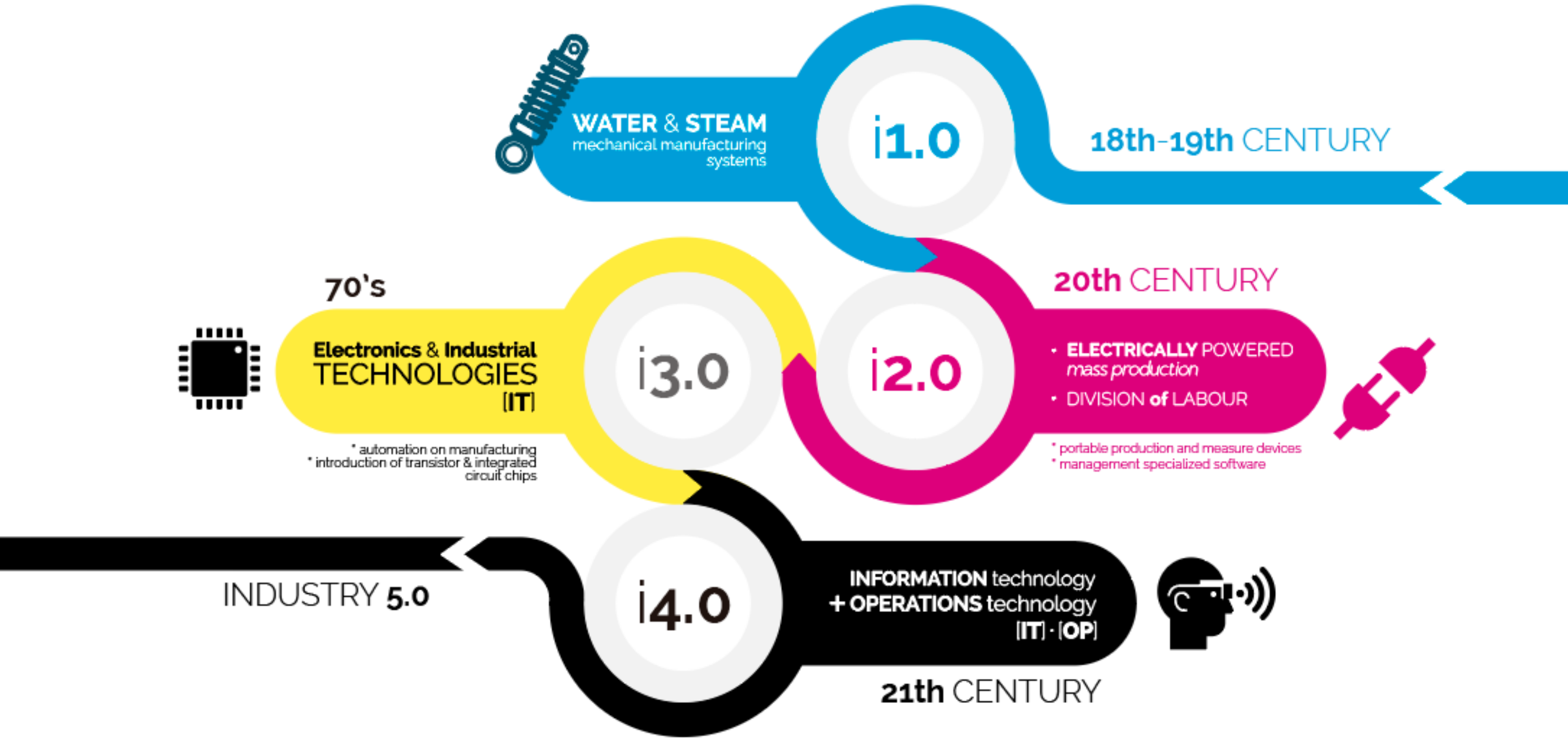


Image 1. *Evolution of the industrial revolutions from 18th to 21th century.* ***Source:*** *Own development.*

revolution was also characterized by the creation of management programs with the aim of increasing the efficiency and effectiveness of manufacturing facilities.

Around 1970, the third industrial revolution ***(Industry 3.0)*** arrived with the introduction of Electronics and Industrial Technologies (IT) with the aim of achieving automation on manufacturing through the invention and manufacture of electronic devices, such as the transistor and integrated circuit chips, making possible to achieve a bigger automation level on machinery and in some cases the replacement of human labor. The integrated systems between hardware and software applications leaded the implementation of effective planning tools that enabled humans to plan, schedule and track product flows through the factory.

2.2. ADVANTAGES *of implementation of I4.0 projects*

Industry 4.0 advantages are related with economic, ecologic and social scopes.

2.2.1. Economic Scope

Talking about an economical point of view, the companies that implements *4.0 technologies* and achieve to merge operation and information technologies and integrate the customer into a highly decentralized manufacturing process, surely will get a flexible and cost-effective manufacturing of products. The use of sensors, actuators and software, will achieve an efficiency level that gets into an almost zero marginal cost, providing or generating also, a digital, product-accompanied services resulting in additional revenue streams (Deloitte University Press) [9].

2.2.2. Sustainable Scope

Ecologically motivated firms should virtualize some processes and then, will minimize physical iteration loops and physical resources usage (as paper for invoices and documents), increase data transparency between partners (to coordinate actions through the monitoring of activities and the consumption of resources in real time) and use feedback data from products and machines (to optimize resource efficiency) in order to establish more sustainable supply chains (Procedia)[14].

2.2.3. Social related Scope

From a social point of view, firms may utilize new forms of human–machine interfaces to improve work safety and enable the development of more ergonomic workplaces [12]. Also, the establishment of better and more dedicated workspaces and work-tools would encourage the workers to do a better and more fluid and comfortable work, taking into account, also, that the machine acts as an extension of the worker and maybe the worker as an extension of the machine itself.

2.3. MANAGERIAL CHALLENGES *into the adoption of I4.0*

The *industry 4.0* is in a phase in which its technologies have to be identified, understood and applied by the companies. There are lots of companies that have not identified the possible economical, sustainable and social benefits that the new technologies can add to their value chain and then it is imperative to establish a right path to do that.

Many roadmaps are developed every year, taking into account the specific characteristics of the environment, companies, users and products, but the challenges (called managerial challenges) that have to be confronted and overcome are similar for almost all cases.

According to Schneider [15] the **managerial challenges** that have to be taken in order to achieve a right implementation of *I4.0* system that entails the improvement in the whole production potential are clustered into:

1. Strategy and analysis
2. Planning and implementation
3. Cooperation and networks
4. Business models
5. Human resources
6. Change and leadership

This work is focused on understanding and defining how the *I4.0* is/have to be implemented and how this is changing the way the *SMEs* are working too. Each cluster shows a section of the logistic and managerial process that the company have to develop, influencing the way the company is structured (*business model*), how and who works into (*human resources*), managerial approaches (*leadership, networks and cooperation*) and how the physical processes are done (*implementation*). So, it's imperative to say that the implementation or the changing of the production process is not only related with the technology of the machinery, is related with the core of the business itself and have to be treated from the first as it; as a change of mentality of the workers, managers, owners and of course a turn into the technologies, processes and relationships with suppliers.

Industry 4.0 is a whole paradigm in the modern times, because wraps up the whole established codes related with the company and the customer itself. Now the whole process can be monitored and tailored depending on the specific needs of the client; so, in some way, the consumer is always getting involved into this process.

The *industry 4.0* have to be treated as a change in the sense of the consumerism itself; **the line between the company and the user is more diffused nowadays**, and the **machines acts as an extension of the worker** (*and maybe the worker as an extension of the machine*); the manager not only is focused on carrying an established business plan, but to organize the whole ecosystem, taking into account: materials, worker safety, quality, production capacity, efficiency, environment impact and customer involvement, while the worker/operator is not anymore focused into an specific task, but related with the whole process and with the capacity to monitor (almost in real time) the whole process, and then, counts with the capacity of intervene and modify it when the situation is required.

This also establish a fading into the line between workers and managers, because every person is involved into the ecosystem, and every task is crucial and definitive into the creation of the final output. The factory is now an ant ecosystem, where the whole scheme behaves as one.

Academic contributions dealing with Industry 4.0 have increased dramatically within the last few years. Scholars have interpreted *I4.0* from the perspective of specific industries, individual companies or the individual in his/her working environment and have discussed the associated economic, ecological and social opportunities [9].

Understanding that the digitization and the implementation of new technological solution would drive into the outstanding *improvement of Industry production* and *efficiency* is the core of this project. Now the question focuses on the specific situations/actions/features/advantages or procedures that one of this SMEs' should adopt onto the road of success towards the *transformation 4.0* of its processes.

2.3.1. **Strategy and analysis** [12]

This challenge is the first one of the list, because is related with the aspects that companies must discuss and take into account in order to be able to make a conscious decision on how to approach and deal with *Industry 4.0* new approaches.

According to Schneider, the transformation must start with *redefining and identifying the business scope* and then, generate and emphasize the active involvement of the company leadership and management areas into the final decision as a crucial success factor. The final decision must be taken taking into consideration the balance between the advantages in the three scopes said (*refer to section 2.2*) and the possible disadvantages, also considering which scope is more important for the company: to achieve the efficiency on production and low cost, to create adequate work conditions or/and to align with an environmental vision of production.

The decision has to comprise the way that the value propositions of the company may shift, which new forms of collaborative value creation and which key drivers for market change have to be taken, and finally, which behaviors, processes and task have to be taken in order to increase the productivity and how will the managers extract the most valuable advantages from the investment.

As a result of this first process, not always the I4.0 is the best option. According to *Laudien and Daxbröck* [16], an **early implementation of *Industry 4.0* may not**

be beneficial in every case, due to certain market characteristics or internal conditions within firms (competition environment) that can lead to several entry barriers, not beneficial within an economic or social scope.

2.3.2. Planning and implementation

One of the most important challenges is the estimation of the costs and benefits of the *Industry 4.0 investments*, as this acquisitions represent the main implementation and entry barriers on the whole process, specially taking into account that the networking effects are difficult to estimate and monetize and that the new business potentials arising from such investments may often only be recognized after the implementation, so it's crucial to get a clear vision about the objectives and the real scopes of the project.

Virtual representations are a good approach taken by several companies in order to simulate the behavior of the novel systems into their existing environment and facilitate decisions about which processes would benefit to be applied and maybe which are not.
Those virtual analysis/simulations may offer significant cost savings without disturbing the ongoing production processes, but also represents a considerable investment, that in some case could overtake the same cost–benefit that aims to solve, being completely unfavorable to do.

The migration between an existing system and a new one have to be done in a gradual way, since buildings, production facilities, business processes and IT systems have grown over time, and, with regard to the technological systems, firms already employ alternative, mutually incompatible products from different vendors or different versions from the same vendor and in some cases the total replacement of the machinery is not the most appropriate approach; the implementation of a I4.0 system cannot simply be based on the depreciation and replacement of the existing infrastructure, but the gradual adaptation of old technologies in a technical and economic sense.

2.3.3. Cooperation and networks

Strategic alliances and collaborative partnerships are important strategic success factors in a modernization process; companies that works alone are generally assumed to result in isolated solutions that may not be able to leverage the full potential of Industry 4.0. According to *Chen & Tsai* [17], *I4.0* initiatives are enablers of the so called "*ubiquitous manufacturing paradigm*" affirming that "*it will be increasingly less important, which process is executed in which particular factory or company*".

The collaboration between companies is really important for *SMEs* because they can complement their lack of resources and expertise, minimize their investment and implementation risks, fully exploit networking effects and better fulfill customer requirements. But it also carries many risks like the difficult of data security and potential loss of know-how.

2.3.4. Business models

The technology is not the only enabler for the *Industry 4.0*; the revolution is done based on a mix of appropriated machinery and a new/adapted business model, taking into account that the value proposition of the company itself will be driven by the use of data, the integration of customers into product and service engineering processes and the increasing importance of the software part of products, and this factors will drive the generation of the business plan. In many cases, the customer may not (only) pay for the tangible asset, but for its functionality, accessibility and associated value-added services.

Some companies believe that Industry 4.0 demands new business models; others, however, interpret Industry 4.0 more as an enabling factor [12].

2.3.5. **Human resources** [12]

The inclusion of a new or different technology into a company impacts the human resource behavior; those impacts have to be understood and strive to develop strategies for shaping the workplace of the future, getting qualifying employees and building digital capabilities.

The challenges can be analyzed from two different points of view, workers and managers:

- **Workers** are assumed to be confronted with a new quality of automation and assistance systems that integrate physical and digital realities and new forms of human–robot collaborations, while easy and repetitive tasks are being automated, and new (more complex) tasks emerge.

- **Managers** and Employees responsible for the management of production processes will be facing an increased complexity of fabrication, the invisible nature of digital information (paperless working) and the decentralization of decision-making, control and coordination functions, which can be automatized. Responsible managers will need to have a deep understanding and knowledge of the overall production process to be capable to lead them in the best way.

In this order of ideas, the networking vision between *Industry 4.0*, *IT* and *operational technology* are also expected to think more broadly across business models, processes and technologies and should thus (*the people*) have a competence profile that is rather interdisciplinary than specialized.

One of the challenges in this case is define how to develop associated skills into the workers related with the arriving technologies. According to *Blümel* [18], several companies have adopted/created the so-called teaching factories or demonstration factories, that facilitate realistic and relevant learning experiences resulting from real-world problems, that can foster the generation of new problem solutions and provide the possibility of learning about learning and be prepared for future new changes into the organization configuration.

2.3.6. **Change and leadership** [12]

The inception of a *I4.0* changes bring forth several organizational and cultural changes into the company, which needs to be governed and controlled by managers, taking into account potential *acceptance problems*, *inertia tendencies* and *expected resistance* of the workers and the system itself. Workers may experience "a loss of control and a sense of alienation from their work as a result of the progressive dematerialization and virtualization of business and work processes.

The *acceptance and behavioral problems* are faced during the whole process, and managers have to be aware about the graduality of the change. Several cases have been reviewed; some companies prefer to change centrally and very consistently from the top, taking a not-so-gradual approach. Other companies start from the bottom and form small, heterogeneous units that develop pilot projects and test solutions in close collaboration with customers, emphasizing the roles of experiments and iterative learning; by other hand, some authors affirm that generally, bottom-up initiatives block the path towards *Industry 4.0* and are not that recommended to be implemented.

According to *Spath* [19], the lack of acceptance by managers may potentially be the result of decentralization tendencies resulting in decision-making competencies being transferred to the operational level and will be reinforced by a general skepticism about automation and efficiency promises by the whole ecosystem.

2.4. *I4.0* TECHNOLOGIES

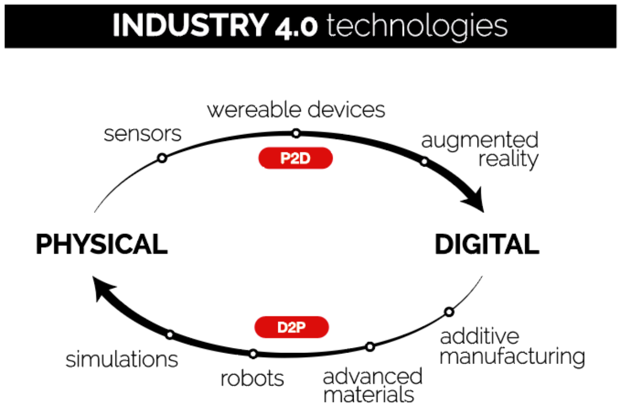


Image 2. *Translation between the physical actions and the digital information through i4.0 technologies.* ***Source:*** *Own development.*

The innovative digital technologies, the **Smart technologies**, can be traced back to two large groups: the first most cohesive and close to **Information Technology (IT)**, which includes *Industrial Internet (of Things)*, *Industrial Analytics* and *Cloud Manufacturing*; and the second, more heterogeneous and close to the layer of **Operational Technologies (OT)**, represented by *Advanced Automation*, *Advanced Human-Machine Interface* and *Additive Manufacturing*. Industry 4.0 technologies merge or integrate IT and OT and applicate it to industrial automation.

The integration is related with the translation of physical actions into digital information (*physical-to-digital or P2D*) and the translation of digital data into tangible actions/elements (*digital-to-physical or D2P*).

Following this idea and according to the *Osservatorio Digital Innovation (Industria 4.0)* of *Politecnico di Milano* [20], the digital technologies can be organized into two groups:

2.4.1. Technologies related with INFORMATION TECHNOLOGY (*IT*)

2.4.1.1. INTERNET OF THINGS (*IoT*)

The creation and existence of new technologies that allows the connectivity, availability of cloud computing, and miniaturization of sensors and communications chips have made possible the connection of more than *10 billion devices in the network* according to *Harvard Business Review* report [21]. These connections have made possible the generation of new methods of efficient and economic production, being called with different names: *Internet of Everything*, *Machine-to-Machine communications* or *Industrial Internet*, being generally called as "*Internet of things*".

According to *Deloitte* [9], the *IoT* is probably the most crucial part or element of *Industry 4.0* developments because it is directly related to the connection between products, services, producers, companies, customers and any other imaginable actor that composes the production network. This connection has been driven by the massive adoption of portable (mobile) elements such as cell phones, tablets, and other wearable devices and the emergence of the cloud as a way to store and process large volumes of data in a very efficient way, in terms of cost-benefit.

The *connection of technologies* is basically the engine of any modern productive system since it allows the ***shared cogeneration of value***, between humans and (especially) machines, allowing then the ***increase of the efficiency*** and the quality of the final products (results). Technologies such as *high-quality sensors*, reliable and powerful *networks*, *high-performance computing* (*HPC*), *robots*, *artificial intelligence*, *cognitive technologies* and *augmented reality* [22] are part of many companies that have modernized their production methods.

A company that is interested in implementing *IoT* in its productive processes will be faced certain types of barriers or challenges related mainly to the management and obtaining of the information (taking into account that the quantity or volume of data may be massive).

When starting to handle a considerable volume of information it is necessary the internal training of the personnel around this issue and the acquisition of storage and processing equipment.

With the ability to add complementary services to the existing product, the company needs to design and implement **customer service processes** and specialized platforms that help customers to manage and understand the information obtained from their products; It is also necessary to create **strategies to promote and "train" clients about the new proposals** that are offered (*this last challenge only applies in the case where the company implements IoT at a post-production level and not in processes productive*).

- **Servitization model**

The introduction of interconnected elements has not only allowed the improvement of industrial processes but has also permit a change in the way value is being delivered to the users, the **core strategy** and the structuring of the **business model**. The *IoT* has allowed the creation or addition of new services together with the already developed products (*enhancing of existing services*) starting from a **business model focused on the product** to a **business model focused on the service** (*in addition to the products*), even changing the approach of the company itself.

With the implementation of **forward vertical integration** (manufacture of new goods and services that complements a product offered already to the market), the reduction in overall risk is sought, making the company much stronger and more competitive in the market and improving the efficiency of the company by integrating processes that complement each other under the same governance structure, incurring a reduction in transaction costs.

Among these processes, the most important would be the **predictive and proactive maintenance**, where a company can (apart from selling a machine, for example) provide the maintenance service every certain time or in due case, inform users about the state of the machines (so preventive maintenance can be programmed), preventing possible future failures.

- **Information Value Loop (*IVL*)** [9]

The *creation of value from the IoT* is a concept introduced by *Deloitte* in which is talked about the "*IVL*" (*Information Value Loop*) and is related to the way in which tangible and intangible actions are interconnected in a productive system through the flow of information.

The loop *starts with a specific action and the subsequent measurement of the state and behavior of this action* in a specific context (through measurable elements defined above and with the help of sensor elements), which generates a certain amount of storable data whose quantity and characteristics depends on frequency or magnitude, risk (accuracy, security, reliability) and measurement time. This information can go through three later stages: *Communication, aggregate* and *analyze*.

Finally (and from the results of the analysis of the information sensed in the first stage of the loop), decisions of actuary type or system configuration (setting) can be made.

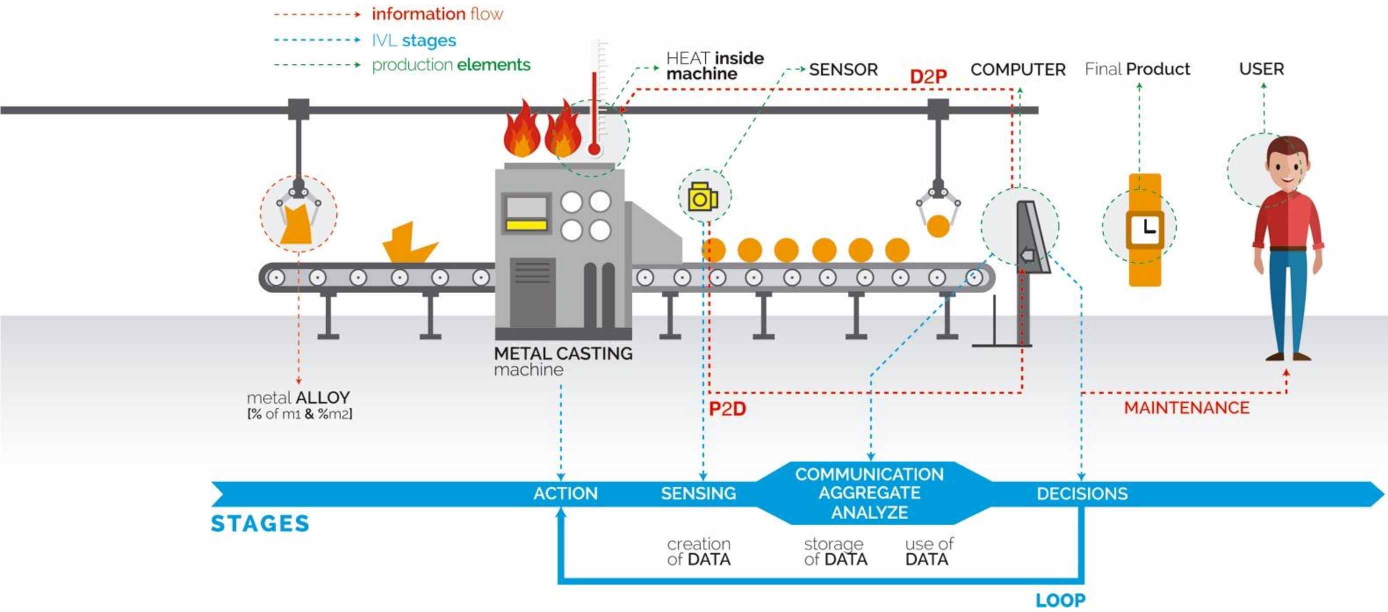


Image 3. *Stages of the Information Value Loop explained through an example of a Metal Casting process where the physical material suffers a transformation through heat and several sensors and computes recognizes, create, storage and analyze the data, which can be used by the final customer, for maintenance or for the process itself. The graph shows the relationship between the information flow and the production flow, showing the integration of the physical and the digital (Go to Image 2).* ***Source:*** *Own development.*

As an example, we can take a *metal-casting machine*, in which the final product is a certain amount of metal, which (to be molded) needs to have a defined temperature and viscosity; These parameters depend on the amount of heat that the machine applies to the metal and the characteristics of the alloy that is introduced to it (as raw material). When leaving the first batch of product, the sensors will measure the necessary parameters and with these results (the analysis can be done automatically or with the introduction of human labor) it will be possible to determine if the internal temperature of the machine needs to be increased, maintained or decreased or if the alloy of the raw material needs to be changed or maintained; thus, the process self-regulates itself around the improvement of the final product.

It is important to mention that all processes are (or can be) connected to each other, IoT feel the connecting point or the glue between them; This relationship between the tangible and the intangible is called: **physical-to-digital** *(P2D)* and **digital-to-physical leaps** *(D2P)*, with the complete cycle IVL being a **physical-to-digital-to-physical cycle**.

2.4.1.2. INDUSTRIAL ANALYTICS

Industrial Analytics (*IA*) can be defined as all the processes related to the **obtaining**, **analysis and subsequent application or use of information (*data*)** generated during a specific action, in our case an *industrial process* (which may include only one portion of the productive process or even the entire life cycle of a product, from the raw material to the use by the end user). Entails a strategic capability that impacts the future competitiveness in any industrial business.

"Basically, Industrial Analytics turns the resources (data) into a valuable product(…)"

The processes of Industrial Analytics seek mainly the improvement or the impulse for the **growth of the income of a company** by means of [23]:

- The improvement of the business models.
- The improvement of the productive processes.
- The improvement of the intrinsic characteristics of the products (the latter as a result of the first two).

According to the ***IOT Analytics*** and the ***Digital Analytic Association of Germany*** [24] (through the *Forbes* portal), the three **principles/objectives/benefits** that are sought when applying *IA* in a company are:

- The increase in revenues
- The increase on customer satisfaction (*and of course attract more customers and increase profits*)
- The improvement of product quality, by having more control over the process.
- Achieving of higher levels of automation on processes.
- Transparency on processes through the *real-time data analysis*.
- Adjustment of offering through the knowledge of user information.
- Creation of new products and services.

❖ Applications of IA

The most accurate applications of these processes are related to:

- Predictive and prescriptive maintenance of machinery.
- Identification and analysis of customer information and marketing.
- Product lifecycle analysis, especially the way in which users use it after having made a purchase.
- Visual analytics.
- Support on remote services and updates of products.
- R&D.
- Data for quality of manufactured products.
- Analysis of stationary products.
- Decision support data analysis.
- Process Automation.
- Cybersecurity.
- Smart Grids and electrical efficiency.
- Connectivity of assets and machines.

These applications are carried out by sub processes within the company related mainly to the *creation and analysis of advanced spreadsheets*, use and development of *own data analysis platforms*, *business intelligence*, *predictive Analysis* and *Simulation tools*, *statistical data analysis*, *artificial intelligence* and *machine learning*.

❖ Classification of *IA* Technologies

The different technologies related to Industrial analytics can be classified according to the stage in which they are developed:

Data collection technologies

This category is one of the most important since when there is a need to make exhaustive analyzes of a specific process (*and there is the proper economic resources and the time to do it*), an immense amount of data is collected.

The obtaining of data is done through sensor elements, either physical or through software, which basically are able to identify indicators and their behavior over time. There may be **tangible elements** (*such as a motion sensor that can count the number of times a mechanical arm transports an element from one side to the other and thus be able to understand the efficiency of that machine in general*) or **non-tangible elements** (*a counter of visits to an online sales site or a customer data collector*). Some used technologies are: *IoT devices*, *ERP Systems*, *MES systems*, *SCADA*, *CRM*.

Connectivity is crucial when establishing channels between the sensor elements and the data collection, storage and analysis center, so the interconnection of the machines is a must (refer to the *numeral 2.5.1.* that talks about the Internet of Things).

Data analysis technologies

The data analysis begins with the storage of all the information gathered by the sensor elements and their subsequent investigation.

To do this, it is necessary to have an infrastructure or the necessary technological resources such as *IoT platforms*, *M2M connectivity*, *Databases*, *Information Security systems*, *APIs* and *Middleware*s (software that acts as a bridge between an operating system or database and applications, especially on a network).

Data analytics describes all the processes that are carried out to **examine, organize and finally understand and extract valuable information for the industrial process** that is being carried out and with this information to be able to make clear and concise decisions.

The two pillars of Data Analytics are:

- **Big Data architectures:** Complex systems of structured storage of information.

- **Artificial Intelligence/Machine Learning:** Customized and advanced algorithms that allow the autonomous analysis of the information. Tackles the creation of programs, capable to carry out some behaviors according to the information provided by outside and with examples.

In data analysis not only limited to organize information, but also to carry out statistical processes, create future models and forecast possible problems and solutions. There are several levels of data analysis, starting with the descriptive analysis, which identifies the current operation of the machine and the process, allowing to identify faults that are occurring or that have already occurred in the past. The real-time analysis allows visualizing the behavior of the production immediately; the predictive analysis allows to collect information and analyze it in order to predict future behavior and thus take action measures and finally the prescriptive analysis that allows creating policies and establish actions that optimize the operation of the team in the future, programming preventive maintenance and avoiding all type of errors.

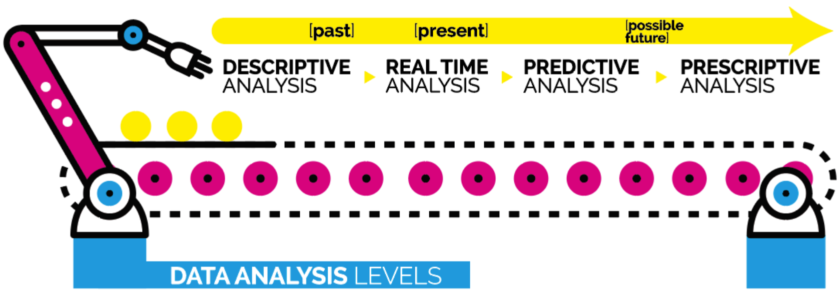


Image 4. *Data Analysis levels.* ***Source:*** *Own development; based on the exhibit 7 of the Industrial Report 2016/2017.*

Technologies for the use of data

After carrying out a thorough process of data interpretation and analysis, this information must be used. For this, it is necessary to ensure the correct visualization and reading of these results by the operators through human-machine interfaces (see numeral).

2.4.1.3. CLOUD MANUFACTURING (*CM*)

The concept of *CM* has varied according to the author and the source that is used, but it is a bit difficult to establish an exact solution and the one accepted by everybody. The first to explain the term was *Li* (2010), who said:

> *"Cloud Manufacturing* is the new networked manufacturing paradigm that organizes manufacturing resources over networks (manufacturing clouds) according to consumers' needs and requirements to provide a variety of on-demand manufacturing services via networks (e.g., Internet) and cloud manufacturing service platforms (…) [25]"

According to *Siderska & Jadaan* [26]*, Cloud Manufacturing* (*CM*) concept can be summarized according to the similarities of various definitions of several authors (the next definition provided is based on the premise of *Siderska & Jadaan*, but is also complemented by personal contributions):

> *CM* is a service-oriented business model based on the fact of virtualizing the distributed manufacturing and assembling resources to share manufacturing capabilities and resources on a cloud platform, with the aim of providing coherent, uninterrupted and high-quality transactions of/into the manufacturing process. It joins emerging technologies, such as *Internet of Things* (*IoT*), *Cloud computing*, *service-oriented technologies*, *virtualization of processes*, semantic web, advanced high-performance computing technologies.

In the *CM*, the services and instruments essential for the complete life cycle of manufacturing (*planning, design, testing, production*) are converted into cloud-based services, which allows the production segments to be managed in a centralized manner; The use of these systems ensures or facilitates the unprecedented flexibility, security and scalability of the production processes. It is considered that the cloud manufacturing concept is an extension of the **cloud computing idea of manufacturing** (*Cloud Computing is the technology that allows the remote use of software and hardware resources such as mass storage for data storage, usually by a payment or subscription* [27]) while the CM carries the **integration and globalization** of system usage.

The *CM* is based on a change in mentality and the way processes are developed, taking advantage of the inherent capacity of physically located (traditional) systems, also providing the possibility of deploying new services in shorter times and the ability to scale/grow/increase its own capacity according to the needs of the market in growing demand and own productive capacities (when exist companies that have plants located in geographically distant sites and serve segments of equally distant markets).

Cloud Manufacturing ranges from the virtualization of the physical resources necessary for the machines until the applications, data and processes on *e*-execution and *e*-collaboration platforms hosted in the Cloud, (*also*) to the productive resources, enabled for example, by platforms (*such as Makercloud*) on which can be loaded the production specifications of an asset (drawings, requirements, volumes) and then, obtain supply proposals [28].

When implementing a production scheme in the cloud, changes are generated in the following aspects [29]:

- Human resources can be managed in a global way.
- The reduction or even the elimination of the need to have equipment and IT personnel in the facilities dedicated to production.
- The impact on the production lines is reduced, when it is necessary to perform hardware maintenance or software updates.
- Instead of each factory or warehouse being managed as an independent entity, all facilities can be monitored and managed at the same time, improving efficiency throughout the supply chain.

- Companies can make adjustments to make products or "*custom*" batches of products more easily, respond to the market buying patterns changes more quickly and make adjustments in the characteristics of manufactured goods.
- By having a complete view of the company's resources, it is possible to perform analyzes and apply business intelligence, to make important decisions in much shorter times.

The *CM* can be identified just as a component of the *I4.0*, because the last one encompasses intra-factory and inter-factory integration, while CM is just focused on inter-factory.

❖ **STAKEHOLDERS on Cloud Manufacturing systems**

The dynamics related to the *CM* are based on the relationships between the different stakeholders; There are three categories of stakeholders: **the SUPPLIERS/PROVIDERS** who are the ones who make their resources available (a product, a service or a mean of production) in the cloud (called *Cloud manufacturing platform*); *the resources* are stored in the cloud while it is managed by **the OPERATORS**, who are basically responsible for guaranteeing the correct functioning of the platform without having any influence with the delivery of the resources to the consumer. And finally, **the CONSUMERS** who make use of the resources according to their needs and establish direct contact with the resources through the online platform, without any intermediary [24].

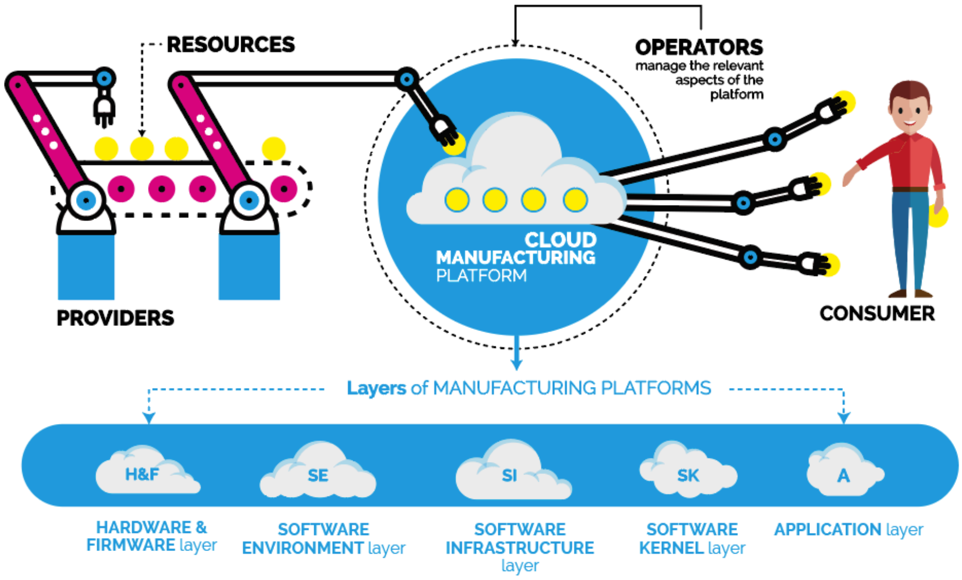


Image 5. *Stakeholders and layers of Cloud manufacturing platforms.* ***Source:*** *Own development.*

The manufacturing platforms can be divided into 5 layers [30] [31]:

- **Hardware & Firmware Layer:** All kind of physical equipment which support upper services of cloud computing, such as large number of servers in data center, network equipment or storage equipment.
- **Software Environment Layer:** Physical resources are converted into virtual resources such as computing, storage and network resources by any virtualization technology.
- **Software Infrastructure Layer:** Fundamental technical resources that supports the function of other layers.
- **Software Kernel Layer:** Provides the basic software management for the physical servers that compose the cloud.
- **Application Layer**: It is the most visible and easiest part to access for users of the service. It is the superficial point of contact between the customer and the resources.

2.4.2. Technologies related with OPERATIONAL TECHNOLOGY (OT)

2.4.2.1. ADVANCED AUTOMATION (*AA*)

Automation, specifically in the field of industry is basically the use of *computerized/digital systems*, *electromechanical devices*, *control systems* and *IT solutions* in order to be used in industrial processes and thus improve their proper productivity (with respect to the processes developed manually).

Advanced automation covers a large area of engineering, including electronics, electrical and mechanical engineering and embrace technical solutions related to control systems, industrial instrumentation, measurement systems, sensing, data transmission, process supervision, information gathering, applications and monitoring in real time, among many more.

The concept of *advanced industrial automation* cannot be confused with the "*mechanization*" of processes, since the latter deals only with the inclusion of machinery (mechanical or electromechanical) that helps a worker to carry out a task (*process developed during the industrial revolution, where the invention and implementation of advances such as the internal combustion engine and electric power made the processes much more efficient, faster and cheaper, but almost always, those technologies had to be managed together with the help of human labor*), while an automated process is capable of **being developed by itself**, of **interacting with the environment** and learning from it (**self-learning**), of **interacting with operators** and **receiving orders** (**reconfiguring** with external help or by itself), **increasing the load capacity**, the **speed of work**, the ability to **standardize the products**, the **overall efficiency** of the process and thus dramatically **reduce costs**.

The fact of talking about advanced automation and its relationship with *industry 4.0* is difficult, since it covers a number of different technologies (*for more information see 2.6.1.2*) and branches, where the only thing they share is their desire to provide technological, practical and efficient solutions to a company that Include productive processes that need it.

The areas of application are equally broad to the technologies used in this field, being easily adaptable to the nature of the company, its processes and the products or services provided. I can differentiate the areas of application depending on the objective of its operation, identifying:

- Measurement, collection and data analysis
- Replacement of human in high-risk tasks
- Support in the transport of materials
- Increased efficiency in goods production
- Follow up of repetitive tasks
- Monitoring of the processes progress
- Faults identification

❖ **Advantages and disadvantages of Advanced Automation** [32]

Automatic processes benefit companies in aspects that cover the entire production process. By acquiring the ability to obtain reliable measurements of important indicators for the company, ensures both the **proper functioning of the machinery**, proper **compliance with production goals**, the **proper use of raw materials and energy resources** and **compliance with environmental, health and safety regulations** (*Good Manufacturing Practices*) that also ensure a **transparent operation of the company** in front of the business environment.

The fact of being able to use **collaborative robots** (*co-robot*) ensures a reliable support to the activity done by the human, and allows the replacement of people in activities that pose a risk for this, for example, activities with hazardous materials, high temperatures, chemical handling (exposure to toxic or very toxic agents, ionizing radiation), handling of large parts, manufacture, handling and use of explosives, work with compressed, liquefied or dissolved gases, jobs that produce high concentrations of siliceous dust or tasks with electrical risks. Being aware of these risks and managing them represents a competitive advantage for the company. Also, and as mentioned several times, can be an improvement in productivity, having robots with better production speed and a high degree of standardization standards.

The use of collaborative robots provides users with a high degree of flexibility through more intuitive and simplified means of re-programming themselves and its functions.

Automation encourages the improvement of the **consistency of processes and products**, eliminating many of the variables attributed to human error, also improving the quality of the result (*being able to carry out high-precision tasks for example*) and even the work environment.

It is important to mention that the use of robots not only requires the replacement of human labor (*which would lead to thinking about the reduction of jobs and thus damage to the population*), but the relocation of people in more consistent tasks with its capabilities, that is, provide the possibility for people to specialize and work on tasks where not only they have to perform a repetitive task, but to carry out analysis processes and execution of more important tasks, thus changing the company organizational structure.
The use of more accurate measurement tools allows to understand each process in depth and thus achieve the control in a more efficient way, identifying previously **unknown faults** and even managing to establish patterns of operation and thus do **preventive maintenance** to the machinery.

Some automated processes can have ***environmental advantages***, by **reducing energy expenditure** through the use of renewable energies, the **reduction of production cycles** and the **saving of the resource** in general (for example some robots are capable of developing tasks without the need for lighting, significant energy savings) and the **measured use of raw materials**.

In organizational terms, the use of advanced tools can **improve the productivity** of workers by assigning more challenging tasks, not repetitive and without so much physical expenditure, can generate an awareness regarding the saving of materials and energy and can encourage people to create products with better quality when they feel helped by a machine/tool.

❖ **Advanced Automation and *SMEs***

On the other hand, it is also important to mention that the acquisition of advanced automation systems is not easy for *SMEs* (*can be inappropriate to integrate capital-intensive robots into their small-scale manufacturing processes*), making these technologies broadly used on big companies with the sufficient capital capacity to do so.
According to the European Commission [30], the principal reasons for the lack of usage of *AA* on *SMEs* are:

- **Low capitalization** and difficult access to finance for *SMEs* in the current economic climate.
- **Lack of awareness of the benefits of robotics** and measurement technology solutions.
- **Low technical competence** outside core business.
- Low capability of *SMEs* for **long term investment**.

❖ **Advanced Automation Technologies**

Below will be shown some of the technologies that can be implemented in companies.

❖ **Collaborative Robots (*co-robots or CoBots*)**

According to the International Federation of Robots (*IFR*), an industrial robot is defined as "*an automatically controlled, reprogrammable, multipurpose* *manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications*" [33].

On the other hand, it is necessary to notice the difference between a traditional robot and a collaborative robot. A *Cobot* or *co-Robot* is one that is designed to support or help a human being in the development of a specific task, which is generally repetitive but has a high degree of accuracy and precision; On the other hand, a traditional robot is generally focused on performing a task without being aware of what happens in its environment and lacking interaction with other entities.

The function of a *Cobot* is based on three essential tasks: **SENSE**, **THINK** & **ACT**. The *Cobots* should be able to feel (*SENSE*) external stimuli (*which vary according to the nature of the robot and the task developed*); these external stimuli have to be converted (*THINK*) to digital signals (*capable of being interpreted by a machine*) and by means of algorithms, they are analyzed. From this analysis, the machine is able to make (*ACT*) coherent decisions (or select between preprogrammed actions) and translate them back to analog signals by means of actuator devices such as mechanical arms, motors, presses etc.

Nowadays, the *Cobots* are capable to be more sensitive to a bigger variety of stimuli and even work together with people in the same space (without having any risk of injury), making them more powerful and helpful for the human; for example, some of them are capable to identify colors, textures, materials, densities and even positions and then work even in difficult and confusing environments.

- **Measurement Technologies**

A measurement provides information about a dynamic variable(s) in the process which is to be controlled [33].

As already mentioned in previous sections, one of the most outstanding functions in industrial automation is taking measurements efficiently and accurately. Those measurements can be of several types, including **measurements of ENVIRONMENTAL TYPE**, which would allow the company to comply with all the standards that most countries require, also allowing them (*in some cases*) to obtain discounts in the payment of taxes and access to government type benefits. By achieving a good management of natural resources, efficiency in the use of energy and materials, it would also allow the company to have a good image in the industry in which it operates, being an important competitive advantage when negotiating and competing with other companies.

The **OPERATIONAL TYPE MEASURES** allow maintaining an order and control over the production process in general and thus ensure a product of excellent quality and homogeneity. They also allow the development of efficient testing systems, based on the weak points of the process and the product (*previously identified by the same monitoring system*), thus establishing a kind of loop in which the system self-configures and/or self-regulates in function of the measurements taken by the *sensing system*, allowing it to have an optimal performance when passing each "*iteration*". These measures can be for a variety of things like pressure, position, direction, temperature, flow, speed, etc.

Drones [34]

The *unmanned aerial vehicle* (*UAV*) or so-called "*drones*" are aircraft that do not need human presence pilotage, that is, they are managed entirely by a remote control from a remote location or they can follow a scheduled flight plan (called autonomous flight drones) ; they are capable of autonomously maintaining a controlled and sustained flight level, and propelled by an electric, explosion or reaction engine.

The use of drones is widely used these days for different uses, from *police inspections*, *security*, *rescue of people*, *identification of fugitives* and *taking pictures and videos*.

In the industrial field, drones allow to **reach sites that are difficult to reach by humans** and to be **able to control parameters** that before could not be controlled; for example, a drone is able to *access and review components of a machine* located at a commensurate height, *inspect turbines and engines*, *review the inventory of products in a warehouse* without the need to raise a machine to a high point, *review electrical lines*, *movement of materials, location of workers*, *track the status of a production* or a *purchase and transport of small size elements*.

In industries like oil & gas, drones allow to monitor data in real time and thus increase the efficiency in extraction and production. It would also allow to follow meteorological and environmental variables that could influence the productive processes (*for example in the case that a chemical element that requires a specific temperature or humidity is used*).

Automated Guided Vehicles (*AGVs*)

The *Automatic guided vehicle* or *AGV* [35], are automatic transport (also are capable to store small quantities of materials over them) systems for small or medium distances (especially of materials), whose use is given especially in warehouses where the internal transportation of parts and the precision of their selection must be very high, or where the quantity and variety of pieces is considerably important (*think about Amazon warehouse*). On industry, *AGVs* are typically used on the raw material handling, movement of finished products, removing scraps and cleaning workplaces and transporting of supplies.

AGVs are able to follow their route by identifying external patterns, such as a line on the floor, magnets (*Automated Guided Carts - AGCs*), lights, lasers (*Laser *guided vehicle - LGVs*), figures and even use a gyroscope and follow them depending on an algorithm configured previously.

These systems are easily **expandable and scalable** according to the needs and are characterized by **great efficiency and versatility**, with the aim of optimizing internal logistics and **reducing pallet transport costs**.

Its main advantages (not having human assistance) are:

- Lack of risks of accidents due to human errors (*injuries, human and material falls, crashes*)
- Ability to fit in limited areas and work on them.
- Work several machines in the same aisle without interrupting the work of the other.
- Possibility of working 24/7 without human intervention
- There is no need for infrastructure to handle materials
- If there is an increase in the volume of activities, the amount of AGVs can also be increased linearly (expandable and scalable)
- Easy reconfiguration of routes or insertion of new machines to serve
- Low maintenance costs

2.4.2.2. ADDITIVE MANUFACTURING (AM) [36]

The *additive manufacturing* (*AM*) or *additive production* is a process in which basically materials of different types are joined (*especially plastics and metals*) with the aim of **produce objects with the guide or based on computer 3d models**. Also called "*3D printing*", the AM melts or transforms the material, recomposing it in layers and forming a piece. Other terms are also used synonymously, such as Rapid Prototyping, Direct Digital Manufacturing or 3D Manufacturing, even if they often refer to slightly different uses of these technologies.

Being a different process compared with the *subtractive manufacturing* (*in which there is a block of material and from this, pieces are extracted to form an element, as would be done when doing a sculpture*), machining or injection molding, the additive manufacturing allows the creation of figures with exuberant, organic or complex forms, that include internal channels and structures type panel, that are possible to realize and sustain when having a single piece and not a composition of pieces produced by parts.

Additive manufacturing as a production option is still at an early stage. The number of users and applications is increasing, but it is still small. Over time the machinery for additive manufacturing will be faster and the processing of various materials will be understood more thoroughly. The implementation of additive manufacturing systems helped to change the mindset of the designers and producers in the companies, by opening the possibility to create elements of a single piece with forms that previously was very difficult to create, also saving money in their production.

❖ Advantages of the Additive Manufacturing

By not having the need to use a mold, the changes that need to be made, can be made quickly, *without the need to invest a lot of money in the productive* details, but only in the computer 3d models. This also allows the design of pieces in a **very short period of time**, the **production of several variety** of elements and the **testing of new products in a more efficient way**. One important benefit is that each unit developed costs the same, making it really accessible to produce one or more units.

The main benefits of the use of these technologies are summarized:

- Production of functional parts in a single stage
- Production of one-piece elements
- Ease to produce on batches
- It is possible to offer massive personalization
- It is possible to achieve non-common geometries.

Additive manufacturing technologies not only includes the use of plastics and metals with 3d printers; The latest advances have allowed the creation of new manufacturing methods, even with materials such as ceramics.

- **Photopolimerization** [37]

Photopolymerization or *VAT photopolymerization* is the oldest 3D printing technology (additive manufacturing) that exists. It basically focuses on the deposition of a liquid in a cuvette which is selectively exposed to an ultraviolet light; the rays of light draw a pattern on the surface of the liquid layer by layer, hardening it and thus building the desired shape.
This method supposes a high level of precision and complexity in the manufactured pieces and allows to have results with a firm and soft touch (*as if they had been polished*).

Once the printing is completed, the piece is immersed in a chemical bath to remove the excess resin and then cured in an ultraviolet light oven.

- **Powder Bed Fusion (*PBF*)**

This method uses various forms of *titanium powder* and *cobalt chromium* as a raw material for manufacturing for a final use. It is based on the application of a thermal energy source to melt certain parts of a powder layer of material, until the complete piece is formed layer by layer. The non-molten powder surrounding the consolidated part acts as a support material for additional features.

There are several sub-methods, among which are: EBM (*Electron Beam Melting*), SLS (*Selective Laser Sintering*), SHS (*Selective Heat Sintering*), SLM (*Selective Laser Melting*), especially used with metals, and DMLS (*Direct Metal Laser* Sintering).

- **Binder jetting** [38]

It is a very versatile 3D printing technology that allows printing in a wide variety of colors thanks to its use of a colored binder.

The process consists mainly in the pulverization of a liquid binder on a bed of powder that then solidifies in cross section; the process is very similar to the Powder Bed Fusion (PBF), with the difference that a liquid is applied on the powder that favors its solidification, while in the PBF a beam of laser light was applied. The materials that solidify thanks to the binder are usually plaster, sand, ceramic and very recently plastic powders.

One of the great attractions of this technique is that it allows printing in various colors and the result does not need much later work, since with compressed air the excess dust is eliminated and if you want to strengthen the model you can apply a layer of lacquer.

- **Material Jetting** [39]

This process is based on the *injection or application of melted material, drop by drop until layer by layer the form is generated*. Common variations include photo-curable resins and UV curing, as well as jets of molten materials that then solidify at room temperature.
The material jetting process uses polymers and plastics.

The main *advantages* of this process include the possibility of **using for multiple material parts and colors under one process**, a **high level of precision** and even the **use of different materials in one piece**. As *disadvantages*, it can be said that there is a limited number of materials (*polymers*) to be used and that it is absolutely necessary to have a base, then, increasing costs.

❖ **Sheet lamination** [40]

Sheet lamination is a technology that is simple in comparison with the others discussed above; it does not need complicated chemical materials or processes. It is based on the stacking (*and bonding*) of sheets of some material (*can be paper, plastic, wood or metal*) one on the other. Each sheet was previously cut (*with a cutter or laser cutter*) in such a way that when they are joined together they all result in an object in three dimensions. The residues or imperfections of each of the layers can be eliminated after the product has been fully assembled.

Because sheet lamination technology does not involve any chemical reaction or high temperatures, it does not require a closed or vacuum chamber, making it easier to build large models. The materials used are also low cost, consistent and easily available. It also allows creating the piece with cables or integrated electronics and the use of different materials in the same piece.

The main disadvantage of this process is the inability to create pieces with a considerable level of precision or with very specific geometries, since it is a slightly more rudimentary process.

❖ **Extrusion of material** [41]

This process is by far the most widespread at this time, since it allows creating models in a simple and economical way and it does not take more than a "*3d printer*", which at this moment can be obtained at not so high prices.

A roll of *thermoplastic filaments* and *pellets* (*FFF*), is heated and melted and is applied by means of a nozzle moved by a mechanical arm, thus building the model layer by layer; in some way the results depends on the quality of the material and the pressure that the nozzle does over it. This technology **allows the use of different colors** and the **creation of models of different sizes** (*exist a 3d printer created at the University of the Andes, in Bogotá (Colombia) that is capable of creating pieces of millimetric dimensions*).

- **Direct Energy Deposition (*DED*)** [42]

In this 3D printing process, metal powder is injected directly into a focused beam of high-power laser under atmospheric controlled conditions. The focused laser beam fuses the surface of the target material and generates a small pool of molten material base. The powder injected in this same place is absorbed in the fusion bath, thus generating a deposit of material. The resulting deposits can then be used to build or repair metal parts for a variety of different applications. This process is essentially a form of welding.

2.4.2.3. ADVANCED HUMAN-MACHINE INTERFACE [43] (*HMI*)

As the name implies, the *Advanced Human-Machine interface* or *HMI* basically deals with the **exchange of information through software between people and "*computers*"**, or machines in general. It focuses on the *design, evaluation and implementation of computer systems* that are able to **identify external signals** and **act in accordance with them** with the aim of becoming a tool for the human being. In this case, these tools supply industrial and productive needs.

Cannot be seen only as the set of tools that make up the interfaces of the machines, but the total *management of the system*, including *external hardware*, *mobile parts* and *software*, and even the *feedback that the machine itself can give*, such as fault recognition or anomalies in the functioning and prompt assistance to these problems.

The *human-machine interfaces* focus on two important pillars:

- **Behavior of the person:** Is studied the way in which the human being does or does not use artifacts, systems and computational infrastructures, their motivations and their needs with respect to these.

- **Behavior of the machine:** It deals with the characteristics of the interfaces of the machines, their ease, usability, errors and restrictions, and how this influences the use and general behavior of the system and the user.

In this case, the role of the *HMI* is to make humans understand what is expected of them in terms of monitoring and active intervention of the machines, establishing and showing the **limits of both people and computers**.

Basically, it is treated a way to *interlace or integrate the real world with the digital world*, seeking above all the *facilitation of tasks for human beings*, increase satisfaction, decrease frustration and minimize errors in the development of tasks, making more productive the development of activities.

❖ **Challenges of HDI systems**

According to *Klein* [44] (*2004*), can be named 10 challenges or objectives at the moment of establishing a HMI system. Those challenges guide the automation components and humans into effective "*team players*".

An effective team work between *Human-Machine* must be based in the assurance that both players:

- **Mutual Commitment:** Agree to "*work*" *together for the same purpose.*

- **Mutually Predictability:** When an activity has to be carried out in the best way, both parties must be able to *identify the behavior of the other* and in a certain way *predict* their possible actions, thus forming a coordinated performance.

- **Directability:** Both parties must have the ability and willingness to change their behavior when is necessary, that is, identify the latent need of the system, be able to receive instructions and act according to that.

- **Common ground:** In order for a process to be done in the most efficient way, both parties *have to be tuned into the same actions*; that is, both the operator and the machine have to *be able to identify the same signs, have the same language (or at least a common language) and in general have a common form of communication*. A clear example of a lack of "*common ground*" would be the fact of an Italian operator operating a machine or reading instructions in Arabic (it is assumed that the person does not have any knowledge of this language), where the flow of information goes from right to left and the letters and even the numbers are incomprehensible for him/her. Another clear example would be the case in which for the machine, a warning of danger is displayed as a blue color light, while for the operator danger is a red light, in this case the person will not be able to identify the feedback that the system is giving and surely the process will not be finally carried out in the best way.

Following the stipulations of Klein, the challenges to build a team, making specific emphasis in the relation Human-Agent (*the concept of "agent" is explained in the next numerals*) are the following:

- **Challenge #1 - A BASIC COMPACT**

Have to be established an entity (*called an **agent***) capable of *monitoring the process* and the behavior of the parties, able to establish the levels and rules of communication between them and to identify faults in the case that happen. It also has the power to decide if an actor is unable or unwilling to continue participating into the process.

- **Challenge #2 - ADEQUATE MODELS:** *Intelligent agents must be able to adequately model the other participants' intentions and actions.*

The agent mentioned in *Challenge #1* must also be able to understand and model the behavior of the other party (*and their own*), their directions and intentions, so that he/she can have some control over the operation and is able to make decisions in the way.

It is important to mention the *relationship and cooperation between agents and the human workforce*, since there has to be a very special communication channel so that the entire production process together with the machine is carried out in the best way.

There is also the *cooperation between agents*, where two or more agents are part of the production monitoring and they share responsibilities regarding the solution of problems. The agents can be directed towards the same objective, but they see this objective from different points of view (for example, in a paper production plant, the agents can be chemical engineers who are aware of the use of material and the manipulation of raw materials and their reactions, mechanical engineers that deal with the proper and efficient management of machines and industrial engineers or Managers who are interested in the efficient management of resources from the monetary point of view).

- **Challenge #3 - PREDICTABILITY:** *Human-agent team members must be mutually predictable.*

The agent has to be able to *predict the behavior of the actors* and also has to follow a predictable performance model for anyone who wants to be involved in the process. Have to be avoided *capricious and unobservable ways of acting* and all actions from any point of view have to be *absolutely observable*.

With respect to this challenge there are several obstacles mainly related to the fact that, when an entity feels very attached to the behavior of the other entity, its behavior can be affected and take unpredictable patterns (*when using shortcuts or simpler ways of doing some process*, for example).

- **Challenge #4 - DIRECTABILITY:** *Agents must be directable.*

A policy system has to be created and implemented which guides and regulates the behavior of all the actors in the process and it is necessary to ensure that they are in agreement and are willing to follow these rules. The implementation of these rules makes it easier to carry out challenge #3 and #2.

- **Challenge #5 - REVEALING STATUS AND INTENTIONS:** *Agents must be able to make relevant aspects of their status and intentions obvious to their teammates.*

It is crucial (*when designing an automatic system*) that the processes and decisions that it takes are *fully visible and understandable to the person in charge*. It is very common that, when a system is very autonomous, operators do not even understand what is happening, so, when a problem or some fault occurs, people will feel very confused and without a basis to make a viable decision. For this reason, it is so important to establish methods and means to show/reveal the states and intentions of the actors when a productive action is being carried out.

- **Challenge #6 - INTERPRETING SIGNALS:** *Agents must be able to observe and interpret pertinent signals of status and intentions.*

The asymmetry in the knowledge about the other(s) (*their possibilities and knowledge*) between a machine, the human and the agents, is a point against the functioning of the system in general. The interpretation of the signals that the other actor is sending is a key point at the moment when the analysis and creation of models and the prediction of the behavior of the other must be carried out (*look for the previous challenges*). This process is especially important when analyzing the relationship between the agent and the operator, being both humans, the probability of receiving erroneous signals and failures in its interpretation is very high, because it depends on a several number of factors related to the human nature.

- **Challenge #7 - GOAL NEGOTIATION:** *Agents must be able to engage in goal negotiation.*

When situations change, team members have to adapt their behaviors to match with it. In this case, the agents have to have a *negotiating role* with the other actors, where they have to be made aware of the new needs and the new challenges they will have to face, and of course, the parameters to be able to work as a team, together with the machines and the other agents involved.

- **Challenge #8 - COLLABORATION:** *Support technologies for planning and autonomy must enable a collaborative approach.*

With the objective to fulfill with the previous challenges, it is necessary to achieve an interaction and collaboration between humans and agents, human and human and agent-agent, and their relationships with the machines.
As explained above, by achieving a collaboration between the participants, it is possible to have a general (*current*) image of the production and be able to have a *future image* of the possible facts too, detect failures and have the ability to solve them in the shortest possible time, be able to decide when an agent, a machine or an operator are not able to develop a certain task and communicate it and then be able to say when the communication protocols between any of the parties is failing (for example, identifying when an operator is not capable to understand the interface of a machine, when the machine and the operator are not able to "*speak*" in the same language, when a group of operators does not agree to operate a system or when there is a failure in general production, involving to the agents).

- **Challenge #9 - ATTENTION MANAGEMENT:** *Agents must be able to participate in managing attention.*

This challenge is related to the timing in which communications are developed among all team members. Both humans, agents and machines have to be able to both identify and communicate any failure at the right time and thus, allow others to make proper decisions and act according to this.

This challenge represents a big problem from the technological point of view, since it is very difficult to create a system so intelligent capable to establish a communication as fluid as humans do. This challenge involves others, in the sense that it is necessary to have actors that collaborates with each other and able to understand each other and predict their behavior in order to be able to create fluid communication channels.

- **Challenge #10 - COST CONTROL:** *All team members must help control the costs of coordinated activity.*

Meeting all the challenges, that is, establishing effective communication channels, coordination between all the parties, protocols and standards for the proper functioning of the equipment, involves of course, an economic investment, where the highest percentage is taken by the design and implementation of a good *machine-human interface*. Being a production system, costs play a fundamental role and therefore it is mandatory for all actors to make their best effort in the search for the *reduction of these costs* and thus the *increase of the total profit of the industrial system* and the company.

3. DIGITAL INNOVATION ON SMEs' PANORAMA

In order to establish or identify a path about the relationships between *SMEs'* and the digital innovation, it's important to show an extensive state of art and success cases of those types of enterprises at Italian and worldwide level.

This section will show how the public and private institutions foster the adoption of new technologies on production processes and will be analyzed some successful cases taking into account that Industry 4.0 is not willing to creating new industries, the greatest digital opportunity lies in the transformation of existing industry and enterprises.

Before starting to talk about the specific initiatives around this topic, is crucial to define: what is a Small and Medium enterprise and how the differences between this definitions changes in the different continents; this information will allow to understand and analyze the specific impact and coverage of each initiative and establish a point of comparison between them.

3.1. SME DEFINITION

Giving a right definition for the "*SMEs*" is really important because it leads the national and private entities to address efforts and resources into the supporting of their growing.

Encouraging the birth, development and growth of *SME* is a key point in the development and empowering of the economy of several countries; in the EU there are more than 23 millions of them, creating more than 75 million jobs (two out of every three private sector jobs) and contributing to more than half of the total added value created by businesses in the EU [45].

The *European Commission* defines five priority areas in which the nations must be focusing in order to encourage the *SME*'s growing: *Promotion of* *entrepreneurship and skills*, *improvement* of *SMEs*' access to markets, improvement of SMEs' *growth potential*, and the *strengthening dialogue* and consultation with SME stakeholders [2]. These actions would lead into the "*fostering of competitiveness and employment*" (*Günter Verheugen, Member of the EC responsible for Enterprise and Industry*) in the whole economic panorama either in Europe or worldwide.

3.1.1. European Panorama

According to the Commission Recommendation of 6 May 2003 [46] (published by the European Union), "the group of "*SME*" is composed by those which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million" [4]. Specifically:

- **Small enterprises:** Fewer than 50 persons, annual turnover not exceeding EUR 10 million.
- **Medium Enterprises:** Fewer than 250 persons, annual turnover not exceeding EUR 50 million.

It's important to highlight that this definition is just approved and adopted in the European area, presenting several changes in other geographical areas.

3.1.2. American Panorama

The situation on America, especially on *South America* is quite different than European one, so it's imperative to establish the main differences in order to arrive into a valuable comparison between the *I4.0* programs. The concept of SMEs in Central and South America varies according to the European concept due to differences in the *level of industrialization* of countries and *monetary exchanges*.

According to the Ministry of Commerce, Industry and Tourism of Colombia (*Ministerio de Comercio, Industria y Turismo de Colombia* [47]:

- **Small enterprises:** Fewer than 50 persons, annual turnover between EUR 0,2 million and EUR 1,2 million.
- **Medium Enterprises:** Fewer than 200 persons, annual turnover between EUR 1,2 million and EUR 7 million.

The minimum wage in Colombia is *COP781.242* [48] (around *EUR 227*) while the minimum wage in Europe goes from *EUR 858,6* in Spain to *EUR 1.498,5* in Germany (difference between 387%-660%).

3.1.3. Asian Panorama

As have been said before, the definition of SME changes depending of the region (continent) and even of the country that is studied. In this case, the definition of *SME* in Asia has multiple meanings taking into account the diversity of economies that Asia has.

According to the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) [49]:

- **Small enterprises:** Fewer than 50 persons, annual turnover between EUR 0,05 million and EUR 0,25 million.
- **Medium Enterprises:** Fewer than 200 persons, annual turnover between EUR 0,25 million and EUR 0,5 million.

In the Asia-Pacific region *SMEs* comprise more than 98% of the number of enterprises. These companies contribute around 17% to the national GDP in the low-income countries (*Bangladesh, Cambodia, Indonesia, Laos, Mongolia, Myanmar, Pakistan, Philippines, Sri Lanka and Vietnam* [50]) including India to about 40 to 50% in the higher income countries like Malaysia and Singapore. SMEs generates the largest number of employment opportunities, second only to agriculture employing more than 50% of the workforce.

Giving a shallow information about the relation between *SME* and the industrialization processes, have to be highlighted that the companies suffer of a *limited access to venture and growth capital* the existence of *cash flow shortages* from long payment cycles and disproportionate barriers in allowing accessing to finance when comparing themselves with larger firms difficult the development of innovative technological implementations [51].

3.1.4. Oceania Panorama

SMEs are a very significant force in the Australian economy. They are important to the economy as they provide employment to a large portion of the Australian workforce, facilitate innovation and entrepreneurship, as well as provide a road for offering specialized and niche products and services to the market [52]. According to the *Journal of Management and Organizations*, the *longitudinal survey of Australian small business* found that *SMEs* constitute 6.1% of all businesses in Australia, and together employ 27.7% of the country workforce [53].

As well as the other continents/regions, the concept of SME changes; in this case was taken the definition on Australia, where the concept and the values of annual turnover of the companies is the biggest one in all the countries observed:

- **Small enterprises:** Fewer than 100 persons, annual turnover not exceeding EUR 15,7 million.
- **Medium Enterprises:** Fewer than 200 persons, annual turnover not exceeding EUR 50 million.

3.2. SME DIGITIZATION PANORAMA [54]

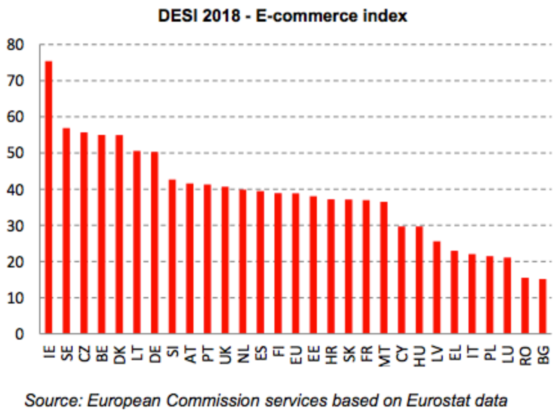
Before speaking specifically about the industries and technologies 4.0, it is very important to show a panorama or state of the art about the way companies are digitizing their processes, their motivations and possible shortcomings so far.

According to the "*European Economy and Society Index about Integration of Digital Technologies Report 2018*" of the European Commission, trends in technological innovation are focused on the digitization of internal processes (*e-Business*) and the massive inclusion of electronic commerce (*e-Commerce*).

The digitization includes: Exchange of information by electronic means, identification of elements by radiofrequency (*RFID*), use of social networks, issuance of electronic invoices and solutions in the cloud. On the other hand, e-Commerce refers to the use of electronic platforms for the marketing and sale of products; In this field, there are two types of e-Commerce: web sales (where the person simply enters a website and buys a product) and EDI-type sales (where an automatic exchange of information is made between machines, based on pre-established commands, making shopping processes much simpler and faster).

The digital transformation of European companies is driven by fast broadband connections, social networks and mobile applications.

Taking a broad view of the state of implementation of this type of projects in Europe (*data from 2018*), only a fifth of the companies in the *European Union* have a high degree of digitization; presenting different situations depending on the country: while 40% of the companies in Denmark and the Netherlands are highly digitized, in Bulgaria and Romania it is 1 in 10.



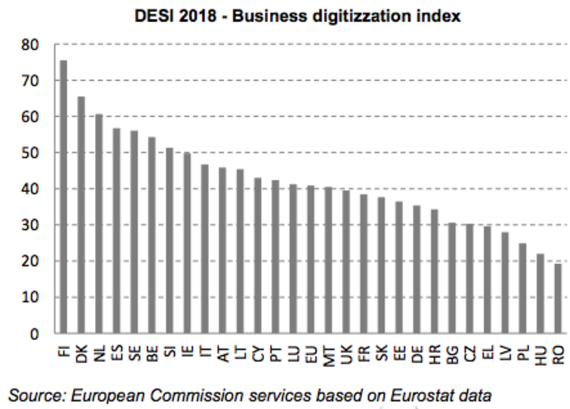


Image 6. *Levels of diffusion of the e-commerce and the digitization of the businesses in Europe through the e-commerce index and the Business Digitization index, created by the European Commision services.* ***Source:*** *European Economy and Society Index about Integration of Digital Technologies Report 2018.*

According to the information provided by the *European Commission services* (*based on Eurostat data*), *e-Business* initiatives are more widespread than *e-Commerce*, being Finland, Denmark and the Netherlands the leaders in this field, placing Italy in the ninth position (of a total of 29 countries compared). According to the business digitization index, more than half of the companies in Belgium have implemented an electronic information exchange system (54%), while the adoption of RFID technologies in Bulgaria is more than double (9.2%) of the EU average. On the other hand, 42.4% of companies in the United Kingdom actively use social networks, while 31.7% of Spanish companies use electronic invoices and have rejected the use of paper in all their processes. Cloud services are adopted by almost half of the companies in Finland (48.4%). On the other hand, observing the e-Commerce index, the percentage of companies that make e-sales (web or EDI) varies from 8% in Romania to 33% in Ireland and Sweden (31%), being the most common to have simply a website where the products are announced. It is not yet common to have EDI protocols in European SMEs.

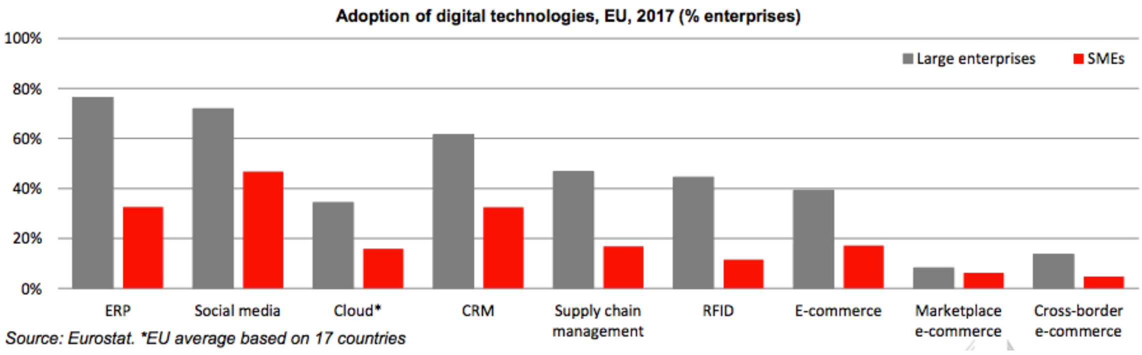


Image 7. *Percentage of adoption of digital technologies on the European Union on 2017 making the comparison between SMEs and Large Enterprises.* ***Source:*** *European Economy and Society Index about Integration of Digital Technologies Report 2018.*

Companies that manage to implement electronic commerce, manage to exploit economies of scale, thereby reducing costs, increasing efficiency in the distribution chain and promoting competitiveness, greatly improving the market in general. In many cases, without these economies of scale, an online business may not be viable at all. This could be especially significant for SMEs that remain confined to a small domestic market with high production costs.

Unfortunately, in countries such as Bulgaria, Romania, Latvia, Greece, Hungary, France and Italy, more than half of the companies have not yet made conclusive plans of investment in digital technologies (generally the only resources they have are a single site). simple web and computers, but do not have access to automated machinery, remote data storage or digital processes without paper). Deepening a bit in this field, less than 50% of these firms make use of social networks, less than 40% have high speed internet connections (>30Mb/s) or *Customer Relationship Management Software* (*CRM*) and less than 10% has exploited B2C commerce electronically.

These data shown are found by sweeping the entire European market. Taking into account the different markets, it is true that there are sectors where digitization is more widespread as in the computer and multimedia sector (between 50% and 70% of its companies). On the other hand, returning to the issue of manufacturing SMEs, only 10% to 40% are digitized, with the digital and electronic manufacturing sector being the most digitized and the least digitized metal and textile manufacturing sector. Later on, you will notice that most of the companies analyzed (in the case studies) are companies that work in the metal-mechanic industry.

3.3. SME & INDUSTRY 4.0

3.3.1. Industry 4.0 existing policies

3.3.1.1. EUROPE

According to the "*Key lessons from national industry 4.0 policy initiatives manual*" [55] (*European Commission, 2017*) diverse policies are slowly launched in European countries, encouraged by facts as: the climate change, scarcity of resources, demographic developments, problems in developing competitive digital industries, low share of employment on the manufacturing sector, need of foster a national industrialization framework and gain competitive advantage. All those factors are summarized on the aim of strengthening the respective country's industrial competitiveness, modernization and ensuring in a better way the sustainable growth on the manufacturing sector.
Each country has its own specific objectives (see *Image 7*).

The majority of the national *Industry 4.0* European policies shown (in the next section) are primarily financed through public means, with a private development scope, and their principal objectives are mostly related with the improvement of the infrastructure and technology applications, and just some of them takes into account the development of personal and working skills (related with the use and optimization of technologies applied yet).

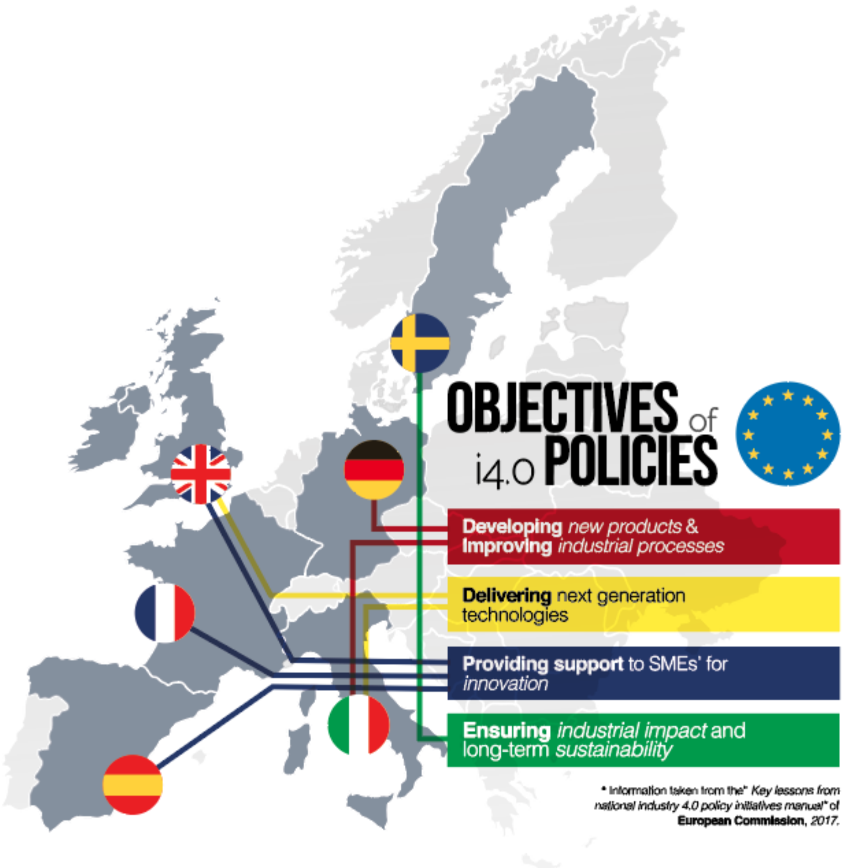


Image 8. Objectives of the specific i4.0 policies in Europe. ***Source:*** *Own Development. Information taken from the "Key lessons from National industry 4.0 policy initiative manual" of the European Commission, 2017.*

3.3.1.1.1. *Germany* – PLATTFORM INDUSTRIE 4.0 (*de*)

Plattform Industrie 4.0 is a public (cooperation of the Federal Government with *BITKOM*, *ZVEI* and *VDMA* companies) German policy started in 2013. Its principal scope is to push the implementation of Industry 4.0 technologies, bundle the expertise in relation and make these technologies available to German companies, especially *SMEs* [56].

The project started on 2011 with the "*Zukunftsprojekt*" (Future-Project) of the Federal Government in the action plan for "*Hightech-Strategie 2020*" plan; then after, with the cooperation of the mentioned companies was officially launched, and in 2015 the platform was expanded adding several actors, being totally composed by: *business representatives*, *technical experts*, *industry associations*, *trade unions* and *representatives from politics*.

Image 9. *Map of the different i4.0 initiatives and project on Europe.* ***Source:*** *Own Development.*

The platform principal activity is based on the **identification of trends**, developments and uses of new technologies on the sector and attempt to support them in relation with the industry. So, the *PI40* doesn't create by itself any activity, standardization or norms, security of networked systems, legal frameworks, researches, nor working arrangements, but recognizes and boosts them [57].

The PI40 has invested €200M presenting results as: *reducing industry segregation*, *transforming research agenda into practice*, *developing reference architecture* and *launching of platform* with 150 members[7]. The application of this policies for more than 4 years has allowed to involucrate/engage SMEs' by providing targeted funding instruments, testbeds and specialized support into their transformation (against the unfamiliarity with these novelties).

3.3.1.1.2. *Sweden* – **PRODUKTION 2030**

PRODUKTION 2030 is a program supported by the *Swedish Energy Agency and Formas* "*VINNOVA*" established in 2013 as an instrument to achieve the goals of the *Sweden Agenda 2030*, presented on 2012. Their principal goal is to work to keep Sweden as an *innovative and competitive* country (in terms of industry). They aim to identify and apply innovations, most of them product of the research, networks and cooperation between actors in the industry.

P2030 is based on the pillar of the Swedish economy: the manufacturing industry ("*Sweden has more global manufacturing companies per capita than any other country in the world*" [58]). Is focused on 6 main areas:

- Resource-efficient production
- Flexible production
- Virtual production
- People in the production system
- Circular production systems and maintenance
- Integrated product and production development

According to the *Digital Transformation Monitor Report* (*European Commission*, 2017), *P2030* entails "the modernization of Sweden's industry base, to make it the primary choice for sustainable production and customized, high-end industrial services, upskill the workforce and facilitate investments in production R&D". It relies into a Bottom-Up approach, where the projects are developed by the main stakeholders with funds coming from VINNOVA and industry co-financing.

3.3.1.1.3. *France* – **ALLIANCE POUR L'INDUSTRIE DU FUTUR**

Created and launched on 2015 as one instrument to raise e new industrial policy of France "*La Nouvelle France Industrielle"* [59], "*AIF*", aims to "support French companies (around 3400 *SMEs*' and mid-market companies) into the modernization of their industrial tools and the transformation of their business model by new technologies" [60]. Is composed by several actors: *academic organizations*, *technology research organizations*, *professional organizations* and *corporate finance organizations.*

Similar to *P203*, *AIF* works into seven working groups:

- Development of the technological offer to the future
- Regional deployment to businesses
- Man and industry of the future
- International standardization
- Promotion of the existing technological offer
- Industry as the window of the future

and 9 "*industrial solutions*" related with specific challenges:

- Data economy
- Smart objects
- Digital trust
- Smart food production
- New resources
- Sustainable cities
- Eco-mobility
- Medicine of the future
- Transport of tomorrow

According to *Larosse* [11], the priorities of *AIF* are based on the launch of a protocol for accompaniment of SMEs by reinforcing the coordination of/with regional programs, developing '*testbed'* platforms that allows companies to test innovative products or new advanced production technologies, the improvement of the integration of start-ups in the *Industrie du Futur' programme*, and the increasing of efforts on training.

3.3.1.1.4. *Netherlands* – **DUTCH SMART INDUSTRY**

Smart Industry ("*SI*") for developing a digital and innovative technology pathway for the country industries was launched on 2013 and is composed by a complete group of Dutch industries, universities, research institutes and policy makers.

The program is based on 3 approaches [61]:

- *Take advantage (look for possible alternatives and opportunities) of existing knowledge*: By fostering the cooperation between target SMEs'.
- *Exploiting the possibilities and opportunities of R&D and factoring ecosystems (FieldLabs), like specialized developing laboratories:* By launching pilot *FieldLabs* (10 in total) [13] and stimulating the knowledge spillovers.
- Strengthen and empower Dutch enterprises, with investments on technological existing advances and former worker trainings.

The project was funded by Dutch government, European Region funds and private financing *[62].*

3.3.1.1.5. *Spain* – **INDUSTRIA CONECTADA 4.0**

The initiative "*Industria Conectada 4.0*" (Connected Industry 4.0) have been launched with the aim of increasing the contribution of the industrial sector in *GDP* (*Gross Domestic Product*), employment by boosting the digital transformation of the *Spanish industry* giving loans to industrial enterprises and through mentoring programs that guides the implementation of the I4.0 [63] focusing on enterprises with industrial activity, in particular SMEs and micro-enterprises [64].

The program is circumscribed in the "*Agenda para el Fortalecimiento del Sector Industrial en España*" (Agenda for the Strengthening of the Industrial Sector in Spain) 2014 and is aligned with the Digital Agenda for Spain (2012-2013).

The project has four strategic areas of action:

- *Guarantee the knowledge and development of I4.0 competences*: through academic and labor training.
- *Encourage multidisciplinary collaboration:* creating collaborative environments.
- *Promote the development of an offer of enablers:* Promoting the development of digital enablers and supporting companies with a focus on technological production.
- *Promote the implementation of I4.0:* establishing a regulatory framework and standardization of procedures.

3.3.1.1.6. *United Kingdom* – **HVM CATAPULT**

The *High Value Manufacturing Catapult* (*HVM*) is the British strategic initiative that aims to be the *catalyst for the growth* and success of manufacturing in the country through the revitalization of the manufacturing industry already implemented. The HVM Catapult's network consists of seven technology and innovation centers (located on Strathclyde, Rotherham, Wilton, Sedgefield, Darlington, Coventry and Bristol [18]) with over *£200 millions* of government investment [65].

The *HVM* enables *UK* to address market needs in specific areas making the country more competitive on the global stage giving scientists, engineers and entrepreneurs access to a set of expertise, experience and knowledge together with the academia, researchers, industry and government [17], this is translated into the access to full scale leading edge manufacturing equipment, world-class expertise and an environment of collaboration between companies.

It's very important to highlight that this program allows the *SMEs* (and also large companies) to establish bounds, partnerships and built networks between them, reducing significantly the risk on investment and fostering the generation of initiatives. The work done by the HVM is focused on leaning *SMEs* in escaping the "*Valley of Death*", it is the name given to the transition between early stage research and commercial application [66].

3.3.1.1.7. *Czech Republic* – **PRŮMYSL 4.0**

The *PRŮMYSL 4.0* Initiative is prepared by the *Ministry of Industry and Trade* of Czech Republic with target audience to policy makers, private sector, R&D organizations, industry associations and academia. Aims to capture the impulses that the new industry trends are imposing through the integration and interconnection of several technologies considering their sustained and rapid development. The subsidies given varies from 25 to 45% depending on the size of the applicant (even when the program has no still a clear private financing model) and the program has not presented results yet because it is still in an early phase [67].

The aim is to *prepare conditions* for the industrial production and non-production sphere for the realization of the new industrial revolution in the *Czech Republic* focusing into the applied research and standardization measures, cyber security issues, logistics and legislation of the topic, putting special effort to "*Internet of Things*" and "*Robotic Automation*" [68].

The principal work done inside the program is related to the creation of a flexible education system, adapting the labor market and regulatory framework and fostering the innovation [20]. The main objectives are:

- Enhance the ability of Czech companies to participate in global supply chains
- Increase the efficiency into manufacturing industry
- Foster cooperation between R&D and industries.

3.3.1.1.8. *Austria* – (*Österreich*) **PLATTFORM INDUSTRIE 4.0**

The Platform for Smart Production (*Plattform Industrie 4.0: Österreich*) started in 2014 from the initiative of the Austrian Ministry of Transport, Innovation and Technology with the aim to *foster the collaboration between stakeholders* and *facilitate technological developments* (related with sustainable solutions) and innovations into the digitization. The program purport to include and merge the forces of companies, researchers and society in general (this fact is not common onto the similar European platforms).

Until 2017 the assigned budget was €300.000/year provided by the Ministry and other members, and €200.000 provided by the membership fees [69].

Its work is based on 6 topics:

- Norms and standards
- Research, development & innovation
- Qualification and skills for Industry 4.0
- Regional Austrian strategies
- The human in the digital factory
- Smart logistics

The principal objectives are related to the *foster of interests* between industry, science, policy makers, employers and employees and the *providing of knowledge* to companies, academia and general public related to digitization, launching initiatives to handle regional, national and international activities.

3.3.1.1.9. *Portugal* – **Programa Nacional para Elaboração e Implementação de Plano Empresarial Estratégico de Digitalização (*Confederação Nacional da Indústria–CNI*)**

(Program still in definition and implementation phase)

The *National Program for the Elaboration and Implementation of a Strategic Business Plan* for Scanning (*Programa Nacional para Elaboração e*

Implementação de Plano Empresarial Estratégico de Digitalização) is an initiative that is being carried out by the National Confederation of Industry – CNI (*Confederação Nacional da Indústria*) with the aim of *ensure*, *encourage* and *support* the adaptation of enterprises to industry 4.0, taking into account that (according to CNI) more than the half of the enterprises are not implementing new solutions into their processes.

The program starts fostering the companies to identify (and understand) the digitization needs of their production plan and then find the strategies and investments required for the readjustment.

The project is being support by the funds of The National Bank for economic and social development – BNDES (*Banco Nacional de Desenvolvimento Econômico e Social*) and the Brazilian innovation and research corporation – FINEP (*Empresa Brasileira de Inovação e Pesquisa*) [70].

This program intends to conquer the manufacturing industry followed by transportation, public safety, energy and health ones.

3.3.1.1.10. *Basque Country* – **BASQUE INDUSTRY 4.0**

Basque Industry 4.0 is a specific program created into the frame of the Advanced Manufacturing initiatives of the Basque Government. The aim of this program is the positioning and leadership of *Euskadi* (*Basque Country*) as an industrial-based economy, based on the promotion of knowledge-intensive manufacturing, providing to the industrial companies (especially SMEs) with the technological capabilities necessary to face the challenges of Industry 4.0 [71].

Those needed capabilities are levered on a network of *R&D infrastructures*, *pilot plants* and *specialized technical knowledge* in different areas of Advanced Manufacturing provided by public Basque institutions and local universities.

The main objective is to develop R&D projects, industrial applicable projects, using and application of cutting-edge technologies and training and acceleration of start-ups related with this topic.

The program is also supported by an *annual congress* where trends and future forecasts in 4.0 technologies and cases of application of Industry 4.0 in automotive, aeronautics, machine-tool and energy are exposed, new technological 4.0 solutions for industry are taught around Cloud Computing, collaborative robotics, Ciberphysical systems (CPS), Virtual and augmented reality, industrial cybersecurity, sensors, Advanced Human-Machine Interfaces, Industrial Data Analytics (Big Data) and Additive Manufacturing; also are presented the advances in the collaborations projects done between industries and start-ups, practical workshops with experts are conducted, turning this meeting into a networking place.

3.3.1.1.11. *Italy* – **FABBRICA INTELLIGENTE**

Cluster Fabbrica Intelligente (*CFI*) is an Italian program (from a non-profit association) that defines itself as "*The Italian proposal for the manufacturing of the future*"; It was launched in September 2012 by the "*Ministerio dell'istruzione, Università e Ricerca*" (Ministry of Educational, University and Research) and is managed by the "*Organo di Coordinamento e Gestione" – OCG* (Italian Coordination and Management Body) with representatives of SMEs of the regions of *Emilia Romagna*, *Liguria*, *Lombardia*, *Marche*, *Piemonte* and *Puglia*. Counts with a budget of €45 million (that according to *Digital transformation monitor of the European Commission* is a low budget for a 4-year program with a national scope) based on €34 million in public funds and €11 million in private funds [72].

The program aims to entail *SMEs* and big companies, universities, research centers, entrepreneurial associations and technological stakeholders into the use of technological 4.0 processes focusing on manufacturing sector, creating a stable manufacturing community based on research and innovation, orienting the Italian manufacturing companies into the transformation toward the creation of new products, systems and processes, encompassing pre-competitive projects (oriented towards the application of technologies and improve of existing processes) and post-competitive projects (related with the development of new specific technologies).

The *CFI* has centralized the diverse actors of the Italian manufacturing industry (in a regionally and nationally level) with the objective of creating a manufacturing community and a general roadmap (periodically developed) that sets the strategic vision on the manufacturing future and the technological path that the *SMEs* must follow or mirror themselves (depending on their own characteristics). This roadmap is developed based on the constant analysis about socio-economical mega trends (in Italy and worldwide) in order to understand the factors that influences the society and how the industry and the manufacturers must deal (and take advantage) of those situations. Those guidelines and contexts must lead to the identification and evolution of *Strategic Action Lines* that incentives the company to solve with the inclusion of digital technologies or different kind of innovations. The whole initiative and the projects related are suitable with a research, improvement and technological approaches [73].

These goals are fed with the development of technological transfer, research and mobility infrastructure sharing, small and sustainable entrepreneurship and human resources supporting activities.

The principal *Strategic Action Lines* developed until now are:

- Manufacturing systems for customized production.
- Strategies, methods and tools for industrial sustainability.
- Factories for humans.
- High efficiency production systems.
- Innovative production systems.
- Evolutionary and adaptive production systems.
- Strategies and management for next generation production systems.

3.3.1.1.12. *Italy* – **FIND MY FAB**

Find my FAB is a private initiative born on Veneto on 2016 with the support of the *University of Padua* and *Veneto Region on the Digital Agenda* that promotes the meeting between Made in Italy companies and the Italian industry 4.0. The web app (dedicated to *SMEs*) collects successful cases on the introduction of 3D printing, internet of things, robotics, big data and cloud, augmented and virtual reality, in business processes and in the development of new products and/or industrial processes. Also, a continuously updated map with the I4.0 stakeholders is shown.

This success cases will lead the companies to know the opportunities around the 4.0 industry and search for *start-ups*, *other innovative companies* and fab labs which can help them to implement those technologies.

The project had no public financing but was supported by a crowdfunding campaign and is based on the results of research done by *Politecnico Di Milano* and *Federmeccanica* that says that Italian *SMEs* are quite excluded from the digital industrial revolution [74].

FIND my FAB aims to create a more "*democratic and participatory 4.0 industry*", starting with the web app that was created with a "*reward*" crowdfunding campaign, offering everyone the opportunity to participate in the project.

3.3.1.1.13. *Italy* – **PIANO NAZIONALE IMPRESA 4.0** [20] [75]

The "*Piano Nazionale Impresa 4.0*" was presented by the Ministry of economic development of Italy (*Ministerio dello Svilupo Economico*) in September 2016 and consists of the implementation of organic and complementary measures to promote innovation, productivity and competitiveness on the Italian industry.

The plan includes concrete measures based on three main guidelines:

- ❖ Operate in a logic of technological neutrality.
- ❖ Intervene with horizontal and non-vertical (sectoral) actions.
- ❖ Act on the enabling factors.

Specifically, it intends to define the *processes*, *government arrangements*, *the legal and regulatory framework* and *the instruments of a financial nature*, that is, public and private economic support. These "*universal*" and "*combinable*" measures can be activated directly from the interested companies, without the need for prior bureaucratic approval.

The project is characterized by two key guidelines: **investment in innovation** (*mainly in the renovation of the technology park, through the modernization of productive works and the introduction of digitalization and the interconnection of machines*) and the **development of skills**, with the objective of *achieving productivity* so that the industry has more competitive advantages in relation to its competition.
The key economic instruments that are carried out are: *super and hyper amortization* and the *implementation of credit facilities to SMEs* for the purchase of capital goods, equipment and digital technologies.

The instruments related to human capital are related to the *creation of a suitable and open labor context towards the evolution and digital transformation of the national companies*, the *stimulus to private spending* in R&D for innovate in processes and products and thus guarantee the future competitiveness of the companies.

Apart from this, tax-type facilities are included for the profits resulting from the use of intellectual property (*patents, designs, industrial models, know-how, trademarks and software protected by copyright*), reduction of fees (*IRES and IRAP*) on income taxes, free, simplified and priority access to the guarantee fund for SMEs, access to "*Crowdfunding*" systems, Italy Startup Visa and support in case of bankruptcy.

3.3.1.1.14. *Belgium (Wallonia)*– **Plan MARSHALL 4.0**

The Marshall Plan 4.0 is a Belgium initiative that entails a budget of *EUR2.9* billion and is planned to be developed during the period of 2015-2019 with the aim of develop five priority areas for the Walloon zone (*Wallonia is the French speaking region of Belgium*) related with the economic redeployment and the structuring of a real industrial policy around the inclusion and adoption of I4.0 technologies.

The five axes are:

1. Making human capital an asset
2. Supporting the development of industry through a policy of innovation and business growth
3. Mobilization of the territory for economic development
4. Supporting efficiency, the energy transition and the circular economy
5. Support digital innovation

The interesting axis to work on are the 2 and 5.

AXE 2. Supporting the development of industry through a policy of innovation and business growth

The "*Administration 4.0*" in parallel with the constitution of an "integrated digital transition plan" counts with a budget of *EUR 850.5* million and supports the development of an economic and industrial policy based on innovation and business growth, through the support on the development of innovative projects through competitiveness clusters taking advantage of their location close to the market.

Stimulates the creation, development and internationalization of innovative companies, the diversification of corporate financing and the facilitation of business transfers.

AXE 5. Support to digital innovation

Counts with a budget of *EUR 244.8* million and aims to incentive the development and integration of digital technologies on industrial processes.

The specific actions of the plan are [75]:

- Strengthen the links between training and education
- Support the development of industry from a technological perspective involving SMEs
- Use the territory as an essential resource in the economic development
- Support efficiency and energy transition integrating a circular economy process
- Support digital innovation integrating industrial and social practices

3.3.1.2. AMERICA

3.3.1.2.1. *Latin America* – POLÍTICA INDUSTRIAL CEPAL-BMZ/GIZ (United Nations)

Created and launched on 2014 by the *United Nations* with the support of the *Department of Competitiveness and Social development of the German Institute for Development Policy* (*DIE*), the CEPAL-BMZ/GIZ cooperation program is a technology and innovation booster that aims to reinforce the industrial policies, sustainable development and science, making significant progress into the improvement and advancement of the economy in Latin America and the Caribbean.

***Image 10.** Map of the different i4.0 initiatives and project on South America. **Source:** Own Development.*

This initiative plains to establish a network between *government representatives*, *technology centers* and *pioneering SMEs* in the use of advanced technology into their production processes, starting with the pioneer projects done by the Chilean government related with the design and application of specialization programs in intelligent industry and advanced manufacturing as well as with the government of Mexico and their policies and incentives to innovation [76].

Apart from these issues, the program aims to work against regional deficiencies in human resources, the difficulties of the use of advanced technologies, raising awareness of the importance of having technological resources, existing gaps and the inclusion of gender in their production and use, being a complete (and most user/worker centered) program in comparison with Europeans.

The principal activities done during the project are:

- Workshops to discuss and position the priority aspects of Industry 4.0.

- Creation of a learning space on the process of industrialization, the use of advanced technologies and the training of human resources.
- Creation of a regional political-technical dialogue space to position and raise awareness about the importance of incorporating advanced technologies in the industry.

3.3.1.2.2. *Brazil* – **RUMO À INDÚSTRIA 4.0 (Agência Brasileira de Desenvolvimento Industrial- ABDI)**

The "*Rumo à Indústria 4.0*" program was promoted by the *Brazilian Industrial Development Agency* – ABDI (*Agência Brasileira de Desenvolvimento Industrial*) and the Federation of Industries of the State of São Paulo – FIESP (*Federação das Indústrias do Estado de São Paulo*); In its first edition, it included 200 Brazilian SMEs with a budget of R$ 500.000 (around EUR 120,000 [77]).

The initiative is based on the *mobilization of the productive sector* with the aim of attracting new opportunities promoted by this fourth industrial revolution. The action plan is based on the creation of a set of strategic actions to promote the implementation of *Industry 4.0*, the diffusion of technologies along the productive chains and the creation of opportunities for development and improvement of the management of those productive processes.

As specific actions, the *participating companies are separated* according to their productive sector and *success cases are presented* in order to expose the key ways to digitize their processes; sectorial diagnosis are done, identifying possibilities and possible perspectives, determining the index of maturity of companies through test beds [78].

At the end of each session, the SMEs receive a report with their level of maturity and a specific Road Map; After this, training in *Advanced Manufacturing*, *Energy Efficiency*, *digitization* and *Connectivity* will be developed, taking into account the needs of each enterprise [79].

3.3.1.2.3. *México* – **PROGRAMA NUEVO LEÓN 4.0 (*NL4.0*)**

Image 11. *Map of the different i4.0 initiatives and project on Central America.* ***Source:*** *Own Development.*

N.L4.0 is an initiative of the government of "*Nuevo León*" state, that seeks the economic development of the zone based on the open innovation scope with human centered values, where the *Government* links *SMEs* and the *academy* sharing talent and knowledge, facilitating the use and creation of infrastructure for its execution. The main scope of the program is the positioning of *Nuevo León* as the leader on Intelligent Industry in the continent, through the creation of an *Innovative Ecosystem* based on the Triple Helix (Government, Industry and Academia), promoting the creation of value and labor capabilities of high added value [80].

The established roles of each part of the helix are:

- **Government:** Generate conditions and incentives for the creation of an ecosystem of the fourth revolution.
- **Academy:** Development of knowledge, technology and specialized talent.
- **Industry:** The role of the industry is based mainly on proposing challenges and possible technological solutions to them, defining the course of the industry and, in general, working together for the development of SMEs.

3.3.1.2.4. *Colombia* – **EMPRESARIO DIGITAL (Ministerio de Tecnologías de la Información y las Comunicaciones de Colombia - MinTIC)**

Empresario digital is an initiative that is being carried out by the Ministry of Information and Communications Technologies – MinTIC (*Ministerio de Tecnologías de la Información y las Comunicaciones*) which seeks to train and certify at least 100,000 entrepreneurs and SMEs in the country from different economic sectors encouraging them into the developing of their skills in the use and appropriation of technology 4.0, specially *ICTs* (*Information and communications technology*), so they can digitally transform their businesses, improve productivity and increase sales [81].
The program is composed of four strategic areas for developed in 36 different sub-programs:

- Electronic Commerce
- Productivity and operations
- Management and administration systems and human resources
- Strategic planning, decision making and updating of production systems

3.3.1.2.5. *Colombia* – **COLOMBIA PRODUCTIVA (*Programa de Transformación productiva - PTP*)**

Colombia Productiva is a public Colombian program of Productive Transformation created by the *Ministry of Commerce* with the support of the *World Bank*.

Its aim is to encourage *SMEs* and large companies into the *optimization of energy consumption*, the *reduction of production and delivery times* and costs, the *implementation of international standards* of quality, the adaptation of the *final production for exporting* and the improving of the *commercial management and human talent*, among other factors that impact on their productivity, quality and export capabilities, through the implementation and utilization of improved 4.0 and digital technologies into their industrial processes.

This program is focused at *SMEs* and large Colombian companies with more than a year of creation into the sectors of agroindustry and manufactures. In this first phase, 400 small and medium-sized companies in the country were called [82].

The work in the companies is divided into five phases of accompaniment and consultancy:

- **Phase 1:** Training into management optimization.
- **Phase 2:** In-depth analysis of the current state of the company in the axes in which the technical assistance will be carried out and definition of needed goals.
- **Phase 3:** Proposal and agreement of the action plan to improve the company's indicators in the selected axes. This plan will contemplate schedule, areas involved, responsible, technologies and measurement methods.
- **Phase 4:** Implementation of the plan, including ordering and buying of needed machines.
- **Phase 5:** measurement of the indicators of the action plan and monitoring of final results.

3.3.1.2.6. *Argentina* – **INDUSTRY TRAINING PROGRAMS of Cámara Argentina de la Máquina, Herramienta y Tecnologías para la Producción (CARMAHE)**

(This program was launched on 23/Feb/18 and is still in definition and waiting for the implementation phase)

The "*Argentine Chamber of the Machine, Tool and Technologies for Production*"-CARMAHE (*Cámara Argentina de la Máquina, Herramienta y Tecnologías para la*

Producción), the *Secretariats of Productive Transformation* and the representatives of SMEs and Entrepreneurs have created a program that aims of bringing 4.0 technologies closer to the manufacturing processes and increasing the competitiveness of country's industry [83].

The initiative contains four fundamental pillars:

- Training of talent.
- Foster the global positioning.
- Improve the infrastructure.
- Establish a regulatory and tax framework.

The program intends to solve the lack of qualified personnel related with digitization processes of large companies and SMEs, promote the smart factory and the performance management in real time, foster the use of electronic performance boards, predictive maintenance and data infrastructure and finally get lower costs and turn firms into more efficient ones.

3.3.1.2.7. *United States of America (USA)* – **MANUFACTURING USA**

The *National Network for Manufacturing Innovation program* (*Manufacturing USA*) is a north American public-private program established in 2014, designed with a vision of U.S. global leadership in advanced manufacturing, bringing together the industry, academia (former universities) and federal partners within a growing network of *advanced manufacturing* institutes to increase national industry manufacturing competitiveness and promote/generate/foster at the same time a robust and sustainable manufacturing R&D infrastructure.

The program is operated by the interagency *Advanced Manufacturing National Program Office – AMNPO* (which is headquartered in the *National Institute of Standards and Technology* (*NIST*), in the *Department of Commerce of United States*), representatives from federal agencies with manufacturing-related missions and partners from manufacturing companies and Universities. It operates in partnership with the *U.S. Department of Defense*, the *U.S. Department of Energy*, *NASA*, the *U.S. National Science Foundation*, and the *U.S. Departments of Education, Agriculture, Health and Human Services (HHS) and Labor*.

M.U works as a catalyst of projects, merging people capabilities, innovative ideas and technology to foster industry and the nation itself. This initiative is related with an extensive network that aims to develop disruptive and applicable technologies and skills needed to prepare U.S. manufacturing workforce for future challenges without losing the domain of the market they have so far, enabling these manufacturers to produce their new products quicker and cheaper by using the community to develop/improve new manufacturing processes.

One differentiating focus of *M.U* is to provide education and training to American workers with the goal of generate "*improved job opportunities and increased economic opportunity in promising technology areas that result in higher wages*" [84].

The *three approaches* that drives the program are:

- Convene and enable industry-led, private-public partnerships focused on manufacturing innovation and engaging U.S. universities.
- Design and implement an integrated whole-of-government advanced manufacturing initiative to facilitate collaboration and information with the federal agencies.
- Coordinating federal resources and programs and overcome technical obstacles to scale up of new technologies and products into the SMEs industrial processes.

3.3.1.3. ASIA

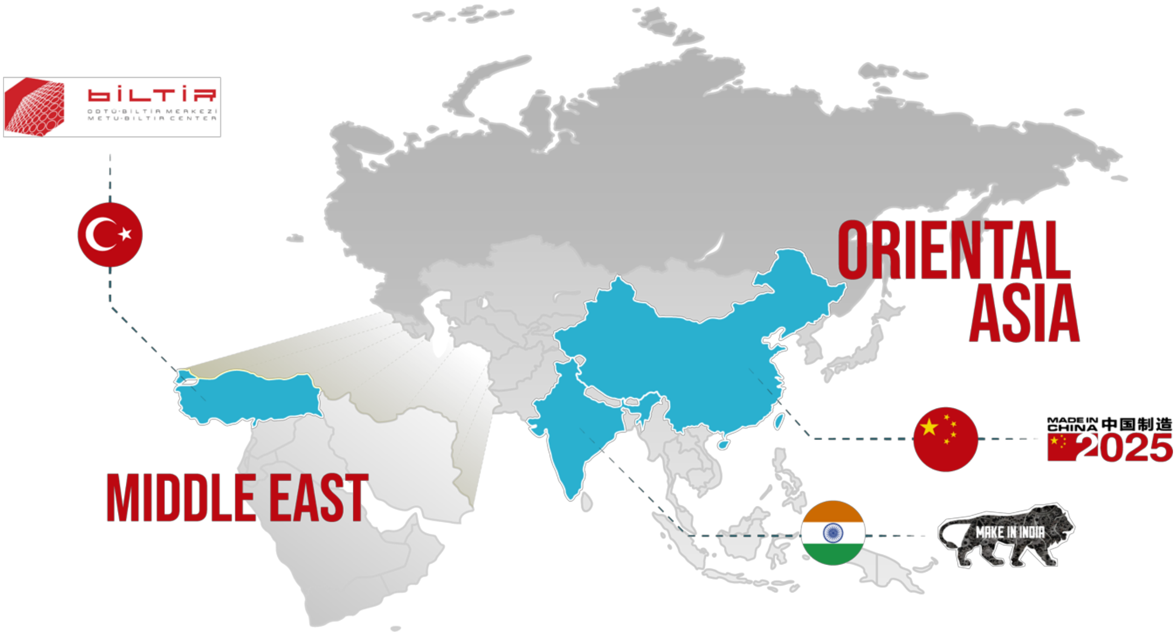


Image 12. *Map of the different i4.0 initiatives and project on Oriental Asia and Middle East.* ***Source:*** *Own Development.*

3.3.1.3.1. *China* – **PLAN MADE IN CHINA 2015**

Made in China 2025 (*MIC2025*) is a program that was developed for more than two years (published on May 2015) by the *Ministry of Industry and Information Technology of China (Zhōnghuá Rénmín Gònghéguó Gōngyè Hé Xìnxīhuàbù)* with the aim on developing and fostering the Chinese industries into the implementation of high technological complex systems, based on innovation and *training* of its personnel at different levels, trying to sustain the quality over quantity and cost.

MIC2025 was born as a result of the *worsening of the internal productivity*, the *deceleration of the economic growth* and the *decrease in the workforce*, generating higher prices and therefore the competitive advantage in relation to emerging markets in nearby countries such as Vietnam and Indonesia [85].

This plan is an extension of the "*Emerging Strategic Industries*" of 2010, and the focus is on developing *state-of-the-art technologies* through intensive investment in *R&D* and industrial property value capturing/standardization (China is currently one of the leader countries in industrial patenting), focusing on the *enterprises growth stage* based on the domestic market taking into account that this development is almost exclusively based on exports [86].

They pretend to achieve an integration of 40% by 2020 and 70% by 2025 of the whole bunch of productive segments on the Chinese industry, counting with a framework of financial and fiscal aid and the creation of 15 innovation and research centers by 2020 (with the objective of reaching 40 by 2025). The program entails the strengthening of *private intellectual property rights* to guarantee to the private and state *SMEs* to capture the benefit of the advances in the fields in which they are assisted and works for.

The specific focuses of the program are:

- New advanced information technology
- Automated machine tools and robotics
- Aerospace and aeronautical equipment
- Maritime equipment and high-tech boats
- Equipment, modern rail transport
- Vehicles and equipment with new forms of energy
- Energy equipment
- Agricultural equipment
- New materials
- Biopharma and advanced medical products

The strategy will be developed in 3 different phases:

1. Reduce technological differences with other countries (*2025*)
2. Strengthen the Chinese position into the worldwide market (*2035*)
3. Be the leader in innovation and industrial technology (*2045*)

3.3.1.3.2. *India* – **MAKE IN INDIA 4.0**

Make in India (*MII4.0*) is an initiative launched by Prime Minister in September 2014 related with the wider adoption of "*Industry 4.0"* through the combination of the industry and the Internet of Things (*IoT*) technology in the country. Is aimed to transform India into a global design and manufacturing center at worldwide level. This project is being developed together with the initiative of the *Government of India* called "*Smart Cities Mission*" that aims to not just involve the industry into the digitization process, but involving also the complete cities, planning to build 100 smart cities across India.

The project's objective is to change the way India manufactures, designs and refurbishes the products; they aim to use the power of big data, high computing capacity, artificial intelligence and analytics to completely digitize the manufacturing sector and the lifestyle of the people in general.

MII4.0 is supported by several local and foreign institutions like the Indian Institute of Science (*IISc*), *Bosch India*, *Boeing* and *General Electric* with investments of more than *USD200* million. So, one key factor about the project is the strong relationships between public entities, government, universities and research centers and the industry itself. This project is adequate for *SMEs* but have operated more into the big company field.

MII4.0 was born as a result of India's critical situations and the desire to face and overcome these situations in the most strategic way possible, also as an invitation to foreign companies to invest in the countries workforce [87]:

- Emerging markets bubble that got into the fall of the India's growth rate to its lowest level in a decade (2013).
- The denomination of India as "*Fragile Five"* economy (emerging market economies that have become too dependent on unreliable foreign investment to finance their growth ambitions (ccc, 2017) [88]).

- Global investors debated whether the world's largest democracy was a risk or an opportunity.
- India's 1.2 billion citizens questioned whether India was too big to succeed or too big to fail.

One important and key differentiator factor of this project is the way the project has been sold and shown to the world: The *Department of Industrial Policy & Promotion* (*DIPP*) and external branding agencies designed a well-structured communication plan, including dedicated help desks, a mobile/pc website that presents a wide array of information with a simple and striking design and a variety of online and physical graphical brochures adapted to all types of public, that allows them to show that the country has industrial power and to empower the people to believe (and work) towards that.

Apart from this, a road map for the single largest manufacturing initiative undertaken by a nation in recent history was created. This document demonstrates the transformational power of public-private partnerships and the steps needed to industrialize certain processes.

Middle East

In Turkey, public and private organizations are developing and attempting to include the I4.0 in their industrial processes. According to *Dr. Sinan Tandoğan* from *Türkiye Bilimsel ve Teknolojik Araştırma Kurumu – TÜBİTAK* (*Scientific and Technological Research Council of Turkey*), the country has several strengths (rapid export growth in the last decade, strong banking sector thanks to structural reforms after 2001 economic crisis and the existence of developed and large domestic markets) that stimulates the growth in the industrial sector.

Public incentives are generous in the country, aimed to *increase private RDI*, use of new industrial technologies and improve research commercialization and entrepreneurship, having as a result the improvement of the competitiveness of the country itself.

Talking about public initiatives, can be summarized: *Tenth Development Plan* (2014-2018), *National Science, Technology, and Innovation Strategy* (2011-2016), *Industrial Policy Strategy* (2015-2018), *Decrees of Supreme Council of Science and Technology* (SCST), being the most important and developed the first one [89].

3.3.1.3.3. *Turkey* (Public) – **Tenth Development Plan**

The Tenth Development Plan is an initiative coordinated by the *Turkish Ministry of Development* focused and designed with a participatory approach, by contributions of public institutions/organizations (more than three thousand academicians, public employees, private sector and nongovernmental organization (NGO) representatives participated and contributed to these committees) and many representatives from other segments of the Turkish society.

The plan was done with the aim of generating a *stable and inclusive economic growth*, taking into account also the industrialization policies, information society, international competitiveness, human development, environmental protection and sustainable use of resources.

Basically, was thought to be the guide for decision makers and stakeholders related with PMIs in directing their resources towards higher welfare-generating areas in the upcoming periods.

Specific actions have been developed during the validity of the plan: Use of public infrastructure investments for promoting strategic investment involving 4.0 technologies, use of public procurements for improving the innovation and green production capacity, improvement of export capacity in smart building technologies, public transportation and signaling systems, the efficient use of country loan and guarantee programs for increasing the exports of capital goods and the incentive (through subsidies) for the acquisition of foreign companies [34].

One important key factor is that this initiative was done with a multi-dimensional view, perceiving the needs and the challenges of the industry but also adopting a human-oriented development framework which allows the community to participate. These policies are covered under the title: "*Qualified People, Strong Society*" [90], being this, one of the four main pillars [34]:

- Qualified people, strong society.
- Innovative production, stable and high growth.
- Livable places, sustainable environment
- International cooperation for development.

According to the *Turkish Industry and Business Organization and BCG* (2016) [91] the expected impact of the adoption of I4.0 technologies on the country in general (*specifically talking about TDP*) are related with:

- Productivity increase of 4%-7% on an annual basis.
- Increase of 5% in employment generation.
- Preparation of bigger know-how base and Higher-skilled labor force.
- Growth of 3%/year on manufacturing.
- Growth of 1% on Turkey GDP.

3.3.1.3.4. *Turkey* (Private) – **METU-BİLTİR Digital Transformation / Industry 4.0 Platform**

METU Digital Transformation/Industry 4.0 Platform was established in 2016, under the leadership of *METU-BİLTİR Centre*, with the participation of various units of *METU Centre* and faculty members from different disciplines. This center has developed more than 200 international projects with a total budget of *492M€* (data of 2016). Also, are an average of 400 R&D nationally funded projects are developed and around 60 *R&D* internationally sponsored projects, related with the industry 4.0 innovative inclusion into the industry and production processes of the region

The goal of the platform is being the bridge between university and industry and hence support Digital Transformation of Turkey creating awareness and preparing strategies, policies and road maps in cooperation with relevant public and private sector organizations adopting a complete holistic approach.

The platform entails solutions and support into the improvement of the effectiveness in manufacturing through expertise in the application of smart systems, system of systems, information and communication technologies and in other *I4.0* technologies on different sectors such as automotive, defense, security, energy and retail. The biggest advantage of them is the capacity to access to specific knowledge and personal capabilities of the university and R&D field, and the cleverness to bond them with public and private investors [92].

3.3.1.4. **OCEANIA**

3.3.1.4.1. *Australia* – **INDUSTRY 4.0 Recommendations Report**

Australian Industry 4.0 is an initiative developed by the *Standards Australia Organization,* the *Prime Minister's Industry 4.0 Taskforce* and counting with the *Commonwealth Government's* support through the *Industry Growth Centers* Initiatives. Is based on the creation of a *Recommendations Report* highlighting the key recommendations for Australia to gain opportunities created from the implementation of Industry 4.0 projects into their industries.

The project is oriented on the establishment of important global networks that incorporate different machinery, warehousing systems and production facilities into the existing processes, producing the growth of an internationally competitive, dynamic and thriving Australian advanced manufacturing sector that boosts the long-term health of the economy and the nation itself. The main objective is to get to supply high value products and services facing the increasingly interconnected global marketplace where the country industries are working for and accomplish achieve the increase in the number of high value jobs created and striking opportunities for business growth, particularly *SMEs* [93].

3.3.1.4.2. *Australia* – **INDUSTRY 4.0 Testlabs**

The *Australian Government*, through the *Industry 4.0 Task Force* within the *Department of Prime Minister* and *Cabinet* and the co-operation agreement with *German Plattform Industrie 4.0* (See 2.1.1.1.), aims to create a network of Industry 4.0 testlabs in Australia. This initiative (also related with the *Industry 4.0 Recommendation Report*, see 2.1.4.1.) will enable *SMEs*, *students* and workforce to work into the transition to the adoption of *I4.0* technologies and learn about Industry 4.0 within supportive and non-competitive environments and then assist *SMEs* with their digital transformation.

Industry 4.0 testlabs aims to improve the competitiveness of Australian manufacturing industries through adoption of innovative technologies and workforce transformation. They will work with stakeholders from industry, government, academia, professional societies and labor organizations, and include the community to achieve a wide vision and training about Industry 4.0.

The *testlabs* will transform Australian industry in three ways:

- Create an Industry 4.0 showcase
- Become an innovation platform
- Be a research, innovation and transformation catalyst

Will be focused on five specific and defined streams: architectures, standards and norms; support for *SMEs*; industry 4.0 testbeds; security of networked systems; and work, education and training [94].

4. INDUSTRY 4.0 for SME (*Italian Context*)

In previous numerals the way in which the technology related to *Industry 4.0* is spreading in the world was shown, with special emphasis on companies that have a small or medium size. Understanding the way that the companies are applying these projects and are supported by external entities (*government entities, universities or private entities*) gives us a clear vision of the importance and progress that different countries /regions /continents are taking around this.

Cultural differences are a very difficult subject to deal with, but it gives us a deeper understanding of how industries operate in different areas of the globe. As can be seen in the previous chapter, the definition of the size of an industry varies depending on the country in which it is developed (*for example, the definition of a medium-sized company is very different in Europe where the currency is much stronger than in America and, in addition to other factors, the industry is more developed in certain cases*) and **the amount of projects and level of investment of the countries in them is a very strong indicator of economic growth**. A country that invests in the improvement of its industrial power is a country that has a definite and strong economic growth plan and therefore it will have more reliable results than a country where the investments in industry are not so strong.

With this in mind, it can be concluded that most incentives for industry 4.0 application are fortunately found in Europe, and this is a very strong indicator of the health of the industry and growth in the future.

Focusing on the point of this document, **the Italian context is a bit particular**. Italy in terms of economy is an anomalous case among the developed countries (*in the European context such as Germany, France and the United Kingdom*) since **for approximately 15 years it has been the country with the lowest growth rate in the region**; In this period the index of inequality has not changed and has remained high in comparison with other countries.

Image 13. *Map of the location of the companies studied in Italy.* ***Source:*** *Own Development.*

According to *Lorenzo Codogno* [95] (*economist, professor at the London School of Economics and general director at the Treasury Department of the Italian Ministry of Economy and Finance 2006-2015*), the reason for this phenomenon is the **difficulty of the country to adapt the public/governmental administration and the industrial and productive structure to the new challenges that globalization brings**, such as *technological innovation* and the *inclusion of new industrial processes*.

On the other hand, it has been seen that in the last year, ***industrial production grew by 3%*** compared to the previous year, there was an **increase of 9.1% in capital goods** (*capital goods are those that are used to produce other goods*), **of 5.7% in intermediate goods** (*they are goods that exhaust their production process, and may or may not be acquired by other economic agents that use it as a consumer commodity or an investment commodity*) and **5.5% in consumer**

goods (*goods consumed by the end user*); in industrial terms, **industrial production accelerated 4.9%** (in 2016 it only grew 1.7%) [96].

Other factors have made possible this apparent improvement in the country's economy, mainly the **increase in banking activity** (*increase of 1.9% in loans for the private sector*) and the **reduction in interest rates**, which produces that the investment in production stuff (*and maybe in R&D towards industry*) is much easier and so the *improvement of the productive processes* and of the *companies in general is encouraged*.

These factors, in one way or another, have encouraged companies in the country to feel attracted to improve their production processes, always with the idea in mind to improve their profits and thus be more competitive in the local and international market. This improvement is made through the implementation of new technologies that benefit both the company, as the consumer, the private sector and the public sector, to return the country (*or the region in which it operates*) much more attractive for investors and for other companies.

In order to understand the way companies are implementing these projects, this work makes important emphasis in the analysis of some cases of success in Italy of companies that have carried out (*or are in the process of*) *Industry 4.0 initiatives*.

The research process is based on the analysis of a series of **successful cases of Italian companies that have implemented *industry 4.0* projects** in recent years. The process consists of different stages, which were developed with the help of the "*Osservatorio Industria 4.0*" team of *Politecnico di Milano*.

As was mentioned in the chapter about "*methodology*" (*See 1.3.),* the process begins with the obtaining of success cases. The cases shown in this report are a mixture between companies previously identified by the "*Osservatorio Industria 4.0*" and other new ones, identified during the work development process. The total number of cases shown are 8.

The search of case studies is a bit difficult and tedious since you have to look for very specific data about companies in not very reliable sources. Companies with the following conditions had to be found:

- That operates in Italy or are properly Italian
- That meets the European requirements to be classified as *SME* (number of workers and annual earnings).
- That have implemented industry 4.0 projects in their productive process (excluding R&D processes).

This information was found looking for sources such as: *articles in local or national newspapers, specialized magazines in industry, Italian business blogs, industry innovation awards* (digital transformation contest is made annually, and can participate companies that innovates in the industry, through this site the names of some companies that would later be investigated individually could be found), *television notes* and *opinion columns*.

When a company that could possibly enter the list was found, had to be done a deep investigation about the *nature of the organization*, *its products*, *objectives*, *organizational structure*, *years of operation* and *characteristics of the innovative processes* (*what type of technology is being applied, in what stage they are, what degree of expertise is in this subject, the budget to invest and the possible sources of external support they have*). After having this information, with the help of the "*Osservatorio Industria 4.0*" team, some of these companies were contacted and appointments were scheduled to meet personally.

The appointments were scheduled with the persons in charge of the matters related to the innovation in processes of the companies; the representatives, managers, CEOs and directors of sales or processes of the companies were generally interviewed. The interviews lasted approximately 1:30h - 2:00 each and were carried out with the help of two interviewers. The language used for communication with the company and the interview was *Italian*.

After having made and recorded the audio interview, we proceeded to make the transcription (*almost at literal level*) of the same, which allowed later analysis and comparison (between cases).

4.1. Analysis Methodology

The analysis of each case is presented individually, showing the information in a similar order of the one done during the interviews, debugging several quantities of information that was not important for this document. For each company will be shown:

- *General characteristics of the company*.
- *Number of employees*
- *Business structure*
- *Product or service offered*
- *Projects I4.0:* For each project is shown its level of implementation, type of technology involved, characteristics, benefits, problems and, if possible, number of people involved in the implementation of the technology or in the management of the same (*this is more related to the staff training*).

This information has to be compared to draw conclusions.
To be able to draw valid and useful conclusions, it is necessary to make a **qualitative and quantitative analysis**.

4.1.1. Qualitative Analysis

The qualitative analysis is based on the comparison of the characteristics of the projects, such as:

- Identify which technologies are most popular in Italy and the possible causes of their success.
- What are the motivations that companies have in implementing these projects.
- In which sources of income companies support themselves.
- What can be the barriers that stop a company from adopting or implementing a *4.0 project*.

4.1.2. Quantitative Analysis

The inclusion of *technologies 4.0* in industries has been growing in quantity and importance over time considering that the modernization of production processes is essential to be aligned with the speed at which the market moves and the customers' demands and competition, so the establishment of a system to measure the level of expertise in the application of this type of projects and the comparison of companies through this variable indicator (and possibly a comparison over time), allows to establish goals, evaluate the programs in the performance of the companies and identify the areas that contribute most to the modernization/improvement of the processes of the Company.

It is very crucial to make a *quantitative analysis* which allows a comparison between companies and their projects **identifying which company is the most advanced, which has more expertise and experience, and which one is important enough to take as an example for other companies that want implement similar projects or take similar paths**. With this comparison it is intended to give a ranking among the cases that are held.

4.1.2.1. TECHNOLOGY IMPLEMENTATION PROGRESS INDICATOR (*TIP*)

To be able to do this analysis, an **INDICATOR**[1] or a **QUANTIFIER** (*a quantifier is the result of a procedure that allows to count some conceptual dimension and that, when applied, produces a number*) will be used. This indicator was designed based on the characteristics of the companies and their projects and is intended to give a ranking and do a comparison between them, in order to understand how this companies are moving between industry 4.0 and **be able to identify the factors that encourage or discourage enterprises into the application of this projects.**

The objective of this indicator is to quantify and compare the progress of the company in terms of implementation of *innovative 4.0 technologies*

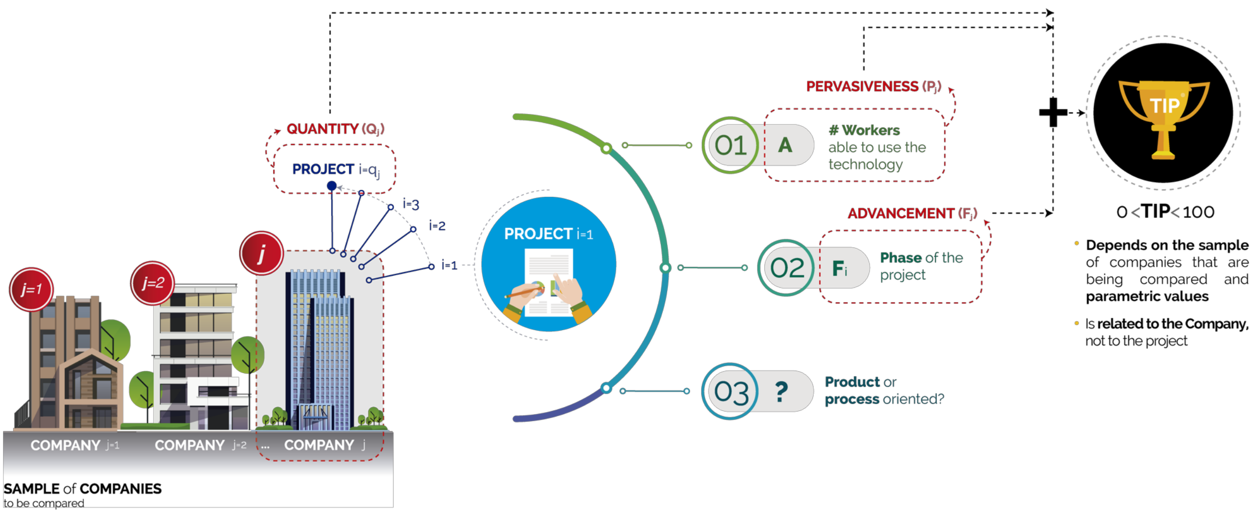


Image 14. Logical flow describing each one of the terms that compose Technology Implementation Progress Indicator. See chapter 4.1.2.1.1. ***Source:*** *Own Development.*

[1] An indicator is a point of reference that provides qualitative or quantitative information, consisting of one or several data, consisting of perceptions, numbers, facts, opinions or measures, which allow to follow the development of a process and its evaluation, and that must be related with the same. (*Collins English Dictionary*).

4.1.2.1.1. LOGICAL FLOW

A certain number of companies which need to be compared according to their level of implementation of industry 4.0 projects are chosen. Each of these companies has a certain number of projects in different phases of development or implementation. Each one of these projects can be analyzed considering three key characteristics:

Characteristic 1: The number of workers that are capable of using this technology or that are somehow affected or involved with the project.
Characteristic 2: The progress phase (*or maturity*) in which is the project and
Characteristic 3: the approach that the project has (projects can be directed towards the *development of products* or the *improvement of internal production processes*).

In order to carry out a reliable comparison, three terms are added, resulting in the TIP indicator:

The first term is called "**PERVASIVENESS**" and shows the diffusion of the project (*or technology 4.0*) in the company; it is calculated by means of the *relationship between the number of workers involved with the project and the total number of employees* (characteristic 1). This term is absolute, since its value does not depend on the size or characteristics of the sample.

The second term is called "**ADVANCEMENT**" and shows the level of application, development or progress in which the company is based on its projects (characteristic 2). This term is relative, since its value depends on the values of the other companies in the comparison sample.

The third term is called "**QUANTITY**" and acquires a higher value the more projects a company has.

The final value of TIP *takes values between 0 and 100*, being the larger, a company with better application of projects 4.0 in comparison with the others. Its value **depends on parametric values** and is **considered relative**, since it depends on the size and characteristics of each of the elements in the sample.

In detail, the three terms that composes TIP are:

❖ TERM 1 = PERVASIVENESS (P_j)

Pervasiveness is defined as the quality of spreading widely or being present throughout an area or a group of people.

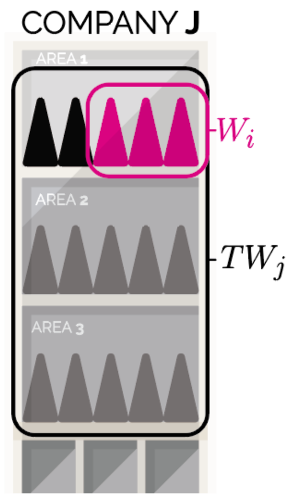


Image 15. Symbolic chart showing the definition of the variables used in the TIP calculation.

This term shows how **widespread is the knowledge and expertise about the use of technology in the company; is a measure of how much the project is involved in the company and its workers**. Quantify the number of workers who are able to use the technology (or is involved in the project) in a specific area of the company (A_i) in relation to the number of people that compose that area (W_i), per project; this sum increases as more projects are applied by the company.

❖ TERM 2 = ADVANCEMENT (F_j)

This term quantifies the advancement (given by the phase) in which a project "*i*" is, **giving numerical values to its different stages/phase.**

This term gives weight to the projects that are more advanced, obtaining a greater value the companies that have achieved a more advanced implementation of their projects. This number increases with the increase of the number of projects (q_j) and has its maximum with the company that have implemented more projects in a more advanced phase.

The phases in which a project can be are:

INITIATION /EVALUATION Phase

The project is in its most embryonic stage where possibly the objective or need of the project is already identified and is being considered, but it has not yet begun or until now it is starting to work on it.

PILOT Phase

The project is in the planning stage, where the idea, the means and the objectives are still being analyzed and we are already working on the development of the process itself. This stage includes the feasibility study, search for technology providers, personnel training and economic and structural analysis.

IMPLEMENTATION Phase

At this stage the project is fully planned and may even be fully implemented, but measurements and tests are still being made before its final release. It is the last stage before being considered fully operational.

EXECUTION Phase

The project is completely working.

❖ **TERM 3 = QUANTITY (Q_j)**

This number is born from the assumption that companies with a greater number of projects (*in any phase*) have an advantage over the others. This term varies according to the number of projects of the other companies compared, having the highest value (*25*) the company with the largest number of projects on the sample taken.

Summarized, the most important features of the TIP are:

- Its value **does not represent the projects** but the company itself.
- Its **VALUE DEPENDS ON THE SAMPLE** of companies to be compared, so its value changes depending on the quantity and characteristics of the companies that make up the sample.
- The value of the *Pervasiveness is absolute* (it does not vary according to the sample), while the value of *Advances and Quantity are relative* (they vary with the sample), so the value of the **TIP in general is considered relative**.
- The results **depend on parametric variable values**.
- It can be differentiated considering the **focus of the projects**, being able to be "*product focused*" or “*process focused*”.
- Its mathematical and logical basis allows using TIP with samples of any size and with projects of different nature, allowing TIP to be **applicable, scalable and useful in several fields**.

4.1.2.1.2. CALCULATION MODEL

Before explaining how each of the three terms of the *TIP* are mathematically calculated, must be highlighted the way in *which* the numerical values related to the weight (*the importance*) of each term in percental format were assigned.

Weighting Systems: Optimal Scaling

The idea behind optimal scaling is to **assign numerical quantifications to the categories of each variable**, thus allowing standard procedures to be used to obtain a solution on the quantified variables.

The optimal scale values are assigned to categories of each variable based on the optimizing criterion of the procedure in use. Unlike the original labels of the nominal or ordinal variables in the analysis, these scale values have *metric properties*.

When specifying the level, is specified *not the level at which variables are measured but the level at which they are scaled*; The idea is that the variables to be quantified may have **nonlinear relations** regardless of how they are measured and **know the specific order** in which they should be, in such a way that **the only variable to decide is the linear distance between the variables**; This is called ordinal quantification. [97]

There are three basic levels of measurement: *nominal*, *ordinal* and *numerical*. In this case is needed to establish a numerical ordinal scale to be subsequently used in mathematically definition of *TIP*. The ordinal-numerical level implies that a **variable's values represent ordered categories with a meaningful metric** so that distance comparisons between categories are appropriate.

It is important to understand that **there are no intrinsic properties of a variable that automatically predefine what optimal scaling level should be chosen** for it. The scales in this case must be chosen in relation to the intrinsic characteristics of the selected variables, in such a way that it has a meaning for the people who will use them and make their interpretation simple [*97*].

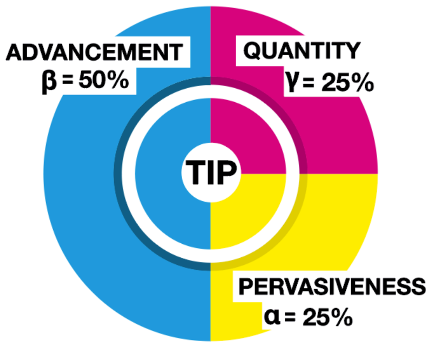


Image 16. Relationship between the weights of each of the terms of the TIP. ***Source:*** *Own Development.*

Focusing on each of the *TIP* terms:

The term **"*Pervasiveness*" composes the 25%** of the TIP Value, "***Quantity*" gives a weight of 25%** of the total value of the TIP to the number of projects that a company "*j*" has implemented (*or is implementing*) and the term **"*Advancement*" number represents 50% of the total value** of the TIP, having a maximum value of "50".

Going into the term "*Advancement*", each of the phases in which a project can be were designated with an ordinally weight.

A value of **12** has been assumed for ***Execution Phase***, **7** for ***Implementation Phase***, **3** for ***Pilot Phase*** and **1** for ***Evaluation Phase***, taking into account that a project in *evaluation phase* is just being considered, without further progress; a project in *pilot phase* is being analyzed, but it does not involve a large number of people and generally does not have important results yet; a project in *implementation phase* is already being developed and needs only to be implemented (*and receive possible feedback*), for this reason the value that has been given is more than the double of the pilot project; Finally, a project in *execution phase* is fully functional, so its value is a little less than twice the implementation phase. It is important to mention that these values are parametric and were chosen in part from my experience with the subject and considering that much information is still missing, incomplete or supposed.

phase (Fj)	value
EVALUATION	1
PILOT	3
IMPLEMENTATION	7
EXECUTION	12

Table 1. *Weights of each one of the phases in which a product can be.*

TIP is expressed as a mathematical expression, considering the following variables:

j = Subscript related with the Company.

i = Subscript related with the i4.0 Project.

Variables related with *Pervasiveness (P_j) term*:

- **W_i = Number of workers in the area who are able to use the technology** or are directly involved in the i4.0 project.
- **TW_j = Total number of workers in the company "j".**
- **α** = Weight of Pervasiveness (AKA: 25).

Variables related with *Advancement (A_j) term*:

- **F_i = Phase of the project *"i".***
- **β** = Weight of Advancement (AKA: 50).

Variables related with *Quantity (Q_j) term*:

- ***q_j= Number of projects** implemented by company "j".*
- **γ** = Weight of Quantity (AKA: 25).

The *indicator/quantifier* ***TIP_j*** is found following the formula:

$$TIP_j = Pervasiveness \ + Advancement \ + Quantity$$

$$TIP_j = P_j + A_j + Q_j$$

$$TIP_j = \left(\sum_{i=0}^{i} \frac{Wi}{TW_i} * \alpha\right) + \left(\frac{\sum_{i=0}^{i} F_i}{max(F_j)} * \beta\right) + \left(\frac{q_j}{max(q_j)} * \gamma\right)$$

By including the multiplier **1/max (Fj)**, is considered the sum of the phase of the projects of the Company "j" in relation to the maximum value of Fj in the sample, considering then the proportion or weight of Fj in the sample. The multiplier **1/max (qj)** considers the proportion of the number of projects of the Company "j" in relation to the maximum number of projects reached among the companies analyzed in the sample; By including this value, *TIPs* can be compared proportionally giving priority to the characteristics of projects itself and the way they have been developed by the Company.

In conclusion, the value of F_j and Q_j **depends on the characteristics of the total number of projects that are being carried** out by the companies compared, taking the maximum value the company that has implemented more projects.

Possible failures and assumptions in the model

- It is assumed that all the required information about the number of people involved in each area and each project *is known* and that the information provided by the company about projects phases *is true*. The model may have *mistaken results* if this information is unknown or does not correspond to reality.
- Decisions about parametric values (*such as the weight assigned to each of the terms*) can be affected or influenced by the lack of accurate data.
- All projects have the same weight and importance.
- The model does not consider the monetary investment in the *i4.0* projects.
- It is assumed that all companies have comparable sizes and characteristics, and then the results of the comparison are reliable. To make the results more reliable, they are compared considering whether their size is medium, medium-big or small.
- TIP was developed after having done the interviews and having collected all the information about the companies, for this reason there is no exact data related to the *number of people working in a specific area* or the *exact number of people who are involved in a specific project*. For the calculation of the TIP values of each company in this paper, the values of the number of workers involved in the project **were estimated** considering the characteristics of each project itself; in this case with the objective of avoiding double counting, when the worker estimate $\boldsymbol{SUM(A) > TW_j}$ is assumed to be $\boldsymbol{SUM(A) = TW_j}$ (*best case*).

4.2. STUDY CASES

4.2.1. Study Case #1 – BROVEDANI SPA

The company, which is more than 47 years old, is focuses on the production of automotive components (*for diesel engines*), design and manufacture of different machines for production processes (*for example, control processes*) or machines that are not on the market (*with specific customized functions, Engineering-to-order*), and auxiliary processes such as turning, washing, heat treatment and finishes. The clients are Italian (18%), European (61%) and outside Europe (21%) and work mainly with small clients, producing few units of each piece.

❖ **General Data**

Revenues: 59 Million *Euro/year*.

Dependents: 391 workers, of which 307 are operators and 84 are White Collar with ages between 43 and 48 years on average.

Size: Medium - Big

Ownership: Private

Headquarters: 4 production points in Italy (Bari and Sicily), Mexico and Slovakia.

❖ **Competitive Advantages and Weak points of *Brovedani SPA***

- Resistance and hardness of the materials used.
- Quality of the proposed manufacture (tolerance of one micron).
- Making personalized products gives them the competitive advantage over companies that make more general products.
- Investment capacity in technology
- The product development process is done with the help of the client (co engineering)

The weak points of *Brovedani* are:

- Complicated costs structure.
- The decreasing in the use of manufactured products in the company (*diesel engines compared to electric motors*).

❖ **Industry 4.0 Projects**

The 2017 investments in *I4.0* were focused on cost reduction. The biggest difficulty when entering such a project is the economic evaluation, considering a large number of variables, because the projects (and the relationship between them) behaves like a complex ecosystem within the company. Generally, the technologies are used to catch information and then to have the ability to anticipate the demands of the public.

***Project #1* (INITIATION/EVALUATION): Additive manufacturing**

This project is being considered until the moment the interview was done, but it has as a restriction the difficulty of using this type of technology when looking for results with a very high quality and specificity as the ones needed.

***Project #2* (PILOT): Connection of machines in the Cloud**

This project has an average planning time of 2 to 3 years, is being developed yet. There is not too much information about it.

***Project #3* (PILOT): HMI**

This project has an average planning time of 2 to 3 years. Based on the implementation of an *HMI system* with *smart glasses* and *touch interfaces* where the worker can see the information on each piece and the proper control plan.

***Project #4* (EXECUTION): Sensorization of machines**

Sensorization of a laboratory machine with a special optical system that allows to instrument and organize the mechanical processing of products with objective data. This machine is capable of analyzing the product and its own performance on its own.

***Project #5* (EXECUTION): Product Tracking**

Product Tracking for maintenance, through the digitization of the information (*the change of paper to digital information*). The objective of the project is to *have the ability to remotely identify possible failures of a product and inform the customer about them*, thus ensuring rapid, fast and safe traceability of the machines.

For the realization of the project it was necessary the *in-depth study of the productive processes*, the *updating of the existing technologies* and the *external control of the products*. This project is commanded by a Project Leader and an Expert in “Lean”. It lasted 6 months in the decision process, 1.5 years in planning and 1 year in implementation.

***Project #6* (EXECUTION): Paperless.**

Eliminate the use of paper in all company processes (*including operational processes*) and thus reduce costs, become more efficient and be environment friendly.

4.2.2. Study Case #2 – *INTERMEK*

The company was founded in 1972 and deals with the turning and milling (*processing*) of *machines parts and tools*, using materials such as polymers and metals. Are able to make custom designs and products and make from one piece onwards. It is a company that operates in an almost a purely Italian market (*85% of its clients*).

They handle a work cycle in which, upon receiving a request from a client, this request goes through two filters that assign some productive requirements (*such as the minimum number of pieces that can be made or the machine that will be used*) until they arrive to the operator, who defines the productive details, the minimum delivery time, the materials to be used and finally the price, thus constructing a proposal.

- **General Data**

Revenues: 4 million *Euro/year*.
Dependents: 40 workers of which 32 Blue Collar (operators) and 8 are White Collar workers (commercial back-office, administrative junior and senior, commercial front-end, purchasing office, logistics and design) with an average age of 35 years.
Size: Small
Ownership: Private with family management
Headquarters: 1 productive site.

- **Competitive Advantages and Weak points of *Intermek***

- Use of machinery and technology to make a product with high standards of quality and precision.
- High delivery speed (*Time-to-market*)

- Generally, the price.
- Product performance.

The weak points of *Intermek* are:

- Punctuality of delivery in some cases.
- Complexity of the products and the requirements of the clients.
- Small size of the company in comparison with some of its competitors, which makes them have better channels of distribution, sale and marketing of their products.
- Dependence of external collaborators who carry out some processes of transformation of the raw material before arriving at the company's facilities.

❖ **Industry 4.0 Projects**

The main objectives of the developed projects are to carry out a *change in the company's organizational structure* and to have a *simpler management of all the production*, both for managers and operators and, of course, to provide a more complete service to customers.

***Project #1* (EXECUTION)*:* Digitization of processes**

Was implemented a digital system that helps to organize the production of the company depending on the product type, the material and the machines (and operators) that has to do it. Each operator has a tablet that allows you to access to this information easily.

It was implemented with the aim of *facilitating communication among the company's stakeholders*, *reducing production costs* (eliminating junk activities), *having greater control over the processes*, the *delivery time* and *production* and *improving working conditions* for the companies' operators.

***Project #2* (EXECUTION): Traceability of operations**

Use of BEACON technology, which allows to receive information about the products and the state of the operations in a warehouse, thus helping to improve the internal processes of the company.

***Project #3 (*EXECUTION): Information in the Cloud**

Creation of a database that stores and updates in real time the most relevant information of the processes, products and materials, having direct connection with suppliers.

4.2.3. Study Case #3 - *BORTOLIN KEMO*

Company founded in 1945 (*73 years of operation*); deals with the design, manufacture and installation of specialized machines for packaging and closure machines. He works mainly with large clients such as *Jhonson&Jhonson* in the European market, Asia and North Africa (90%).

❖ **General Data**

Revenues: 16 Million *Euro/year*.
Dependents: 90 workers of which 50 are Blue Collar and 40 White Collar (2 people in administrative positions, 8 in the commercial area and the rest are engineers who work in production and design of parts). They have ages between 35-40 years.
Size: Medium
Ownership: Private with family management

❖ **Competitive Advantages and Weak points of *Bortolin Kemo***

- They have experience with specific niches, which allows them to establish high prices but with a high quality with respect to their competitors.
- They have the infrastructure to prepare special orders for customers, providing a more specialized service.
- High variety in products.
- They have a larger size than their competitors.
- Punctuality in the fulfillment of deliveries.
- Wide advertising channels.
- Almost 100% of the products are made inside the company (they handle almost the total of the productive chain).

The weak points of *Bortolin Kemo* are:

- Within the company there is no strategic plan with respect to I4.0.

❖ **Industry 4.0 Projects**

There is no figure that manages the projects of I4.0, but there are relationships with external entities (such as software developers) that allow the creation of products with new technologies.

Project #1 **(IMPLEMENTATION): Traceability of processes**

Remote maintenance services and real-time traceability of processes through cameras and mobile phones, which allows customers to know the status of their order instantly. This project took a year and a half to be planned and is finalizing the implementation phase, but is not yet operational. The company already had some of the necessary technologies for its implementation and with the vast majority of trained personnel for its management, making the process of adaptation much easier when the initiative becomes operational.

4.2.4. Study Case #4 – *TSM*

This B2B company was born in 2001, after the modification of the family business group, *Gruppo Moro*. They deal with the **design, assembly and commercialization of cleaning machines** (*scrubbers, sweepers, vacuum cleaners and polishers*) that are recognized in the world for being SMART: Simple, completely Mechanical, Accessible, Reliable and Tough. These machines are mainly used in interior spaces such as supermarkets, hotels and hospitals.

The company does not manufacture the products, it only deals with assembly (manual) and sale. They work mainly with the European (*40%*) and external (*50%*) markets, including Russia, the USA and Asia.

Despite being born with the knowledge background of the *Moro family group* that has been operating since 1882, *TSM* was born as a startup and remained that way until the year 2005. Up to now it is managed by two brothers, one is an engineer and deals with the technological part while the other is focused on the management of the company.

They were winners of several certifications and awards for the creation of a machine that is capable of cleaning with ultraviolet rays, avoiding the use of chemicals or detergents. This machine was not commercially successful, since *50%* of distributors' sales are focused on the cleaning products used by these cleaners and then were not interested.

- **General Data**

Revenues: 3.6 Million *Euro/year.*
Dependents: 15 workers, of which 7 are White Collar and 8 are Blue Collar. They have average ages of 30 years.
Size: Small

Ownership: Private with family management.

Headquarters: 1 central headquarter.

- **Competitive Advantages and Weak points of *TSM***

- The service and the proximity to the distributor of the products, but not with the end user, needing less distribution channels.
- Offer to the suppliers the storage of the products (*warehousing*).
- They are leaders in very specific markets (*cleaning small sites outdoors, called "microvoirie")* where competitors do not enter because they are very small.

The weak points of *TSM* are:

- They are still very small compared to the competition and therefore do not have broad distribution channels like the others.

- **Industry 4.0 Projects**

I4.0 technologies in this case are applied to the products mainly, not so much to the internal manufacturing processes of the company, so **the main objective is not to create a product that is only efficient, but an intelligent machine**; they see the use of new technologies as a tool not only to create new products, but to **keep the customer loyal**, so *their goal is more strategic/marketing than technical*. Its size is still small, and the volume of production/assembly is also low, so they have not felt the need to automate in a big scope their processes.

There is a figure within the organizational structure that is responsible for the ideation of new products, identification of new opportunities and of course the inclusion of new technologies in these devices and another person who is aware of the digitization of processes; the search for competent people in this field is still difficult for them.

***Project #1* (PILOT): IoT Cleaner**

Creation of a machine focused on the outdoor spaces cleaning, capable of showing information that allows its control, operating status, map its position and the behavior of the cleaning operator and plan the maintenance.

This project will be supported by a *platform that will show information to operators*, *cleaning companies* and *distributors*, who can know where and how machines are operated and thus understand customers (make predictions in terms of consumption and to be able to support to the dealer during after-sales).

***Project #2* (EXECUTION): Automation at product level**

Project in collaboration with the *Università Sant'Anna di Pisa*, in which a washing machine that is able to automatically follow its operator without having to be guided was developed; the tracking is carried out by means of *laser scanners*, in addition to a series of *proximity sensors to avoid obstacles*, *inclination* and *acceleration sensors*; It has a *rechargeable battery* that lasts 8 hours, so that the machine can work a full shift of work. The product was launched in *May 2018*. This project included the use of sensors and robotic automation elements.

***Project #3* (EXECUTION): Digitization of internal processes**

Since 2015, a "*digital kanban system*" has been implemented that allows the issuance of orders and the scheduling of production shifts through an electronic system, thus reducing the waste of time and paperwork.

4.2.5. Study Case # 5 – *PALAZZETTI*

Company that deals with the **production and marketing of fireplaces, stoves and all related products** (*such as coatings and supplements*) at B2B level, focused on large customers. Despite the fact that their sales are made through immediate companies, they have a *strong relationship program with the client* that includes several communication channels (*Palazzetti app, fairs and events*), putting the customer at the *center of the experience*; especially in this type of products, where the useful-life is very long, it is very important to allow the client to have a *complete pre-sale experience*, where he/she can see, feel and touch the product and thus be sure about a decision.

Their biggest challenge in terms of product is finding a way to innovate and maintain their products updated.

❖ **General Data**

PALAZZETTI
IL CALORE CHE PIACE ALLA NATURA

Revenues: 65 million *Euro/year.*
Dependents: 250 employees.
Size: Medium-Big.
Ownership: Private with family management.
Headquarters: 2 manufacturing points in Italy.

❖ **Competitive Advantages of *PALAZZETTI***

- Manage a product whose base and operation has not changed in hundreds of years but have managed to keep it updated.

❖ **Industry 4.0 Projects**

***Project #1* (EXECUTION) - Product HMI**

They have developed an *electronic sensor system* for stoves, which allows them to remotely control the operation of the product from interface as tablet or Smartphone (through an app) and thus improve customer service, identify faults, control temperature, on and off, and give a quality after sales assistance.

4.2.6. Study Case # 6 - *MEC+*

It is a company that manufactures **precision mechanical elements of any kind especially for the medical and automotive sector**, among several others. Its service is based on the *manufacture and assembly of parts from the customer's own designs* or also the **service of assistance and co-creation** with the customer in the design of the components, using materials such as aluminum and techno-polymers; therefore, they do not have products or a catalog of their own.

They move in a market 90% Italian and 10% European (*in nearby countries such as Switzerland and Germany*) with small and medium size companies.

The production process begins with the *arrival of a quotation request*, which is usually accompanied by a 3D model of the product to be developed; This model is *inserted in a CAM simulator* where the production cycle is simulated in less than a couple of hours and thus *creates a model* based on materials, costs, transportation and production requirements. From this information a *quote is generated*, which is accepted or rejected by the client. Once an order is made, there is a planning system which allows communication with the operator and thus the optimization of the production sequence.

- **General Data**

Revenues: 3.2 Million *Euro/year.*
Dependents: 35 workers with an average age of 40 years. 1 engineer, 10 on sales.
Size: Small
Ownership: Private with management by two partners.
Headquarters: A single establishment.

- **Competitive Advantages and Weak points of *MEC+***

- High quality in the product.
- Punctuality in delivery times.
- They have the machinery and infrastructure that makes them capable of producing almost any type of mechanical product, considering some restrictions of sizes and materials, of course.
- Have created a network of collaboration with other 5 companies that allow them to have outsourced services (*mainly molded of plastics and rubbers*) and then develop greater productive capacity.

The weak points of *MEC+* are:

- There are companies that, having a larger size, can make use of economies of scale and offer better prices.

- **Industry 4.0 Projects**

Projects on *I4.0* are focused on the **improvement of the efficiency in the processes** and the collaboration between production areas through the **exchange of data**. There is no person in charge of this type of initiatives.

It is used a management software that was implemented 3 years ago and that allows the *integration of digital systems with the needs of the company*. The time of implementation and adaptation of/to this tool was long.

***Project #1* (INITIATION/EVALUATION): Collaborative robots**

They are considering the implementation of collaborative robots in the "*parts assembly"* processes.

***Project #2* (IMPLEMENTATION): Digitization of processes on real time through an HMI and IoT connection system.**

The factory has implemented *displays* that show *production information*, tablets with barcode guns and the *digitization of order information*, the *performance of each machine*, the *amount of parts that have been manufactured* and those still to be manufactured, the *productivity* and the *remaining time of elaboration*.

All the machines are networked, and the information is shared between them, the management software and even the clients, allowing to remotely monitor the production in real time.

Project development time: 4 years in total.

***Project #3* (EXECUTION): Vertical warehouse**

Implementation of an *automatic vertical warehouse* in connection with the *business management plan* and the implementation of a digital system that replaced the use of printed paper in the internal processes of the company. The main problem related to this technology is the lack of knowledge and experience in its management by the staff.

Three different software are managed: *Management software*, *Team System Software* (for data transmission) and *Vertical Warehouse Software*.

Project development time: 1 year in total.

4.2.7. Study Case # 7 – *PREMEK*

The company was founded in 1978 and deals with the **manufacture and assembly of mechanical parts for all types of machines**, working for sectors such as *optics* and *industrial automation*. They work 70% with external market.

- **General Data**

Revenues: 10 Million *Euro/year.*
Dependents: 80 workers of which 55 are Blue collar (*expert operators*) and 25 White Collar.
Size: Medium
Ownership: Private with family management.
Headquarters: 1 headquarter.

- **Industry 4.0 Projects**

The concern for implementing technologies 4.0 was born in 2005 and is aimed on achieving general benefits at technical and administrative levels, with an annual investment of 8% of their total revenues. With it implementation the production times have been extended to 18 continuous hours. They have created a team that deals in part with the creation of these initiatives, led by an engineer who knows the specificities of the technologies.

The biggest challenge was the coordination of the new software and hardware with the management software that was had and the resistance that some workers putted on the adoption of new technologies.

The *motivation to make 4.0 projects* arises from the observation of similar companies that have more elaborate organizational structures and have bigger profits; thus, analyzing these cases of study (*through interviews*) they have managed to understand what their needs and obligations in this field are.

***Project #1* (EXECUTION): Automated Vertical Warehouse**

Is used an *Automated Vertical Warehouse* that allows to store and access the manufacturing equipment and the finished parts in a more agile way. The project was born at the time when the quantity of pieces that were produced was large and a way to handle them efficiently was needed. The Warehouse needs 5 workers (*2 Blue Collar and 3 White Collar*) full time to manage it.

***Project #2* (EXECUTION): Sensorization and interconnection of the machines and process digitization**

In order to control the management and production, be more efficient and improve documentation, the system allows an integration between hardware and software (and the management software) and so, through an Ethernet connection, obtain information in real time, which allows to make decisions and make changes in the parameters of production before failures occur. At this moment there are 40 network machines and the configuration of an additional 10 is waiting.

The use of paper printed in the office has also been eliminated and an app has been created that allows to remotely access all the data of the orders and of the clients.

4.2.8. Study Case #8 – *SARIV*

This company was part of a family group founded in the 60's. Deals with the metalworking area, focusing on the **production of rivets for the automotive** and data management sectors (*also related to the same sector*). They are capable of managing large amounts of information related to their products and the complete traceability of the components used in them, in compliance with the provisions of the Kyoto treaty. Its production model is based on *Make-to-Order* (*MTO*) and *Made-to-stock (MTS)*.

❖ **General Data**

Revenues: 7 Million *Euro/year.*
Dependents: 40 workers; 25 Blue Collar, 15 White Collar.
Size: Small
Ownership: Private with family management.
Headquarters: 1 Headquarter in Padova.

❖ **Competitive Advantages of *TSM***

- Know-How
- High problem-solving speed that allows them to respond quickly to market needs

❖ **Industry 4.0 Projects**

They have invested annually around 30% of the invoiced in the creation of 4.0 projects and counts with a group of 3 full-time engineers dedicated to this topic, then, everything is developed internally. This company began to implement technological innovation projects even before the term "*Industry 4.0*" was discussed, which puts them at the forefront of this issue; The main motivation was the *need to improve the processes and place themselves above their competitors*, without the creation of a specific plan of action other than the objective of digitizing the whole company.

***Project #1* (INITIATION/EVALUATION): Data collection of each product**

It is planned to print by laser a code to each rivet and in such a way by means of reader and sensor systems, to collect information about each product made in the factory, and so, also measuring the performance of the machines. Clients will be able to enter through a VPN platform and verify the quality control of their products, being a strong point of their product in comparison with others; they will to stablish a powerful relationship between product, process and customer. This project is being developed a month ago and there are 12 more months left.

***Project #2* (EXECUTION): Digitization and analysis of production data**

Since 2011 (*the project lasted 1 year in planning and implementation*), they have a complete system of sensors into the machines that allows them *obtaining real-time production information* and check their status, do risk management and analyze them for quality control related to regulations around the automobile sector (*use of Statistical Process Control software*), ensuring the improvement of the product in terms of safety and quality. All the machines are connected in a network.

***Project #3* (EXECUTION): Automated Warehouse**

Use of a fully automated storage warehouse.

4.2.9. Study Case #9 – *BELLINI*

Company that works in the sector of lubricants at industrial level for niche markets, especially in the metalworking sector. they also produce other types of products such as motor oils and hydraulic oils. They are oriented to the Italian market (90%), although in the last few years they have been carrying out expansion projects to other European markets (10% by 2018).

Its manufacturing process is based on blending, where there is a base manufactured externally and the chemical components that complete the recipe are added, which means that they have a very short lead time (the average time to make a product is 2 hours).

❖ **General Data**

Revenues: 26 Million *Euro/year.*
Dependents: 56 workers, 4 logistics, 12 operators, 6 on laboratory and 34 on office. In total there are 12 Blue Collar and 44 White Collar.
Size: Medium
Ownership: Private with family management.

❖ **Competitive Advantages and Weak points of *BELLINI***

- The level of R&D that is included in the development of the product.
- They are considered as leaders in bio industrial lubricants.
- The ability to have both standard lines and totally custom products.
- Constant technical assistance to the client which translates into an excellent pre and post sales service.
- Its partnerships with state education associations (such as *Federchimica Milano* and *Confindustria Bergamo*) to give specialized courses to their workers.

The weak points of *Bellini* are:

- They are small in comparison with competitors which does not allow them to handle large volumes.

❖ **Industry 4.0 Projects**

To develop these initiatives, they were closely linked to the help of the suppliers, who offered them options for new technologies and to the company's own workers, who have the capacity to give their own feedback about the processes, since they are the ones who they are properly handling the machines and understand their failures and advantages; apart from this they already had certain skills and related knowledge (they require that all their workers have at least a college diploma). With each change or update of technology, workers received training courses (about 15 hours a week that included theory and practice) that made them more competent in their work.

They have a vision of industrialization based on the interaction of the various stages of production. The key point is the desire to make each process (and interface) easier for both the worker and the end customer.

The main obstacles were the resistance of the operators at the beginning, thinking that the machines were going to replace them and the fear of not knowing how to use the tools

Project #1 **(INITIATION/EVALUATION): Automatic Compactable Warehouse**

Winery that opens or closes as accordion depending on the real space needed, thus saving space.

***Project #2* (PILOT): Automated Guided Vehicles (AGV)**

For transportation and storage of tools, raw materials and finished products. The project is in the first planning phase.

***Project #3* (EXECUTION): Digitization (Sensorization) and production data analysis**

Implementation of a sensorized system in the production machinery based on PLC (and SQL bridge), which allows them to obtain in real time data of the process, such as temperature and chemical compound status, to be able to access this information remotely (even from a smartphone) and have control over the storage sites. The application has a system of alarms that alert workers when a process is not being carried out in the correct way.

***Project #4* (EXECUTION): Automation of valve and silos systems**

System of electromechanical or hydroelectric valves that allows the measurement and control of their behavior, avoiding possible failures in the system. They have sensorized floats that control the level of filling of the silos and avoid the overflow of the material.

***Project #5* (EXECUTION): Centralized process control**

Creation and implementation of a centralized control panel and remote control (tablet) that allows each operator to handle every detail of the production from any point of the factory as in a single point.

4.3. COMPARISON

The process of comparing the companies and the specific cases is done considering the **qualitative characteristics** and the **quantitative results** obtained through the aforementioned methods. The qualitative comparison will mainly focus on the *differences and similarities between the companies*, considering their size, sector, type of market in which they work and the specific objectives they have when developing I4.0 projects.

The expected results with this analysis will focus on the understanding about the possible motivations and/or needs that influence a company's decision to start the I4.0 journey; **These results will be of great help in being able to *guide other companies that may have similar organizational structures or that face similar challenges and do not find the proper way to begin an adequate process of modernization.***

The second part of the analysis is focused on the **quantitative results**, which will be clearly based on the ***TIP indicator***.

The analysis will be developed by **differentiating the projects that are focused on the modernization of the company's internal processes ("*TIP process"*) and projects focused on product development ("*TIP product"*),** which will allow the understanding of the company's strategy and compare similar firms.

There will be two types of analysis: **the FIRST ANALYSIS (called *"generic comparison"*) aims to compare the 9 cases of study without making any differentiation between the actual size of the companies** (*the sample is composed by all the 9 companies compared*), which gives a general ranking and allows identifying what are the *possible reasons, strengths and weaknesses that they guide the company towards a good process of technological innovation*.

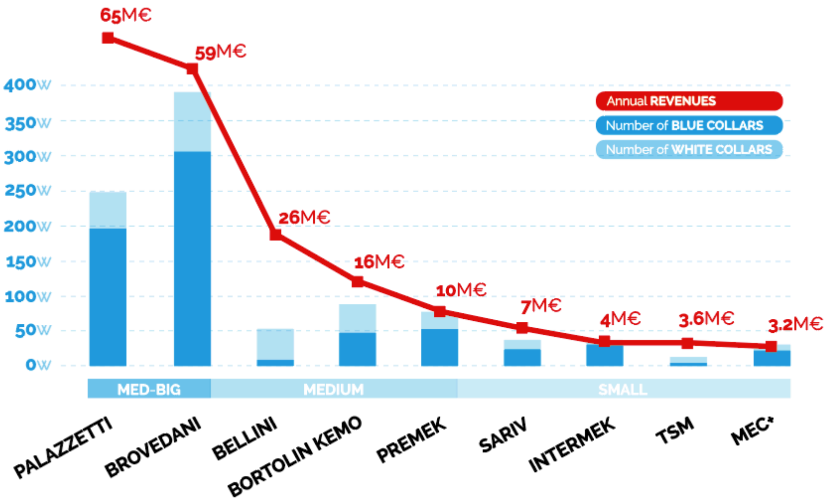
The **SECOND ANALYSIS** is made considering that the *study cases* are based on companies that sometimes work in similar industries but have different organizational structures and sizes. It is assumed that large companies have the ability to invest more money in *machinery, R&D and human resources*, and so, develop projects more accurately and quickly than companies where the number of workers and resources is otherwise scarcer. Based on this premise, two different analyzes are carried out, **the first only considers a sample composed by medium-sized companies and the second, only by small ones** (considering the definition of SMEs in Europe). The TIP values change according to the sample taken.

The first analysis includes two case studies of companies (*Brovedani and Palazzetti*) that exceed the annual income established to be called "*Medium size*", which makes them classified in a category between <u>*medium and large*</u>.

Although this document focuses on *SMEs*, it was decided to include these two cases in the analysis *due to the fact that the cases are very interesting* and with the aim of **identify if the size of the company or its amount of income are influential factors in the i4.0 project development and application**.

The results shown in the analyzes **REPRESENT A PHOTOGRAPH of the current state of the company at the time of the interviews** (*March 2018*) therefore the positioning of the companies with respect to the sample may change over time. Companies are expected to advance more rapidly in the implementation of *4.0 technologies* and the *TIP values* increase over time too.

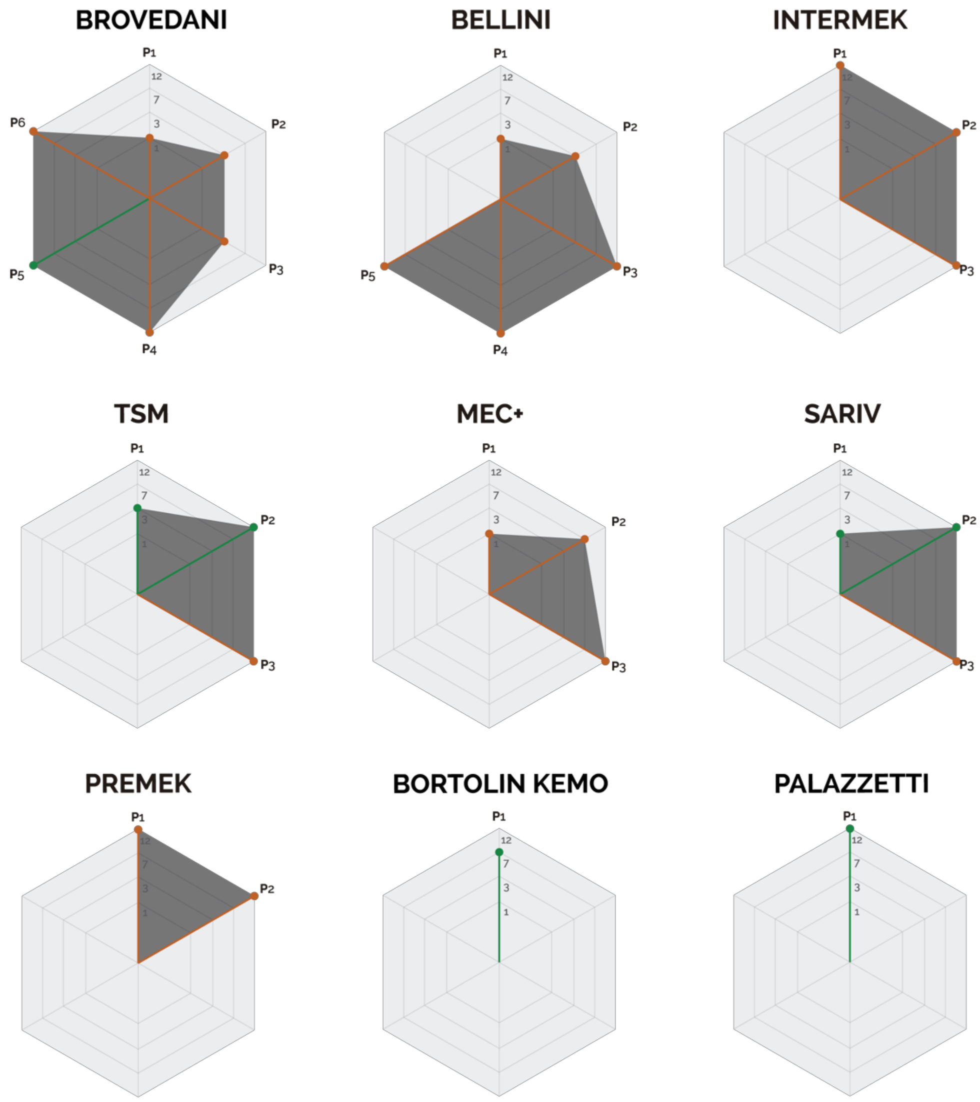
4.3.1. General Data about the companies and cases



Graph 1. *Annual revenues, number of workers and classification of the companies studied.* ***Source:*** *Own Development.*

Graph 1 shows the relationship between the annual income of the companies and their general size (*based on the number of workers*). Except *Bellini* and *Palazzetti*, **the number of workers is almost directly proportional to the income of the company**, and **the number of Blue-Collar workers (*usually machine operators*) is much higher than the White Collar (*usually executives and office workers*), this is because generally the companies are moving in a productive and manufacturing sector**.

Graph 2 shows the level of progress (phase) in which each of the projects of each of the analyzed companies is located, making a difference according to the project's focus, either in product or in process. Taking a quick look at this graph allows us to **understand that the larger the area occupied in the grid, the more advanced the company is with respect to the others**. Additionally, companies are displayed according to the value of their general TIP (see Graph 3 - page 148).



Graph 2. *Advancement phase (1 for evaluation, 3 for Pilot, 7 for implementation and 12 for execution) and focus of each of the projects (green for "product" and orange for "process") of the Companies compared.* ***Source:*** *Own Development.*

4.3.2. QUALITATIVE COMPARISON

The qualitative comparison begins with understanding the strengths of each company and thus also understanding the needs that they have.

Image 16 shows the competitive advantages (within a group of 9) that each of the companies stands out from itself, being factors of differentiation or source of comparison between the sample to be compared.

More than *50%* of the companies stand out for the *quality of their products* and *44%* for having the *infrastructure and resources to invest in the improvement of production processes*. This means that **an important factor that must be considered when improving the quality of the product is to improve the quality of those production process, by investing in innovation, i.e. in projects I4.0** (*machinery that has greater precision, handling a greater number of materials*).

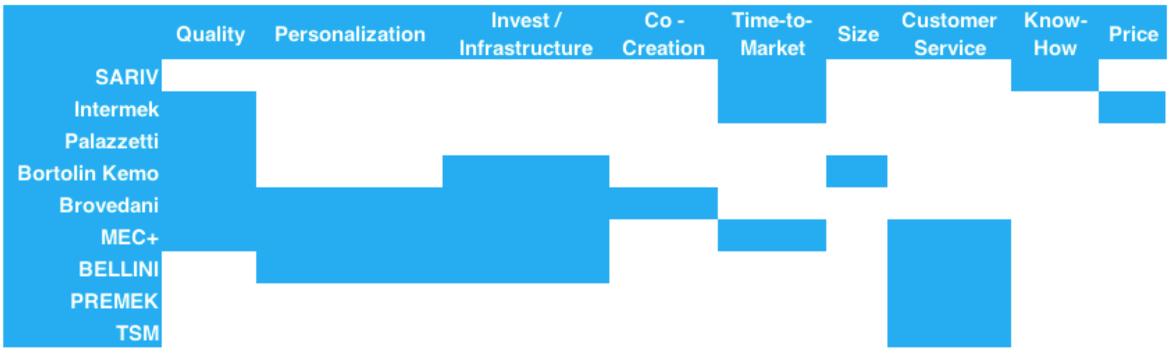


Image 17. Strengths and competitive advantages of the companies studied; The blue squares show the characteristics that each company highlights of themselves. ***Source:*** *Own Development in base of interviewed information.*

Personalization and customer service **play an important role in the companies` competencies**, being a very strong competitive advantage; customization is achieved by *modernizing production processes, reducing production times*, including different materials and *using additive manufacturing technologies*.

The customer service is translated into the existence of a *pre and post-sales service* and the generation of new additional services, possibly through technology (*product sensing, maintenance alerts and possibility of storage of the products before being distributed*).

Strangely, **companies do not identify their know-how as a competitive advantage**, which leaves room for thinking that **investments in R&D are scarce** and the *inclusion of new technologies is a response to the latent needs of the company and to position itself above its competitors*. In fact, **less than *45%* of the companies interviewed have established a team that is responsible for these projects** and **only 1 company developed an action plan** based on the training of all its personnel and thus the most appropriate inclusion of new technologies (*this company is the same as the action plan, Bellini*). **The interest in investing in knowledge and training of personnel does not depend on the size of the company but on the objectives pursued**.

It is very important to recognize that for the companies analyzed **the modernization process usually did not start with the establishment of an action plan and a team of specialized people but was carried out following the needs at the moment and seeking support** (*usually outside of the company*).

For the sample Companies, the **main motivations** for carrying out I4.0 are:

- Costs reduction
- Simplify the management of company processes, communication between workers and improve working conditions.
- Develop more efficient and smart products.
- Improve efficiency in processes (*use of resources and time*), such as the elimination of paper expenses and the use of new technologies for communication.
- Acquire competitive advantages that make them stand on top of the competition.

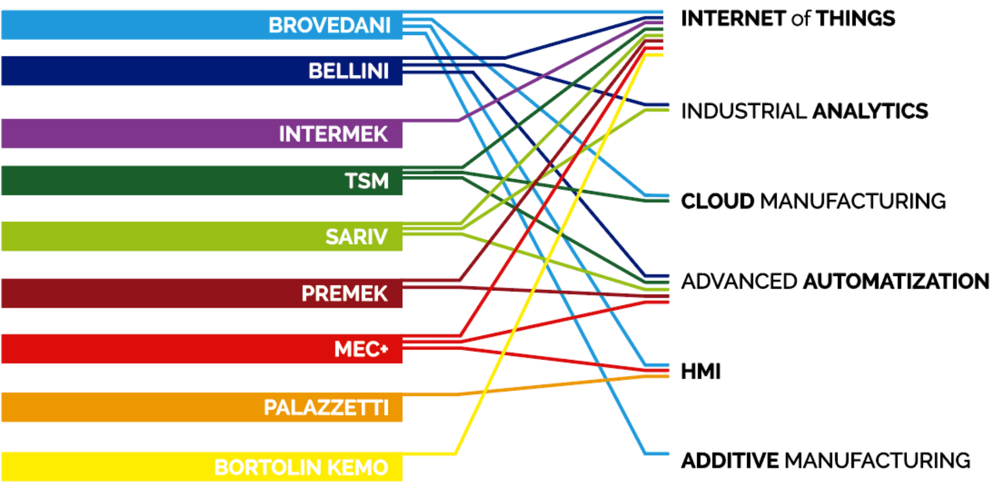


Image 18. *Industry 4.0 technologies applied (or in process of application) by each company.* ***Source:*** *Own Development.*

Focusing now in the technologies applied by each company, can be seen that the ***Internet – of - Things*** and the ***Advanced Automation*** are the most popular, since almost all companies pursue the *digitization of their processes and the sensorization of their machines and products* (*8 of 9 cases*) and the use of machines such as *Automatic Warehouses*, *AGV* and the *automation and control of the processes*, also related to the *human-machine interfaces*.

In contrast, additive manufacturing is not very popular among the sample of companies interviewed (*1 of 9 companies is up to now in the process of initiation*), especially because the inclusion of this type of technology is *expensive and it is difficult to achieve results with high quality standards and precision* as those needed i.e. in the metalworking industry. The additive technologies are still in the *development phase* and their use has to become cheaper to become massive and profitable. Sample interviewed companies do not feel very motivated about this technology yet.

4.3.3. QUANTITATIVE COMPARISON

FIRST ANALYSIS: Generic Comparison

In this case, the *TIP indicator* was found for each of the cases *without considering the size differences between the companies*.

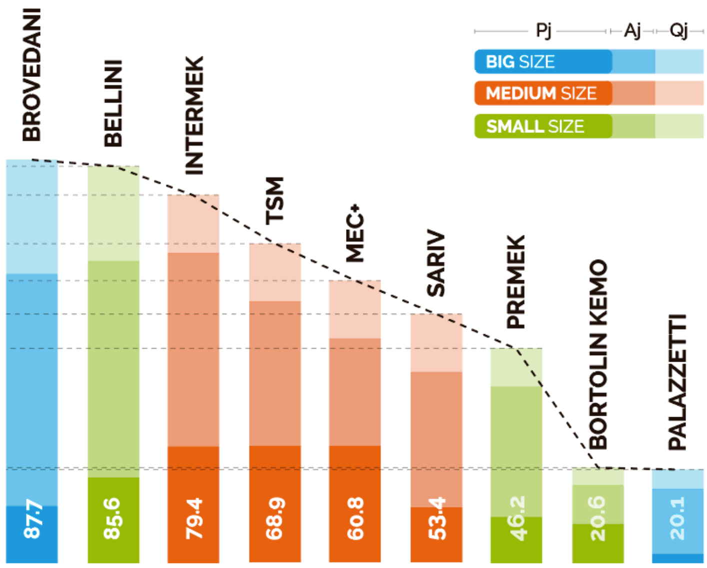
Three types of TIP were found:

- ***General TIP:*** Compare all companies equally.
- ***General Product TIP:*** Does not consider company size differentiation and only takes *product development projects*.
- ***General Process TIP:*** Does not consider company size differentiation and only takes *processes development projects*.

*For ease of reading, in this chapter the graphs dealing with general TIP will have blue color, while those dealing with **product TIP will be green** and **TIP process will be orange**.*

The possible faults that this comparison can have are focused on the fact that a large company has more resources and employees to invest in the implementation of new projects, while a much smaller companies cannot do it, making the comparison of someway imbalanced, throwing data that maybe is not so reliable. In any case, it is done to visualize the effects of the size of the company with respect to *I4.0.*

Graph 3. *General Technology implementation Progress Indicator (General TIP) of each company in relation with their size (by color) and the composition of the result, showing each term (Pervasiveness, Advancement and Quantity)*
Source: *Own Development.*



An important conclusion of this information is that **the size of the companies is not necessarily a determining factor in the successful implementation of I4.0 projects**, since, even when the second largest company (*Brovedani*, in terms of income) has the highest factor, the largest company (*Palazzetti*) has the lowest factor of the sample. The only aspect that can affect the I4.0 projects in some way related with the size is the **company's investment capacity**, that of course is a key factor in any project development but **would be a fault to affirm that the company size is directly proportional to the I4.0 money investment, it depends on the <u>WILLINGNESS</u> of the company to invest in this**.

Brovedani has the highest value (*TIP=87.7*), followed by *Bellini* (*TIP=85.6*) while the lowest is *Palazzetti* (*TIP=20.1*).

Brovedani is the largest company of the group, with 6 projects (*the largest number of projects in progress*), from which 3 are fully operational, 2 are being planned and 1 is in the evaluation phase; also has a very big workforce, with a total of 391 workers. Their projects focus on the **improvement of their production processes** (*in the case of the elimination of paper, the scope of the project is 100% of its workers*) and therefore the reduction of costs and *the* obtaining of data to provide a better service to the client. The high value of the TIP is due to the fact that it is the company that has an important **planning competence and capacity to implement projects**, has the greatest impact and has the greatest **initiative in continuing to innovate**, as it still has three projects in development. Mathematically, the high value of *Brovedani* is due to the fact that it is the company with the largest number of projects in the list and has the highest value in terms of *Advancement* (phase), positioning it above the others; On the other hand, some projects are in early stages, so they do not involve a large number of people, having a value not so high in terms of pervasiveness.

Although *INTERMEK* is one of the smallest companies on the list (*it has only 40 employees and revenues of 4M€),* it is one of the ones with the clearest objective in terms of *I4.0*. They have identified that their biggest weakness is their size and the difficulty they have of having access to large distribution channels and advantages of economies of scale, apart from operating almost exclusively with the local (*Italian*) market; to cope with this, they have decided to create competitive advantages by optimizing all their internal processes (*but not around the product*), **having as a clear objective to achieve a "*change in the organizational structure of the entire company*"** that allows them to have **simpler**, **friendlier processes**, fast and therefore with lower cost, which would allow them to expand, grow and compete with bigger companies and/or in other markets. In my personal opinion, ***Intermek* is one of the most interesting companies to analyze and take as example**, because despite of their limitations, they have reach certain level of expertise and organization that locates them over similar companies or even over biggest ones (that even counts with more resources and people), having a *TIP=79.4*, just 9% less than the highest value, which belongs to a Company with more than 14 times *Intermek* annual income, showing again that the size of the company, number of employees and/or annual income are not a determining factor in the success of *4.0 projects* in this type of companies.

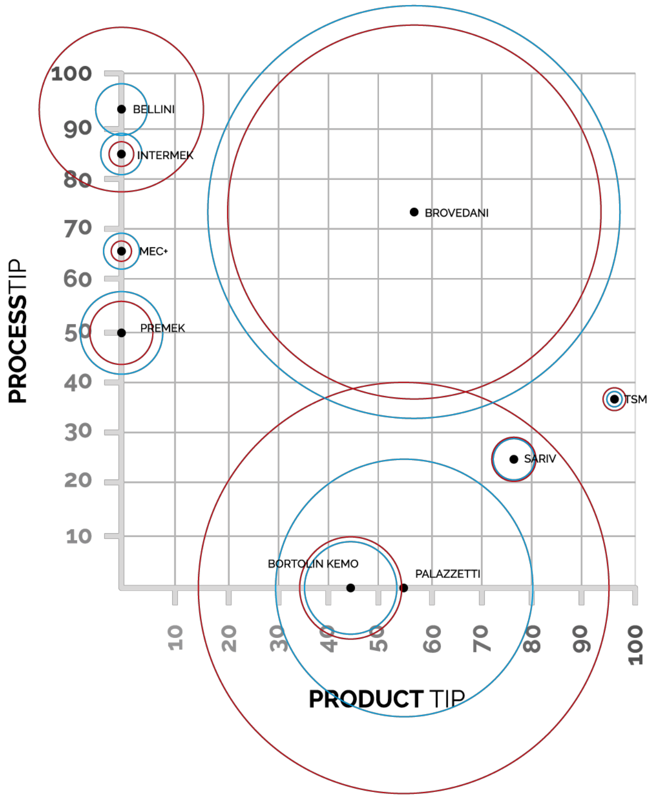
On the other hand, the second worst company (*according to the analysis*) is *Bortolin Kemo* (*TIP=20.6*). Although it has the 4th best annual income of the group and a considerable number of workers (*it is a medium-sized company*), they have not managed to implement any *I4.0* project (*the only project they still have in the last part of the implementation phase*). BK calls itself the "*leader*" in the market of packaging machines and consider that they have an "*optimal production infrastructure*", on the other hand, **they have the desire to innovate their technologies, but they have not defined a special role within the company** that analyzes and organizes this type of projects, leaving its development to people outside the company. It is possible **that the <u>lack of organization</u> and an <u>action plan</u> is the reason why the implementation of**

***I4.0* is not done in the most optimal way**, even when they have the experience, monetary and human resources.
A similar situation occurs with *Palazzetti* (*TIP=20.1*), where despite being a company with sufficient resources and a significant number of workers, they have focused on keeping their product (*stoves and fireplaces*) upgraded but **do not intend to improve their processes productive**, they are only interested in improving the product and so, customer service. Its low value is due to the small number of people involved in its unique project in relation to the large number of blue collar operators that the company has.

The case of *Premek* is interesting to analyze since it is one of the few companies that have a *clear understanding of the advantages of including technologies 4.0 in their processes* and have also established a *clear strategic plan*, a *defined role and even a certain number of weekly working hours* in this topic, but even so their TIP is not high. The reasons for this phenomenon are based on the lack of capacity (possibly lack on speed) in the implementation and generation of new projects, having only 2 ones being developed.

4.3.3.1. Generic - Product and Process analysis

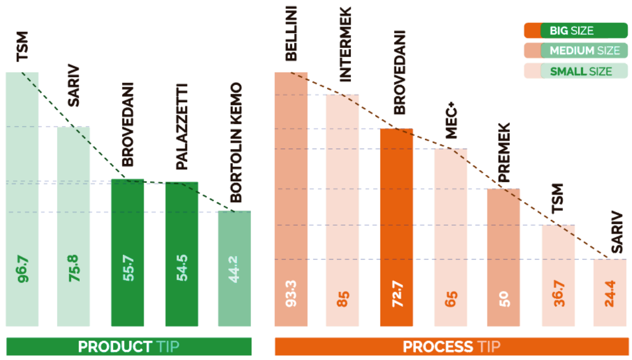
When the *differentiation between product and process TIP is made*, the position of the company can be identified in terms of the approach it has given to its 4.0 projects.



Graph 4. *Comparison between Product TIP and Process TIP for each of the compared companies and their size (red circle represents annual revenues and blue circle represents number of workers).* ***Source:*** *Own Development.*

Graph 4 shows the position of the companies in terms of their focus on product and/or process in a two-axis diagram; This view is useful since it allows us to understand the way each company applies the i4.0 projects and conclude the factors that have a beneficial influence on this process.

Observing the *Graph 4* can be seen that *Brovedani* has a privileged position with respect to the others (*in tune with the results of the general analysis*), also having



Graph 5. *Exact values of Product TIP and Process TIP of each company.* ***Source:*** *Own Development.*

a spot between both axes, which means that **it has a mixed approach between process and product improvement.** Reaffirming what is written in the general analysis, *Brovedani* stands out for its great capacity and desire to plan and implement processes (*having the largest number of projects among the sample*), while ***Bellini,*** **having a focus on the processes and the goal of turning each operation simple and friendly for both the worker and the customer**, has the highest position on this axis, followed by *Intermek*.

It can also be observed that *TSM* has the highest position in terms of product development despite the fact that its *general TIP* is not very high in comparison with the others; This is because their *4.0 projects* **seek only to create an intelligent and fully functional vacuum** for their clients and thus generate loyalty with them (*they have a trajectory of more than 100 years in that*), additionally **they are not incentivized to include improvements in their processes** since they are still small with respect to their competitors and their production and assembly volumes are low, making it not worth the investment and effort.

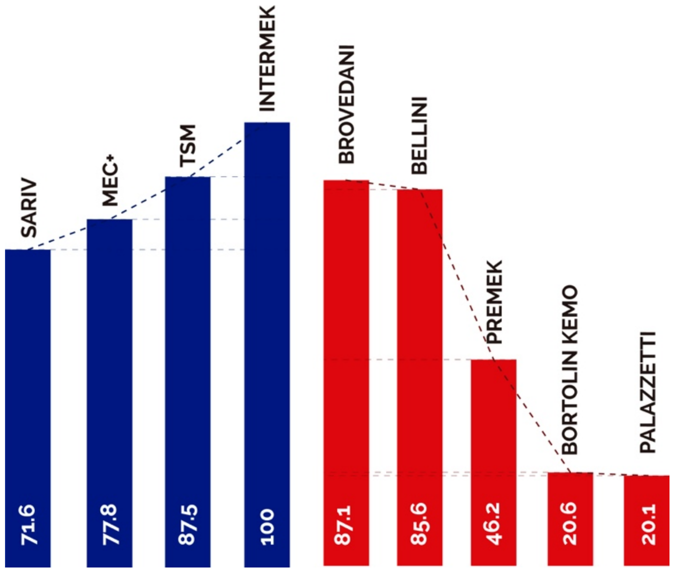
This suggests a very interesting conclusion: **a factor of success in projects 4.0 is the willingness of companies to invest money and efforts in this (not related to size or income); this will is influenced by the specific needs of the company, its products and processes**, so it is valid to affirm that the **relationship between a company and the *4.0 technologies* is a personal**

issue that responds to the inner characteristics of the company, its operations and the market in which they work.

4.3.3.2. Size Oriented Comparison

As explained in the previous sections, in this case, the size of the companies is considered when determining the *TIP indicator*; this allows the *segmentation of the analysis* and analyze the factors that influence on it. *Graph 6* shows on one side (right/red) the values of TIP, taking as sample only medium-large companies and on other side, a sample made just with small companies (left/blue).
It is important to mention that *two different analyzes* were made **considering separated samples** from each other. For graphic reasons and ease on results reading, all the values were included in Graph 6.

For the ease of the reader, the **Small companies are represented with dark blue color** and **Medium-Big ones with red color**.



Graph 6. *Technology implementation Progress Indicator (TIP) of each company in relation with their size, making one comparison just with small size ones and other one with the medium-big size ones, not considering product or process focus.* ***Source:*** *Own Development.*

As expected, the values of the medium-large companies did not undergo any change, since the *Brovedanis'* and *Bellinis'* values of “*number of employees*” and “*number of projects*” of are still maintained as the highest in the list (see Graph2). On the other hand, when small companies are separated, the *maximum value of projects* is *i=3* (*all 4 companies compared have 3 projects*) and the *maximum number of workers* is *Mi=40* (*of Sariv*). Once again it is possible to verify **that the annual income and the size of the company are not influential factors around the modernization of the processes, there is no correlation**, considering that in the sample taken, *Sariv* has the largest income and size.
The reason for *Sariv* to have the least TIP value in comparison with the other small companies is due to the **low pervasiveness of their projects**, being these focused on *specialized personnel*, set side by side with projects such as "*paperless*" of TSM in where the vast majority of the staff is involved.

Although the profiles of *Intermek* and *Sariv* are very similar, both have the same number of projects and even employees, *Intermek* has been able to develop the 3 projects faster (See Graph 2) and has a bigger pervasiveness, having an approximately 28% higher TIP.
Carrying out a deeper analysis of this case (and agreeing with what was written in the general comparison, page 149), can be seen that *Intermek has focused on carrying out several projects, but using only technologies related to the Internet-of-Things*; this fact means that they have been able to acquire experience and expertise in this subject and can exploit it from different angles, always addressing the improvement of the efficiency of production processes and a profound change in the structure of the company.

So, following the example of *Intermek*, **for some companies it is advantageous not to DIVERSIFY the use of technologies, but to focus on one (or some) and become an expert, managing it with great depth and being able to exploit it at its maximum**, especially when the company's resources, as in the case of *Intermek*, are not abundant and depend a lot on external factors and actors.

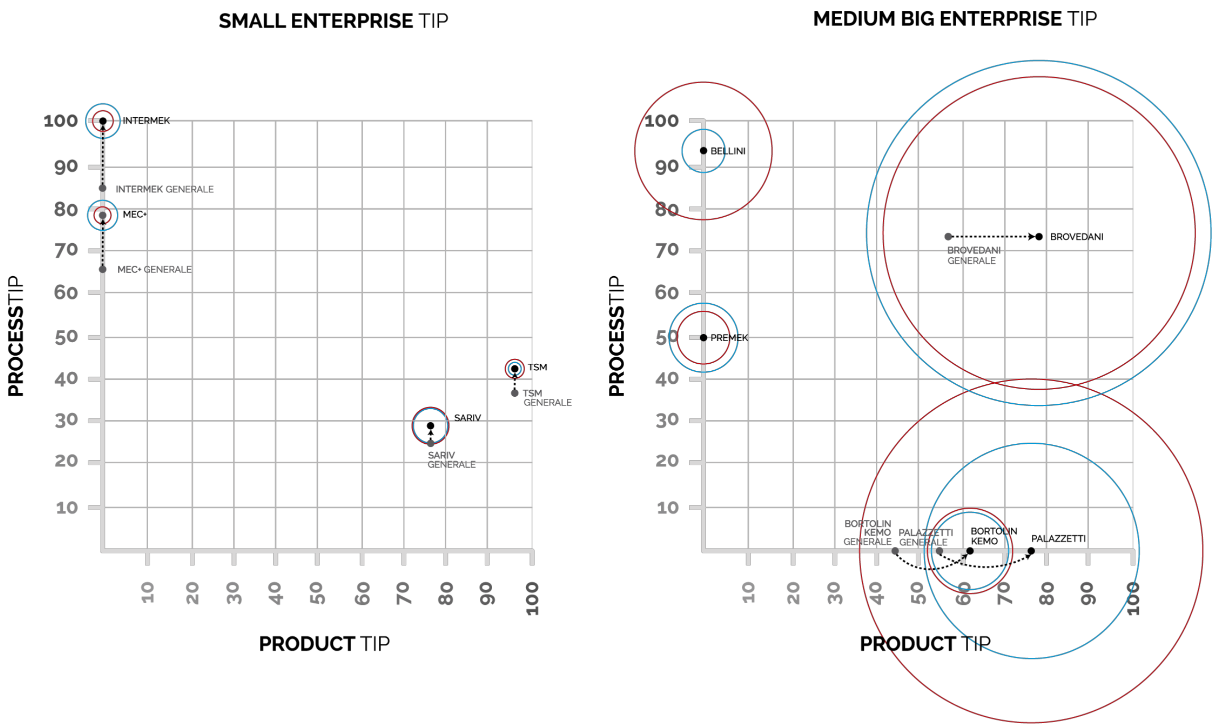
A key factor focuses on <u>the ability to develop a clear and concise objective and generate projects that have a transcendence in the Company, producing improvements at a general level</u>.

It is also interesting to analyze that the reasons why *Intermek* has the value of *TIP=100* over the other small companies are due to the fact that the three projects are in *advanced stages* and as it was previously said, they are focused on the *digitalization of the own processes of the company* (like the elimination of paper), which makes its pervasiveness perfect (its projects affect all the members of the company). It is important to note that apart from the fact that its TIP is the largest among small companies, it is the third largest in the general count, being one of the <u>most interesting cases to analyze</u>. Many companies can take their actions as a way forward, because being a company that despite its limited level of resources has managed to develop successful projects that involve their workers and generate positive results, clearly state the **lack of correlation between size, income and application of projects 4.0**

From Graph 6 can also be seen that somehow the small companies (*dark blue color*) have a better performance in terms of the implementation of *I4.0 initiatives* than the medium or even big companies (*red color*), even when their resources and size are considerably smaller. This dramatic difference may be due to their **desire to acquire competitive advantages that allow them to access new markets and compete with these larger companies**. Also, as mentioned above, companies such as *Intermek*, *TSM* and *Sariv* have established specialized positions and much more structured, organized and strong action plans that have allowed them to reach high levels in comparison with firms such as *Bortolin Kemo* or *Palazzetti,* which despite having between *55%-80%* higher annual income than its smaller colleagues, it has a very poor and disorganized management of new technologies.

Size Oriented - Product and Process analysis

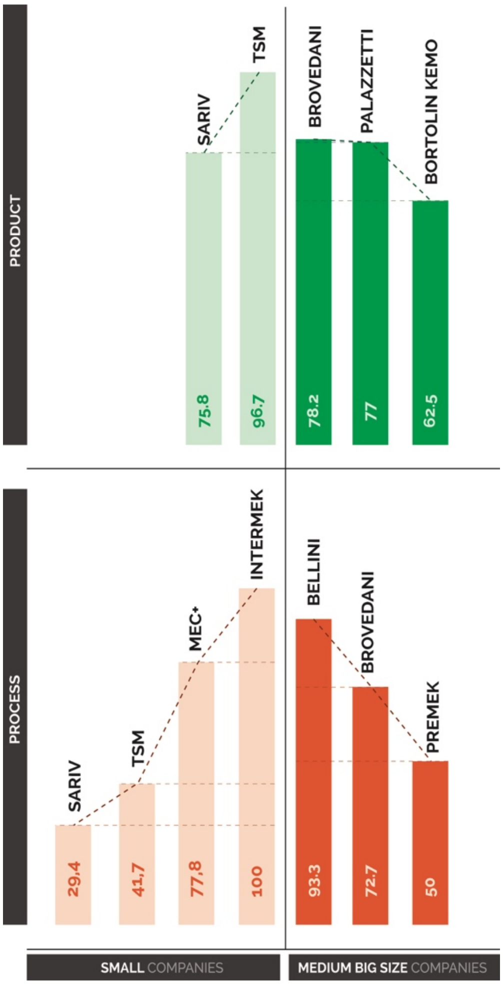
In the same way as in the general analysis, in this case can be located the companies in a two-axis area and see the relationships between them.



__Graph 7.__ Comparison between Product TIP and Process TIP for each of the compared companies making differences from their sizes (a. Small Enterprises and b. Medium-Big Enterprises); red circle represents annual revenues and blue circle represents number of workers. The dotted lines show the trajectory from the general comparison to the Size-oriented comparison __Source:__ Own Development.

Graph 7 shows how *TSM* has the highest value in the x-axis (Product) but has a low value in terms of process development, which gives to them the second place in the *general comparison*, while *Intermek* continues to have a privileged place despite only locating on the y-axis.

In general, the values increased in the process “y” axis while they remained constant in the product “x” axis; This is because Small companies such as *TSM* and *SARIV* are more focused on the improvement of products than their processes, giving them the lead in this field compared to others, while *MEC* and *Intermek* are purely focused on their internal processes.



Graph 8. *Exact values of Product TIP and Process TIP of each company.* ***Source:*** *Own Development.*

The values of *Brovedani*, *Bortolin Kemo* and *Palazzetti* increased drastically on the "x" product axis, since small companies such as *Sariv* and *TSM* have a greater number of projects focused on the product; its absence (in the specific comparison) causes those values to move to the right.

In general can be seen that **not necessarily the diversification in terms of projects is a positive factor (or negative),** there are companies with a high level of diversification and a high TIP (*Brovedani*), but others such as *TSM* where diversification has not made it overcome to the others; On the other hand, there are companies such as *Intermek* or Bellini that focus on the process and have a considerable level of advancement on industry 4.0 applications.

5. CONCLUSIONS

[1] Industry 4.0 represents the fourth industrial revolution and is supremely important since it is developing in real time, which allows us to be in contact, identify it, understand it and generate strategies of appropriation or adoption around it, putting into operation new technologies and allowing companies present themselves to the world as avant-garde, acquiring different competitive advantages over their competition and therefore (*generally*) climbing positions in their respective fields. In a world where information is worth gold, new IT and OT technologies allow to develop cleaner, more efficient, safer and more transparent processes, thus improving customer service and reducing costs, thus being a beneficial factor for all stakeholders related to it.

[2] The **TIP indicator** is a simple way to give a quantitative value to the level or progress in the implementation of technological modernization projects. This index can be used not only for projects 4.0, but also to measure and compare progress in any other type of projects and/or contexts *(whether industrial, social, economic and so on)* since it takes into account only the number of projects implemented, the number and characteristics of the companies compared, and the volume of people involved, having a much greater scope than the one shown in this document. It is important to keep in mind that it is limited by several assumptions and does not represent a definitive value, but only a signal that facilitates this type of analysis.

[3] Any company that has the need to implement new technologies **is in the capacity to do so** (*if it counts, of course, with the necessary economic resources*). **The modernization of industrial processes is not linked or available only to large companies**, **it is linked to the needs of the company, the product, the service and the end user**; These needs determine whether or not it is necessary to modernize the processes and whether it is worthwhile for the Company or for the client. The Companies have the support of Governmental entities *(depending on the geographical area)* that provide either economic aid, innovation development platforms or means by which knowledge can be acquired and get in touch with other companies with more experience and expertise in the subject.

[4] **The size of the companies** (*income and number of workers*) is not a determining factor in the successful implementation of an *industry 4.0 project*; although is decisive the amount of money that is determining or is willing to invest in the improvement of their processes, in the training of personnel and in the research and development of new products. A factor of success is the **willingness of companies to invest** and update their processes, rather than the size of them.

[5] **The clear goals and objectives to be pursued,** and the specific actions to be done to achieve them have to be defined before starting any I4.0 initiative through the development of an **action plan**: Cost reduction, process optimization (*simplification, use of resources, improvement of time*), improvement of the work environment (and working conditions for employees), environmental objectives or/and improvement of the product performance.

[6] For achieving the success, it is crucial to build a **specialized team and formal roles** that focuses on the optimization of processes. These professionals have the responsibility to *identify the needs of the company*, *identify the type of solution* that would adapt well to each specific case (taking into account the resources and objectives), establish relationships with external entities (public or private) that contribute with knowledge and expertise to the project, and finally to *organize other workers around the adaptation* into these new technologies (considering that, from the analysis done, one of the most challenging factors is to achieve the adaptation of workers - especially the most traditional ones- to these new technologies).

There is a relationship between the establishment of one (or several) formal figure(s)/role that deals with I4.0 issues: the investment in improving the expertise and knowledge and the TIP value. 44% of companies that have done so are inside the 50% with better TIP, being an indicator that, the highest the investment in R&D is made (*or at least in training their employees*), the better or more efficient is the company in implementing new technologies.

[7] As a general conclusion (*making a connection line between the previous conclusions*), the success of a Company in the implementation of 4.0 projects is the result of a **harmonious conjunction between the factors previously** exposed: the ***willingness and desire to innovate***, the development and implementation of an ***action plan***, the establishment of ***specialized roles*** and the ***capacity to carry out the projects***. From the cases analyzed, some companies fail when lacks one or more of these factors, as in the case of *Premek*, where despite of having an action plan, specialized roles and a team, they lacked the discipline to move forward with the projects, making it impossible to finish them in an expected time.

[8] **Diversification in the application of 4.0 projects in terms of product projects and process improvement projects is not necessarily a positive (or negative)** factor that ensures a better positioning of the company against its competitors. Among the cases analyzed, there are both highly diversified companies and companies focused on one extreme in their *projects 4.0*, both with high values of *TIP*, showing that the *speed of implementation and generation of new projects and the ability to involve the company's personnel* are more important that the focus that these projects took. The decision about which path to take (*what technologies to apply*) is based purely on the *company's objectives*, the *action plan developed* and the *core values* that are to be developed or strengthened.

[9] From the case studies analyzed in the previous document, it can be concluded that **<u>there is no generic and general path</u>** for any type of company that wants to modernize its processes, improve its products or include *4.0 technologies* in its work; there are limiting factors in the implementation of projects 4.0 as the amount of income of the company, but more importantly, the amount of money and resources that are willing to invest in these types of projects. The characteristics of the company, its objectives, the approaches they have for their products and services and the relationships with their competitors and environment are factors that influence these decisions, making **"the implementation of projects 4.0" a result of multiple internal and external factors of the company itself and the industry in where is working on.**

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