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Industrial Internet of Things: the state of adoption in Italy and a data-driven business framework

Supervisors: Prof. Angela Tumino

Co-supervisor: Dr. Elisa Vannini

Author:

Virginia Masi Matr. 918533

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Abstract

Obiettivo. L'Industrial Internet of Things rappresenta una tecnologia abilitante fondamentale per la digitalizzazione del settore industriale in un'ottica 4.0. Lo scopo della tesi è analizzare lo stato di adozione delle soluzioni Internet of Things per la Smart Factory in Italia, evidenziandone proprietà e barriere. Inoltre, in un'ottica di sviluppo futuro, le soluzioni Internet of Things nel contesto industriale sono viste come le leve per passare da un data-resistance ad un data-driven business.

Metodologia. Diverse fonti sono state utilizzate per il completamento della tesi. L'analisi della letteratura è servita per ottenere una panoramica delle tecnologie e delle proprietà che caratterizzano l'Industrial Internet of Things. Successivamente, attraverso un'indagine inviata alle grandi aziende italiane, è stata effettuata un'analisi dello stato dell'arte della Smart Factory in Italia. Infine, è stata analizzata l'offerta tecnologica delle piattaforme IoT utilizzando fonti secondarie.

Conclusioni. L'output della tesi consiste nell'analisi dell'adozione di soluzioni IoT da parte delle grandi aziende italiane, anche rispetto alle piccole e medie imprese, e nell'analisi dell'offerta di piattaforme IoT. Il lavoro ha permesso di costruire un data-driven business framework, un modello concettuale basato sulla valorizzazione dei dati ai fini decisionali nel contesto industriale. Ha inoltre consentito di indagare l'effettivo sfruttamento dei dati da parte delle aziende italiane, a vantaggio delle stesse e dei propri clienti attraverso una matrice valore-dati.

Abstract

Objective. The Industrial Internet of Things represents a fundamental enabling technology for the digitization of the industrial sector in a 4.0 perspective. The purpose of the thesis is to analyze the state of adoption of Internet of Things solutions for the Smart Factory in Italy, highlighting their properties and barriers. Furthermore, with a view to future development, look at Internet of Things solutions in the industrial context as levers to move from a data-resistance to a data-driven business.

Methodology. Several sources have been used for the completion of the thesis. The analysis of the literature served to get an overview of IoT technologies and properties that characterize the Industrial Internet of Things concept. Subsequently, through a survey sent to large Italian companies, an analysis of the state of the art of Smart Factory in Italy was carried out. Finally, the technological offer of IoT platforms was analyzed using secondary sources.

Conclusions. The output of the thesis consists in the analysis of the adoption of IoT solutions by large Italian companies, even with respect to small and medium-sized enterprises, and in the analysis of the IoT platform offer. The work allowed to build a data-driven business framework, a model based on the valorization of the data for the decision-making purposes in industrial context. It also allowed to investigate the actual exploitation of data by Italian companies, to the benefit of the business and its customers through a value-data matrix.

Executive summary

Introduction

Technological advances and digitalization in everyday life have led to the increase of rapidly changing customers' need and requirements, on the other hand the fierce of competition in global market has risen. With a view to satisfying these new demands, staying ahead with competitors, enhancing product and service quality and raising profits, enterprises opt to implement new technological means and seek for new approaches to increase productivity. *Industry 4.0* is the response to the newly created challenges in fast-changing and evolving environment. It constitutes a new level of organization and control throughout the entire value chain and it puts emphasis on the development of smart factories aiming at transforming conventional industries into intelligent ones. The most important added value which Industry 4.0 brings, and that clearly distinguishes from the third industrial revolution, is to be found in the seamless systems integration and a hyper connectivity that goes beyond the factory walls.

One technology in particular can bring a systemic change in the industrial sector, the *Industrial Internet of Things*, 'reinventing' a sector which account for approximately two thirds of the global economic output and that, according to Accenture, it may drive economic gains of 14.2 trillion dollars by 2030.

Every object (machine, system, product and service) within the industrial sector becomes intelligent and connected, acquiring its own identity in the digital world. A first aspect to consider is the *seamlessly connection of devices*. In this matter, the network connectivity alternatives are very important, as they allow all objects to communicate and to exchange information with each other; they can be classified into seven clusters of IoT technologies distinguishing mainly costs, coverage and data rate: RFId, Personal Communication, Wi-Fi, LPWAN, Wireless LAN, Power Line Communication and Cellular. However, it is not just connectivity, IoT has had profound implications on the ability to *capture data* previously out of user reach; it is about combining connected devices with automated systems to gather data for the purpose of *analyzing and acting to optimize industrial operations* and *drive measurably better outcome* for customers.

For this purpose, among the technologies utilized in combination with IIoT, Cloud Computing allows industrial companies to take advantage of "on demand" remote resources for archiving, processing and accessing data, and supports computational resources which process data and extract value from Big Data, Analytics. Knowledge acquired by these resources combined with the company's learning and experience evolves into insights, know-how and decision support enabling companies to reach higher level of competitiveness. Today, there is an ever-growing interest for IoT platform which can satisfy both the need to store and secure data and run analytics on the cloud, and process data at the edge for IoT applications requiring real-time response.

There are three main macro area in which the Industrial IoT is applied. First of all, the **Smart Factory**, conscious and intelligent where IoT technologies allow to switch from a reactive maintenance logic to a proactive maintenance one, estimating the remaining time before a fault on machine occurs and thus realizing the maintenance intervention when is needed minimizing risk of costly downtime and extending the useful life of the machine. They enable an effective quality management, constantly monitoring a host of machine and process parameters that impact product quality and enabling to develop a quality control model so that the machine automatically adapts to fluctuations in variables such as environmental conditions. By tracking the power conception of each device, managers acquire visibility to benchmark the underperforming devices with the best performing devices and energy utilization can be in this way optimized, also it can be adapted to the production capacity; by tracking RFID tags they can have a real-time visibility of the materials being processed in the factory and route them efficiently.

A second area is **Smart Supply Chain**. In IoT enabled transportation and logistics, the products are incorporated with sensors along embedded tags. When the good moves, the flow can be traced by various participants in the supply chain. Further, the product becomes totally autonomous and various decisions can be taken by the readers from the obtained information; this leads to the end to end visibility in the supply chain and warehouse management, ensuring that the product is in the right place at the right time.

A third area and one of the newest trends in smart applications is **Smart Lifecycle**. The acquisition of extremely huge amount of data that allows better product development and longer product life-cycle, with activation of additional services for the customer after the product is sold.

Industrial Internet of Things results not only in a production-technical change, but also in extensive organizational consequences and opportunities. It opens the way for more flexible value propositions; manufacturers provide customers with individualized product, expand their offer with innovative services, which are strongly data-driven and based on the collection, monitoring and analysis of machine condition data. Data-driven core of the IIoT enables employing novel revenue streams, e.g., dynamic pricing, pay-by- usage, and performance-based billing. To conclude, despite an increasing individualized and service-oriented product, IIoT also allows the optimization of production systems regarding cost, reliability, time, quality and efficiency.

Research objectives

This thesis has been developed within the research conducted by the Internet of Things Observatory of Politecnico di Milano. The purpose was to analyze the state of adoption of the Industrial Internet of Things solutions for the Smart Factory in Italy; to understand the level of knowledge of these solutions by large Italian companies; to understand the initiatives already undertaken by companies in which area of interest and in what state of progress as well as the activation of additional services; the main goals companies intended to achieve and the barriers to their implementation; to investigate the future directions concerning these solutions; whether the health emergency has changed priority given to project based on IoT technologies and how the initially planned budget has changed. The results were analyzed with respect to those of the survey involving Italian small and medium-sized enterprises (this was managed by third parties) as well as with respect to the results of the questionnaires of previous years. Another analysis involved the offer of IoT solutions and in particular software platforms.

What has emerged is that companies are moving towards a more consistent use of these technologies and, by leveraging the extrapolation and exploitation of data enabled by IoT technologies, they are trying to make business decisions. On the basis of these considerations, last part aims to identify the building blocks of data-driven business framework, to frame the requirement to seize the best opportunities for cost containment and value achievement. Then, starting from the results of the Italian scenario, a data-value matrix was constructed in order to investigate the exploitation of data by Italian companies to the benefit of the company itself and its customers.

Methodologies

Among the research methods: a literature review allowed to understand the development context of Industrial Internet of Things, the main frameworks elaborated and all the different application areas; as primary source, a survey which involved 153 Italian companies allowed to evaluate the state of adoption of Smart Factory solutions in Italy, their features (area of interest, state of progress, obstacle encountered, data usage, …) and future directions; as secondary sources, a census of interested initiatives implemented around the world in Industrial IoT field and a census of the IoT platform offer.

The adoption of the Industrial Internet of Things solutions for the Smart Factory in Italy

The survey in which 125 Italian companies took part aims at investigating the initiatives already launched by firms and check out future areas of interest. Results are compared with the ones of the 689 small and medium-sized enterprises; this better completes the Italian framework made up of two very different realities, which are in two different phases as regards the adoption of IoT practices.
The topic of the Internet of Things is at the center of attention of bigger realities, in fact only 6% of respondents do not know the phenomenon, 64% of companies have already activated projects in this field and 30% did so this year. On the other hand, smaller realities have a very different level of diffusion, still 74% has never launched any project. Nevertheless, this percentage has decreased compared to what emerged from the last edition of the survey and the interest in activating future projects has also increased, to date 52% of them declared themselves interested in undertaken initiatives for Industry 4.0 in future.

In this year's survey it was relevant to investigate the Covid impact on the launch of IoT project and the two sides of the coin: on one hand the economic impact might have excluded these technologies, on the other hand the technologies might have acquired a higher value, reaching greater flexibility in demand and reducing risks in the supply chain as the ones recently experienced with the emergency. What emerge is that for the most part businesses did not change the launch of IoT projects due to the Covid situation because the theme is a priority and it was so already before the emergency; IoT technologies are seen as 'must have' for the future of their businesses. For this, largest part said that investments remain the same as already planned while half claimed that investments will increase but it would have been increased anyway.

On the other hand, emergency and lockdown put a strain on the financial statements of small and medium-sized Italian companies: some are unable to assess whether the issue is a priority, others declared that the theme

has decrease in importance as a consequence of the Covid. Despite this, among small businesses there are also those who recognize that Covid has made the issue more priority than before and that they have been pushed to start these projects precisely to manage the impact of Covid in the company in order to be more digital.
On the contrary, objectives that have driven large companies are to be found in efficiency (78% of cases, never so high in the previous survey editions) and efficacy that IoT solutions can bring. Besides the will of reaching higher level of competitiveness, they have a growing attention towards sustainability which, according to future forecast, soon will have nearly the same importance (24%) as the access to incentives of the Industry 4.0 national plan that in 2018 had prompted a company out of two to start industrial IoT project. Thanks to IIoT technologies, companies can lead business to operate more ethically towards industrial processes and operations that do not create unnecessary excess waste and that also do not consume more resources than they generate. This can be seen well if the areas of greatest interest are better investigated.
Companies are mostly focused on innovating processes within the plant, 64% of launched projects are in the **Smart Factory** field, specifically projects aiming at optimizing the production process and concerning energy management are the most widespread. These are also the areas with a higher percentage of executive projects: for both, 60% of initiatives are fully implemented. Analyzing the specific areas of interest of **Smart Logistics** with an incidence of 29%, it is clear that goods traceability is a key aspect for companies both along the supply chain (26% of cases) and within the warehouse (25%). **Smart Lifecycle**, with an incidence of 7%, is the less relevant area among the large companies conversely to SMEs (half of those who initiated projects did so in this area); executive projects are really low compared to preliminary and pilot ones.

For 80% of companies there is the will to activate projects, the percentage rises to 83% for those who have already started projects and drops to 67% for those who have not activated them. Indeed, those who are most likely to start new projects are those who have already undertaken initiatives and reaped their benefits.
Being for the most part tangible objectives that drive companies, these can evaluate the benefits associated with the projects. Comparing the results with those of 2019, it emerged that those who did not evaluate the benefits more than halved while those who did a complete cost-benefit analysis doubled this year.
In retrospect, respondents can assess the obstacles faced. Half of the companies find themselves poorly prepared for the issue relating to IIoT, lacking both knowledge and competences. Also, a big slice does not understand the profound value of these solutions in companies and this is can be attributed again to a lack of knowledge. The level of knowledge of these solutions is in fact barely sufficient on average, while the launch IoT projects required a solid knowledge involving the adoption of new technologies but also the management of an infrastructural and organizational change. A positive sign is that the lack of knowledge and of understanding of true value are becoming less relevant. On the other hand, a less positive one is that still a significant portion of companies who recognize a relevant gap in skills have not yet acted to fill it.
For sure, a crucial point remains the technological obstacle of integrating old and new systems and the economic aspect of these solutions.

Two interesting aspect to be analyzed concern the activation of services and the use of data. The launch of Industrial IoT projects allowed companies in 82% of cases to offer services for their customers: the majority are informative services (81%) as the possibility to receive notifications in real time and to activate automatic emergency calls in case of danger; to follow energy management services, monitoring consumption and proposing action to improve energy efficiency, and preventive maintenance ones, helping in addressing minor issues before they escalate into unplanned outages. Companies which offers services of asset monitoring to predict potential problem are less, 24% of the sample but these advanced services are foreseen to grow till 33%. Providing services of this kind may be beneficial: customer can, through information on imminent failures, act and avoid a production stop and associated costs while vending companies can collect a lot of data on the machine useful for understanding common problems and improving some aspects on their machinery.
When it comes to data, the analyzed sample is divided in two parts: companies that still do not collect data are few (8%) but still the majority of the sample does not make a proper use of the collected data (36%), on the other hand, among those who instead manage data, 16% declare that they use them in raw form, while 29% reprocess them to obtain useful information, thus those who make the most advanced use of them are twice as high as the former.

Subsequently, in order to deepen the analysis of the Italian scenario, several interviews about the most interesting projects were conducted. Each interview not only allowed a greater level of detail but also to understand the logical thread that united the activities put in place by the company towards the corporate goal.
For *Itelyum*, national leader in management and valorization of industrial waste, the goal is to move from a "data resistance" business, in which data are acquired in a trivial way, to a data driven business. Leveraging on IoT technologies and by combining specific software for data management with the use of a public cloud, the company undertakes to enhance the data by putting it at the center of the decision-making process. In order to learn how to read data and install processes capable of discovering trends and building *predictive routines* the interviewee foresees a 3-year period learning path. Even if the road to arrive at processes that alone build predictive routines is still long, the company is very projected towards the smart factory and sees it as the key for transforming its business and even for its survival.
For *Lavazza*, coffee quality plays an important role to stay ahead of the competitors. Grinding process was fundamental to be monitored as impacted by several variables, environment and machine, and as it affects the quality of coffee. Company decided thus to optimize the process in this way: machines data are collected thanks to some sensors, later these are sent, together with the data of the previous quality control, to a Cloud platform; learning from the behavior of the historian, the system predicts the expected quality of the test and, on the basis of this, it predicts the best setting to put in the mill. To be effective the response of the prediction of the quality needs to be in real time, algorithm needs to be optimized even when processing large amounts of data and thus AI is fundamental.
Prima Industrie, leader in the development, production and marketing of laser systems for industrial applications, has been turning its attention for several years toward Industry 4.0 and the IoT, which according

to Prima Innovation Manager can guarantee the highest competitiveness in a global market highly dynamic. The company is halfway through the set goal of enhancing data. In 2018, it has launched a project consisting in connecting its laser cutting machines in a single environment and extracting as much useful data as possible collecting them in a dedicated platform. Prima is making correlations and first analyzes in order to understand common issues and parameters to monitor, and also it aims at exploiting what learned, to better design the subsequent machines optimizing their development process. The success and failure of the project resided in data: giving the fact that many of the customers with which Prima collaborates are in the automotive sector and these are typically reluctant to share production data, the toughest obstacle was data sharing. Prima tried to overcome this obstacle focusing on guaranteeing cyber security.

The technological offer: IoT Platform

After demonstrating the growing interest of companies in IoT solutions, it useful to enter into the merits of the tools that can be used by companies in order to make the solutions feasible. IoT software platforms are seen by companies as the easiest way to mitigate the complexity of managing heterogeneous smart devices and ensure low initial development costs and maximum flexibility and scalability. For this reason, they are becoming more and more widespread: by the end of 2019, there were 620 publicly known Internet of Things platform, which was more than twice as many as 2015. Not only the startups, but even the big players of the market have moved in the development and offer of IoT platforms.

In order to provide an overview of the offer status, 121 platforms present on the market have been analyzed mainly looking at their functionalities and their areas of application. Alongside the specialist platforms, which have a vertical approach and offer a reduced set of functionalities, there are general platforms having a horizontal approach and covering many functionalities in order to satisfy more needs with a lower level of in-depth analysis. About half of the companies provide device management functionality as core in the platform in order to mitigate heterogeneity of devices and guarantee connectivity to the Internet and communication between objects. 22% of solutions are general cloud-based platforms delivering general ICT services, hosted computing and data storage resources and covering a broader spectrum of functionalities. More of less with the same percentage, data analytics and business intelligence, which process data streams either at the edge or in the Cloud in order to provide useful insights and support a better decision-making.

Looking at the application scope, large majority of platforms are multi-application platform which can be used in many industries and contexts. On the other hand, 10% of platforms has a specific focus on Industrial IoT use, 3% on Smart Factory and 1% on Smart Logistics. According to Statista and the leading IoT market research firm, IoT analytics, 50% of all profiled IoT Platform companies have a dedicated focus on manufacturing/industrial use. Industrial platforms are built in order to fit better the industry requirements: guarantee a secure and robust integration between OT and IT, support solutions which are device-light and data-heavy, and process and analyze also at the edge emphasizing uptime and minimizing data loss in critical operations environment. To reap the benefits there are the industrial enterprises which can have a powerful advantage in terms of operational visibility and control of plants and equipment. According to Gartner, the

50% of these enterprises will use industrial Internet of Things (IIoT) platforms to improve factory operations, up from 10% in 2020. Also, it foresees that through 2025, 25% of large global industrial enterprises will acquire or invest in an IIoT platform company; up from 5% in 2020. Actually, startups and SMEs companies remain the most numerous (53%), but the big players recently entered the market are more and more present (47%). Reason behind the smaller players survival is that there are many niches in IoT, thus by focusing on specific industries some smaller firm can bring the value that larger horizontal players cannot. Even if market is not consolidating, it is concentrating around few providers. Specifically, in 2019 the top 10 of the 620 providers held 58% of market share: Cloud companies Microsoft with Azure and Amazon AWS, followed by Huawei, PTC and IBM with IBM Watson IoT.
The trend is towards complete platforms offering more functionalities: even if there are some core features, a large number of analyzed platforms cover albeit to a lesser extent the other aspects. Also, more and more robust and scalable, offering the opportunity to add more and more devices but not at the expense of require extensive infrastructure planning or long lead-times. The aspects to be taken into consideration for the choice of the platform are different and go beyond the design constraint and its core characteristics. An important aspect on which lies the value of the platform is its openness towards different hardware devices as well as towards other platforms offering complementary services. Companies do not just choice a single platform, they also choice the ecosystem of actors that surrounds it: physical device manufacturers, connectivity providers, integrated systems and OEMs, and cloud service providers.

A data-driven business framework

From the analysis of the state of adoption of IoT technologies for Industry 4.0 in Italy and targeted interviews, it has emerged that companies are moving towards a more consistent use of these technologies and, by leveraging the extrapolation and exploitation of data enabled by these technologies, they are trying to make business decisions. The IoT has been called the 'backbone' of today's data-driven economy, we are witnessing a new paradigm in which an ecosystem of people, machines and things exchange data and information. A study conducted by the MIT Center for Digital Business in 2011 found that companies which adopted *'data-driven decision making'* achieved productivity that was 5 to 6 percent higher than could be explained by other factors. A 5 percent increase in output and productivity is significant enough to separate winners from losers in most industries. The ability to effectively capture and use data is described by Kevin Ashton as '*what defines the Internet of Things*', but this is still a challenging for businesses: in the Italian scenario, half of the sampled companies makes use of the data, but just 30% of them re-elaborates them; on a global level, according to Aruba, while nearly all (98%) organizations that have adopted Internet of Things technology say they can analyze data, nearly all respondents (97%) believe there are some challenges in creating value from this data.

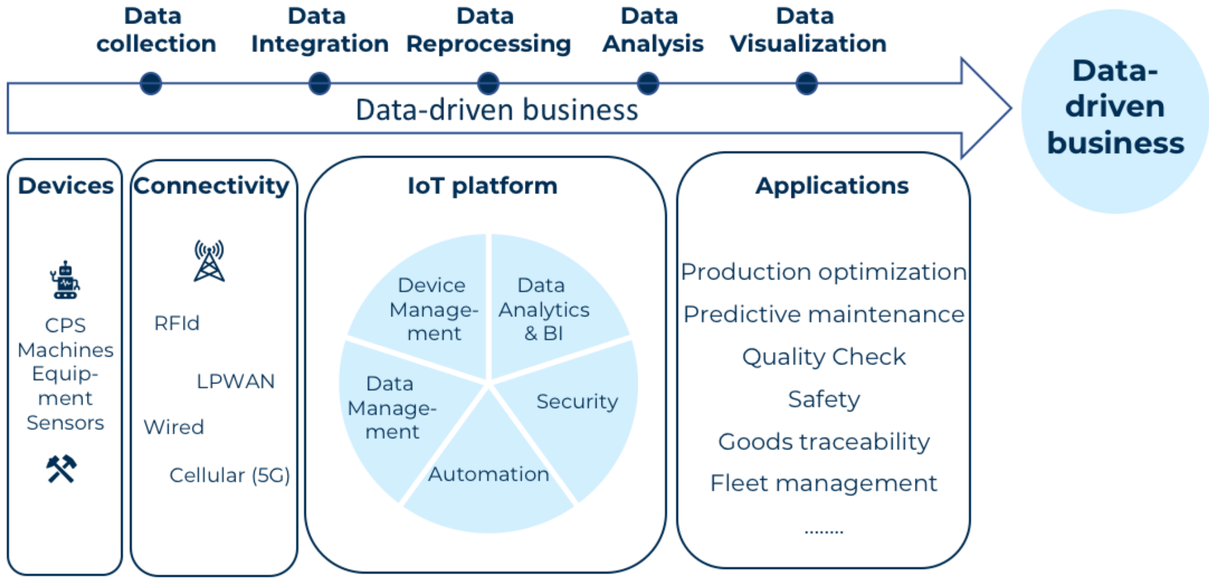

Figure 1: Data-driven business framework

On the basis of these considerations, a framework for data enhancement in decision-making process has been built, the data-driven business framework. It contains all the relevant aspects that the company must rely on to move to a data-based business model to seize the best opportunities for cost containment and value achievement. The building blocks at the bottom of the framework are also the layers of the Industrial Internet of things solutions: from left to right, *smart devices*, *connectivity* enabling communication and data transmission between different devices, and *IoT platform* to get value from data, creating and managing applications, running analytics, and securing data. By relying on these, data can be leveraged in different *application areas* shown on the right. Above, the *data lifecycle* line which allows to move from data collection to data applications, in which data are the basis for making business decisions and allow for increased visibility on operations as a whole, automation (automated collection and automated decision making) and efficiency**.**

A data-value matrix

After seeing how companies can use data and the advantages that derive from their exploitation in business decision, it is interesting to understand at present in what context the data is used most, and which are the areas that have not been exploited yet. Considering again the Italian companies which took part in the questionnaire and jointly analyzing projects' areas of interest and data utilization, it is possible to give a clear vision of the actual and potential use of data that benefits the company and the customer. The data-value matrix is constructed as follow: on the y axis, the use of data ranges from a high and profitable use of data by the company to still low data utilization, on the x axis, the application areas of Industrial IoT typically divided in Smart Factory, Smart Supply Chain and Smart Product Lifecycle are instead rearranged with a view to applications with a beneficial impact on the company and the customer. Or better, projects improve current business processes, assets and products, but taking a systemic view, direct and indirect effects can be evaluated, and areas can be categorized from purely *process* areas to areas that improve the *product* and the outcome for the customer.

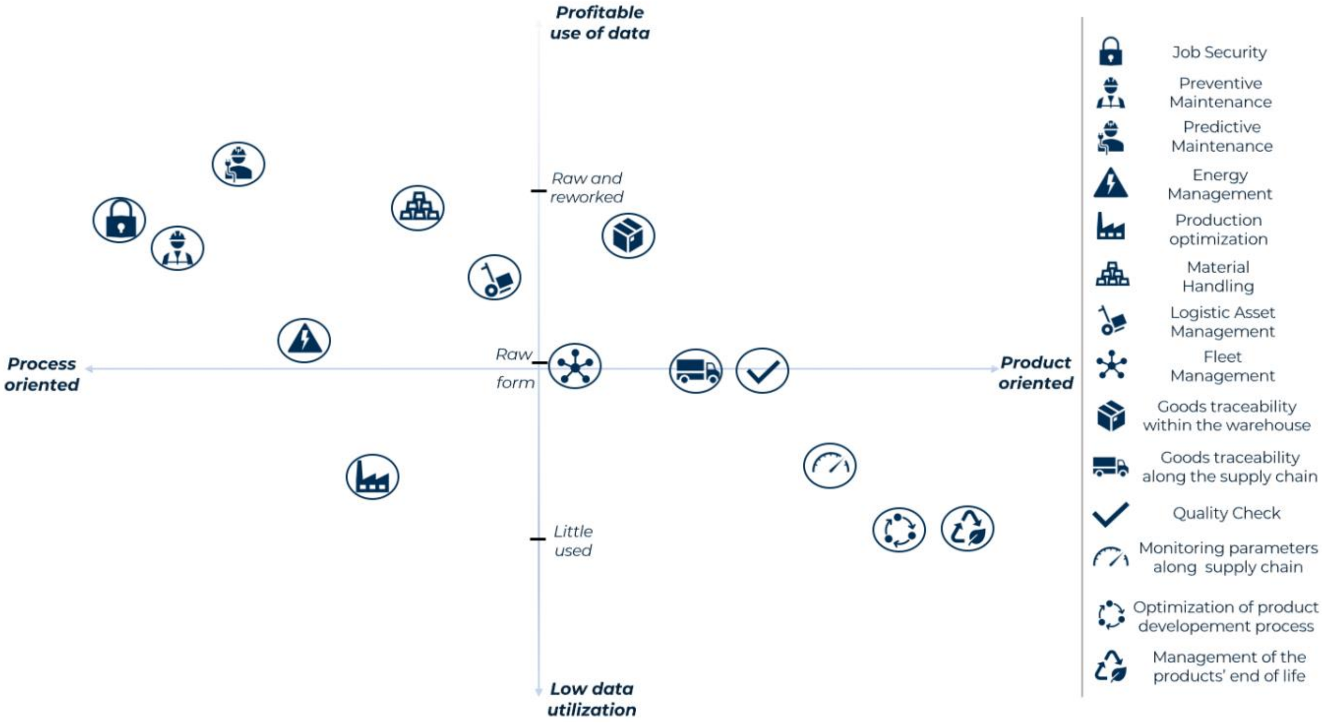

Figure 2: Data-value matrix

Findings

Many authors and specialists have emphasized on the one hand the importance and value, on the other the urgency of IoT technologies in the industrial field. Attention is very little as it is expected that the growth in the total number of IoT devices will provide substantial economic and social benefits in terms of cost savings, value creation, productivity improvements and overall economic growth. The industrial sector is moving faster than others because industrial companies see IIoT not just as a technology but as existential for their businesses. These two sides, importance and urgency also emerged in the interviews conducted. The analysis conducted at the Italian level has shown that the issue is much discussed, there are numerous projects that are being carried out regardless of the Covid situation as they were already considered to be priorities. Alongside mature applications such as those in the factory walls and to a lesser extent those aiming at controlling and managing the supply chain, there are new applications involving more customer-centric products and services which open up new business deals.

However, along with the benefits ranging from production efficiency to measurable better results for customers, there are significant barriers in the industrial context. Alongside barriers related to technology and integration between legacy operational systems and information systems, there are barriers of lack of adequate knowledge of the solutions that not only involve a change of technology but are placed in an important infrastructural and organizational change.

The Industrial Internet of Things is a concept in continuous development. Today, the offer has grown exponentially, and the conditions are created for a complete offer that seeks to overcome problems of interoperability between devices and data sharing. What defines the Internet of Things is the ability to effectively capture and use data, increasingly seen as a corporate asset. In the last part of the thesis, it is highlighted how data can be the key to effectively increase the productivity and business competitiveness. If companies make business decisions based on experience and intuition, it is only with data and analysis that the company can be brought to increasingly higher levels of competitiveness at this time, benefiting from a greater visibility, automated decision making and ever greater efficiency. The interconnection between devices and their use generate a lot of data which, if properly analyzed, provide invaluable information on business and customers.

Limitations and future development

A limitation of the thesis lies in the fact that sometimes it was not possible to contact roles that typically manage or are involved in IoT projects in the company to answer the questionnaire. This meant that the contact in question had less visibility on the projects, he was not fully informed, or he did not have a detailed knowledge of technical issues. Secondly, a more important limitation lies in the created data-value matrix which was made starting from two questions from the questionnaire. It was assumed that the answer given on the use of data was associated with each project launched in the company, not being able to investigate the real use of data in relation to each technology applied in the various fields and only trusting in the fact that by equipping itself with tools to collect as well as process data , the company has applied the same logic in order to improve and streamline all the processes on which it has focused. Also, the x-axis of the matrix was created in a qualitative way by understanding what could have a big impact on a purely corporate level and what could have an impact also for the customer. In the future, it could be interesting understand not only how data is used but in what applications and in what way. In addition to this, also try to understand in what perspective companies are using data, whether for the purpose of improving processes or creating value for the customer with a more complete offer or a transparent and fast response.

Chapter 1. Industrial Internet of Things

1.1 Introduction

Technological advances and digitalization in everyday life have led to the increase of rapidly changing customers' need and requirements, on the other hand the fierce of competition in global market has risen. With a view to satisfying these new demands, staying ahead with competitors, enhancing product and service quality and raising profits, enterprises opt to implement new technological means and seek for new approaches to increase productivity.

Technologies entering the manufacturing space revitalize the sector and bring him back to the fore on the scene. Manufacturing was in fact seen for decades as an engine of growth, but then global economy stops growing, conversely growth has declined for the last 50 years. Times of big growth have been fueled by big manufacturing revolution. It happens 3 times, every 50 to 60 years: the steam engine in the middle of 19th century, the mass production model at the beginning of the 20th century and first automation wave in the 1970s. Each revolution creates huge growth because have injected huge productivity improvement [Scalabre, 2015].

Currently, manufacturing is undergoing a revolution that the World Economic Forum called the industry's greatest change in more than 100 years, the fourth industrial revolution. The most transformative one yet for manufacturers, changing the way they think about resource allocation, production processes, material handling and the workforce [Accenture, 2015]. Major technologies are entering manufacturing space boosting industrial productivity by more than a third [Scalabre, 2015]. Thanks to greater flexibility, more efficient data utilization and tighter integration of underlying systems, manufacturers will be able to boost production efficiency and increase workforce flexibility and product quality. Industry 4.0 is thus a response to the newly created challenges in fast-changing and evolving environment. It constitutes a new level of organization and control throughout the entire value chains and it puts emphasis on the development of smart factories aims to transform conventional industries into intelligent ones [Lampropoulos, Siakas, Anastasiadis, 2019].

One technology in particular can bring a systemic change in the industrial sector, the *Industrial Internet of Things*. Every object (machine, system, product and service) within the industrial sector becomes intelligent and connected, acquiring its own identity in the digital world. Everything, down to the smallest piece of equipment, have a certain degree of built-in intelligence; the ''intelligence'' of a central system is moved into every piece of equipment [Zuehlke, 2010]. A first aspect to consider is the seamlessly connection of devices. However, it is not just connectivity, IoT has had profound implications on the ability to capture data previously out of user reach; it is about combining connected devices with automated systems to gather data for the purpose of analyzing and acting. The Industrial Internet of Things is about connecting all the industrial assets, including machines and control systems, with the information systems and the business processes, so that the large amount of data collected can feed analytics solutions and lead *optimal industrial operations*. Data also enable the creation of new functionalities: product, process and services that open *new revenue streams*, *transform business models* and *drive measurably better outcome for customers*.

1.2 Industry 4.0

A revolution is a rapid, wide scale change which disrupts and transforms society. Schwab describes an industrial revolution as the appearance of 'new technologies and novel ways of perceiving the world [that] trigger a profound change in economic and social structures', emphasizing the unleashing role of technology in past revolutions and the significant impact it has on society, its welfare and the overall environment.

The *First Industrial Revolution* started in Britain, in the 18th century, and marked the passage from agrarian and handicraft economy to the one dominated by industry and machine. It was powered by a major invention, the steam engine, which enabled the mechanization of processes, leading to the creation factories. It resulted in creation of new wealth and jobs, and increased living standard.

A century later, with the *Second Industrial Revolution,* factories first met electricity which allowed the development of mass production, with the advent of assembly line and specialized division of labour.

Third Industrial revolution, also referred as the 'Digital Revolution', began in 1970s, when electronics and information technologies started to be used in factories to automate production; some of the most relevant technological advancements were the Programmable Logic Controller (PLC) and the Internet.

The world is now witnessing its *Fourth Industrial Revolution* and according to the coiner of the term, the World Economic Forum founder Schwab, this transformation will be unlike anything humankind has experienced before. If a revolution is disruptive per se, Schwab pointed out this is at the 'nth power' due to its scale, scope and complexity. It is '*characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres*' and it is evolving with greater velocity, affecting various industries and countries across the world calling for a total overhaul of the existing systems. Thus, not only the speed of current breakthroughs has no historical precedent, also the breadth and depth of these changes are imponent, they extend the impact of digitization in new and unanticipated ways.

A host of technologies are changing physical and digital worlds: artificial intelligence (AI), robotics, the Internet of Things (IoT), 3D printing, biotechnology, quantum computing. 'The embryos of some of these new technologies can be traced back to the mid- 1980s, but to witness their impact on production and sectors, we had to wait until the turn of the century' [De Propis, Bailey, 2020] when a massive boost in computing power and reduction in cost, along with miniaturization, made those suitable for industrial use.

This current wave is fundamentally changing the way businesses operate [Davies, 2015], creating a completely new production model inside the factory and between firms. Alongside the concept of fourth industrial revolution, in fact, there is the paradigm of **Industry 4.0**, which specifically addresses the industry domain and its digital transformation. The name originates from a project conducted by the German government meant to encourage the digital transformation of its strong manufacturing sector and increase its competitiveness in the global market [Davies, 2015]. Several socio-economic drivers contributed to the creation of this initiative as the movement of manufacturing jobs away from Germany due to the lower cost of labor in other parts of the world and the changing demographics that were leading to labor shortages.

Industry 4.0 may help to reverse the past decline in industrialization and increase the added value of production to the economy. Research by Accenture, in fact, estimates that Industry 4.0 technologies as the Industrial Internet of Things (IIoT) could add as much as $14.2 trillion to the global economy by 2030 and significantly improve the long-term job growth in part by bringing manufacturing back onshore.

Industrial system thinker Scalabre explained the bigger implication of Industry 4.0. It will create a huge macroeconomics shift with factories relocated in the home market (in the world of scale customization, the proximity is the new norm), smaller and agile (scale does not matter anymore, flexibility does), operating in a multi-product, made to order basis. Globalization will enter in a new era: the east to west trade flows will be replaced by regional trade flows. A new model which produces just next to the consumer market, much better for the environment.

Soon after the Germany, other government-led initiatives were introduced all-around the world to support the transition towards a digital transformation of the organizations such as 'Industrial Internet' in North America, 'Industrie du future' in France, and 'Industria 4.0' in Italy.

In all these initiatives, the role of Industry 4.0 technologies was central: they have been seen as mediums to potentially improve productivity and competitiveness, increase energy and resource efficiency and effectiveness and, hence, protect the environment. The most important added value which Industry 4.0 brings, and that clearly distinguishes from the third industrial revolution, is to be found in the *seamless systems integration* and a *hyper connectivity* that goes beyond the factory walls. Industry 4.0 technologies permeating in the manufacturing industry enable a greater interconnection and cooperation between their resources: assets, people and information both inside the factory and distributed along the value chain to which customers, suppliers, distributors belong to.

Germany Trade and Invest defined industry 4.0 as the technological evolution from embedded systems to cyber physical systems. Cyber Physical Systems (CPS) are automated systems that enable connection of the operations of the physical reality with computing and communication infrastructures. Thus, connected systems where physical and digital merge. CPSs made decentralized decisions, monitoring the processes happening within factories, and have the capability of connecting and cooperating with each other though standard internet-based protocols. These intelligent, resilient and self-adaptable machine [Lee, Bagheri, Kao, 2015] are the constituent of the so called '*Smart factory'*, distributed on large scale, self-organizing, highly automated and demand driven [Accenture, 2015].

Deepening on this point, according to Schwab, there are 4 design principles for a factory to be considered smart:

1. *Inoperability*: the ability of machines, devices, sensors and people to communicate and process information with each other via IoT;
2. *Information transparency*: the creation of a virtual copy or 'digital twin' of the physical world using sensor data, providing operators with vast amounts of useful information needed to make appropriate decisions;
3. *Technical assistance*: assistant systems are designed to support operators by aggregating and visualizing data comprehensively so that urgent problems could be solved on a short notice;
4. *Decentralized decisions*: interconnection and information transparency allow for operators to make decisions both inside and outside the facilities while CPSs to make decisions on their own and perform tasks as autonomously as possible.

Industry 4.0 can offer a number of benefits for organizations. The new paradigm allows increased **production flexibility**: process automation, real-time data about product and the use of configurable robots means that a variety of different products can be produced in the same production facility. This **mass customization** allows the production of small lots (even batch size one), due to the ability of rapidly configure machines to adapt to individual customer specifications and additive manufacturing [Davies, 2015] which allows the designing of more complex, stronger and lightweight products. This is according to Scalabre the most important element, scale customization, 'the product you want, with functionalities and design you want, at the same cost and lead time of the product that is mass-produced like your car, your clothes or phone' [Scalabre, TedTalks, 2016]. The customer can enter as early as possible in the value chain [Stock, Seliger, 2016] and also change order at any time during production with no charge. [1]

[1] Haier's Shenyang Interconnected Refrigerator Factory thorough its COSMOPlat platform digitally integrate the entire factory process and supply chain, enabling customers to communicate their preferences directly to the factory. Not only does this make customers participants in the transparent design and production process, but it also allows for product customization according to consumer demands and even different or unique requests.

This production flexibility also encourages innovation, since prototypes or new products can be produced quickly without retooling or setup of new production lines [Davies, 2015].

Thanks to digital designs and virtual modeling of process, the **speed** with which a product can be produced will also improve answering to the need of a faster time to market. Analyzing data from sensor, it is possible to monitor both **product quality** and machine status. As regards the latter, advanced analytics in predictive maintenance can ensure a higher **productivity** with less machine failures and lower downtime.

A more efficient use of human workers, doing more knowledge work and hard-to-plan task and working side by side with robots on jointly task.

In time, industry 4.0 will also provoke changes in **business models**, enabling new revenue streams for manufacturers. Selling functionality and accessibility of products instead of only selling tangible products (‘selling light not light bulbs’) and driving better outcomes for customers.

1.3 Industry 4.0 technologies

According to BCG, Industry 4.0 is powered by nine technology trends which are transforming production ‘*from isolated, optimized cells to fully integrated, automated, and optimized production flow, leading to greater efficiencies and changing traditional production relationships among suppliers, producers, and customers’*.

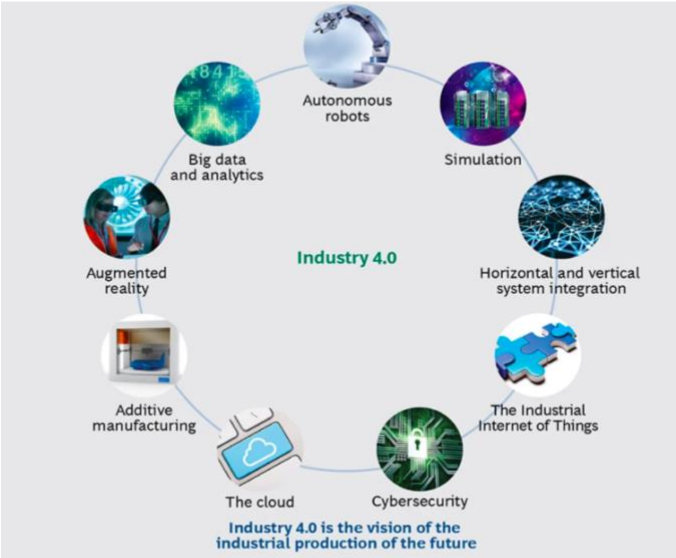

Figure 3: Industry 4.0 technologies (BCG, 2015)

1. **Big Data and Analytics.** The ever-growing use of sensors and networked machines has resulted in the generation of massive amounts of data. However, these inputs can’t be processed using traditional statistical methods due to the high volumes and variety of formats generated [Witkowski, 2017]. Thus, new analytics techniques have been developed in order to interpret and analyze these data for insights which lead to better decisions and also strategic business moves. Combining Big Data with high-

powered analytics, on one hand it is possible to improve flexibility and efficiency (for example determine root causes of failures and defects in near-real time, optimize production quality and saves energy), on the other it is possible to provide new and innovative offerings.

2. **Autonomous Robots.** If before, robots were programmed in rigid sets of instruction, in Industry 4.0 they will adapt their behavior to suit the context, making use of artificial intelligence algorithms capable of endowing machines with cognitive abilities. Robots are becoming more autonomous, flexible and cooperative; as recent advances indicate robots extend and enhance human capability. MIT researchers for example have successfully designed a system that lets robots learn complicated tasks solely by observing humans. Next, they hope to modify the system to help robots change their behavior based on verbal instructions, corrections, or a user's assessment of the robot's performance [MIT News, 'Showing robots how to do your chores', 2020]. Moreover, robots can increase the speed and accuracy with which operations are performed, increase workers safety by replacing them in demanding or dangerous activities and reduce costs of labor and reworking.

3. **Simulation.** Simulations is suitable to perform scenario planning. It leverages on real-time data to mirror the physical world and creates a virtual model, which can include machines, products, and humans. This allows operators to test and optimize the machine settings for the next product in line in the virtual world before the physical changeover [Brunelli et al.,2017], thereby driving down machine setup times and increasing quality. Other uses could be using virtual models of the factories for the training of workers so that the real resources remain available.

4. **System Integration.** The paradigm of Industry 4.0 is essentially outlined by three dimensions of integration:
   1. *Horizontal integration* of all the participants of the value chain including suppliers, customers and business partners;
   2. *Vertical integration* along company's different functions and hierarchical levels from manufacturing to marketing and sales;
   3. *End-to-end engineering* across the entire product life cycle from raw material acquisition to manufacturing, product use and dismantlement [Stock, Seliger, 2016]

5. **The Industrial Internet of Things.** Accenture defines the Industrial Internet of Things as 'a universe of intelligent products, processes and services that communicate with each other and with people over the Internet'. It has emerged as the industrial application of Internet of Things, the network in which every everyday object potentially acquires its own identity in the digital world [Osservatorio Internet

of Things]. Three distinguish features of the Internet of Things are context, omnipresence and optimization. The first refers to the possibility of an advanced object interaction with an existing environment providing information such as location, physical condition or atmospheric conditions. Omnipresence illustrates the fact that objects are much more than just connections to a user network and in future they will communicate with each other on a large scale. Optimization is the expression of the functionality which every object possesses [Witkowski, 2015].

6. **Cyber security.** Data will play a key role in the transformation of manufacturing, but it poses significant challenges in terms of security. Facilities become digitally connected both on the manufacturing floor and beyond the factory with external partners, thus it is important to guarantee an adequate level of security from cyberattacks without limiting the capability to exchange data and information. More than before, it is essential to guarantee secure communications and sophisticated identity and access management of machines and users.

7. **The Cloud.** The Cloud delivers computational services through visualized and scalable resources over the Internet. The scalability of resources makes Cloud interesting for business owners, as it allows organizations to start small and invest in more resources only if there are further rises in demand [Zhong, Xu, Klotz, Newman, 2017]. Firms can benefit with a remote IT infrastructure for the storing, managing and processing of data: they can avoid upfront cost and complexity of owning and maintaining their own IT infrastructure and simply pay for what they use. In turn, providers can achieve economies of scale delivering same services to a wide range of customers. Using cloud services companies can also move faster on projects and test out concept without time taking procurement and big upfront cost. Furthermore, it is particularly important in the integration across the different players of the supply chain and to share and communicate in real-time freeing the memory space of local devices.

   Among the three delivery models, the IaaS (Infrastructure as a service) with a completely virtualized computing infrastructure, PaaS (Platform as a service) offering not the complete infrastructure yet the framework needed, deploy, manage, and update software products, and finally SaaS (Software as a service), a fully developed software solution.

8. **Additive manufacturing.** Additive Manufacturing, also called 3D printing, encompass a set of manufacturing processes where 3-dimensional objects are created by the successive addition of layers of material. This technology is widely used to create individualized products and enable mass customization, especially in the case of complex design. 3D printers instantaneously produce any customized design and they are able to produce a batch on one product at the same cost and lead time as batch of many [Scalabre (BCG), TedTalk, 2016]. High-performance, decentralized additive

manufacturing systems reduce transport distances and stock on hand [Lorenz, Rußmann, Wladner, 2015]. 3D printing has already improved plastic manufacturing and it is now making its way through metal, two industries which represent the 25% of the global manufacturing production.

9. **Augmented Reality.** Augmented Reality turns the surrounding environment into a digital interface by placing virtual objects in the real world, in real-time. Creating an immersive user experience opens up many possibilities for business; augmented-reality-based systems support a variety of services: selecting parts in a warehouse and sending repair instructions over mobile devices, provide workers with real- time information to improve decision making and receive work instructions [Lorenz, Rußmann, Wladner, 2015].

1.4 Industrial Internet of Things

Industrial Internet of Things represents one of the enabling technologies for the digitalization of the industry with a view to 4.0. Industrial Internet of Things refers to the extension and use of the Internet of Things in industrial sectors and applications. In order to understand better the concept and understand why it matters talk about its industrial application, it is useful to mention its origins and the characteristics that make this technology disruptive. A first aspect to consider is the *seamlessly connection of devices*. Internet of Things is based on a ubiquitous connection to the Internet, which turns common objects in smart ones, capable to sense the surrounding environment, transmit and process acquired data, and then feedback to the environment. The declining cost of sensors since the start of the new millennium has been a main driver in the rise of IoT (term coined in 1999 by Ashton) which was 'born' according to Cisco at 'the point in time when more things or objects were connected to the Internet than people' (2008-2009). Forecasts suggest that by 2030 around 50 billion of IoT devices will be in use around the world [Statista].

However, it is not just connectivity, IoT has had profound implications on the *ability to capture data* previously out of user reach; it is about combining connected devices with automated systems to gather data for the purpose of analyzing and acting.

Many authors and specialists have underlined on the one hand the importance and value, and on the other the urgency of these technologies in the industrial field. The Industrial Internet of Things takes IoT technology on a much broader scale, while the consumer side can be considered a market niche. It will reinvent many sectors that account for approximately two thirds of the global economic output, driving economic gains of 14.2 trillion dollars by 2030 [Accenture].

'Now the spotlight is shifting to industry because this is where the biggest transformation is taking place and where the greatest value will be created over the coming decade' [Annunziata, TedTalk, 2013].

'The industrial sector is moving faster than others because industrial companies don't see IIoT as just technology but as existential for their activities. In other words: not moving is not an option' [Roese, IoT Solution World Congress, 2016]

It is useful to start with providing a clearer definition of the concept:

'A system comprising networked smart objects, cyber-physical assets, associated generic information technologies and optional cloud or edge computing platforms, which enable real-time, intelligent, and autonomous access, collection, analysis, communications, and exchange of process, product and/or service information, within the industrial environment, so as to optimise overall production value'

Boyes, Hallaq, Cunningham, Watson, 2018

The Industrial Internet of Things is about connecting all the industrial assets, including machines and control systems, with the information systems and the business processes, so that the large amount of data collected can feed analytics solutions and lead optimal industrial operations.

Machine-to-machine (M2M) communications via programmable logic controllers (PLCs) and supervisory control and data acquisition (SCADA) systems have been around since the 1960s, providing data logging and telemetry. But these systems and their sensors are meant to operate in a local, closed-loop environment, for minute-by-minute sensing and control. Introducing IIoT expands the types of things sensed, the area over which they can be sensed and the time horizon, by making possible the integration of data over time to show performance [Jablokow, 2019].

What makes IIoT distinct is the convergence of Operational technology (OT) and Information Technology (IT), where the network of operational processes and systems merges with production management, manufacturing execution, logistics and enterprise planning systems. This enables a higher system integration in terms of automation and optimizations, as well better visibility of the supply chain and logistics.

IIoT is utilized in combination with other innovative technologies. A new paradigm Cloud-of-Things has appeared to describe the fusion between *Cloud Computing* and IoT technologies [Bangui,2018]. It allows industrial companies to take advantage of "on demand" remote resources for archiving, processing and accessing data; it supports and guarantees the access to computational resources which process data and extract value from *Big Data*, Analytics. The Knowledge acquired by these resources combined with the company's learning and experience evolves into insights, know-how and decision support enabling companies to reach higher level of competitiveness.

Yet, Cloud cannot satisfy the IoT applications that require real-time response. However, this is essential in an industrial environment where the requirement, in addition to have a continuous operation, is a reactive system (with control almost in real time, to the hundredth of a second) [Osservatorio Internet of Things]. Recently, *Edge Computing* has been proposed to bring cloud services closer to the IoT end-users, becoming a promising paradigm [Bangui,2018]. For devices that need to make rapid decisions, processing data locally (at the network edge) allows them to respond much faster while for the ones that merely collect data load on networks can drastically be reduced by analyzing data locally and transmitting only relevant information back to the cloud server. In factories, real-time data is vital to control automated robotic production lines, helping to ensure the safety of workers walking around a site and maintain high product quality and efficiency levels. Siemens provides an example of how the Edge could be applied in factory to have a timely response.[2]

[2] Siemens provides an example of how the Edge could be applied to predictive maintenance. If a robot responsible for capturing the electronic components and placing them on the packaging line fails, the products fall to the ground and the line must be stopped for emergency maintenance. Thanks to a peripheral device that collects data from sensors on the

Cloud and Edge are thus synergistic: time critical operational tasks and production-based analytics sit better in the real time processing capability of the edge layer while non-time critical activities such as continuous improvement analysis, overall asset performance analysis, scheduling and the management of cost better at the enterprise level, in either a centralized cloud-based environment.

Today, there is an ever-growing interest for IoT platform which can satisfy both needs to store and secure data and run analytics on the cloud, and with edge capabilities. For this reason, a chapter (Chapter 4) will be dedicated to the platforms for which classification and an overview of their market will be given.

In the following paragraphs the architecture of the Industrial Internet of Things, the technologies that support the exchange of data between heterogeneous devices and the network, and the main application areas will be explained.

1.4.1 The Architecture

A reference architecture is a higher level of abstraction description that helps identify issue and challenges for different application scenarios [Sisinni, Saifullah, Han, Jennehag, Gidlund, 2018]. The main requirements for the development of an Industrial Internet of Things architecture are represented by modularity, scalability, and interoperability between the different technologies used in the industrial environment. While IoT is human-centered, IIoT is machine-oriented and is based on existing technologies and devices for reliability. The IIoT systems are a special class of IoT systems that have additional requirements related to latency, real-time capabilities, security, reliability, and safety [Ungurean, 2020]. Furthermore, there must be consider a large number of industrial networks (fieldbuses) and the presence of many heterogeneous systems such as devices, sensors, programmable logic controllers, and human-machine interface, which collaborate within the IIoT system.

The Industrial IoT architecture models have a multilayer structure but there is not a general consensus on the number of layers. The International Telecommunication Union supports an IoT architecture made of five layers (sensing, accessing, networking, middleware and application layers) while others identify three major layers for IoT (perception, network and service layers).

The one represented in the Figure 4 is a three-tier pattern released by the Industrial Internet Consortium in its document “Reference Architecture” (version 1.9, 2019). The widely accepted architecture is composed by edge, platform and enterprise tiers:

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robot, the device can be monitored, and it is possible to predict when a component such as the robot's suction cup is about to fail and to proactively plan maintenance before costly errors occur.

- The *edge tier* collects data from the edge nodes (sensors, controllers, actuators), using the proximity network
- The *platform tier* consolidates, processes and analyzes data flows from the edge tier. It receives, elaborates and forwards control commands from the enterprise tier to the edge tier. This can be seen better in Figure 4, the data flow goes towards the enterprise layer while the control flow in the opposite direction. In addition, the tier provides management functions for devices and asset and offers non-domain specific services as data query and analytics.
- The *enterprise tier* implements domain-specific application and provides end user interfaces. Also, it is the command center which issues control commands to the platform and edge tier [Industrial Internet Consortium, 2019].

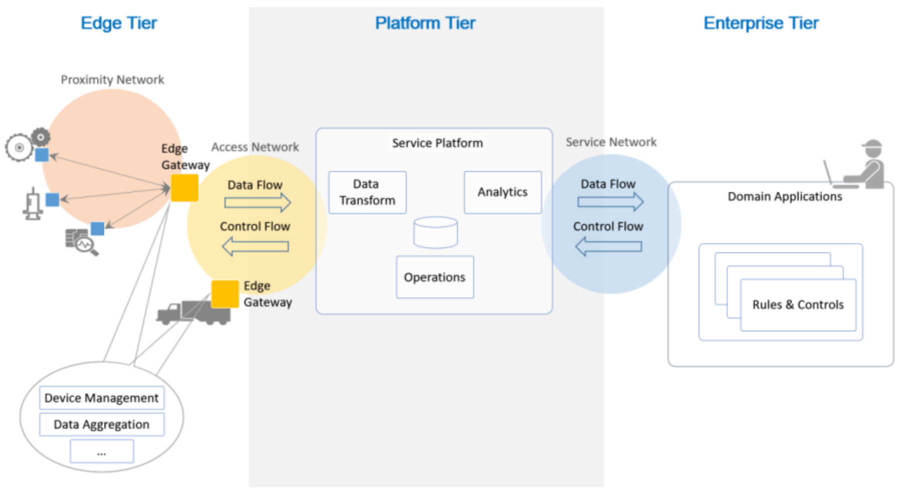


Figure 4: Three-tier IIoT system architecture (Industrial Internet of Things consortium, 2019)

1.4.2 The connectivity

Understanding the Internet of Things technologies is fundamental in order to have a complete view of the current state and development prospects of the application scenario. The technologies will be better explained below, classified according to a study done by the observatory Internet of Things:

- *Passive Radio Frequency Identification (RFId):* is the simplest technology with which an object can integrate into the Internet of Things. RFID refers to a wireless system comprised of two components: tags and readers. The reader has one or more antennas that emit radio waves at several frequencies and receive signals back from the RFId tag; tags use radio waves to communicate their identity and other information to nearby readers. Passive RFId tags have no internal power source, they are instead powered by the electromagnetic energy transmitted from an RFId reader. This technology with a range of 3-10 meters is especially used in production and logistics in order to track goods across the supply chain.

- *Active Radio Frequency Identification (RFId):* provides additional features compared to passive RFId thanks to the use of a battery, which improves communication performance (reading distance) and enables autonomous operation, without the need for interrogation by the reader.

- *Personal Communication*: a group of standards for communication in short- range networks (PAN - Personal Area Network) designed for consumer applications and characterized by very narrow communication bands (such as Bluetooth low-energy, ANT, Near-Field Communication). The diffusion of these technologies has received a significant boost thanks to their integration with most of the latest generation mobile devices (smartphones, tablets). Some considerations for the industrial application: Bluetooth can operate over much greater distances than several meters and it performs well even in harsh conditions, conversely to Wi-Fi is immune to interferences, relatively low-power system, it can be incorporated easily, and it can detect and rectify bit errors via the receiver. The latter characteristic is really important in industrial field because real-time measurements must be precise. The latest standard has introduced mesh applications, enabling a communication on a larger scale, and decrease resource usage. For these reasons, this technology can be effectively used for low-cost yet incredibly accurate indoor location and asset tracking solutions.

- *Wireless Bus*: a "wireless" alternative to wired solutions that have already been used in the industrial world for some time but technologies belonging to this cluster do not allow sophisticated communication architectures. The most widespread technology is Wireless M-Bus, a protocol supporting the 169 MHz frequency band, designed to be a robust, power efficient, long range wireless communication solution. M-bus was originally defined for Smart Metering and still today it is strongly applied in this field. Cellular technology, more expensive in terms of energy consumption, requires at least one more change of the gas meter batteries. This cost but above all the operating costs related to the technicians' outputs mean that the preferred technology for this application is still the 169MHz WMBus technology.

- *Wi-Fi*: these protocols allow wireless access to local broadband networks. Developed for multimedia applications, which require the transmission of a large amount of data, they have high energy consumption, which entails severe limitations of applicability in the IoT field. In particular, it is not a feasible solution for large networks of battery-operated IoT sensors especially in the Industrial IoT scenario. However, recently there has been an approach to the IoT world with the release of Wifi 6: a new single standard for both broadband and IoT applications. Version 6 reduces energy consumption and support a large number of devices with MU-MIMO e OFDMA, protocols first introduced in the world of cellular communication that allow to distribute the signal simultaneously to all connected devices and to manage access to the channel of each device. Wifi 6 aimed to create a dense environment (dozens of Wi-Fi devices connected at the same time) that was equally functional.

- *Mesh Low-Power Networks (RMLP):* networks formed by low-power nodes and characterized by complex, self-configuring network architectures, capable of supporting dynamic data routing and optimized for low energy consumption such as ZigBee. Both low power and high reliability make ZigBee one of the most popular protocols in the home automation sector (used by major brands and platforms such as Amazon, Google, Apple) and commercial building installation markets. Until the emergence of LPWAN, mesh networks have also been implemented in industrial contexts, supporting several remote monitoring solutions. Nevertheless, they are far from ideal for many industrial facilities that are geographically dispersed, and their theoretical scalability is often inhibited by increasingly complex network setup and management.

- *Low-Power Wide Area Networks (LPWAN):* it is characterized by a long-range, cellular-like coverage, and by typically very low energy consumption, which often allow it to exceed 5 years of autonomy. Partly due to the use of a very narrow band (frequencies below 1GHz) and a very low transmission speed (data-rate). Also, the use of narrow channels guarantees a high scalability of the network, i.e. the number of nodes managed by the same concentrator. Connecting all types of IoT sensor, LPWANs facilitated numerous applications such as asset tracking, environmental monitoring, facility management and consumables monitoring. Existing technologies operate in both licensed (NB-IoT, LTE-M) and unlicensed spectrum (MYTHINGS, LoRa, Sigfox). For the context of smart manufacturing and IIoT in general, proprietary solutions based on LoRa at 2.4 GHz will be an element of considerable interest in the coming years. They can combine elements of flexibility, scalability, good performance in terms of throughput and reliability, with very low energy consumption.

- *PLC (Power Line Communication):* the transmission of information takes place by modulating the electrical signal used for the power supply. There are both protocols designed for the residential world and for the medium and high voltage network: the main difference concerns the maximum communication distance and the supported data rate.

- *Cellular networks (3G, 4G, 5G):* these are the usual cellular communication technologies, i.e. GPRS, GSM (2G), HSPA (3G), LTE (4G). Due to the high energy consumption, they are mainly applied in the cases in which they can be powered, as well as in combination with RMLP and Wireless Bus for communication between second-level devices and control centers. A regards Industrial IoT, they fit well for fleet management application, but they are also widespread for connected cars. Cellular next-gen 5G with very high throughput (higher than 1 Gb/s) and ultra-low latency (up to 1 ms) is positioned to be the future of augmented reality. At the same time 5G has the potential to transform the factory floor.

5G: Transforming the Factory Floor

Most factories today are connected by wired connections with traditional Fieldbus or Industrial Ethernet, serving as a backbone for connecting field-level equipment to control systems and PLCs. The latest 5G specification (3GPP Release 16) targets factory automation with ultra-reliable, low latency communication, enhanced massive type communication and enhanced mobile broadband. 5G Networks could support a significantly higher number of devices, besides 5G enabled devices could "offload" some of their processing to the network allowing for less complex and cheaper devices. Thus, 5G enables factories to take full advantage of sensors and the IoT for asset monitoring and automation, along with artificial intelligence and machine learning capabilities. Much of this will happen on-premises, but also increasingly in the cloud thanks to IIoT platforms. While the 5G specifications mature, the "network edge" could serve as a hot spot for innovation between the hyper-scalers, carriers, and IIoT platform providers to deliver latency-sensitive IIoT applications for industrial automation. Microsoft has recently launched Azure Edge Zones and acquired Affirmed Networks with the aim of bringing cloud-based 5G networks to the market [Software AG, 2020].

1.4.3 The Application Areas

There are three main macro area in which the Industrial IoT is applied [reference is made to the classification given by Osservatorio Internet of Things]:

- *Smart Factory*: advanced control production, safety at work, maintenance, material handling, quality control, waste management.
- *Smart Supply Chain*: traceability / monitoring of logistics activities inside the factory through RFId tags and sensors;
- *Smart Lifecycle*: improvement of the new product development process (e.g. through data from previous versions of connected products), end of life management, supplier management in the new product development phase.

SMART FACTORY

The future of factory is going to involve a new integrative, where not only all manufacturing resources (sensors, actuators, machine, robots, etc.) are connected and exchange information automatically, but also the factory will become conscious and intelligent enough to predict and maintain machines, to control the production process, and to manage the factory system. This kind of factory is known as Smart Factory [Qin, Liu, Grosvenor, 2016].

When the factory is equipped with IoT, then it paves the way to access the real time information and efficient collaboration. A plant manager can be informed the status of machines and production from any locations and this can considerably reduce the downtime for decision and action. The quality control can be effectively achieved by shutting down the production process when the problem is known in advance and the product wastage is totally eliminated [Santhosh, Srinivsan, Ragupathy, 2020].

Smart Factory comprehends several applications in different contexts of the factory, the main ones are shown below together with some examples.

***Production optimization*.** The IoT covers the scope of data collection and transmission over unimaginably large areas by eliminating the distance barriers that bound DCS and SCADA. Using the IoT, production can be optimized in different ways: applications range from improved production planning and machine preparation, to pure optimization of the OEE (Overall Equipment Effectiveness), up to the adaptation of the plant to the production needs in continuous evolution, satisfying the individual needs of customers according to a logic of mass customization.

In *BMW* the optimization of automotive production lines is guaranteed by 3500 robots provided by *Fanuc*, worldwide manufacturer of factory automation that includes over 110 robot models including anthropomorphic, collaborative, lifters. In the automotive company, the use mainly concerns the construction of car bodies and the production of doors and hoods.

Another striking case of how new technologies allow improvements in production and in general of how the Industry 4.0 paradigm allows the creation of an intelligent factory is given by *Schneider Electric* and its plant of *Le Vaudreil*. The most innovative digital tools have been implemented in this factory, such as *EcoStruxureTM Augmented Operator Advisor* which allows the use of augmented reality to speed up operations as well as maintenance, obtaining an increase in productivity between 2 and 7%. Thanks to this and other innovative applications, the plant was included among the nine most advanced sites in the world, what is called a ‘lighthouse’ plant (2018 Annual Meeting of The New Champions, World Economic Forum).

Preventive and predictive maintenance. IoT technology allows for real-time, remote condition monitoring. Monitoring one or more parameters such as the number of pieces made or the hours of operation of the machine, companies can plan when to carry out maintenance interventions. This result in less equipment downtime, fewer interruptions to critical operations, a longer asset life, improved efficiency because assets in good repair tend to operate better and increased workplace safety. But, technologies also allow to switch from a reactive maintenance logic to a proactive maintenance one. For example, by monitoring one or more parameters (e.g. machines noise, vibration) on a machinery equipped with sensors it can be estimated the remaining time before a fault occurs and thus realize the maintenance intervention when is needed minimizing risk of costly downtime and extending the useful life of the machine. Recent analysis shows that the market for predictive maintenance applications is poised to grow from $2.2B in 2017 to $10.9B by 2022, at an 39% annual growth rate. According to recent research IoT and advances in analytics leads to an efficiency gain of 25% - 30% in industries implementing the IoT enabled predictive maintenance [Santhosh, Srinivsan, Ragupathy, 2020].

More and more companies are offering these solutions based on a service logic. The application, developed by *Wylmco* on *Solair's IoT Application Platform*, has allowed *Aerofilters* to collect and process useful data over the network for the management of filters installed at customers. Not only it allows to receive data through the cloud and monitor the pressure of the filters and numerous other data transmitted by the pressure gauge, but also to trigger alarms when the filter is saturated or when it is about to reach saturation in order to perform proper routine maintenance in the first case, predictive in the second. This is very important because when the pressure drop of the filters exceeds the design value, the performance of the system is compromised with often very serious consequences and high costs.

Quality control. Effective quality management relies on the ability to constantly monitor and control a host of machine and process parameters that impact product quality.
Once several sources of quality problems have been diagnosed, manufacturers can develop, using sensor inputs, a quality control model so that the machine automatically adapts to fluctuations in variables such as environmental conditions.

An interesting case is the quality control project carried out by *Siemens* in its *Amberg plant* where more than 16 million products based on Simatic technology (controllers, HMIs, etc.) are produced. Staufer, manager at Siemens, tells about the company project in an article on Ingenuity. The PCB of the SIMATIC controller is tested by X-Ray during the manufacturing process to ensure the absolute excellence of the solder contact, the process however requires long production times. To alleviate the bottleneck, Siemens developed an algorithm to predict the likelihood of manufacturing defects and thereby increase the yield in production. First, Siemens data analysts defined 40 different data sets such as XY-Offset, solder temperature and solder paste volume, then trained the algorithm by collecting data and transferring it to their MindSphere Cloud System. The AI algorithm was then loaded into the Siemens Industrial Edge Management System, the Edge Application was deployed on the local Edge Device from production, in order to analyze the data locally, without having to transfer the data to the Siemens Cloud MindSphere. Thanks to this, the quality of production has improved reaching 12 defects per million. Also, by linking intelligent machines with data-rich components and workers, innovation cycles have been shortened and productivity raised [Davies, 2015].

Energy management. Energy plays a vital role in manufacturing and is often the second major operating cost [Santhosh, Srinivsan, Ragupathy, 2020]. Implementing IoT can access the data from the device level and it is possible to pinpoint the devices which are under performing. By tracking the power conception of each device separately, managers acquire visibility to benchmark the underperforming devices with the best performing devices. Energy utilization can be in this way optimized. In the case of *Geico Taikisha*, world leader of automated systems for painting automotive bodies, the energy consumption is not just controlled but also adapted to the production capacity.

Material handling. RFID tags provide real-time visibility of the materials being processed in the factory and allow them to be routed efficiently. Within the materials handling space, IIoT opportunities for data exchange are vast, including automated transportation, storage and picking, sorting, automated guided vehicles, robotics, palletizing and picking - all elements that can accommodate integrated smart devices (smart sensors, controllers, readers, scanners, security systems, cameras, frequency converters and more).

Work safety. IoT technologies allow to monitor of the position and movement of operators. It is the case of *Ford* which at the Blue Oval plant in Valencia has experimented a pilot project of connected suits to monitor workers' movements in order to optimize posture and improve comfort on the assembly line.

Safety also means identifying dangerous environmental conditions, a tag inserted in the workwear garment can detect and monitor its state of conservation in order to ensure the protective efficacy or a wearable device can monitor the health of workers working in extreme conditions. *CFB Balducci* and *North Star* implemented respectively RFId and wearable technologies in order to guarantee safety on workplace.

SMART SUPPLY CHAIN

In IoT enabled transportation and logistics, the products are incorporated with sensors along embedded tags. When the good moves, the flow can be traced by various participants in the supply chain. Further, the product becomes totally autonomous and various decisions can be taken by the readers from the obtained information. This leads to the end to end visibility in the supply chain and warehouse management, ensuring that the product is in the right place at the right time [Santhosh, Srinivsan, Ragupathy, 2020].

Goods traceability within the warehouse and along the supply chain. *Tecnoacciai* testifies how even a small manufacturing reality can become a smart factory. The warehouse, where all the pieces have been classified and monitored, is characterized by a close man-machine interaction: the system, based on the order requirements, proposes to the operator the pieces suitable for the customer's needs, among the pieces proposed by the machine, the operator chooses and one of the large monitors in the warehouse, when illuminated, signals the presence of the chosen piece (if it is contained in a drawer, this opens and a laser beam indicates the chosen piece) simplifying operations and lead times research.

A bigger reality is the *Novelis* Digital Factory which differs in different types of aluminum, therefore different processes, intended for equally diversified scenarios. The primary need of the site in Milan is to track the handling of aluminum coils and to know in real time which type of metal is being produced, automatically monitoring its progress, for lean management also of storage in the different types of warehouses and subsequent order fulfillment. All this was possible thanks to RFID technology and 11 RFID stations scattered along the roller track.

However, traceability goes beyond the concept of operational efficiency and optimizations of operations. The notions of transparency, fair trade or sustainability are gaining importance in customer purchase decisions [Deloitte, 2017], at the same time technologies such as IoT and Blockchain are able to merge with each other to revolutionize traceability practices within supply chains and radically improve the safety standards, for example that concerning the food world.

Monitoring of parameters along the supply chain. Interesting examples concern sensor applications for monitoring the cold chain. Italian companies in the food sector such as *Conad* introduced tags and temperature sensors on load units driven by the desire of guaranteeing quality to its consumers. Also, *Grandi salumifici italiani* introduced sensors to automate the controls of goods and monitor the cold chain in its trucks and *Parmacotto* to supervise the shuttling of semi-finished products from one plant to another.

Logistic asset management. Tracking and tracing can be also applied to logistic asset, such as pallets, roll containers. The French company *Alstom*, which develops and markets systems, equipment and services for the railway sector, wanted to automate the tracing of its equipment for production and maintenance of trains in its Sesto San Giovanni site. BLE (Bluetooth Low Energy) Tags / Beacons have been affixed to the company assets, which transmitted data to the EchoBeacon fixed to the ceiling close to the areas to be monitored: mini BLE gateways capable of monitoring the presence of Tags and therefore detecting the equipment.

Fleet management. *Michelin* has shifted its business model from selling tires to selling also services. Leveraging IoT, the French tire manufacturer launched EFFIFUEL, a system that uses sensors to collect data inside trucks (fuel consumption, tire pressure, temperature, speed and position), sends data to the Cloud analyzed by experts who provide recommendations on eco-driving techniques. The tire maker offers a contractual agreement to meet predefined targets or provide a refund in proportion to expenses incurred.

SMART LIFECYCLE

Smart Lifecycle is one of the newest trends of smart applications derived from the acquisition of extremely huge amount of data that allow better product development and longer product life-cycle. The two main application are the following.

Optimization of the product development process. *Rockwell Automation* has developed cloud-based solutions, sensors and devices to predict equipment failures along the supply chain and monitor its performance in real time. The acquired data was subsequently used by the company to refine the design and processes of its products and avoid future failures.

Management of the "end of life" of the products. Connecting the product and extracting useful information allows to fully understand how the product is used, any issues or to activate additional services for the customer after it is sold. *Eleven Seventyseven* (1177) has opened a new innovative sales channel implemented through vending machines with iSelf Ingenico technology. The project involved the installation of a series of vending machines in transit and impact areas, a total rethinking of the point of sale, and the adoption of new digital payment systems. The vending machines implemented by 1177 provide and receive information and are connected to other machines. With this logic, 1177 is able to develop new projects and manage the relationship with its customers differently, who can, for example, order products online and then collect them at the vending machine that is most convenient for them.

1.4.4 Business Models

The Industrial Internet of Things results not only in a production-technical change, but also in extensive organizational consequences and opportunities [Arnold, Kiel, Voigt, 2016]. It poses large impact on business models of manufacturing companies and stimulates them to rethink their value creation and value capture strategies.

Offering. For traditional companies, creating value meant identifying customers lasting needs and manufacturing well-engineered solutions [Hui, HBR, 2014]. IIoT opens the way for more flexible value propositions; manufacturers provide customers with individualized product and even perform a batch-size-one production, answering to the growing demand of personalization and switching from the ’push into the market’ of better products to specific solutions ’pull from the customer’. Also, they expand their offer with innovative services, which are strongly data-driven and based on the collection, monitoring and analysis of machine condition data. Despite an increasing individualized and service-oriented product, IIoT also allows the optimization of production systems regarding cost, reliability, time, quality and efficiency [Arnold, Kiel, Voigt, 2016].

Customers. An improved, long-term and direct customer relationship is created. Novel offerings, enabled by the IIoT, require integration of customers in collaborative way. Customer is called to make its contribution since the product and service engineering and design. Thus, on one hand the customer is more engaged becoming a partner for the company, on the other hand the latter can have a comprehensive understanding of the needs and ensure customers retention. Moreover, more service-orientation allows company to address new target customers, also beyond industry borders. With regard to distribution channels, emphasize the importance of open and transparent web-based platform concepts allowing for not only the integration of web-enabled devices and connected services, but also of customers and partners [Arnold, Kiel, Voigt, 2016].

Infrastructure. Decentralized control and production processes together with the connection of object frame the core of the IIoT. These major aspects require new key activities in the company. Data management and data mining activities are used to systematically detect patterns and transform big data into valuable knowledge enabling automated decision-making to play a relevant role [Brettel, Friederichsen, Keller, Rosenberg, 2014]. Consequently, manufacturers face novel core competencies, in particular mechanically and hardware-oriented firms have to develop software know-how. Whenever a manufacturer does not have these competencies available or is not willing to perform novel key activities, partner networks serve as strategic success factors in the context of the IIoT; they provide companies with specific expertise.

Finances. With regard to financial aspects, the data-driven core of the IIoT enables employing novel revenue streams, e.g., dynamic pricing, pay-by- usage, and performance-based billing. Despite IIoT large investments in IT infrastructure, it also comes along with several cost reduction potential to be captures: reduced complexity, maintenance, inventory, manufacturing, logistics, and quality costs [Arnold, Kiel, Voigt, 2016].

1.4.5 Industrial Internet of Things Trends

- *IoT as a Service (IoTaaS)*: this concept is an emerging trend among technology companies. Just like software-as-a-service, IoTaaS provides solutions to customers: the management, control and release of connected devices as a service. It best serves businesses interested in leveraging IoT that however lack the time, knowledge, or resources to build the required infrastructure. Service providers, as

Microsoft, Amazon or IBM, offer hosted IoT application platforms. Platform providers offer APIs for a wide range of devices, sensors and actuators, giving companies the ability to quickly set up a complex ecosystem of heterogeneous "things" and begin capturing real-time information from all connected data sources. Providers take care of device management, advanced analytics, security, updates and other features made possible by the platform, organizations save time and resources such as creating a cloud backend for a specific hardware device. IoT platform market is growing interest and for this reason it will be analyzed better in Chapter 4.

- *Cloud & Edge*: companies have the opportunity to acquire data from more and more sources, this requires processing power that spans multiple locations. In order to exploit data and achieve ever higher level of competitiveness companies need to opt for both the Cloud and the Edge. Edge computing allows to process data locally and in real time avoiding latency issues common in cloud-based solutions; on the other hand, Cloud allows for affordable, scalable solution for storing data ideal for historical analysis. Using both is beneficial: for example, AI can be trained to recognize patterns and detect threats in the Cloud, and then the model can be embedded into the production system to detect issues in real time.

- *Predictive Maintenance*: analysts estimate a compound annual growth rate (CAGR) of predictive maintenance of 25-40% quickly scaling into the multiple billions. Data used to predict and improve machine health and reduce downtime makes sense to process engineers tasked to derive increasing operational value at scale. Predictive maintenance is evolving thanks, in part, to AI applications, augmented realty ad digital twins. Companies can create digital representations of what is happening in real time and this capability offers the ability to remotely monitor and control physical assets without ever physically interacting with them, analyzing a variety of scenarios and acting on the information generated by connected assets.

- *Location tracking:* geo-location capabilities are evolving. Companies can combine location-tracking solution with other technologies. For example, manufacturing companies can manage their physical assets by monitoring their location with GPS-enabled sensors and using AI to track environmental and security conditions.

Chapter 2. Research objectives and methodologies

2.1 Research objectives

This thesis has been developed within the research conducted by the Internet of Things Observatory of Politecnico di Milano. The purpose was to analyze the state of adoption of the Industrial Internet of Things solutions for the Smart Factory in Italy; to understand the level of knowledge of these solutions by large Italian companies; to understand the initiatives already undertaken by companies in which area of interest and in what state of progress as well as the activation of additional services; the main goals companies intended to achieve and the barriers to their implementation; to investigate the future directions concerning these solutions; whether the health emergency has changed priority given to project based on IoT technologies and how the initially planned budget has changed. The results were analyzed with respect to those of the survey involving Italian small and medium-sized enterprises (this was managed by third parties) as well as with respect to the results of the questionnaires of previous years. Another analysis involved the offer of IoT solutions and in particular software platforms.

What has emerged is that companies are moving towards a more consistent use of these technologies and, by leveraging the extrapolation and exploitation of data enabled by IoT technologies, they are trying to make business decisions. On the basis of these considerations, last part aims to identify the building blocks of data-driven business framework, to frame the requirement to seize the best opportunities for cost containment and value achievement. Then, starting from the results of the Italian scenario, a data-value matrix was constructed in order to investigate the exploitation of data by Italian companies to the benefit of the company itself and its customers.

2.2 Methodologies

Different sources of information were used to conduct the analysis and provide an overview of the Industrial Internet of Things theme. Three different kind of sources were identified:

1. Literature Review

The research activity was firstly supported by an analysis of the literature that allowed to understand the development context, the main frameworks elaborated and all the different application areas.

The most relevant sources on the Internet were the scientific search engines Science Direct, Scopus and Google Scholar. Through these it was possible to access various papers, selected by searching for keywords such as ‘Industrial Internet of Things’, ‘Smart Factory’, ‘Industrial Internet of Things framework’, ‘IIoT Concept’, ‘Internet of Things’. In order to have a more updated version of the theme, more recent papers were preferred, in particular from 2015. For this thesis work, not all the papers relating to the topic have been analyzed but only the most important and representative ones.

2. Primary Sources

As primary source, a survey in collaboration with the Internet of Things Observatory of Politecnico di Milano was conducted. The questionnaire, composed by 21 questions, was sent to 1387 Italian companies.

It was sent to company representatives, preferring among these the roles of IT manager, production manager and logistics manager as people at the forefront of starting smart factory projects. However, other positions were also taking into consideration. It allows to collect 153 responses in about two months, from 6th July to 1st September 2020. The complete questionnaire, ‘*Survey on Internet of Things projects for the Smart Factory in Italy*’ is presented in Appendix.

3. Secondary Sources

In order to provide examples of successful and interested project implemented there were collected initiatives in Industrial IoT field. In particular, a census of these type of projects was made in collaboration with the Internet of Things Observatory of Politecnico di Milano (the initial database contained 273 projects and 84 new ones were added for the thesis). For each of them was specified the name of the project, involved partners, company, the geographical area, the scope, type and brief description of the project together with technologies used and type of service offered.

In addition, in order to have an overview of the IoT platform offer, another census was carried out in collaborations with the Internet of Things Observatory of Politecnico di Milano. It contains 121 platforms (through an online research there were selected 48 new platform which were added those already surveyed by the observatory). For each of them have been reported in a database some general data about company or product (company and platform’s name, platform site, a general description of the platform, headquarter nation, company type and platform year of birth), the application scope and the functionalities offered.

Chapter 3. The adoption of the Industrial Internet of Things solutions for the Smart Factory in Italy

3.1 Introduction

This chapter intends to outline the state of the art of Industrial Internet of Things in Italy. In order to investigate the initiatives already launched by firms as well as check out future areas of interest, a survey was conducted (Section 2). The questionnaire, composed by 21 questions, was sent to 1387 Italian companies.

An overview of the different questions asked is reported below.

- general information about the respondent (name and surname, role, mail, contact number and his availability for a possible interview);
- the level of knowledge of Internet of Things solutions for the industrial context;
- whether the company has launched IoT projects for Industry 4.0 in the past to support factory or logistics
- how much the health emergency situation has changed the priority given to projects based on IoT technologies and if it is foreseen an increase in investment for these initiatives for the next year;
- the progress of the projects launched in the three areas of Smart Factory, Smart Logistics and Supply Chain, and Smart Lifecycle as well as the activation of additional services;
- the main goals the company aimed to achieve and to what extent the benefits enabled by the Internet of Things were assessed;
- whether and how the data collected were used by firms;
- the type of technologies involved: wired, wireless or both;
- what were the major barriers encountered for the project development and how to bridge the skills gap if present;
- the budget investment allocated;
- information about the upcoming projects company is planning to launch with relative timing, technologies involved and additional services;
- what the main objectives underlying the launch of any IoT projects could be;
- whether the product offered is connected and, in particular, if it only transmits information or it also communicates with other connected devices.

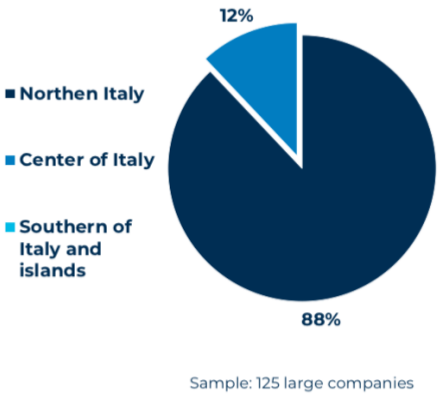
Subsequently, in order to deepen the analysis of the Italian scenario, several interviews about the most interesting projects were conducted. Quantitative analysis was useful to understand the main trend in Industrial IoT field, however thanks to a descriptive analysis it can be understood what the path of the companies has been: from the first considerations and motivations regarding the technologies of Industry 4.0 to the actual implementation of the projects. The interviewed cases together with the most relevant points of discussion are reported in Section 3; in order to contextualize and reinforce the concepts addressed by respondents, the drafting of cases was also been integrated with some information obtained from online articles.

3.2 The survey analysis

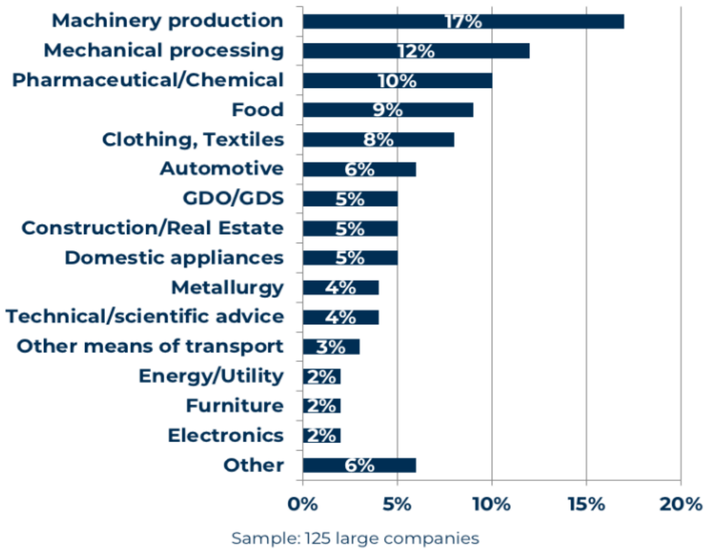
The survey was conducted with the collaboration of the Internet of Things Observatory of Politecnico di Milano through the Opinio platform. The questionnaire was sent to company representatives, preferring among these the roles of IT manager, production manager and logistics manager, as people at the forefront of starting smart factory projects. However, other positions were also taking into consideration.

It allows to collect 153 responses in about two months, from 6th July to 1st September 2020. Respondents who had only indicated personal information together with who had answered one / two questions were excluded from the analysis. In the end, 125 responses were considered.

Before analyzing the survey responses, the reference sample composed by 125 companies was better understood. First of all, for each firm the geographical location has been traced, referring to the company's headquarters. Following this, as expected, it emerged that most of the companies, about 90%, operate in northern Italy, a tenth in center of the country and less than 1% in the south or in the islands. Secondly, through the Ateco code it was identified the sector in which each company operates. Among the most representative sectors of the sample are to be highlighted machinery production (17%), mechanical processing (12%), pharmaceutical/chemical (10%), food (9%) and clothing/textiles (8%). As it can be seen from the graph 2, many other branches are present but to a lesser extent.



Graph 1: Sample geographic area

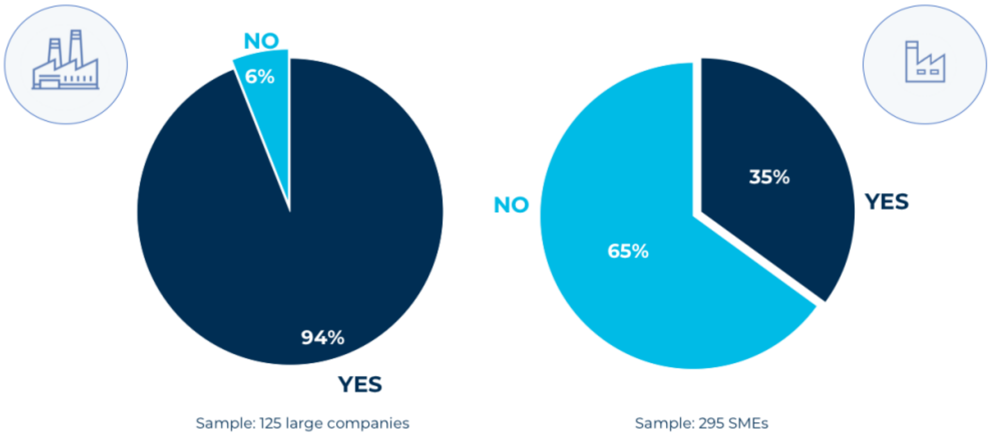


Graph 2: Sample sectors

All along the discussion, results of this year questionnaire will be compared with previous years when same questions had been tested, and then they will be likened with the outcomes of questions aiming at understanding how situation will evolve in the future. The various questions will therefore be analyzed for themes following the logical flow rather than the order in which the questionnaire was structured.

Results sent to large Italian companies will be compared with the ones of small and medium-sized enterprises. The latter refers to a survey which has involved 689 SMEs. The questionnaire was structured with similar questions, nevertheless it was managed by an external company that collaborates with the Observatory. This better completes the Italian framework made up of two very different realities, which are in two different phases as regards the adoption of IoT practices.

Question 2: Have you ever heard of Internet of Things (IoT) solutions for Industry 4.0? How did you find out?



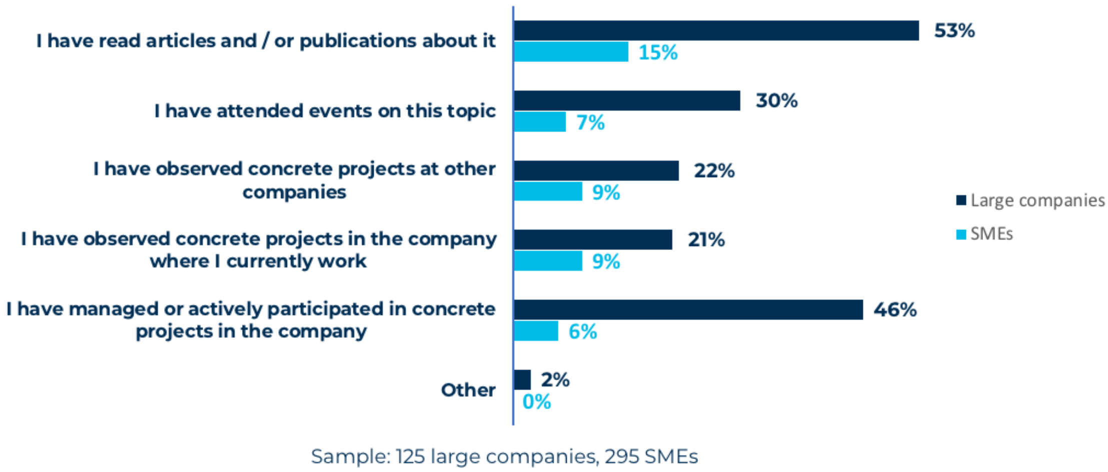
Graph 3: Knowledge of Industrial IoT solutions

The first question aimed to test the actors' knowledge about the Industrial Internet of Things. In order to help respondents in assessing their awareness on the topic, some examples were given: such as the use of technology-connected machinery to predict a failure or minimize downtime, and the use of sensors or RFId technology to monitor goods position and temperature along the supply chain.

It is confirmed this year, as previous ones, the fact that almost all of the interviewees (94%) are aware of the subject. As shown in Graph 4, more than a half of the respondents read articles in this regard while the 46% have actively managed/participated in concrete projects in the company in which they currently work.

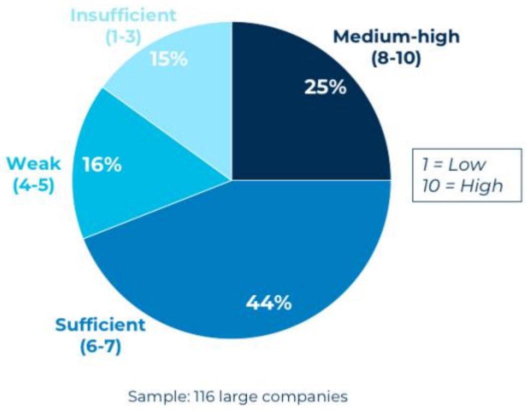
The situation is considerably different for small medium enterprises. Only the 35% of them have already heard of Internet of Things solutions for Industry 4.0. Representatives who have managed projects in the company are the 6% of respondents while those who have just observed them are 9%.

This first comparison confirms how these two realities, large and small enterprises, are in two different stages of knowledge and, as you will see, of adoption.

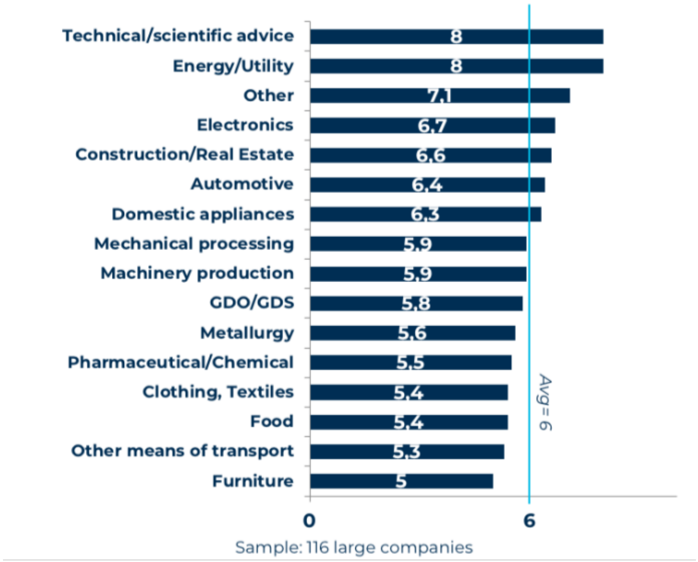


Graph 4: Mode of knowledge

Question 3: How do you assess your level of knowledge of IoT solutions for Industry 4.0?



Graph 5: Level of knowledge

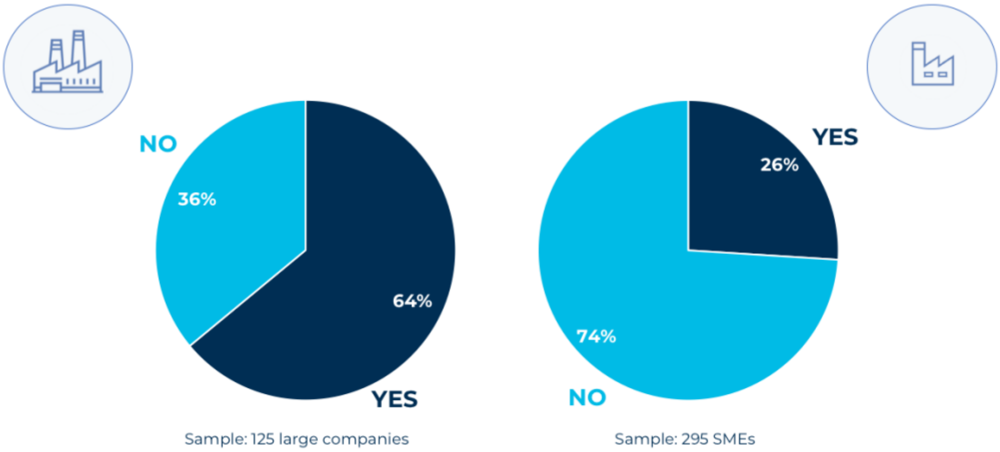


Graph 6: Average level of knowledge per sector

Going deeper into detail and investigating how well prepared the companies are on the subject a different picture results: almost all the large companies heard of Internet of Things solutions, but the level of knowledge is barely sufficient on average. Indeed, most of representatives rate their knowledge 6 or 7 on a scale of 1 to 10. The remaining respondents are divided between a very low level of awareness and very good one. It is interesting to see how the situation changes if it is considered the “knowledge” of individual sectors: both technical/scientific advice and energy/utility sectors have on average a level of 8 over 10 (see Graph 6).

Unfortunately, as seen above, these two sectors are not among the most populous in the sample. Considering the two most significant of the sample, instead we see that they are exactly on the general average.

Question 4: Has your company initiated IoT projects for Industry 4.0 in the past, to support factory or logistics activities?



Graph 7: Launch of IoT projects for Industry 4.0

From the first question it emerged that half of the respondents has already participated in concrete projects in the industrial IoT field, while a fifth has already observed these projects in the company he works for. In confirmation of this, 64% of large companies claims that they have already activated projects in this field, as it can be seen from the Graph 7.

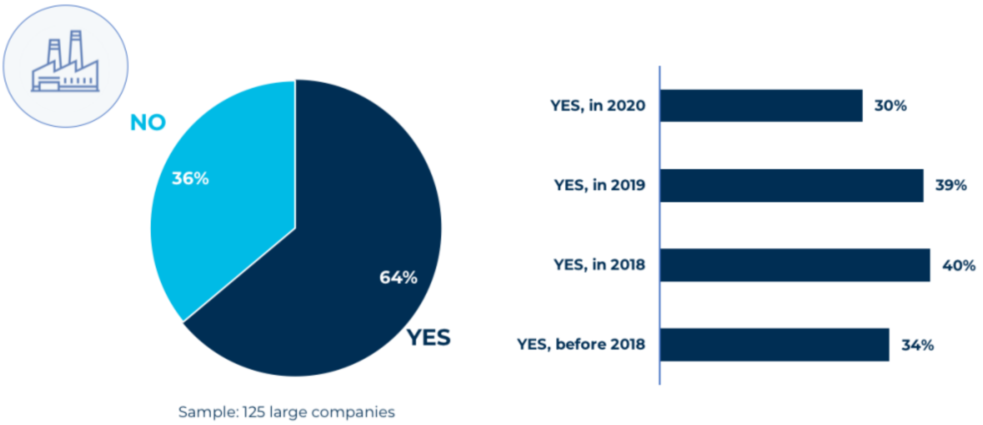
Once again SMEs are in an inverted situation with a number of active companies equal to 26%. This is not surprising since, as seen with the first question, the percentages of those who had observed or participated in projects were low. The negative response of 74% is however slightly better this year compared to previous one: as it can be seen in the table below, the 79% of the companies involved in the analysis last year had not started any project yet. By re-proportioning the positive responses, it seems that, in the period 2018-2020, 24% of companies has launched new initiatives compared to 13% resulting from the previous survey. The positive result is a sign of an increasingly involvement of these smaller businesses in these innovative issues.

	Large companies		Small-medium enterprises	
	2019 Survey	2020 Survey	2019 Survey	2020 Survey
Last 3 years	54%	49%	13%	24%
Before	12%	15%	8%	2%
NO	34%	36%	79%	74%

Table 1: Launch of IoT projects for Industry 4.0

Graph 8 shows the single percentages of the last three years as well as the one that refers to years prior to 2018. Projects launched in 2018 exceed those started in previous years. In 2019, the interest in IoT solutions for

Industry 4.0 is confirmed, with a number of projects that equals those of 2018. For 2020 it is useful to make some considerations. First of all, as mentioned above, the survey ended in early September and does not consider the whole year. Secondly, the health emergency, the impact of which will be analyzed later, could have engraved in slowing the launch of new projects and it is likely to expect an increase in the initiatives when the situation allows certain investments to be made, excluding initiatives encouraged by the emergency itself. Finally, it is conceivable that several large companies have already started projects in the past years and they are simply completing or adjusting them before undertaking new ones. In the light of these considerations, this year's result (30%) is to be considered very good, a sign of how much companies are projected towards increasingly innovative solutions.



Graph 8: Launch of IoT projects for Industry 4.0

Before entering into the substance of the projects launched, it is useful to understand if and to what extent the emergency situation has affected the projects planned for 2020.

Question 11: In light of Covid-19, is the launch of projects based on IoT technologies a priority?

Covid-19 pandemic had surely an impact on both large companies and small-medium enterprises. According to an Istat survey conducted in May 2020 with the aim of collecting assessments directly from companies on the effects of the health emergency and the economic crisis on their business, over 40% of businesses report a more than 50% drop in turnover, more than 50% expect lack of liquidity for expenses in 2020, and 45% have been suspended their operations until 4 May. The health emergency and the consequent blocking of activities have had more important consequences on small businesses, which represent 92% of the Italian fabric.

Even large companies, however, for necessity have had to give priority to the immediate, focusing on the needs of their people, customers and suppliers, and on the effective management of discontinuities in the Supply Chain.

On the other hand, precisely the recent supply problems experienced could lead the companies with cross border activities to review their supply chain by reconsidering their suppliers and production sites. The system, which was built up on the wave of globalization and spread of just-in-time methods, had made it possible to reduce production costs but now it has become more vulnerable. Indeed, it is plausible to consider that, in order to mitigate risks, companies will accelerate the race towards “reshoring”. The latter goes hand in hand with investments in automation and robotics. Thanks to technologies as Internet of Things for Industry 4.0 and Artificial Intelligence, companies can on the one hand benefit from new savings, on the other reach greater flexibility in demand and reduce risks in the supply chain.

In the light of these considerations, there are two sides of the coin: on one hand the economic impact can exclude these technologies, on the other hand the technologies may acquire a higher value. Companies may have changed their priorities following the health emergency. For this reason, companies were asked whether in this situation the launch of projects concerning Internet of Things technologies have become more of a priority or take a back seat.

	Large companies	SMEs
Yes, situation has made issue even more priority	12%	15%
No, the health emergency has made the issue less priority than others	18%	25%
Nothing has changed, the issue was a priority even before health emergency	43%	11%
Nothing has changed, the issue was not a priority even before the health emergency	21%	22%
I don’t know	8%	26%

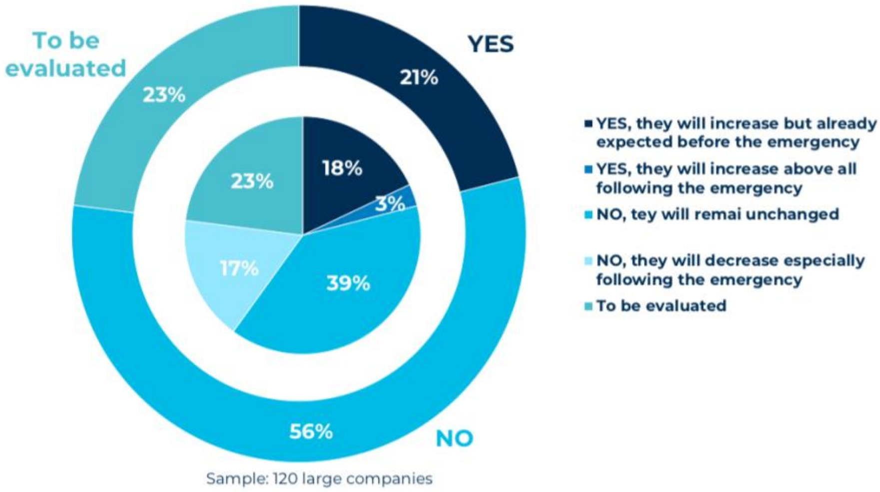
Table 2: Covid impact on Industrial IoT projects

Looking at the data concerning the impact of Covid on the launch of IoT projects, very different results can be observed for large and small-medium enterprises. For the former, the majority (43%) stated that the Covid situation did not change the launch of IoT projects as they issue was a priority even before the emergency while 12% of them declared that the situation made it more priority than before. Following these results, it can be said that mostly the companies have already evaluated IoT technologies as ‘must have’ for the future of their business or they simply have already understood the opportunities offered by the IoT in the industrial world and intended to reap the full benefits.

While for most large companies, IoT solutions in the company were already a priority, in small businesses there are more companies that recognize that Covid has made the issue more priority (15%) than those who already considered it a priority before the emergency (11%). For that 15% it seems that a program of renewal is fundamental, and it is likely that they realized how necessary it is to create the skills they should have invested in before the pandemic: to be more digital and data-driven, to be more agile and flexible.

However, the most evident results from smaller realities are for those who said nothing has changed because the issue was not a priority (22%) and for those who declare a decrease in importance of this theme as a consequence of the Covid (25%), as seen emergency and lockdown put a strain on the financial statements of small and medium-sized Italian companies. The highest percentage is then for the ones unable to assess whether the issue is a priority (26%).

Question 12: In light of Covid-19, do you foresee an increase in investments in projects based on IoT technologies for Industry 4.0 in the next 12 months?



Graph 9: Foreseen investments in IoT projects for Industry 4.0

According to the results, 21% plan to increase investments relating to IoT project while 56% do not foresee any increase. Both among the respondents of the first and second groups (that is, those who will increase them and those who will not increase them), the largest slices are relative to those who believes that the health emergency has not changed the launch of the projects, in line with what was emerged above: the largest part (39% of respondents) said that planned investments remain unchanged while 18% claimed that investments will increase but it would have been increased anyway.

On the other hand, especially following the emergency, a 3% foresee to increase investment and conversely 17% expect to decrease the budget dedicated to these projects (this in line with the 18% that find those projects less priority),

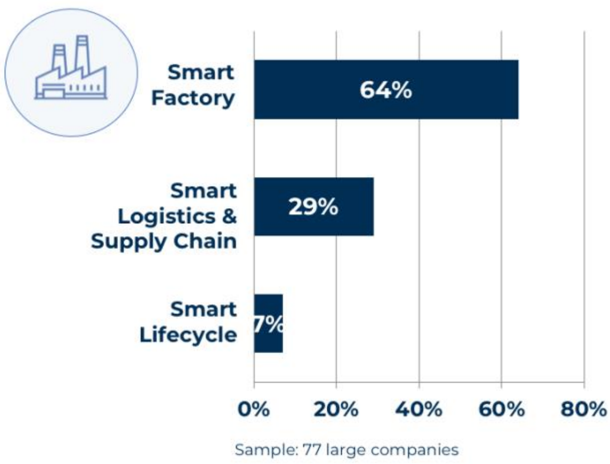
Thus, in total, 20% of the 120 sampled companies are planning to modify their investment plan while on the contrary, about 60% do not foresee changes for the next year following the emergency: given this percentage, it can be concluded that for these large realities, the health emergency did not change the balance and as seen, mostly did not change as they issue was a priority even before the emergency.

	Large companies	SMEs
Yes, they will increase especially as a result of the health emergency	3%	11%
Yes, they will increase but it was already foreseen before the health emergency	18%	13%
No, they will remain unchanged	39%	30%
No, they will decrease especially as a result of the health emergency	17%	12%
No, they will decrease but it was already foreseen before the health emergency	0%	3%
I don't know, we have to evaluate	23%	30%

Table 3: Foreseen investments in IoT projects for Industry 4.0

Also for small-medium enterprises, a good slice stated investments will remain unchanged (30%) while others have not yet assessed whether and how will change (30%). Before it was noted that percentage of smaller companies that, following the emergency, attributed greater importance to IoT projects was higher compared to the share of larger ones. Here too it should be noted that the fraction of those who will increase their investments following the pandemic is higher: 11% versus 3% of large companies. As a result of this, overall, we find that in small and medium enterprises, emergency has a slightly more pronounced response.

Question 5: What is the progress of each IoT project for Industry 4.0 launched by the company?



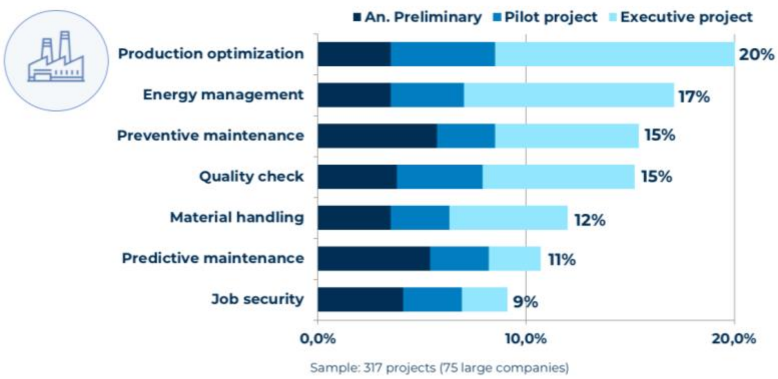
Graph 10: Project application areas

	2018	2019	2020
Smart Factory	65%	63%	64%
Smart Supply Chain	23%	25%	29%
Smart Lifecycle	12%	12%	7%

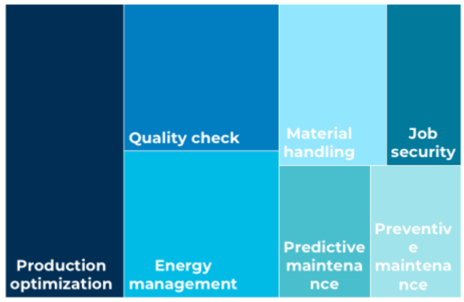
Table 4: Comparison between application areas

Graph 10 shows the smart field of application of Industrial Internet of Things: the factory, the supply chain and the product. As it can be seen, companies are mostly focused on innovating processes within the plant: 64% of launched projects are in the Smart Factory field. Looking at this percentage over the years (Table 4), we found that this is stable result. In contrast, the second cluster for number of initiatives, Smart Logistics and Supply Chain, is affected by a positive trend over time which brings it from 23% to 29%.

Finally, the Smart Lifecyle has an incidence of 7%. An explanation of a smaller percentage this year will be detailed after, it is useful anticipate tough that this latest survey does not evaluate supplier management in the lifecycle management process. Smart Lifecycle which is the less relevant area among the large companies is in reverse the most widespread among the SMEs. According to the small medium enterprises survey results, half of those who initiated projects did so in this area, to the same extent to optimize the product development process and product end-of-life management.



Graph 11: Smart Factory functionalities



Graph 12: Smart Factory functionalities for companies new to IIoT projects

As far as innovation in the **Smart Factory** field is concerned, projects aiming at optimizing the production process (20%) and concerning energy management (17%) are the most widespread. These are also the areas with a higher percentage of executive projects: for both, 60% of initiatives are fully implemented.

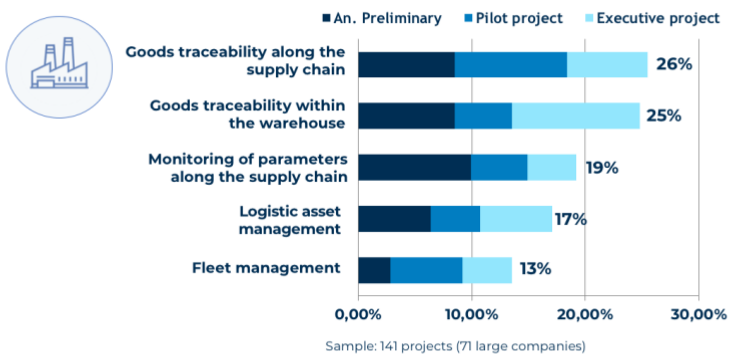
Companies, which activated IoT initiatives for the first time this year, have chosen not only to make production process and energy management more efficient but also to install advanced system for quality assurance (Graph 12). As evidence of projects in this area, the Romagna consortium Agrintesa has installed made in Italy 4.0 technologies in order to automate the quality check of its kiwifruit: the plant built by Ser.mac in Cesena is equipped with a complex neural network able to see any defective areas of organic tissue better than the human eye and translate them into digital images (HDiA- High definition innovative agrovision technology).

	2018	2019	2020
Product optimization	22%	21%	20%
Preventive maintenance	-	16%	15%
Predictive maintenance	19%	13%	11%
Quality check	17%	14%	15%
Material handling	14%	12%	12%
Energy Management	18%	15%	17%

Table 5: Comparison of Smart Factory functionalities over the period 2018-2020

Looking the table showing how percentages change across the year (Table 5), it can be seen that the adoption of IoT solution to optimize production and be energy efficient has always been relevant. Compared to last year there are not great variation between the different functionalities: predictive maintenance projects slightly decrease but energy management ones increase. In 2018, higher percentage are recorded, in particular that referred to predictive maintenance catches the eye. A consideration that can be made though is that for that year the launch of preventive maintenance project was not tested. The two maintenance strategies are developed on different operational plans, but they share the same final goal of avoiding malfunctions and sudden breakdowns. It is therefore conceivable that some projects were to be included in preventive maintenance, a step which often precede the predictive one, and that therefore there is no actual a decreasing trend for these projects. On the contrary, as will be seen below, the trend is growing. This is what Prima Industrie is seeking by integrating more and more sensors on its laser cutting machines in order to monitor the parameters estimating time residue before a failure occurs.

Analyzing the specific areas of interest of **Smart Logistics**, it is clear that goods traceability is a key aspect for companies both along the supply chain (26% of cases) and within the warehouse (25%). Even at looking at past years, projects in these two areas have been the most numerous. Always looking at the Table 6, it is highlighted a greater attention in monitoring parameters along the supply chain (19%) as well as managing logistics assets (17%). Interesting examples concern sensor applications for monitoring the cold chain for which Italian companies in the food sector have been precursors driven by the desire of guaranteeing quality to consumers: Conad introduced tags and temperature sensors on load units and started an experiment on pallets, Grandi salumifici italiani introduced them to automate the controls of goods and monitor the cold chain even in the trucks that transport the products; Parmacotto to supervise the shuttling of semi-finished products from one plant to another.



Graph 13: Smart Supply functionalities

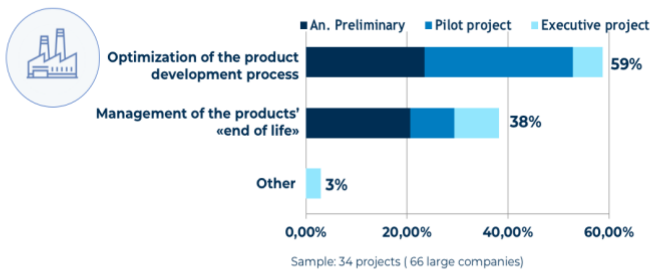
	2018	2019	2020
Goods traceability along the supply chain	33%	29%	26%
Monitoring of parameters along the supply chain	14%	15%	19%
Logistic asset management	8%	16%	17%
Goods traceability within the warehouse	31%	24%	25%
Fleet management	14%	15%	13%
Other	0%	1%	0%

Table 6: Comparison of Smart Supply Chain functionalities over the period 2018-2020

To conclude the overview of logistic projects, some considerations on fleet management initiatives. These are slightly fewer in percentage respect to previous years, but equal in number. Moreover, if only the companies new to industrial IoT projects are analyzed, it was found that 1 out of 3 logistics projects precisely concern the management of the vehicle fleet.

The third application of the Industrial Internet of Things is **Smart Lifecyle**. As anticipated, according to what emerged from this year's questionnaire, the projects in this area turned out to be fewer in number. Executive projects are really low compared to preliminary and pilot ones. Survey results highlighted a prevalence of projects aiming at optimizing the product development process (59%) compared to ones to handle products' end of life (38%).

This latest questionnaire does not evaluate supplier management in the lifecycle management process as previous ones did. In light of this, comparing the percentages over the years loses relevance.

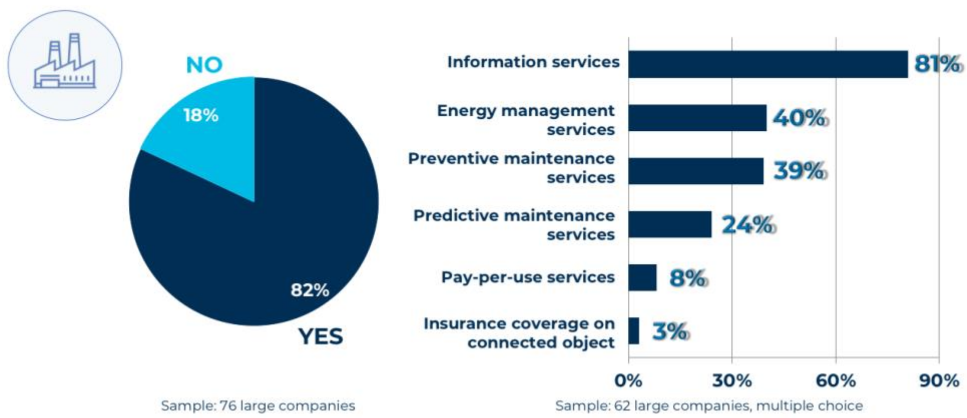


Graph 14: Smart Lifecycle functionalities

	2018	2019	2020
Optimization of the product development process	46%	37%	59%
Management of the products' "end of life"	26%	32%	38%
Supplier management in lifecycle management process	26%	26%	-
Other	3%	5%	3%

Table 7: Comparison of Smart Lifecycle functionalities over the period 2018-2020

Question 6: For the IoT applications for Industry 4.0 that you have launched, have you foreseen the activation of additional service?



Graph 15: Activation of additional services

The launch of Industrial IoT projects allowed companies in 82% of cases to offer services for their customers. Before analyzing services offered is useful to briefly make a consideration on why there is such a positive response from companies. The study ‘*Servitization: a contemporary thematic review of four major research stream*’ [Raddats, Kowalkowski, Benedettini, Burton, Gebauer, 2019] provides a holistic account of the literature on servitization reporting some conceptual studies about manufacturers’ motivation to introduce services to their portfolio offering:

- from an economic perspective it is convenient to adopt a servitization strategy both because products is less profitable and because the service is a stable income over time;
- from the point of view of strategy, offering a solution and not a product guaranteed companies to differentiate from competitors;
- also, customizing the offer translates into a better and more lasting relationship with the customer.

Looking at the Graph 15, the majority of the provided services are informative as the possibility to receive notifications in real time and to activate automatic emergency calls in case of danger. To follow 40% have activated energy management services, monitoring consumption and proposing action to improve energy efficiency, and 39% preventive maintenance ones, helping in addressing minor issues before they escalate into unplanned outages.

Companies which offers services of asset monitoring to predict potential problem are less, 24% of the sample. This percentage has not grown compared to 2019; as mention before with predictive maintenance projects, looking at the entire period 2018-2020 is deceptive. In fact, as will be seen later with future trends in service activation, predictive maintenance services are foreseen to grow. Providing services of this kind may be beneficial: customer can, through information on imminent failures, act and avoid a production stop and associated costs while vending companies can collect a lot of data on the machine useful for understanding common problems and improving some aspects on their machinery as in the case of Prima Industrie which will be explained in Section 3.

	2018	2019	2020
YES	85%	82%	82%
NO	15%	18%	18%

Table 8: Activation of services in the period 2018-2020

	2018	2019	2020
Information services	89%	71%	81%
Energy management services	41%	42%	40%
Preventive maintenance services	-	45%	39%
Predictive maintenance service	39%	26%	24%
Pay-per-use services	11%	9%	8%
Insurance coverage on connected objects	4%	-	3%

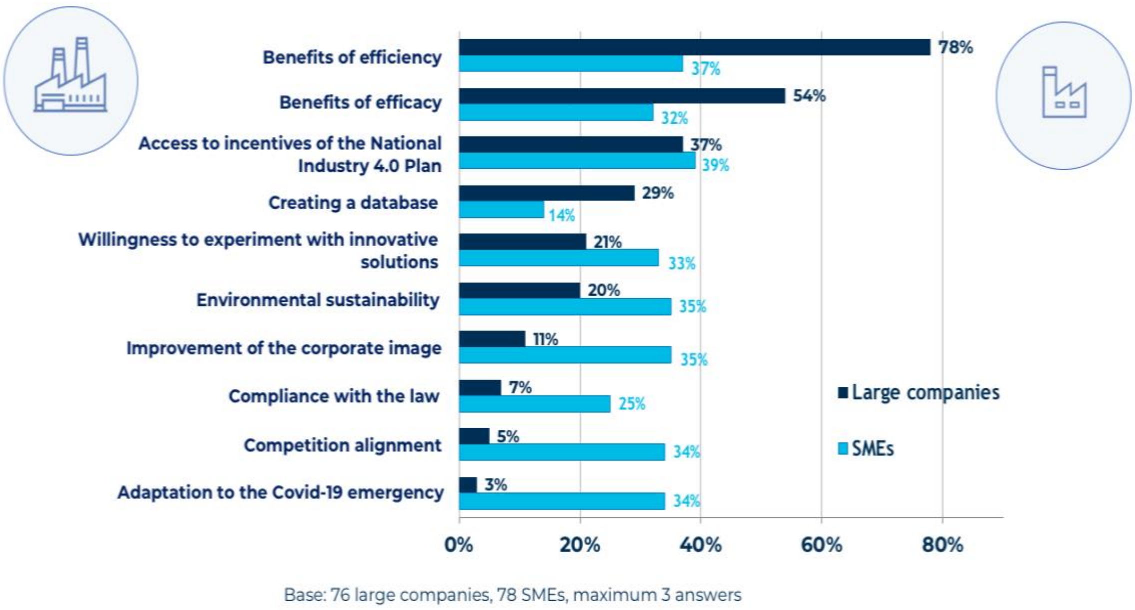
Table 9: Type of activated services

Question 7: What were the main objectives that led the company to start IoT projects for Industry 4.0?

Drivers which may lead companies to start this type of projects can be many. First of all, tangible aspects leading firms to high level of *competitiveness*: on one hand benefits of efficacy such as improving production process' quality, on the other efficiency ones, thus producing same results with less costs or times. Efficiency can be also in the form of better energy performance and lower air, water and soil pollution with the aim of improving *environmental sustainability* and promoting green business strategy. IoT solutions which bring with them concepts of innovation and sustainability can also leverage on intangible aspects such as improving the *corporate image* ensuring better visibility to customers, suppliers and all the other stakeholders.

These solutions allow switching to a connected system of objects, plant and machinery, which generate a huge amount of data, such as the one regarding the real use of machinery or the areas with greater inefficiencies. This data in turn can be exploited to experiment with *innovative solutions.*

Companies can assist these desires accessing *incentives* from the National Industry 4.0 Plan which has provided significant facilities for the benefit of all firms that will invest in Research and Development. Finally, to conclude the overview of possible targets, behind the start of the projects there could be the will of adapt to the constraints of *law and regulatory obligations*, to align with *competitors* and, in the light of the current scenario, with the *emergency*.



Graph 16: Industrial IoT project goals

Looking at the survey results, in Graph 16 it emerges that the interest of large companies is in the first place explained by the will of reaching higher level of competitiveness, pursuing benefits of efficiency (78% of cases) and efficacy (54%). To follow, accessing incentives of the national plan (37%) and creating a repository of data to be then exploited (29%).

These four objectives were also the most relevant in the previous years (Table 10), however in 2020 the percentage of companies which have pursued efficiency objectives has grown, reaching the maximum level so far. Another interesting aspect is the growing attention towards sustainability which grows by 5% in a year.

The industrial sector is, according to the Energy Information Administration, one of the highest energy users accounting for 54% of global delivered electricity. IIoT allow to monitor the amount of energy used by the machine and, in case it uses too much, reduce the power outlets creating a more sustainable use case better for the environment [Ismail, 2019]. In 2018, the World Economic Forum (WEF) published its Internet of Things Guidelines for Sustainability, which investigated 643 applications of IoT technology. The research found that 84% of use cases were addressing, or could potentially address, the UN's Sustainable Development Goals.

Thanks to these technologies, companies can lead business to operate more ethically towards industrial processes and operations that do not create unnecessary excess waste and that also do not consume more resources than they generate.

Even for what regards goals pursued, small medium enterprises were not directed towards a few relevant objectives but many with similar relevance. In order of importance, even if with similar percentages, access to incentives, efficiency targets, environmental sustainability and improvement of corporate image. The other objectives are not far apart, with the exception of the creation of databases which is the least interesting for these smaller enterprises. From this picture the greatest gaps between companies of different sizes emerge: while large companies are very projected towards efficiency and have little interest in aligning themselves with the competition and the health emergency, in contrast SMEs give a high importance to evaluate and equate competitors' offer and manage the impact of Covid in the company.

	2018	2019	2020
Improvement of the corporate image	12%	16%	11%
Benefits of efficiency	75%	70%	78%
Benefits of efficacy	59%	50%	54%
Access to incentives of the National Industry 4.0 Plan	45%	36%	37%
Compliance with law	12%	6%	7%
Competition alignment	3%	8%	5%
Creating a database	37%	31%	29%
Willingness to experiment with innovative solution	24%	33%	21%
Environmental sustainability	16%	15%	20%
Adaptation to the Covid-19 emergency	-	-	3%

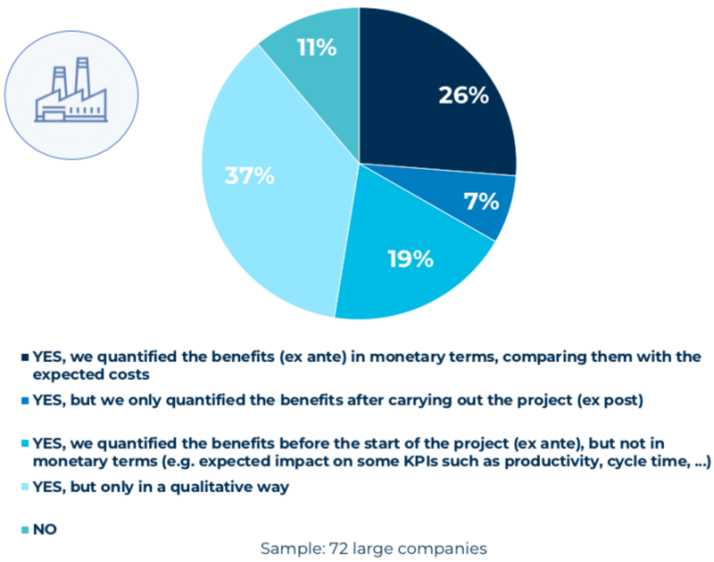
Table 10: Comparison between objectives over the period 2018-2020

Question 8: With reference to the projects started, have the benefits enabled by the Internet of Things been evaluated?

A seen in the previous question, it is typically the benefits of efficiency and effectiveness that drive companies to start projects in the production, logistics and product fields. From the range of benefits that IoT solutions offer, some will be provided below:

- Productivity improvement resulting from process automation
- Waste reduction thanks to intelligent inventory monitoring
- Less time wasted due to equipment failure
- Reduction of environmental costs and benefits deriving from lower energy consumption
- More efficient production thanks to real-time diagnostics
- A better customer experience resulting from the forecast of customer needs and a dynamic reaction
- Greater profitability

Since achieving these benefits emerged as the main goal, it is likely to be assumed that these have been taken into account. The question goes to investigate this aspect but also to understand to what extent they have been considered.

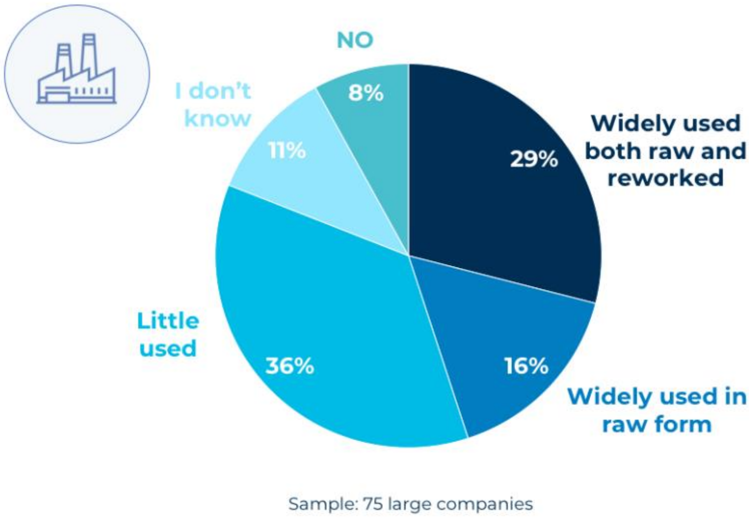


Graph 17: Benefit assessment

As it can be seen in Graph 17, only the 11% of the companies involved stated they did not assess the positive effects given by the initiatives. Therefore, as expected, majority of the respondents evaluated the benefits resulting from the launched projects. Considering instead the modality assessment, it emerged that 37% of them did so in a qualitative way, 26% did a complete cost-benefit analysis, 19% quantified benefits but not in monetary terms while the 7% did it but only at the project end.

Comparing the results with those of 2019, it emerged that those who did not evaluate the benefits more than halved while those who did a full analysis increased from 15 to 26% this year.

Question 9: Have you used the data that you have collected through IoT projects for Industry 4.0?



Graph 18: Data utilization

Considering 75 large companies responding to the Survey, in Graph 15, it can be seen that one company out of ten fails to establish the level of data use, sometimes because the technologies are still not very mature. Hence the sample is divided in two parts: 45% make use of data, 44% makes little use of it or not at all. More in detail, companies that still do not collect data are 8%, percentage which has decreased over time (Graph 18), while the majority of the sample gather data from systems and devices, but it still does not make proper use of it (36%).
Among those who instead collect and manage data, 16% declare to use them in raw form, while 29% reprocess them to get useful information those who make the most advanced use are double in number compared to the former. Among the latter there is the case of Prima Industrie which, by exploiting the data of its laser cutting machines, collects information that is fundamental to understand the use made of the assets and exploits them primarily to make technical improvements to machinery and then to propose new improved versions. Thanks to the feedback generated, Prima optimizes the development process of its products.

Cases of this kind are rarer in the context of small and medium-sized companies, as shown in Table 12, they stop at a previous step: they widely use data collected only in raw form, without making reworkings. Still for these firms, the share who use poorly the data collected is prevalent, a sign that there is room for improvement in this direction: once the use of data is widespread and complete, a sharp increase in the provision of services built with data will also be plausible.

	2018	2019	2020
No	11%	10%	8%
Little used	30%	35%	36%
Widely used in raw form	27%	24%	16%
Widely used both raw and reworked	32%	31%	29%
Don't know	-	-	11%

Table 11: Data utilization over the period 2018-2020

	Large companies	SMEs
No	8%	14%
Little used	36%	45%
Widely used in raw form	16%	31%
Widely used both raw and reworked	29%	8%
Don't know	11%	3%

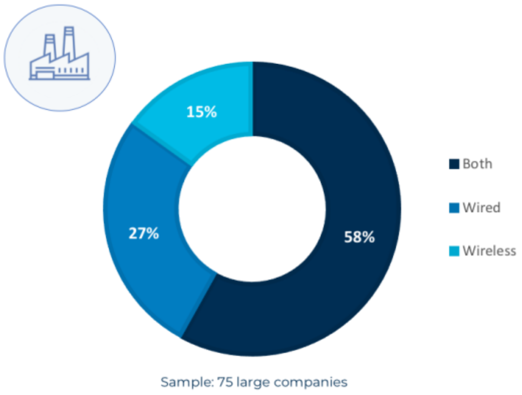
Table 12: Data utilization for large companies and SMEs

Question 10: Are the launched projects based on wired and/or wireless IoT technologies?

This year reliance on both wired and wireless technologies is reconfirmed. And it is even slightly more pronounced compared to 2019. For companies which instead choose a single technology, wired one seems preferred, reversing last year's results.

The technology must be evaluated considering its characteristics and compatibility with the intended use of it, therefore in relation to its application area. Wired and wireless technologies can be compared on the basis of various parameters such as reliability, mobility, speed, security, etc. [Saranya,2017]. When dealing with wired networks, companies have more control over what devices can connect to the network: there is more control over the security protocols on those devices making it less likely to contract malware or be prone to cyber-attacks. Companies may prefer Ethernet connection because overall faster, with lower latency and it is free from frequency interference typical of Wi-Fi networks. However, huge strides have been made towards as it was analyzed in Chapter 1, there are new wireless solutions and new versions of those already on the market that have low power consumption and good performance in terms of throughput and reliability

Companies which adopt IoT sensors technology may prefer migrating to wireless technologies as it is a more practical connection due to the small size and the capillarity typical of these sensors. On this line, added-value services for industrial environments are being enabled by wireless solution: units placed on power line to monitor status, temperature, condition; data accessible from smartphone and so on. Moreover, the huge number of devices that Industrial IoT will bring encourage the adoption of a wireless network. As it was seen, wireless technologies combine elements of flexibility and scalability. For this reason, it is expected that in the future companies, previously exclusively based on wired technologies, will use more and more wireless ones, even if in combination with pre-existence wired technologies.



Graph 19: IoT technologies

	2019	2020
Wired	19%	27%
Wireless	25%	15%
Both	56%	58%

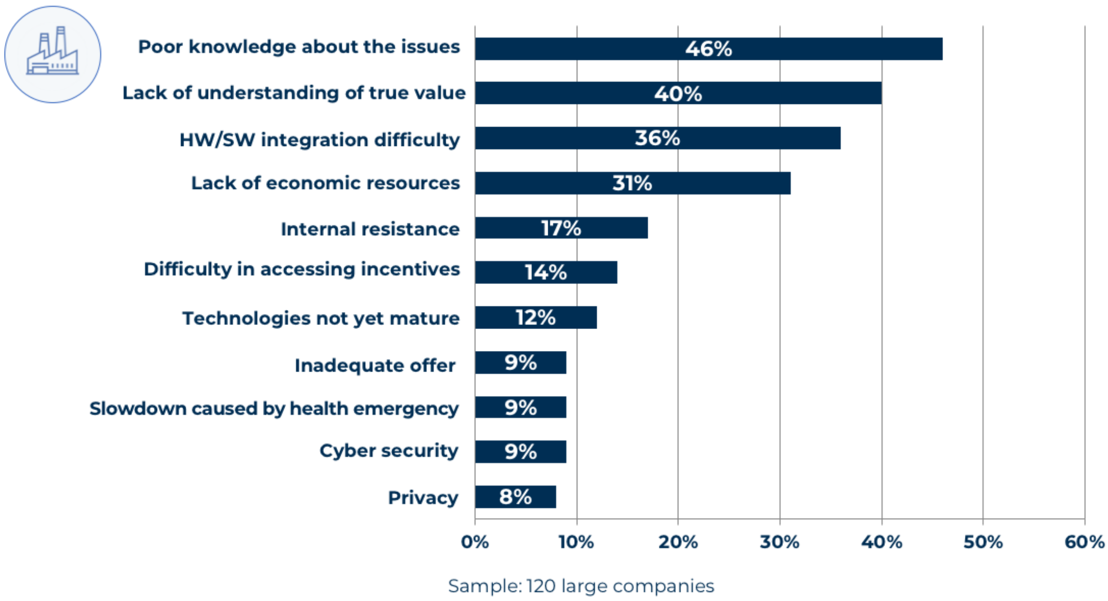
Table 13: IIoT technologies in 2019 and 2020

Question 13: What are the barriers (internal and external) that in your opinion can slow down or prevent the launch of IoT projects for Industry 4.0?

Several barriers could hinder or slow the start of new projects. First of all what the project itself entails, it involves adopting new technologies and often managing an infrastructural and organizational change. Therefore, companies may find themselves poorly prepared for the *issues relating to Industrial Internet of Things*, they may *lack personnel* capable of carrying out projects that it is also able to manage the *integration of new and old hardware and software*. Some of the actors who exhibit a lack of knowledge of the issues may also *not understand the real value of the intended solutions* disagreeing with those who promote them and making *internal resistance* to the start of new projects. On an economic level, there could be a *problem of availability of resources* necessary to implement the solutions as well as *difficulties in accessing the incentives* envisaged by the national industry 4.0 plan; barriers which hinder the start of projects.

Companies could then decide to postpone the project launch waiting for the *technologies* to be fine-tuned and reach an *adequate level of maturity* or until the *appropriate products or suppliers* to carry out their project are found in the market

Also, behind the development of Internet of Things project, there is the processing a large amount of data. This is what brings countless benefits to the system but also makes it vulnerable, thus a great attention to *privacy* and *cyber security* issues is required. These are very relevant aspects when it comes to technologies in general and IoT diffusion: every IoT devices added to the corporate network become a potential new point of attack, thus devices must be secured ensuring also the protection of all the information generated by them for the good of the company and its customers.



Graph 20: Barriers to Industrial IoT projects

According to the 120 large companies taken as sample, the biggest restraints come from the lack of knowledge of the issues together with a problem of competences (46% of cases). In the light of what emerged previously about the level of knowledge of the IoT solutions, this response does not surprise. However, an interesting aspect can be seen from the 3-year results table (Table 14): this obstacle seems becoming less and less relevant with percentages going from 62 to 46. The barrier that was previously linked to the lack of knowledge, namely the fact of not understanding the profound value of these solutions in companies, also goes from 53 % to 40% in the period 2018-2020.

As previous years, 36% of companies quoted a technological obstacle highlighting how the integration between old and new systems remains a crucial point: in order to lay the foundations for the launch of projects it is necessary to adopt technologies which are compatible and easy to be incorporated with existing business applications. In addition to this, 31% recognized the economic aspect of solutions; considering the scarcity of economic resources, the start of projects may be delayed to a time of more prosperity.

	2018	2019	2020
No barriers	-	-	5%
Poor knowledge about the issues	62%	53%	46%
Lack of economic resources	26%	31%	31%
Difficulty in accessing incentives	10%	9%	14%
Internal resistance	16%	28%	17%
Lack of understanding of true value	53%	47%	40%
Inadequate offer	12%	8%	9%
Technologies not yet mature	13%	15%	12%
HW/SW integration difficulty	36%	40%	36%
Privacy	8%	11%	8%
Cyber security	12%	13%	9%
Slowdown caused by Health emergency	-	-	9%
Other	7%	4%	4%

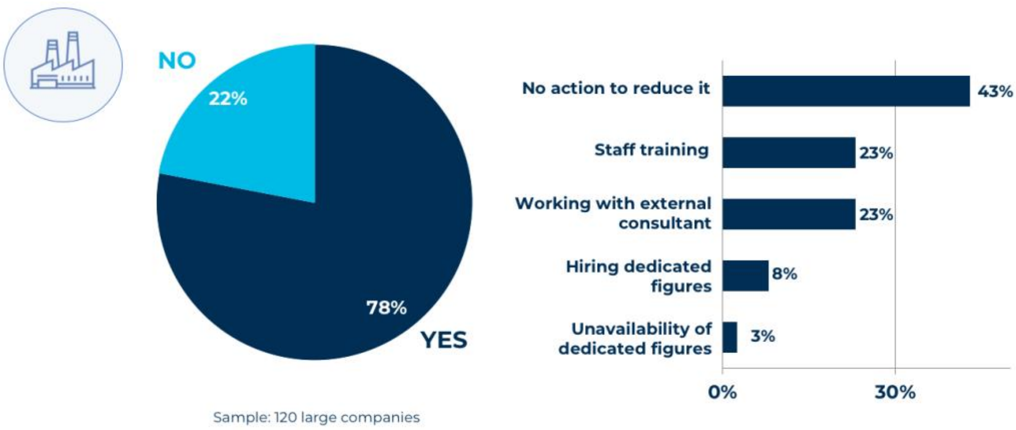
Table 14: Barriers to IIoT projects over the period 2018-2020

	Large companies	SMEs
No barriers	5%	31%
Poor knowledge about the issues	46%	21%
Lack of economic resources	31%	21%
Difficulty in accessing incentives	14%	8%
Internal resistance	17%	9%
Lack of understanding of true value	40%	15%
Inadequate offer	9%	8%
Technologies not yet mature	12%	11%
HW/SW integration difficulty	36%	12%
Privacy	8%	10%
Cyber security	9%	7%
Slowdown caused by Health emergency	9%	-
Other	4%	2%

Table 15: Barriers to IIoT projects for large companies and SMEs

A surprising aspect are results of small and medium enterprises (Table 15) which for 31% believe that there are no particular difficulties in starting new projects. One out of five recognizes the lack of knowledge and the lack of internal skills as potential barrier, always one in 5 believes that the economic aspect is relevant as the scarce availability of money affects the start-up or at least the timing of the projects.

Question 14: If the company believes to have a skills gap related to launching and managing IoT projects, how do bridge the gap?



Graph 21: Skills gap and action to reduce it

As just highlighted, almost half of large companies highlighted how the problem of lack of knowledge and the lack of internal skills is among the top three barriers in launching Industry 4.0 projects. In reality, companies which recognized to have a lack of skills are much more, the 78% of the companies takes as sample. Compared to last year this figure is slightly less negative as the companies that considered not to have the right

skills were 81%.
In order to make up for the lack of expertise, 23% of companies have already planned training sessions for their staff, 23% decided to work with external consultant with the aim of finding specific skills and the 8% were inclined to hire new professional figures. This year, companies seem to prefer to increase employees' competences rather than make new hires.

Although the analysis shows that there is this relevant gap, still a significant portion of companies (43%) have not yet acted to fill it.

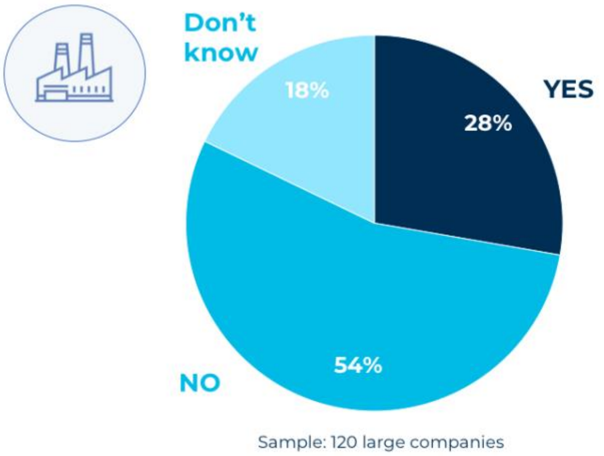
	2019	2020
No, we don't have a skills gap	19%	22%
Yes, there is a skills gap but for the moment we have not taken specific actions to try to reduce it	42%	43%
Yes, there is skills gap and in fact we are training out staff	21%	23%
Yes, there is a skills gap and in fact we are hiring new dedicated professionals	16%	8%
Yes, there is a skills gap and in fact we are working with external consultants with specific skills on these issues	23%	23%
Yes, there is a skills gap but we are unable to find new professional figures on the market and/or external consultants	2%	3%

Table 16: Skills gap and action to reduce it over the period 2019-20

Question 15: With reference to the investment plan for 2020, has a budget been allocated for the implementation of projects IoT for Industry 4.0?

From the analysis emerged that more than a half of the sample companies did not allocated a sum to be spent in Industrial IoT project. Probably that many companies, in relation to the health emergency, have diverted part of the investments previously allocated to IoT projects in other directions.

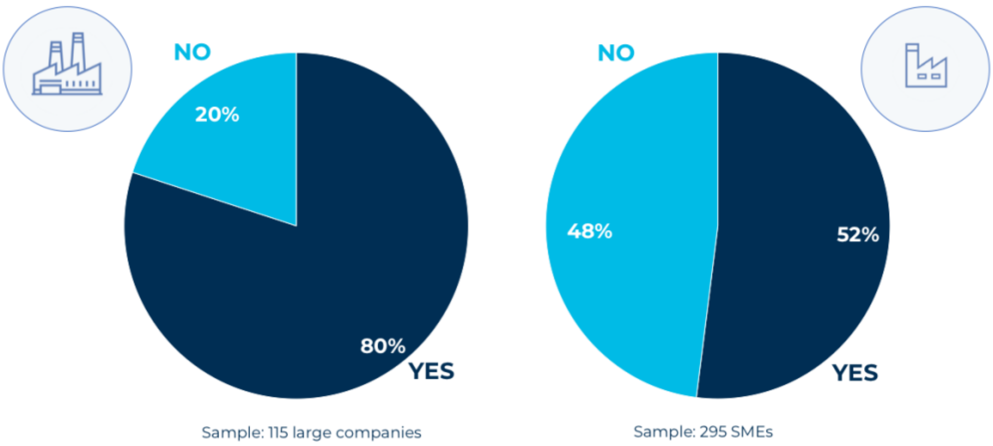
On the contrary, about 30% have taken these into consideration in the investment plan attributing them large sums of money. Among these, one provided for the allocation of 10 million euros, a limit that has been imposed by the law in relation to planned investments at least 3 times higher.



Graph 22: Budget intended for Industrial IoT projects

After analyzing what has been put in place by companies so far, projects and services, the following questions will evaluate the future scenario.

Question 16: Does the company plan to launch IoT projects for Industry 4.0 in the future?

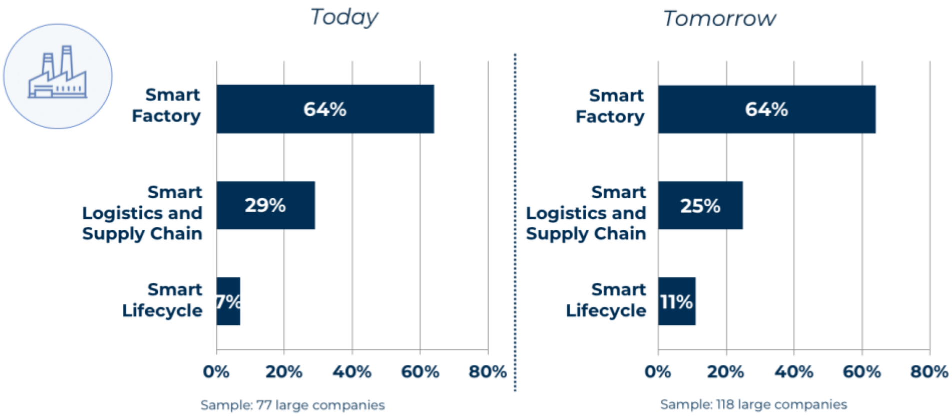


Graph 23: Willingness to launch IoT projects in future

First of all, it was asked to each representative whether the company plans to launch IoT projects for Industry 4.0. For 80% of companies there is the will to activate projects, a figure perfectly in line with 2019. The percentage rises to 83% for those who have already started projects and drops to 67% for those who have not activated them. Indeed, those who are most likely to start new projects are those who have already undertaken initiatives and reaped their benefits.

For what regards small and medium enterprises, 52% of them declared themselves interested in undertaken projects for industry 4.0. Interest grew by 3% compared to last year.

Now, specific areas of interest will be analyzed and compared to the one referred to projects already undertaken by companies seen in Question 5. In future, 64% of companies are planning to activate Smart Factory projects. Thus, this area of application is again the most widespread.
In second place in terms of number of planned projects, the logistics field (25%) for which, however, the interest seems to be slightly decreased compared to that emerged from the projects already carried out. Finally, 11% of the sampled companies are planning to activate Smart Lifecyle projects. Although this area corresponds to the lowest percentage, it seems to acquire more importance than in the past.

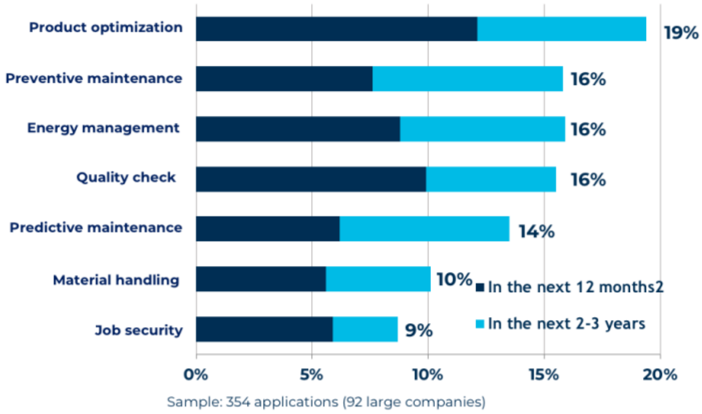


Graph 24: Comparison between present and future application areas

Regarding factory projects, companies plan to activate many of them inherent to the optimization of production processes in order to allow an optimal use of the available resources for example preparing machinery, supporting operators or improving the production scheduling. The majority of these project will be undertaken in the next 12 months.

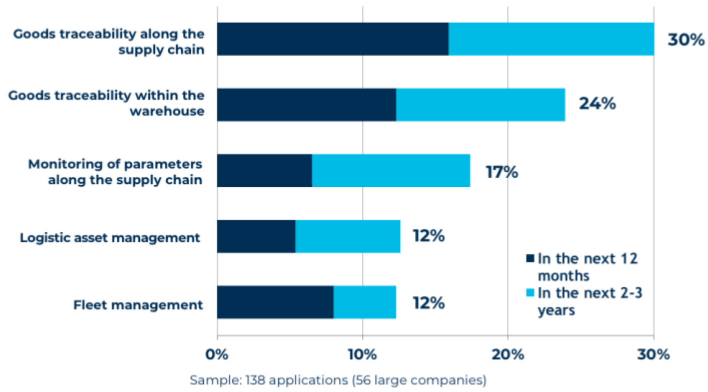
16% of companies remain interested in activating (or extending) projects to better schedule maintenance on machinery in order to extend the useful life and make machinery increasingly reliable by minimizing sudden breakdowns. Compared to projects already started, on the other hand, there will be an increase in projects that aim at not just keeping machinery in "as good as new" conditions yet predicting the onset of a fault on those thanks to an in-depth study and a constant monitoring of their parameters. For those who have already activated preventive services this is a further step for achieving a smarter factory. As can be seen from the Graph 25, half of the maintenance projects will be launched within the next year while the remainder in 2-3 years.

For all the other functionalities there not big variation, there are no interests other than those that have prompted companies to start projects in the past.



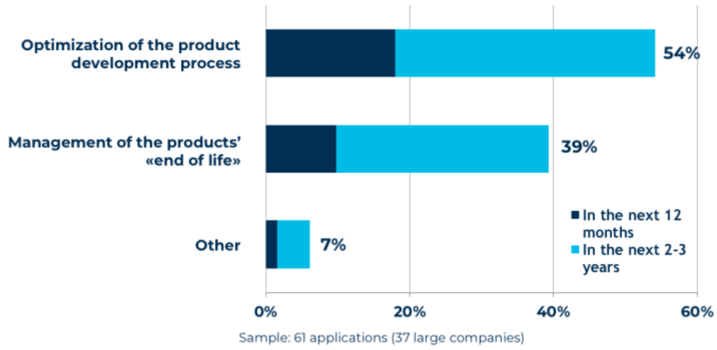
Graph 25: Future Smart Factory Functionalities

For what regards future logistic projects, 30% of sample companies is interesting in undertaking project to trace its goods along the supply chain: leveraging the use of RFID tags, Internet of Things and sensors, firm can have all the information necessary to map products in real time and manage the entire logistics process. It is increasingly important today to have the right goods at the right time to support production and distribution and to move them quickly, without waste or downtime.



Graph 26: Future Smart Supply Chain functionalities

As mentioned before, the interest in managing the product in its life cycle is growing compared to the projects already activated. This means, from conception to design, from development to production, up to managing its end of life.
Although companies are giving more and more space to these initiatives, most are not ready to activate them in the next 12 months but plan to start them at least in two years. This can be been in the graph below.

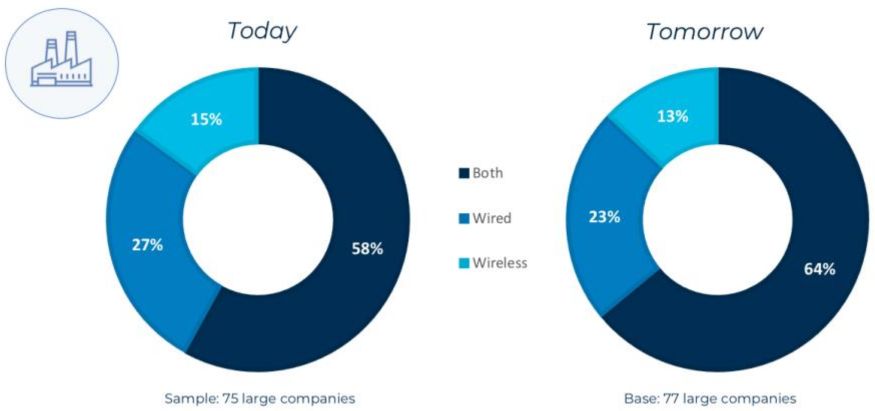


Graph 27: Future Smart Lifecycle functionalities

Question 17: Will the future project be based on wired or wireless technology?

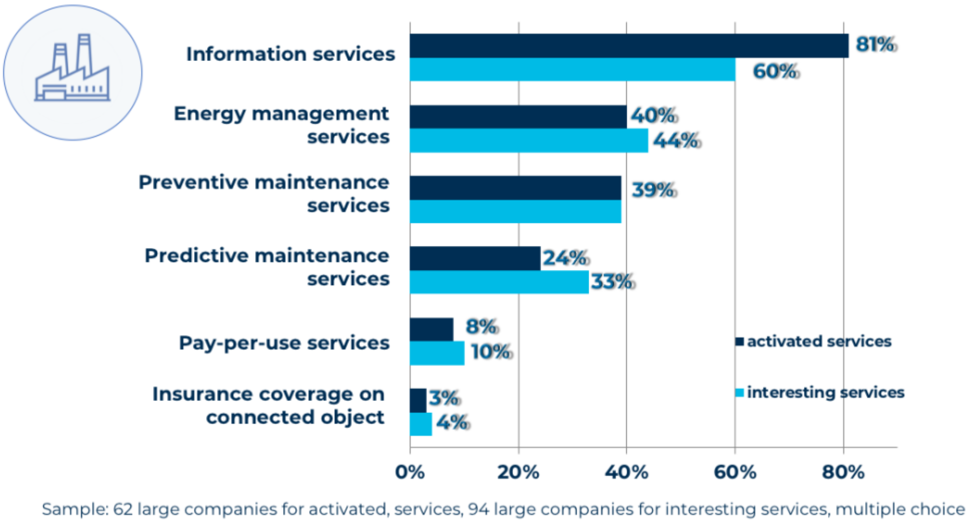
As seen, companies have more frequently chosen both wired and wireless technologies for all those projects undertaken in the past. When only one type of technology was used, the wired one was preferred. For future projects one technology is not excluded over another: in general, the use of both is preferred, 64% of the time. Compared to the past, companies intend to consider both technologies more and more and less and less individual technologies.

Then, same considerations of question 10 can be made: the optimal solution depends on the business use case. And this also involved the use of both technologies for a same application case.



Graph 28: Comparison between present and future technologies

Question 18: Is the company interested in activating additional services enabled by Internet of Things technologies?



Graph 29: Comparison between present and future additional services

As anticipated in question 6, interest in activating information services loses importance, in particular 21 percentage points, even if it will remain the most widespread type of service among companies.

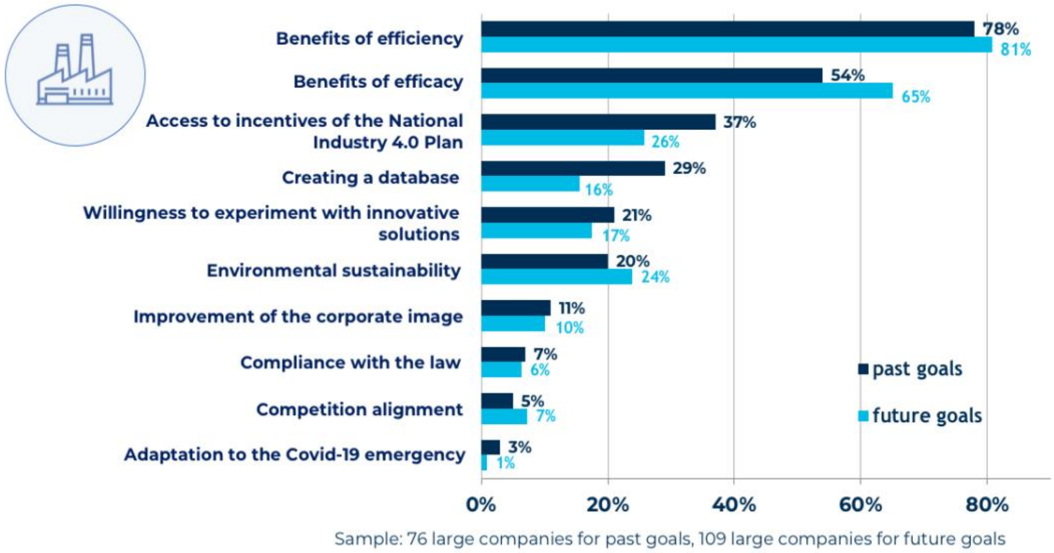
On the contrary, excluding the preventive maintenance services which remain the same, all the others increase. It can be therefore anticipating a clear transition from the provision of "basic" services to increasingly "advanced" services.

Especially for predictive maintenance services, a positive data emerges: the interest is growing from 24% of already activated services to 33% of interesting services.

Question 19: In your company, what could be the main objectives underlying the launch of any IoT projects for Industry 4.0 in the future?

As it can be seen from the Graph 30, large companies are really projecting towards benefits of efficiency and efficacy. Furthermore, as highlighted in question 7, improve sustainability is an objective always more important for companies as well as for their stakeholders (24%). Graph shows that soon it will have nearly the same importance as the access to incentives of the Industry 4.0 national plan that in 2018 had prompted a company out of two to start industrial IoT project.

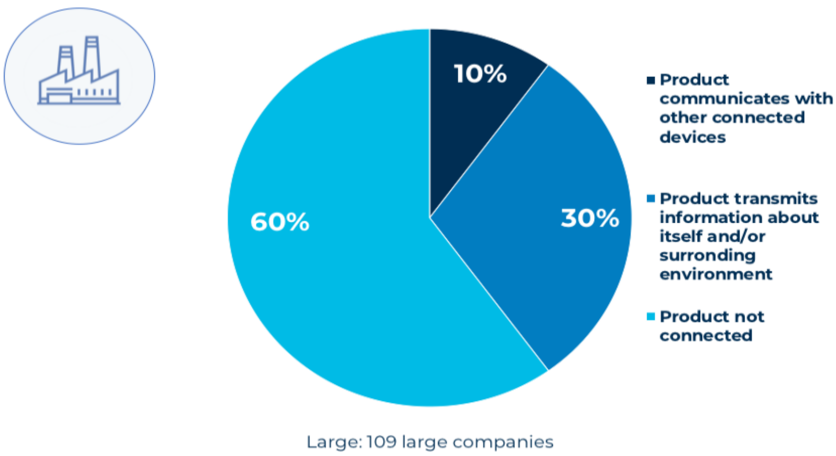
Unfortunately, creating a database of rich data from connect objects goes from 29% to 16%: this result is not very positive. The collection and then the use of this data can lead, for example, to a better use of machinery, to investigate some trend in the analyzed parameters and so on. As will be seen in Section 3, almost all of the cases interviewed concentrated on the collection and exploitation of data, seeking to improve the process and optimize machines parameters.



Graph 30: Comparison between past and future goals

Question 20: With reference to the product offered by your company on the market, which of these is the most correct statement?

The question evaluates with reference to the product offered by the company whether this is connected to the network and transmits information. Therefore, all companies that do not offer products but only services have been excluded from the sample.



Graph 31: Product connection

As it can be seen from the graph, a large portion of companies still have not yet exploited the possibility of making the product connected and intelligent allowing firm to monitor its status, to control it remotely and to improve its performance. In particular, 60% of them stated that their product is not connected.

On the contrary, there are 30% of the companies which stated that the product is connected and transmits information about itself and / or the surrounding environment and can be controlled remotely. Connected means first of all that product data may alert companies to changes in circumstances or performance and secondly that firms can have a history of the product and thus they are able to understand how the product is actually being used.

Finally, 10% of the products are not only connected but they also communicate with other connected devices of the company or other companies. If with standalone products company and its customer can benefit from all those advantages just mentioned, allowing more devices to talk to each other, even more value can be created. And the value grows exponentially as more and more devices company is able to connect.

As a result of these data, it can be concluded that the status of product connection is still low, and it will take a few years to reverse the situation.

3.3 The interviews

The analysis allowed to evaluate the state of the art of the Internet of Things initiatives in the industrial field giving an overview of the launched and future projects with related technologies and enabled services. Furthermore, on the one hand the objectives that push the start of the projects have been investigated, on the other the main obstacles which prevent the spread of such initiatives have been understood. In this section some of the projects considered interesting and for which the respondent was willing to tell more were deepened through an interview.

Interviews were carried out on call in collaboration with the observatory and they have been structured on the basis of the questions already pre-existing in the survey. First of all, by asking the respondent to talk in detail about the *interesting projects*, then continuing to ask about the most encountered *obstacles* and finally about *future initiatives*, both those that extend existing projects and those with a completely different application area. Furthermore, looking at the answers given in the questionnaire, other points, peculiar to each case, were discussed.

The paragraphs below deal with the most relevant point emerged in each interview to which information from online articles has been integrated.

The result is an overview of the activities implemented by each company and the logical thread that unites them toward the business objective.

3.3.1 ITELYUM

Itelyum is a national leader in the management and valorization of industrial waste and global pioneer of circular economy. The company offers integrated and sustainable environmental processes: regeneration, purification and waste management. These processes allow to supply products, more precisely regenerated lubricant bases and high purity solvents, and services, such as purification of chemical waste and used solvents from chemical industry and services to producers of special waste (collection, storage, transport, …).

This year, Itelyum decided to launch the first pilot projects in *production optimization*, *preventive* and *predictive maintenance* and *energy management* with the rationale of achieving the **"Smart Factory"**. Leveraging on IoT technologies, company aims to move from a "data resistance" business, in which data are acquired in a trivial way, to a *data driven business*. Itelyum has already automated many of its activities and acquired useful data but, at the moment, these are stored in a Digital Control System which is not connected to the network; therefore, they are not easily accessible. By combining specific software for data management with the use of a public cloud, the company undertakes to enhance the data by putting it at the center of the decision-making process. The company also wants to make decisions based on as much information as possible, which is why equipment with intelligent sensors will been disseminated along the production plants. In this way, the data coming from the DCS will be complemented by those collected by the sensors

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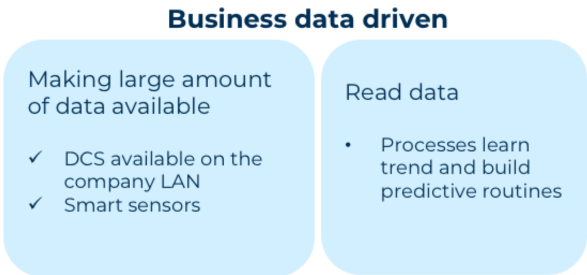


Figure 5: Itelyum business strategy

Company has set a first goal for January 2021: make the workstations operational with sensors and flow meters to have yield in real time and a continuous signal.

A second objective, for which the interviewee foresees a 3-year period learning path, is to learn how to read data and install processes capable of discovering trends and building *predictive routines*.

On the line of the corporate strategy, the benefits that the company aimed to obtain alongside a better efficiency of the processes was a better environmental sustainability. The interviewee, however, attributes an even important role to these projects and says:

"The launch of IoT projects in the industry is essential to ensure survival from today to the next 5 years and must also be accompanied by a review of the business model as well as by the development of new products in the specific sector"

Following the interview, the main concepts can be summarized, and some considerations made:

- company had already automated production activities and it is already equipped with first advanced tools according to an industry 4.0 perspective and this is mainly due to its sector history;
- it is nevertheless in a "first stage" of IoT projects in the factory. It has already done case analysis and have a clear idea of how to manage the transition from data collection alone to its exploitation in order to improve decision-making processes. At the moment, it is moving towards the adoption of enabling tools, software and cloud on the one hand, and intelligent equipment on the line on the other;
- even if the road to arrive at processes that alone build predictive routines is still long, the company is very projected towards the smart factory and sees it as the key to transforming its business.

3.3.2 LAVAZZA

Lavazza, leading Italian company in the production of roasted coffee, has undertaken several Industrial Internet of Things initiatives.

Already in 2017, the company had created connected machines in the small office environment. Machines were connected to a mobile application handed over to the managers in order to improve assistance and prevention services and then to obtain information improving the assets base both for Lavazza and its customers.

The company has then activated both projects to trace goods in the warehouse and manage logistic assets, and initiatives to improve management of machinery and production lines.

In this regard, company decided to focus its effort in *optimizing a key process*, grinding; fundamental to be monitored as impacted by several variables, environment and machine, and as it affects the coffee quality, playing an important role for the company to stay ahead of the competitors. Tracking the product quality levels and monitoring the machine working state in real-time allows the production managers to identify potential anomalies in advance, preventing low production quality. The two main parameters to be monitored are the time and the temperature to be used in the process. Data produced by the machines has to be integrated with those built by operators.

Entering into the merits of the process, data of machines is collected thanks to some sensors, later these are sent, together with the data of the previous quality control, to a Cloud platform. Learning from the behavior of the historian, the *system predicts* the expected *quality of the test* and, on the basis of this, it *predicts the best setting* to put in the mill. It is clear that under this process, Artificial Intelligence comes into play: to be effective the response of the prediction of the quality needs to be in real time, algorithm needs to be optimized even when processing large amounts of data.

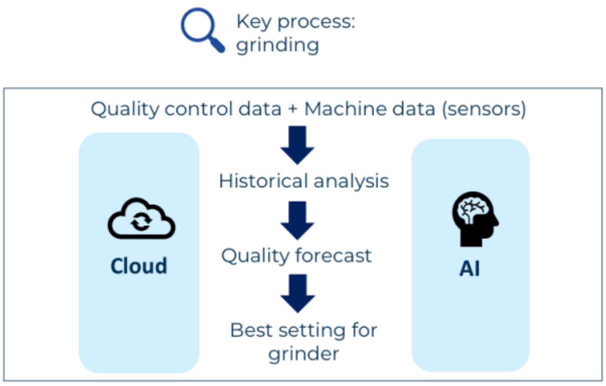


Figure 6: Lavazza grinding process

Respondent explained that the project just described was actually divided into two phases. Company started with a pilot who included the phases of data collection and quality forecasting, after which it started an executive project to arrive at also foreseeing the setting of the grinder and then, closing the circle, sending grinder data.

Next steps will aim to extend this information and decision-making process to other grinding processes. According to the interviewee, it will not be a trivial replication as each mill is independent and the success of future projects will depend on the one hand on the process itself, on the other from the data which is not always organized well. Very important is also the involvement of the people who must be committed to success, as in this case.

In conclusion:

- For Lavazza, it can be said that it is at an “advanced stage” of adopting IoT technologies, exploiting them in some of its production processes;
- The grinding process is being optimized: leveraging on both IoT technologies and Artificial Intelligence, quality of the batch can be predicted any time in advance and following, improvements in the settings of machine can be made;
- Following the already obtained and tangible benefits, the company intends to extend this logic to other grinding processes as well trying to manage in the same way the obstacles that it will face.

3.3.3 PRIMA INDUSTRIE

Prima Industrie is a leader in the development, production and marketing of laser systems for industrial applications, machines for sheet metal working, and industrial electronics and laser sources. The company has been turning its attention for several years toward Industry 4.0 and the IoT, which according to Prima Innovation Manager can guarantee the highest competitiveness in a global market highly dynamic.

In 2018, the firm activated the first project consisting in *connecting its laser cutting machines* in a single environment and extracting as much useful *data* as possible. The starting point was to focus on machines already sold and around the world. On this machines data, collected in a dedicated platform, Prima is making correlations and first analyzes in order to understand common issues and parameters to monitor. Following this, the company will be able, exploiting what it has learned from the analyses, to better design the subsequent machines and therefore *optimize the development process of new machines.*

The success and failure of the project lies on data. In fact, among the obstacles, the toughest was *data sharing.* This because many of the customers with which Prima collaborates are in the automotive sector and they are typically reluctant to share production data. What the company tried to do to overcome this obstacle was to secure the customer by focusing on *cyber security*.

Given the potential of this solution, able to enhance data for improving products, project was also extended to new additive machines. On these, more sensors have been installed in order to monitor parameters in real time, such as machine temperature, and do more predictive maintenance. On the wave of Industry 4.0, on the one hand, an attempt was made to make the machines as smart as possible with the use of augmented reality, and on the other hand to improve the quality of the process with architectures that approach zero-defect manufacturing.

To conclude, Prima is halfway through the set goal of enhancing data:

- Connecting machines to a single platform, it has improved process efficiency and optimized machine performance;
- The data platform is then being exploited to look for correlations between the data coming from the machinery in order to understand some common problems;
- Next step will be to improve the life cycle of subsequent machinery taking into account what has been learned from the analyses.

3.3.4 AB MAURI

AB Mauri is a global company active in the production of yeast and ingredients for bakery and pastry. A food company that is, however, more similar to medium and large-scale chemical firm as it produces not only yeast for bakery but also pharmaceutical. Precisely for this feature, like the big companies on the chemical sector, it was "automated" about 30 years ago and today it counts on fully automated processes under a digital control system and 100% remote control of signals.

The company activated initiatives both in Smart Factory and Smart Supply Chain fields; projects were activated before 2018 and still in these three years. The factory present itself as system of signals, which allow to be managed remotely. Over the year, the company tried to integrate as many signals as possible until reaching 10000 signals of command, in jargon called I/O.

According to the interviewee, with a system entirely based on signals, it becomes easier to discover trends and patterns that concern all the instruments such as Ph, temperature, flow, oxygen meters. Data are collected not only on the machinery but also on the production lots because, as in a chemical company, it is necessary to trace the batch up to the expiry date of the product.

In the future, the company will aim to monitor and control an increasingly large slice of the plant with a view to continuous improvement and secondly to connect even those non-core plants in order to directly remote signals to machinery manufacturers.

3.3.5 AGRINTESA

The Agrintesa cooperative was not among the companies which took part in the survey, it is however a very interesting and unique case.

In 2017, the consortium inaugurated the largest kiwi processing plant in Europe. The investment of 5 million euro concerned the line of calibration, in which products are divided according to uniform weight classes, and packaging.

Leveraging on made in Italy 4.0 technologies, Agrintesa has succeeded in *automating the quality check* of its kiwifruit. All the fruits are "photographed" and a software is able to select them by discarding those with external defects but also by dividing the lots on the basis of the quality / internal ripening.

In particular, the plant built by Ser.mac in Cesena is equipped with a complex neural network able to see any defective areas of organic tissue better than the human eye and translate them into digital images (HDiA- High definition innovative agrovision technology). As already said, the machine quality system detects not just external defects, but also the internal quality of the single fruit, i.e. it is able to identify the anomalies of the fruit pulp.

Stamping, labeling and traceability processes are also fully automated and will allow constant and precise control of the individual fruit up to the end customer. To complete the processing plants two new rapid cooling tunnels were added for the management of the product destined for overseas export.

Chapter 4. The technological offer: IoT Platform

4.1 Introduction

After demonstrating the growing interest of companies in IoT solutions, it useful to enter into the merits of the tools that can be used by companies in order to make the solutions feasible. If the demand of these solutions has grown, the technological offer has matured more and more and new trends have emerged.

One in particular concerns IoT software platforms, software elements that reside in the network and offer services to facilitate the development of IoT applications. Platforms of this type, placed in the middleware layer, were the first to be born with the purpose of mediating between hardware and application layers. It is in particular this latter layer where the greatest difficult lay: the large variety of connected objects lacked a unique communication standard thus managing them is quite complex. Existence of the platform and the use of API standard instead guarantee a reduction in complexity associated with networking and managing a any kind of connected device.

Furthermore, what the platform ensures is flexibility and scalability. Almost all of them are offered in Platform-as-a-Service mode with prices defined on the desired service level (considering for example the number of endpoints the client requires). This allows the company to avoid large initial investments and to have the opportunity to expand the solution over time.

According to the Internet of Things observatory of Politecnico di Milano, the year 2015 sanctioned the maturation of IoT software platforms, which become the main enabling factor for new connected products and services: the reduction of complexity, costs and time-to-market are the key factors.
A first element of maturation of the market is given by the fact that, not only the startups, but even the big players of the market have moved in the development and offer of IoT platforms. If risks associated with newborn companies are always high, large companies can bring more stability to the offer and exploit synergies with pre-existent cloud services.

According to Statista, by the end of 2019, there were 620 publicly known Internet of Things platform, which was more than twice as many as 2015. A first aspect to differentiate the platforms is to consider the functionalities that the platform offers. To this end, the main functionalities found following an analysis conducted by the observatory in 2015 will be reported in the next paragraph. On the basis of how many and to what extent the functionalities are offered by the different platform, two categories can be distinguished.

Alongside the specialist platforms, that offer specific functionality, general platforms covering many functionalities are developed in order to satisfy more needs with a lower level of in-depth analysis.

Subsequently, the application areas of the platforms will be addressed: platforms can be used in different fields or can be specific for one or few industries. Always relying on Statista, it can be seen as one platform over two is focused on manufacturing/ industrial use and one over five on supply chain use.

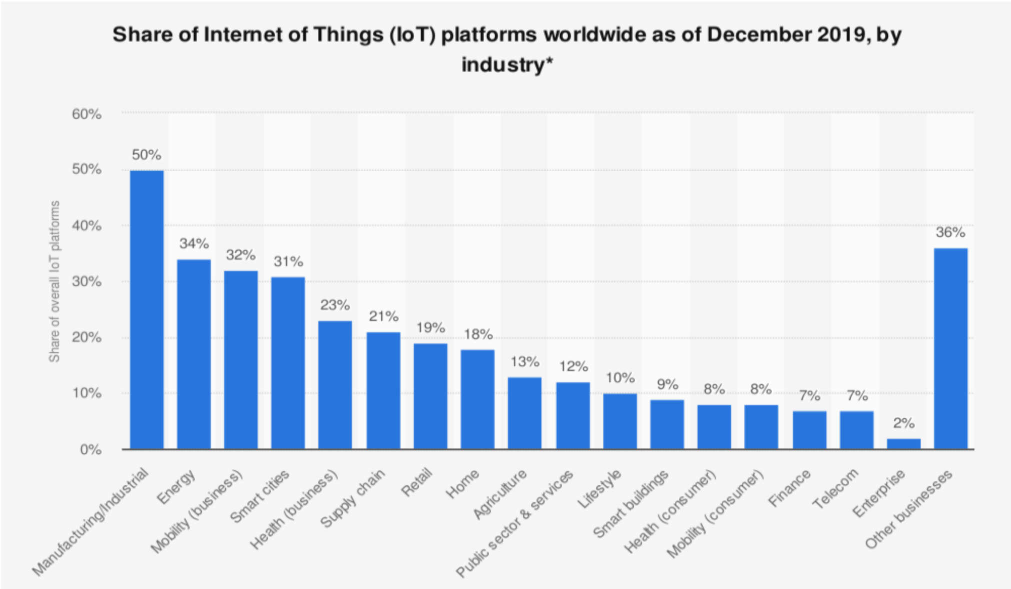


Figure 7: Global share of Internet of Things Platform by industry (Statista, 2019)

For this reason, a special mention will be made for industrial platform, which bring a powerful advantage in terms of operational visibility and control of plants and equipment. Gartner, every year, tries to give an overview of the most interesting trends of this market and evaluates the most interesting Industrial IoT platforms (reference is made to the offer for three asset-intensive industries, manufacturing, transportation and utilities) in a matrix according to completeness of vision, or how providers are able to attract and support industrial enterprises, and the ability to execute, thus quality and efficacy of processes and procedures enabling providers to be competitive. In the four quadrants: leaders, visionaries, challengers, niche players.

Later, a research on the IoT platform will be presented. Through an online research there were selected 48 new platform which were added those already surveyed by the observatory. The 121 IoT platforms have been analyzed mainly looking at their functionalities; many interesting cases were found.

4.2 Platform features

With reference to the classification provided by the observatory, the platforms can support the following **functionalities** shown in the figure, in addition they can provide the typical cloud-based functions.

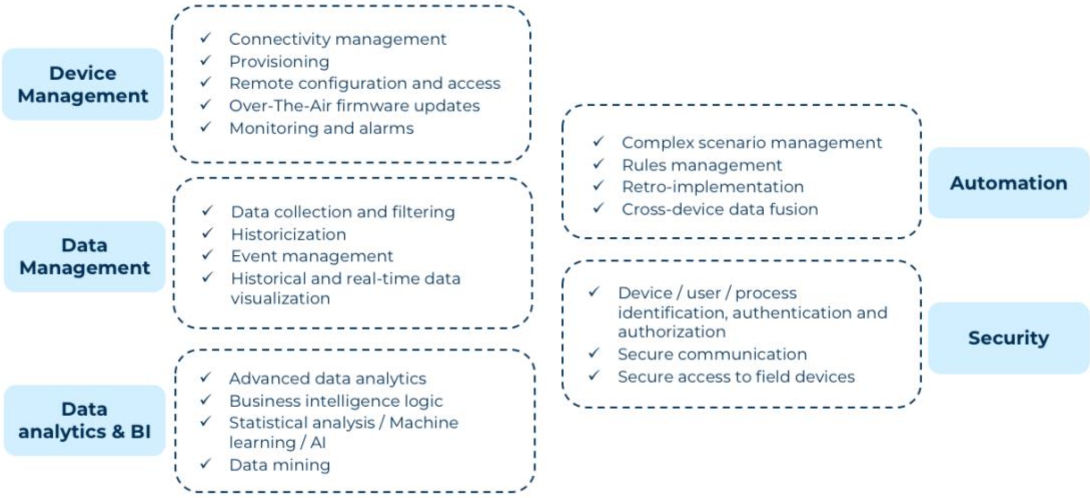


Figure 8: Classification of the main functionalities offered by IoT platforms (Osservatorio Internet of Things)

More in detail, functionalities are:

- **Device management**: platforms allowing to connect and manage the fleet of IoT devices facilitating the management of industries and businesses. More complete solutions include the provisioning and configuration of devices, Over-the-air updates and a whole system for monitoring devices and error detecting;
- **Data management:** platforms managing data at scale dealing with collecting pure data from endpoints and edge devices and historicize it in the Cloud. Both historical and real time data can be viewed and consulted by companies;
- **Data analytics and Business Intelligence:** platforms having analytics capabilities such as rule engines, event stream processing, machine learning and data visualization. Processing of data streams either at the edge or in the Cloud in order to provide useful insights and support a better decision-making;
- **Automation:** platforms using data from devices or previous trigger record in order to define actions or rules on devices and also to report back information to devices;
- **Security:** platforms focused on securing information through an identification, authentication and authorization process for devices as well users, securing communication and access to devices.
- **General Cloud Based**: platforms delivering general ICT services, hosted computing and data storage resources; data from various sources is stored in the Cloud, aggregated and abstracted to enable data analysis.

Based on the functions offered, specialist platforms and generalist platforms are distinguished:

- **Specialist platforms** have a vertical approach, implementing a reduced set of functions in depth, with typically a focus on the *facilitated management the fleet of devices and data acquisition*;
- **Generalist platforms** have a horizontal approach satisfying more needs with a lower level of depth; they focus on an *advanced and transversal use of data* from analysis involving machine learning and analytics, to data fusion, to management of rules, till its transformation in useful information.
  These can be formed following two different path: on one hand generalist platforms may be the evolution of native IoT platforms who were originally born in a specific application area but which then have broaden their scope to include other features till offering many services; on the other hand, platforms born as traditional cloud solutions which are evolved over time including IoT features, in particular cloud based solution to which providers add functionality for the management of devices.

Below, two examples for these two categories are given.

Helium- specialist platform

Helium is in the top 20 IoT startup to watch in 2020 according Forbes.

It is an Internet of Things developer platform for building network and transferring IoT device data to and from the Internet. The platform is built on a peer-to-peer wireless network that simplifies internet connectivity for IoT sensors and devices; in particular, what differentiate Helium is its ability to provide wireless coverage for low power Internet of Things (IoT) devices.

Google Cloud IoT- generalist platform

Google gives a complete set of tools to connect, process, store and analyze data at the edge and in the Cloud. A platform consisting in cloud services and an integrated software for peripherical/on-premise processing with machine learning capabilities. Data from cloud and from the edge are acquired by Cloud IoT Core and utilized for making downstream analysis thanks to Google Big Query (ad hoc analytics) or Cloud Machined Learning Engine (technical machine learning applications). Results can be visualized in dashboards.

Google also provide function of device management, providing the tool to discover how efficiently devices operate, to manage global asset and perform firmware updates. Through the use of Google Maps, company can view in real time where the assets are, in which places they have traveled and how often they have moved.

Google Cloud IoT has customers ad Paypal and Bloomberg.

4.3 Platform areas of application

Platforms on the market can be applicable to multiple context and field or on the other hand can be industry-specific. Multiple-application platforms are higher in number. This latter can cover specific functionalities with the characteristic that these functionalities are applied to many fields, but for sure a good slice of multi-application platform is made up of platform offering General-Cloud based services which are applicable to every reality. One example of a multi-application platform is indeed the one just seen, Google Cloud IoT, which presents different use cases: predictive maintenance, real-time asset monitoring, smart cities and buildings, supply chain management, healthcare, retail and many others.

On the other hand, some platforms have been developed in specific fields: Industrial IoT, Smart mobility, Smart city, eHealth, Smart metering and so on.

According to Statista (Figure 7) and the leading IoT market research firm, IoT analytics, 50% of all profiled IoT Platform companies now have a dedicated focus on manufacturing/industrial use. Typical use cases of IoT Platforms in the manufacturing space include condition monitoring and predictive maintenance, general dashboards and visualizations, energy monitoring, and quality control.

To reap the benefits there are the industrial enterprises. In particular, according to Gartner, the 50% of these enterprises will use industrial Internet of Things (IIoT) platforms to improve factory operations, up from 10% in 2020. Also it foresees that through 2025, 25% of large global industrial enterprises will acquire or invest in an IIoT platform company; up from 5% in 2020.

Industrial Internet of things platform are built on order to fit better the industry requirements. Within asset intensive industry, in fact platforms need to guarantee a secure and robust integration between Operational Technology and Information Technology Also, reliable and resilient because security issue can be involved and failure identification and recovering on critical devices must be assure. IIoT solutions are device-light but data-heavy: a low number of endpoints (in the thousands or tens of thousands) compared with commercial and consumer-centric IoT solutions reaching hundreds of thousands or millions; a very high volume of data generated by the endpoints, along with the frequency and velocity of data. The data generated by IIoT sensors is often critical to the operation of end devices and may also contribute to the safety of the environment. Thus, processing and analyzing at the edge are more significant in IIoT solutions to address safety, as is emphasizing uptime and minimizing data loss through sophisticated and segmented network design.

Platform allows companies to securely manage all the connected people, systems and things within an IIoT ecosystem. Specific requirements are to be found in the managing of the industrial network, having the ability to monitor and control an array of heterogeneous range of industrial IoT devices, automating the ingestion of IoT data and make it available to other elements on the network, guaranteeing a ubiquitous connectivity between peer systems. Also, it is fundamental to collect and analyze machine data in real-time and set alerts and notifications to know when faults occur, to apply analytics over edge and could data in order to gain insight on business operations. With these insights, decision-making can be improved, and system operations can be optimized.

Thus, key functionalities of these platform are device management and the data analytics.

Cerebra- IIoT Platform

Flutura is a niche player in the 2019 Gartner's Magic quadrant. In 2016, the startup launched on the market Cerebra, is an Artificial Intelligence Platform tuned for Industrial IoT with use cases in heavy machinery, manufacturing and oil and gas industries. The platform's strength centers on its analytics; it has "the advanced capabilities to integrate physics, heuristics and Machine Learning based models to generate actionable business insight". The Cerebra's expertise resides in Nano-apps, defined as a form of analytics-focused digital twin, that target specific IoT asset operational analytics. It resides in proven algorithms for diagnostics and prediction of machine condition. This means for example predicting a failure of an equipment or even predicting quality of the output before it's manufactured. Cerebra uses a Hadoop structure (in addition to in-memory store, document stores and other time series store variants for offline query capability), supports real-time streaming analytics and leverages a RESTful architecture to support API-based analytics queries.

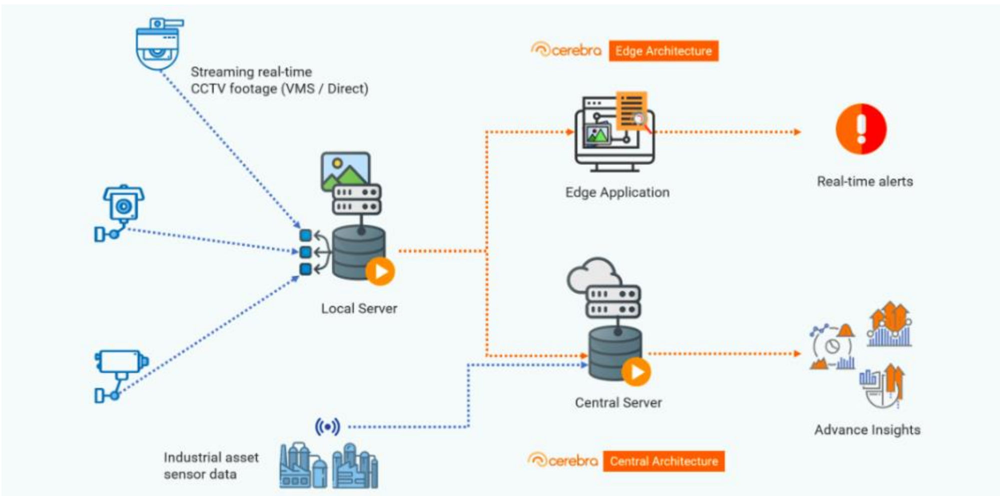
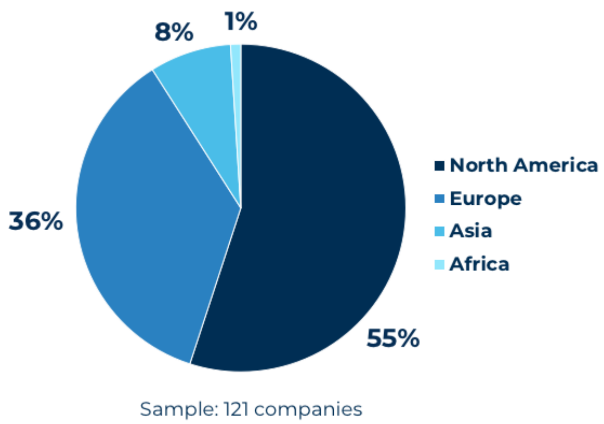


Figure 9: Cerebra architecture

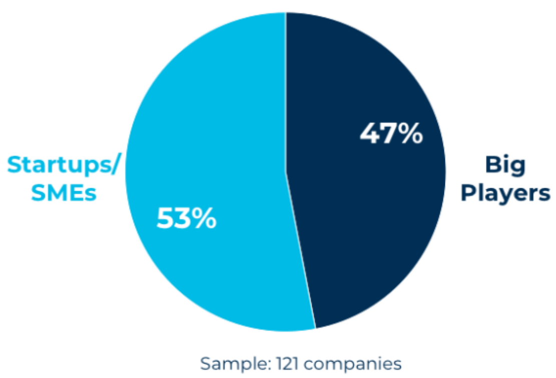
4.4 Research on IoT platforms

In order to evaluate the supply side, 121 platforms which are present internationally were analyzed. For each of them have been reported in a database some general data about company or product (company and platform's name, platform site, a general description of the platform, headquarter nation, company type and platform year of birth), the application scope and the features offered.

As can be seen in Graph 32, platform providers are mainly from North America (55% of companies) and from Europe (36%).
Startups and SMEs companies remain the most numerous, but as it can be seen from the Graph 33 the big players recently entered the market are more and more present.



Graph 32: Platform providers by continent



Graph 33: Platform providers dimension

According to IoT Analytics, the market is not consolidating: there are an ever-growing number of startups as well as larger companies or joint ventures. Reason behind the smaller players survival is that there are many niches in IoT, thus by focusing on specific industries some smaller firm can bring the value that larger horizontal players cannot.

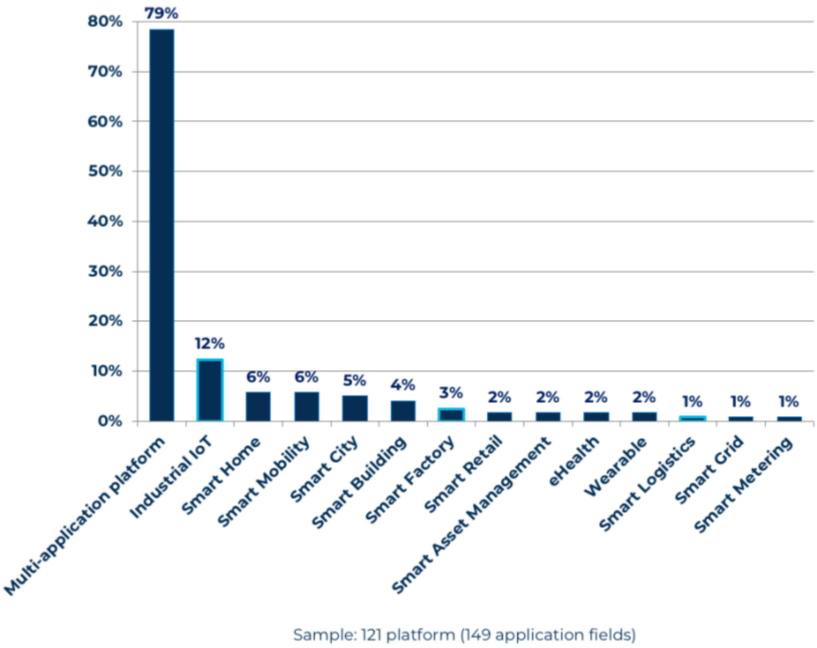
Even if market is not consolidating, it is concentrating around few providers. Specifically, in 2019 the top 10 of the 620 providers held 58% of market share. The first five are to be mentioned: Cloud companies Microsoft with Azure and Amazon AWS, followed by Huawei, PTC and IBM with IBM Watson IoT.

In 2018, Microsoft planned to invest $ 5 billions over the next four years to boost IoT business with the ambition to create software and hardware ecosystem that spans distributed computing infrastructure from edge devices and sensors to services in Azure cloud.

Amazon Web Services cloud computing platform has been bolstered with the acquisition of the 2lemetry startup and its Ting Fabric platform (March 2015, for an undisclosed amount).

PTC which acquired ThingWorx (2013, for $ 112 million) and Axeda (2014, for $ 170 million). But acquisitions involved many other big players: Samsung which invested in the acquisition of a home automation platform, Smart Things (2014, for around $ 200 million); Cisco acquired Jasper (February 2016, for a figure of approximately 1.6 billion dollars), to complement its IoT service offering; Google acquired Xively IoT Platform (2018, $ 50 million).

Looking at the application scope, large majority of platforms are multi-application platform which can be used in many industries and context. On the other hand, if only platforms developed for specific applications are investigated, platforms for industrial IoT use including solutions relating to Smart Factory and Smart Logistics are 10%, while those relating exclusively to the Smart Factory and Smart Logistics are respectively 3% and 1%.

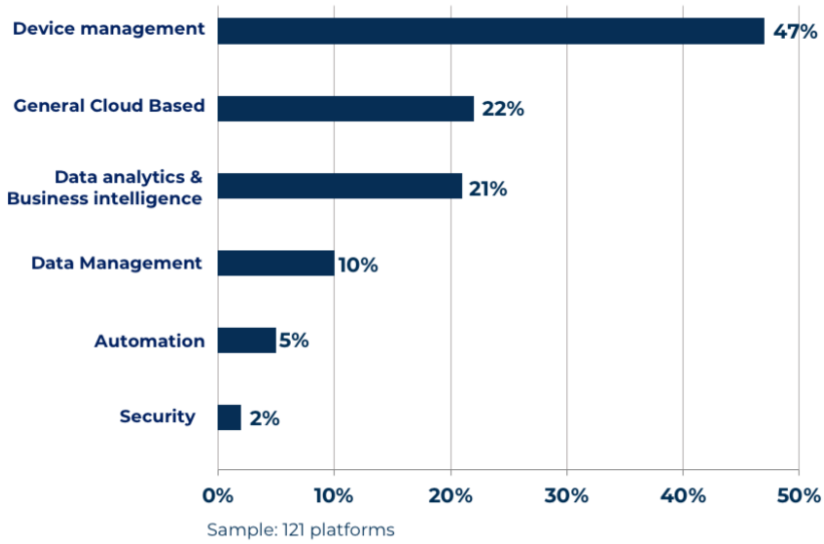


Graph 34: Platform application scope

As it can be seen from the Graph 35, the functionalities most widespread is device management. In particular, about the half of the companies provides this feature as core in the platform in order to mitigate heterogeneity of devices and guarantee connectivity to the Internet and communication between objects.

22% of solutions are instead general cloud-based platforms delivering general ICT services, hosted computing and data storage resources and covering a broader spectrum of functionalities.

More of less with the same percentage, data analytics and business intelligence, thanks to which the data is enhanced and becomes the key element for making business decisions. To follow, data management (10%) in order to capture, integrate and manage data at scale, automation (5%) to define actions and rules on process and objects and lastly security (2%) to ensure reliable communication and data privacy. With regard to this latest result, it can be said that some platforms provide security systems but few platforms are focused on offering 360 degree security taking into consideration sensor, device, edge, cloud infrastructure and network security.



Graph 35: Platform functionalities

The market, although not consolidated, has matured over the years. More and more platforms are offered in the market both by startups and large companies. These platforms seem to be more complete for what regards functionalities offered: even if there are some core features, a large number of analyzed platforms cover albeit to a lesser extent the other aspects.

Platform are more and more robust and scalable, offering the opportunity to add more and more devices. But, expansion of registered devices does not to require extensive infrastructure planning or lead-times.

An important aspect on which lies the value of the platform is its openness towards different hardware devices as well as towards other platforms offering complementary services.

But it is becoming more and more evident that companies do not just choice a single platform, they also choice the ecosystem of actors that surrounds it: physical device manufacturers, connectivity providers, integrated systems and OEMs which integrate the platform in their information systems and utilize it to market their own solution respectively; finally, cloud service providers. This last category is fundamental because it evaluates the openness of the platform towards other platform or services based on cloud.

It is clear that the aspects to be taken into consideration for the choice of the platform are different and go beyond the design constraint and its core characteristics.

Below, an example case of a comprehensive approach in the IoT platform market.

Huawei's Ocean Connect IoT Platform

The key example comes from a major telecom equipment supplier. Huawei offers a complete platform with management of devices and data, connectivity, application and cloud functions. It also provides related offering (an IoT edge router and an open source operating system) as well as allied services such as analytics, security and professional services.

Huawei has been working with partners from a wide range of fields and industries to build customer-centric solution promoting the development of an industry ecosystem.

What Huawei's offering includes is also its extended ecosystem of components and hardware partners and this help to simplify customer's sourcing challenges. Dozens of mainstream chips, modules, devices, and applications from thousands of partners in multiple industries are pre-integrated into the ecosystem, offering a wealth of business options for enterprise customers.

Another important relationship is the one with connectivity providers, in this case mobile operators managing the lower part of the architecture from the view point of their network connection and interfacing with platform. Huawei worked closely with them to provide smarter IoT connection services and a facilitated interfacing, on the other hand mobile operators themselves with the help of Huawei are trying to offer a full end-to-end solution to customers as it was recognized that there is much more value downstream, closer to end customer. An example of a successful partnership with connectivity provider is the jointly release of China Telecom's open IoT platform from China Telecom and Huawei.

Partnership cases also concern the ones with Cloud service providers as iSoftStone which successfully integrate a cloud solution for environmental protection on Huawei's platform.

Huawei has recently activated new collaborations with Microsoft, TIM, Digicom, WAGO, and Eluminocity. With more than 20 alliances and solution partners, firm has offered new solutions in the field of Smart Cities, manufacturing, finance and energy.

On the customer side, more than 200 of the world's top 500 companies have chosen Huawei as digital partner.

Chapter 5. A data-driven business framework and a data-value matrix

5.1 Introduction

Chapter 3 made it possible to frame the state of adoption of IoT technologies for Industry 4.0 in Italy with an in-depth analysis given by targeted interviews. What has emerged is that companies are moving towards a more consistent use of these technologies and, by leveraging the extrapolation and exploitation of data enabled by these technologies, they are trying to make business decisions.

The IoT has been called the ‘backbone’ of today's data-driven economy. Even at an industrial level, where typically data was used in isolation, i.e. the machine recorded its own process information but the information was rarely used by others, we are witnessing a new paradigm in which an ecosystem of people, machines and things exchange data and information.

On the basis of these considerations, a framework for data enhancement in decision-making process has been built, the data-driven business framework. In the next paragraph it will be presented together with its building blocks which allow to frame the requirement to seize the best opportunities for cost containment and value achievement.

Thanks to the questionnaire in which large companies took part, it was then possible to investigate in more detail to what extent the data is used to improve processes on the one hand and products on the other, to the benefit of the company and its customer. This will be displayed through a matrix presented in the Section 3.

5.2 A data-driven business framework

A study conducted by the MIT Center for Digital Business in 2011 found that companies which adopted *‘data-driven decision making’* achieved productivity that was 5 to 6 percent higher than could be explained by other factors, including how much the companies invested in technology. Data-driven decision making is defined not only by collecting data, but by how it is used in making crucial decisions. The central distinction, according to MIT professor Brynjolfsson, is between decisions based mainly on “data and analysis” and on the traditional management arts of “experience and intuition.” A 5 percent increase in output and productivity is significant enough to separate winners from losers in most industries.

In the globalized, digital and real-time connected economy, activities are proceeding at an accelerated pace, exponentially raising the level of competition. At stake is the company's survival on the international scene, which requires customization and localization of products and services, operational efficiency, decision-making speed and time-to-market, process governance and forecasting skills. In this context, it has been seen how IoT technologies applied both in the factory, along the supply chain and on the product itself have led to increasingly higher levels of competitiveness. According to a research report from Aruba, across the industry sector, 83 percent of sampled companies report increased business efficiency and another 80 percent found better visibility across the organization.

At the same time, the data generated thanks to the application of these technologies on corporate assets and products are the lever on which to act to make decisions at the level and at the company.

What emerged in the Italian context both as a result of the *questionnaire* in which the companies participated and as a result of *targeted interviews* is that companies have moved towards a more consistent use of technologies and are trying to move to a more consistent use of data: half of the sample companies makes use of the data, in particular 30% of them re-elaborates them. But they are still at the early stages if we think of a data-based system that generates insights at the level of operations as a whole and allows to move from descriptive logic, that is, it uses data to understand what has happened or is currently happening, to predictive, that is it matures them to understand what can happen and eventually act autonomously.

This is also well reflected on a global level, where according to the same research of Aruba it is highlighted that while nearly all (98%) organizations that have adopted Internet of Things technology say they can analyze data, nearly all respondents (97%) believe there are some challenges in creating value from this data. More than a third (39%) of companies do not extract or analyze data within corporate networks and therefore lose information that could improve business decisions.

The ability to effectively capture and use data is described by Kevin Ashton as ‘*what defines the Internet of Things*’, but this is still a challenging for businesses.

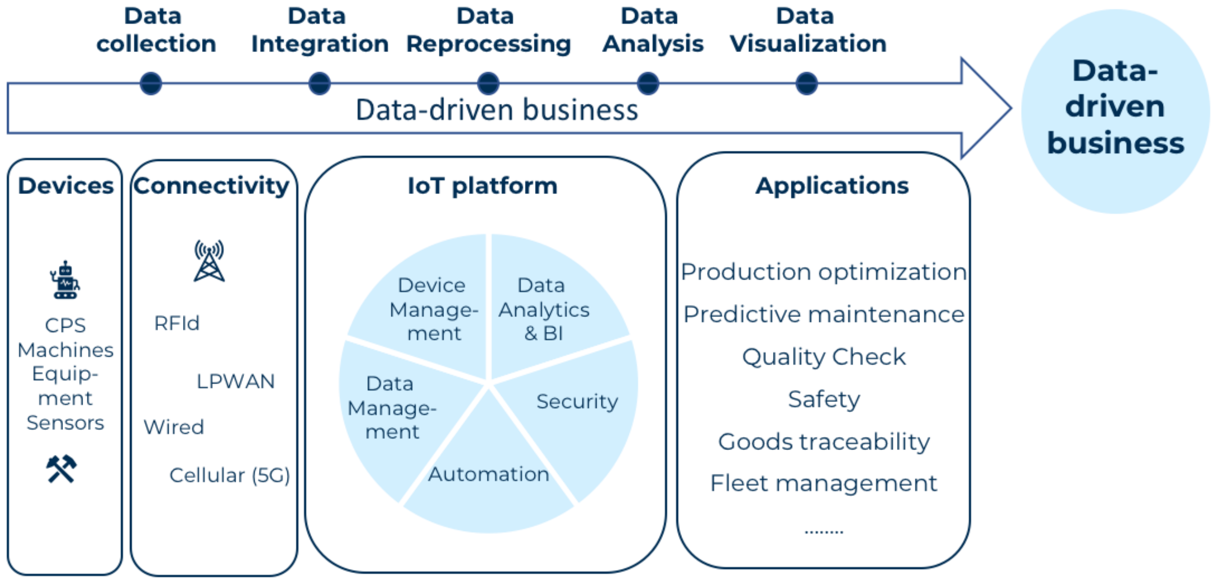


Figure 10: Data-driven business framework

I built the framework to contain all the relevant aspects that the company must rely on to move to a data-based business model. The building blocks at the bottom of the framework are also the layers of the Industrial Internet of things, the picture must be read from left to right. Fundamental elements of a system based on data are *smart devices* (for itself or legacy devices with an intelligent part), *connectivity* and *IoT platform*. These were central elements addressed in the drafting of the thesis as above all in the industrial context there are relevant to consider the interoperability of data and the security issue. By relying on these, data can be leveraged in different *application areas* shown on the right. All the most common applications of industrial IoT are considered, those which have been described in Chapter 1 and whose state of use is evaluated in the questionnaire, from factory-level applications to extended supply chain applications till product applications.

Above, the *data lifecycle* line which allows to move from data collection to data applications, in which data are the basis for making business decisions and allow for:

- **Increased visibility:** data provides insight into not only individual asset performance, but operations as a whole. This helps decision-makers pinpoint areas for opportunity, whether it be poor performing shifts, recurring machine downtime, or other production bottlenecks.
- **Automation:** there are two categories of automation that data driven strategies can support. The first is the *automated collection* of data because being operation properly outfitted with devices and software, the process of data collection no longer requires effort. The second component of automation is the use of data for *automated decision making*. Manufacturers can move from descriptive to predictive analytics, thus they first use data to understand what has happened or is currently happening,

but eventually mature to understand what can happen and have the opportunity to act on it autonomously.

- **Efficiency:** data complements lean manufacturing as it gives manufacturers the information they need to streamline production processes and minimize waste.

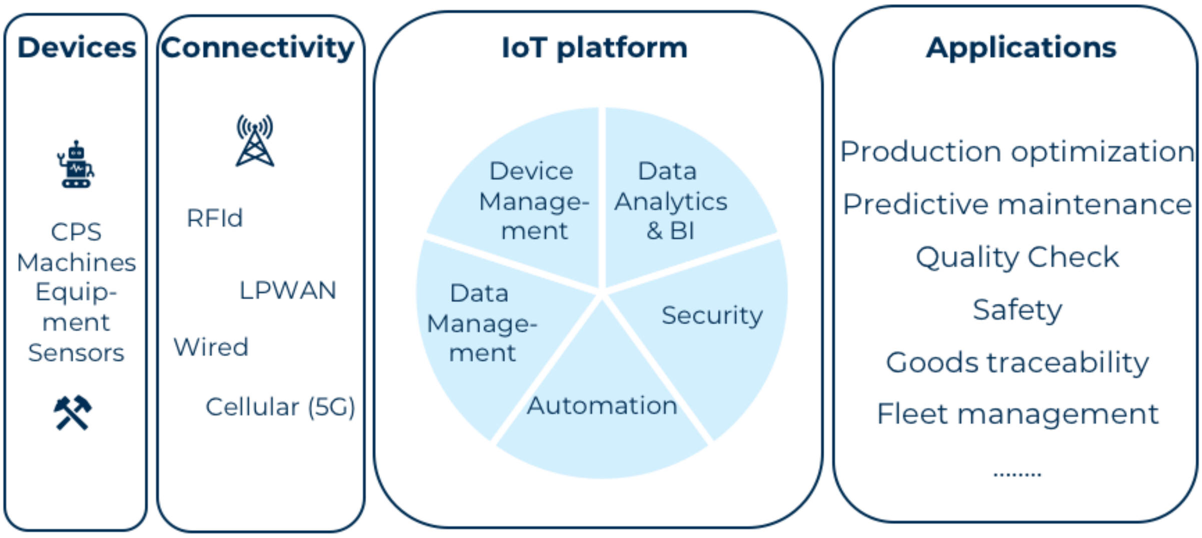


Figure 11: Industrial Internet of Thigs layers and building blocks

Going into the details, the elements and resources that allow companies to set up a data-based system:

- **Devices**. In Chapter 1, it has been seen how the hearth of IoT is constituted by devices called *smart objects* because, in addition to being made up of traditional physical components, they also have ‘intelligent’ components: sensors, actuators, processors, controllers. These objects may display self-awareness feature, which includes identification (i.e. the possession of a unique digital identification), localization (i.e. the ability to know one's position) and status diagnosis (i.e. the ability to monitor operation and need for assistance). Also, they may have three different capabilities in relation to the type of information received: capability of sensing or receipting certain information from outside (state variable as temperature or pressure), metering capability (flow variable as electricity or heat consumption) or the ability to perform a specific action that changes the status of an element [Osservatorio Internet of Things, 2015]. These capabilities can also be added to legacy assets, such as plant instrumentation, equipment, machine and systems; in particular equipping these elements with sensors real qualities can be translated into virtual information.

- **Connectivity.** The purpose is to enable direct connection between devices to extract and transmit data to the network. Smart and legacy devices have different connection interfaces, the connectivity layer brings everything together and *enable communication and data transmission* between different devices. According to the questionnaire results in Chapter 3, companies are mainly using a combination of wired and wireless technologies, this enable to collect industrial data from physical layer and transmitted with high throughput and low latency to upper levels for further processes. As seen in Chapter 1, different wireless technologies are feasible option for industrial use: RFId, short-range technologies as Wi-Fi, Bluetooth, ZigBee and long-range ones as Cellular and LPWAN.

Among the Low-Power Wide Area Networks, characterized by low power consumption and a wide area coverage, there are the popular connectivity technologies LTE-M and NB-IoT: these allow transmission of small amount of data continuously, leading to significantly better coverage and low cost of modules and data; they allow secure and minimum interference being deployed on licensed spectrum; also, they allow a continuous tracking and monitoring of assets with a low-latency threshold. Among the LPWAN, LoRa technology operates instead in the license-free frequency bands. LoRaWAN communication protocol is open allowing operators and companies to set up own network and infrastructure unlike its competitor SigFox and it utilizes two layers of security, this is a primary concern for any mass IoT deployment especially in an industrial context.

Connectivity layer assures *data security* by protecting the framework from unauthorized access and make a sure transmission of data on every phase of data lifecycle. For this purpose, there are various protocols: IPv6 offers an unlimited number of IP address and a platform for bidirectional connection among devices, MQTT targets large industrial environment that needs to be controlled and monitored by the cloud server, OPC-UA provides three-level security architecture.

- **IoT Platform.** In order to get value from the Internet of Things, it helps to have a platform on which to create and manage applications, to run analytics, and to store and secure your data [Lamarre, 2017]. As it has been seen in Chapter 4, platforms can be classified according to the functionalities they exhibit. Based on the analysis conducted on 121 platforms on the market, it emerged that about half of them offer device management functions (network management, app development, provisioning and updates), more than 20% are general cloud based platforms that offer a wide range of functions by managing data in a transversal way and interfacing with other IT systems, and a 20% offers advanced data analytics and business intelligence logics that allow the extraction of information, the basic element of any IoT solution. According to Statista, by the end of 2019, there were 620 publicly known Internet of Things platform, which was more than twice as many as 2015. Furthermore, actually one platform over two is focused on manufacturing/ industrial use and one over five on supply chain use.
- **Applications.** Chapter 3 made it possible to have an overview on the applications. Leveraging on IoT technologies, companies are mainly focused on innovating processes within the plant (64% of respondents), firstly optimizing production, improving energy efficiency, assuring a proactive maintenance and an advanced quality control. Also, 29% of companies applied RFId tags and sensors for a smarter logistics: products displayed and traceable within the warehouse and along the supply chain and logistics assets managed in the best possible way. The remaining 7% have exploited the huge amount of data from their products in order to optimize the product development process or guarantee a longer product life-cycle.

Figure 12: Data lifecycle

Before getting concrete information from data, data needs to pass through multiple steps. The journey from data collection to data visualization can be named as *'data lifecycle'*. As it has been seen, IoT data can be sourced from many types of devices and retrieved via numerous communication protocols and transmitted via networks. The starting point is data collection:

- *Data collection*. Data is mainly collected by means of the IoT: equipment and product data can be collected in real time through sensors, RFId and other sensing devices. Some examples: sensors make it possible to continuously measure, monitor and report ongoing operational status of manufacturing equipment and products, as temperature, vibration and pressure; Radio frequency identification systems enable the identification, tracking and management of prices or materials necessary for production.

- *Data integration*. This step alleviates the problem of interoperability: organizations use a variety of data management systems, also legacy system, and this means that there a variety of data formats within a single working entity. Through integration, data are combined and stored in a data warehouse or through cloud computing thanks to which data storage can be achieved in a highly cost effective, energy efficient, and flexible fashion [Tao, Qi, Liu, Kusiak, 2018]. As seen, with a unified platform data collection problem can be overcome while providing the interoperability between device and system, managing data and contributing applications in dynamic OT/IT environments.

- *Data reprocessing*. It refers to a series of operations conducted to discover knowledge from a large volume of data. Data must be converted to information and knowledge for manufacturers to make informed and rational decisions. Above all, data must be carefully preprocessed to remove redundant, misleading, duplicate, and inconsistent information. Data reduction is the process of transforming the massive volume of data into ordered, meaningful, and simplified forms by means of feature or case selection [Tao, Qi, Liu, Kusiak, 2018]

- *Data analysis*. Cleaned and simplified data is exploited through data analysis and mining to generate new information. The effectiveness of data analysis can be significantly enhanced through a variety of techniques, including machine learning, large scale computing, and the use of forecasting models.

- *Data visualization*. Visualization is intended to clearly convey and communicate information through graphical means, enabling end users to comprehend data in a much more explicit fashion, for example real-time data can be visualized online via users' smart terminals, in this way results of data processing are made more accessible, straight- forward, and user-friendly.

A fact is that the volume of data collected along the entire value chain and product life cycle is increasing at an unprecedented rate. The data now covers all aspects of production and daily operations in manufacturing companies. What companies can do to increase their competitiveness is be guided by data. This means on the one hand putting together all the resources to make data collection feasible and then trying to have a systemic vision on all stages of the process.

Starting from the design phase, through data analysis, new information on customers, competitors and markets is revealed. Based on the understanding developed through data analysis, designers can accurately and quickly translate customer voices into product features and quality requirements so that producers will become "closer" to customers and more agile in dealing with a dynamic and evolving market.

Secondly, during production, the manufacturing process and equipment are monitored and tracked in real time. In this way, manufacturers can keep abreast of changes. Data analysis can lead to informed decisions about if, when and how to regulate manufacturing processes and equipment. Furthermore, the data can facilitate the control and improvement of product quality. Data analysis can provide early warning of quality defects and a quick root cause diagnosis, which can be quickly determined. As a result, production systems can be adjusted in a timely manner to control product quality.

Finally, regarding product use, potential product malfunctions, attempts to take precautionary actions, such as preventative maintenance, fault prediction, and automatic activation can be identified early on.

'*Effective data analytics are essential to using. How well an industry or individual company utilizes the massive influx of data unleashed by IoT objects will greatly determine its competitive advantage and future success. informs a supply-chain manager about inefficiencies or security holes in the supply chain; and it will be the data that gives businesses a greater insight into its processes and products than ever before'* [DuBravac].

5.3 A data-value matrix

Porter in an article for the Harvard Business Review makes some considerations on *how the data is used*: if in the past companies generated data relating to production activities, data that came from the same systems and that they used for production rather than for the place of work, with the advent of *connected products,* data assets are also enriched with data created by the products themselves. And these are data that 'arise' not only in the production phase, but also for the subsequent phases, for example testing and packaging with all the new possible evolutions. To all this are added the data that arrive from the product in its life outside the factory, starting from the journey to the sales networks or to customers, the data relating to transport and logistics, which are linked to the data produced in their life customers.

After having seen how companies can use data and the advantages that derive from their exploitation in business decision, it is interesting to understand at present in what context the data is used most, and which are the areas that have not been exploited yet. In order to do so, the Italian companies that took part in the questionnaire were taken into consideration again.

Going to jointly analyze *Question 5* of the questionnaire, or the *areas of the projects* activated, and *Question 9* of the questionnaire, or to what extent the *data* generated by new technologies are exploited, it is possible to give a clear vision of the actual and potential use of data that benefits the *company* and the *customer*.

Intersecting the two questions, a matrix was constructed. On the y axis, the use of data ranges from a high and profitable use of data by the company to still low data utilization. On the x axis, the application areas of Industrial IoT typically divided in Smart Factory, Smart Supply Chain and Smart Product Lifecycle are instead rearranged with a view to applications with a beneficial impact on the company and the customer. Or better, projects improve current business processes, assets and products, but taking a systemic view, direct and indirect effects can be evaluated, and areas can be categorized from purely *process* areas to areas that improve the *product* and the outcome for the customer.

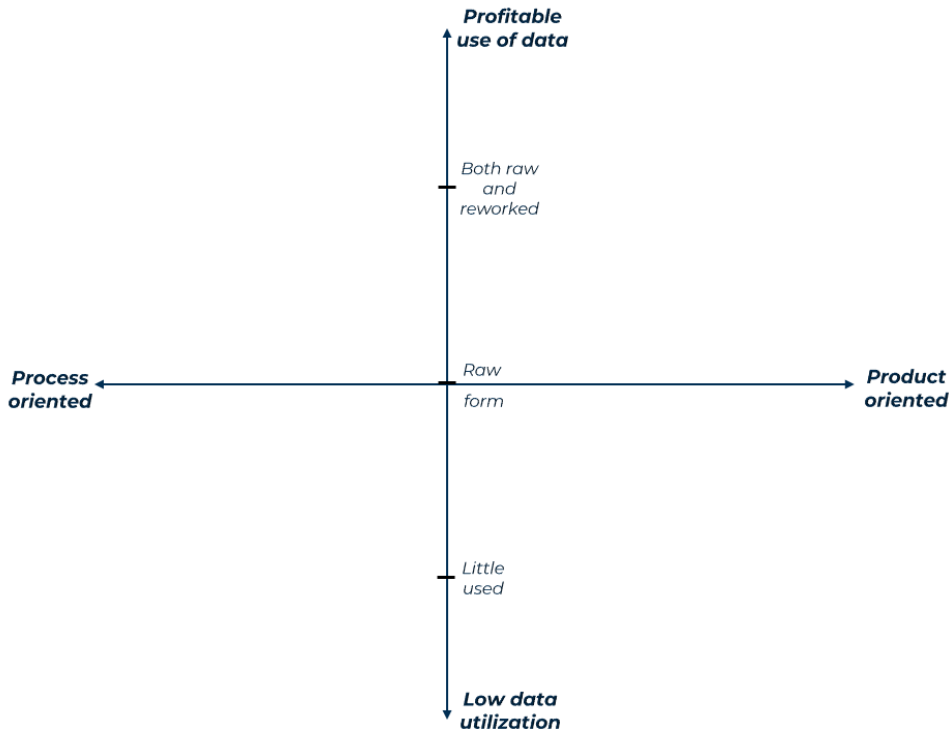


Figure 13: Axes of the data-value matrix

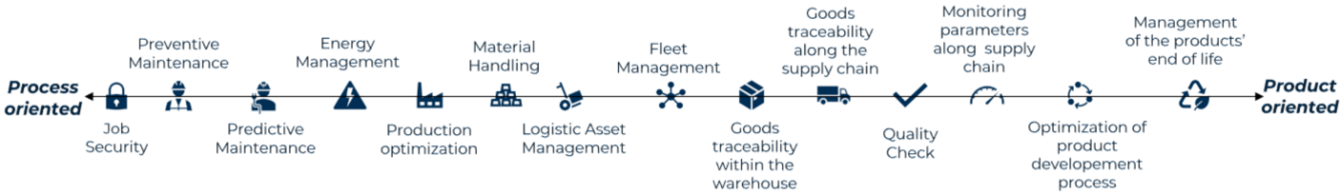


Figure 14: Value axis-areas of applications

Looking at figure 12, starting from the left, there were firstly considered applications aiming at improving *safety* in the workplace, *preventive and proactive maintenance management* in order to reduce breakdowns and extend the useful life of machinery and at optimizing use of *energy and production*. Leveraging on these, company can improve profitability and operational efficiency.

Then *material handling*, or monitoring of products during internal movements in the factory, and *management of logistics assets*. For example, RFID applications for asset management used for the handling of raw materials, semi-finished and finished products allow to systematically track product flows, making production and internal handling operations more efficient, thus increasing productivity of the company as a whole. These are applications that make the process more accurate and yet have an impact on the product itself.

By acting on *corporate fleets*, the company improves maintenance and optimizes the corporate fleet management process, planning the most convenient routes. In addition to saving time and money for the business, it ensures a better customer service with better communications, transparency and orders fulfilled faster. For this reason, it has been mid-positioned considering the positive impact for the company and for the customer.

An element of certain competitive impact in *warehouse logistics and supply chain operations* is the ability to keep track of all information on incoming and outgoing product batches and serial numbers and to follow their path to the consumer. From a supply chain point of view, in fact, traceability makes it possible to identify and isolate the "link" in the chain that has not complied with the defined requirements, avoiding the involvement of all those involved in the creation of the product and its distribution; for example, tracking movements makes it possible to isolate and quickly withdraw from the market those batches of goods made with unsuitable materials. Traceability can turn into a strategic factor of competitiveness, optimizing the entire supply chain more efficiently so as to increase the overall value offer.

Quality check with the two aim of assuring quality and controlling the quality; on one hand means setting up adequate processes to prevent errors and flaws in product, on the other making sure that product corresponds to the requirements in testing phase where excellence is ‘making it right the first time’.

Monitoring supply chain parameters also helps quality assurance for example monitoring the clod chain to ensure the shipment doesn't become compromised before they reach the market. Lastly, *optimization of product development process* and the *management of the product' end of life*. The developments of existing or new products are defined and post-sales product collection services are activated. Current business processes are being improved and products are better positioned to solve customer problems and increase real and perceived value.

For what regards application areas, projects in a state of preliminary analysis were excluded as it is obviously a premature phase in the context of data enhancement. Regarding data utilization, the few replies that indicated they did not use the data in any way were excluded. A fundamental assumption was that of associating the answer given regarding the use of data to each project initiated by the company, not being able to investigate the real use of the data in relation to each technology applied in the various fields. However, it is confident in the fact that by equipping itself with tools to collect as well as process data, the company has applied the same logic in order to improve and streamline all the processes on which it has focused.

In the table below, the results, in which the most significant percentages are highlighted. Below, these results filled the matrix and tis four quadrants.

	Little used	Raw	Raw and rielaborated
Job security	25%	33%	42%
Preventive maintenance	30%	30%	41%
Predictive mintenance	13%	33%	53%
Energy management	39%	25%	36%
Production optimization	45%	25%	30%
Material handling	25%	25%	50%
Logistic asset management	29%	36%	36%
Fleet management	38%	23%	38%
Goods traceability within the warehouse	26%	26%	47%
Goods traceability along the supply chain	33%	28%	39%
Quality check	31%	34%	34%
Monitoring parameters along the supply chain	40%	30%	30%
Optmization of product development process	50%	30%	20%
Management of products' end of life	50%	33%	17%

Table 17: Data utilization for each application area

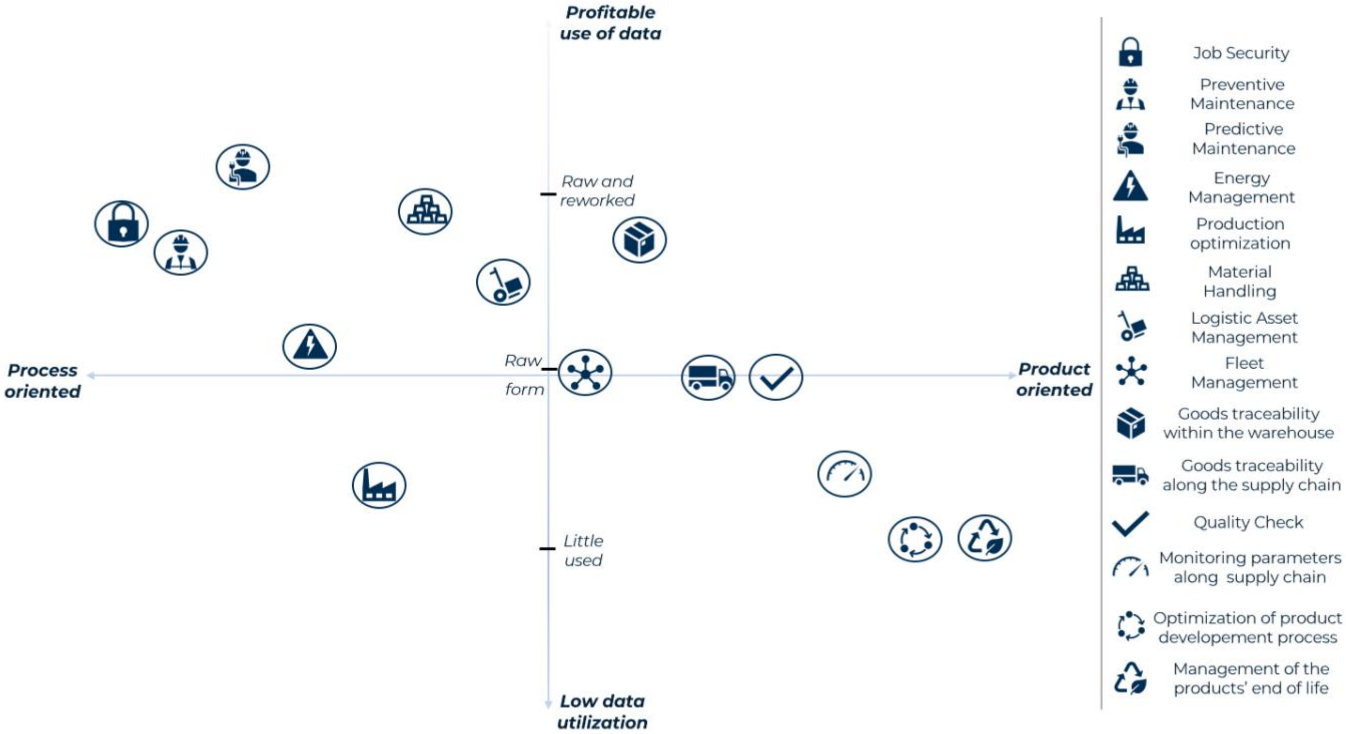


Figure 15: Data-value matrix

In the **upper left quadrant**, there are applications that focus on the improvement of pure business processes and whose process data are in a good state of use. This is the case of applications such as *predictive maintenance* for which in most of the projects in this area data have been widely used by predicting the failure of a piece or a machine in advance. Machinery data is extremely valuable as they reduce the risk of costly downtime and provide machines to run efficiently for longer over time. In addition to this, applications aimed at guaranteeing the *safety* of workers: such as sensors, which monitor temperature and humidity levels or other conditions that can cause damage to employees, and which can send messages to the emergency services when they detect anomalous values; wearable devices that can understand the level of fatigue and risky movements for operators.

In the **lower left quadrant**, on the other hand, solutions aimed at *optimizing production* have fallen. If the projects in this area were the most numerous among those adopted by Italian companies, the data from IoT sources are in general still little used. Applications that are aimed at improving the production process can be varied: such as sensors readings connected to a dashboard that displays the data collected by the machinery, describing in detail any anomalies in performance and alerting manufacturers of any urgent problems, or analyses which enable to plan production in adaptation of the production needs in continuous evolution.

It must be considered that in order to have substantial benefits in production it is not enough to focus on efficiency improvements on individual machines as they are reduced benefit, the challenge is instead that of optimizing the entire process. Traceability of data throughout the process allows manufacturers to consider upstream and downstream dependencies and determine the most effective improvements. In this sense, the improvement of production is to be considered challenging.

In the **upper right box**, for applications aimed at *tracking products in the warehouse*, good use of data is made. Think as mentioned above of RFId solutions to have all the information on incoming and outgoing product batches and serial numbers. These are fundamental in context as the one of the companies interviewed AB MAURI: data are collected not only on the machinery but also on the production lots because, as in a chemical company, it is necessary to trace the batch up to the expiry date of the product.

If we consider applications that go beyond the walls of the factory and towards the consumer, the data is more difficult to process. *Product data along the supply chain* as well as those relating *to company fleets* can increase company competitiveness on the one hand by ensuring better customer service with the best communications, transparency and orders fulfilled faster, on the other hand the fastest efficient process.

In the **lower right quadrant,** solutions that would increase the value of the offer for the customer, but which are not yet adequately used are both linked once again to the supply chain (in line with what has been said above) and related to the product itself. Following Question 20 of the questionnaire where the connection status of the product was investigated, it was found that 60% of the products are still not connected. This exemplifies the fact that these kinds of product-centric solutions are inherently less popular.

On the other hand, if smart lifecycle applications are considered, solutions which acquire value when a great reworking of data is made, it appears that we are still at the beginning of an improvement on the product side or a sale of support services.

Combining the fact that an increase in projects in this area is expected in the future (as shown by the questionnaire) and that there are first interesting cases concerning data collection, it is assumed that tomorrow data will be exploited more and more. Prima Industrie exemplifies this trend that mainly involves sectors such as machinery manufacturing: connecting products (machines) and extracting as much useful data as possible when they are in the hands of customers, making correlations and analyzes to understand problems and parameters to monitor, allow to generate after-sales services, and at the same time take advantage of what has been learned allow to better design subsequent machines, optimizing their development process.

'After using data collected from a variety of sensors to interpret historical performance patterns and root causes, companies need to take a forward-looking perspective: How can the collected data be used to improve the intermediate process and product sales? What kinds of products and services can lead to new sources of income in the future? And what kind of IoT applications can open up new markets' [Deloitte].

Chapter 6. Conclusions and future work

6.1 Findings

After analyzing the framework that contains the relevant aspects that emerged in the thesis, the work is concluded by bringing out what has emerged both following the reading of the papers on the subject and above all following the analysis on the adoption of the Industrial Internet of Things solutions.

First of all, the reason why it is important to investigate and enter into the merits of Internet of Things solution for Industry 4.0. Many authors and specialists have emphasized on the one hand the importance and value, on the other the urgency of these technologies in the industrial field. The estimated benefits are huge, again citing Accenture, the IIoT will reinvent many sectors that account for about two thirds of global economic output, generating economic gains of $ 14.2 trillion by 2030. Attention is very little as it is expected that the growth in the total number of IoT devices will provide substantial economic and social benefits in terms of cost savings, value creation, productivity improvements and overall economic growth. The industrial sector is moving faster than others because industrial companies see IIoT not just as a technology, but as existential for their businesses.

These two sides, importance and urgency also emerged in the interviews conducted. The analysis conducted at the Italian level has shown that the issue is much discussed, there are numerous projects that are being carried out regardless of the Covid situation as they were already considered to be priorities. Alongside mature applications such as those in the factory walls and to a lesser extent those aiming at controlling and managing the supply chain, there are new applications involving more customer-centric products and services which open up new business deals.

However, along with the benefits ranging from production efficiency to measurable better results for customers, there are significant barriers in the industrial context. Alongside barriers related to technology and integration between legacy operational systems and information systems, there are barriers of lack of adequate knowledge of the solutions that not only involve a change of technology but are placed in an important infrastructural and organizational change. Respondents acknowledge that there is a lack of skills in the company and very often they are not compensated. However, the success of a project strongly depends on the skills and commitment of the people involved.

The Industrial Internet of Things is a concept in continuous development Today, as seen, the offer has grown exponentially, and the conditions are created for a complete offer that seeks to overcome problems of interoperability between devices and data sharing. Even the relevant problems in the industrial context such as that of safety are increasingly taken into consideration as they are critical to the success of I-IoT initiatives. Recently, members of the Industrial Internet Consortium have developed a common security framework and approach for evaluating cybersecurity in industrial Internet of Things systems. Relying on a secure network, data will also be stored and exchanged more freely.

Data is increasingly seen as a corporate asset. In the last part of the thesis, it is highlighted how data it can be the key to effectively increase the productivity and business competitiveness. If companies make business decisions based on experience and intuition, it is only with data and analysis that the company can be brought to increasingly higher levels of competitiveness at this time, benefiting from a greater visibility, automated decision making and ever greater efficiency. The interconnection between devices and their use generate a lot of data which, if properly analyzed, provide invaluable information on business and customers.

6.2 Limitations and future development

In this paragraph, on the other hand, the limits of the work carried out are addressed. In the search for contacts for the questionnaire, roles such as IT, operations or logistics managers were preferred as they are more informed and more involved roles in these projects that precisely concern production, logistics and their internet connection. A limitation of the thesis lies in the fact that many times it was not possible to contact these roles for the questionnaire and this meant that the contact in question had less visibility on the projects, was not fully informed or did not have a more detailed knowledge of technical issues and therefore, instead of precise information, the interviewee sometimes replied "I don't know". However, this limit can be overcome by always trying to identify the best person so as to have a more precise study that reflects the activities and characteristics of the projects carried out.

Secondly, a more important limitation lies in the created data-value matrix. First of all, as mentioned, the answer given on the use of data was associated with each project launched in the company, not being able to investigate the real use of data in relation to each technology applied in the various fields and only trusting in the fact that by equipping itself with tools to collect as well as process data , the company has applied the same logic in order to improve and streamline all the processes on which it has focused.

In addition to this, the x-axis of the matrix was created in a qualitative way by understanding what could have a big impact on a purely corporate level and what could have an impact also for the customer.

In the future, it could be interesting understand not only how data is used but in what applications and in what way. In addition to this, also try to understand in what perspective companies are trying to use the data, whether for the purpose of improving processes or to create value for the customer with a transparent and fast response and a more complete offer.

Appendix- Survey on Internet of Things projects for the Smart Factory in Italy

"OSSERVATORIO INTERNET OF THINGS"

INDUSTRIA 4.0

SCHOOL OF MANAGEMENT DEL POLITECNICO DI MILANO

Indagine SUI PROGETTI internet of things per l'INDUSTRIA 4.0

Obiettivo dell'indagine: **approfondire lo stato di diffusione in Italia dei progetti Internet of Things (IoT) per l'Industria 4.0**.

L'espressione *Industria 4.0* esprime una visione secondo cui, grazie alle tecnologie digitali, le

imprese industriali e manifatturiere aumentano la propria competitività ed efficienza tramite l'interconnessione e la cooperazione delle proprie risorse (impianti, persone, informazioni), sia interne alla fabbrica sia distribuite lungo la supply chain.

Il paradigma IoT sta acquisendo sempre più chiaramente il ruolo di tecnologia abilitante dell'Industria 4.0, grazie ai suoi numerosi impieghi per ottimizzare l'uso delle risorse e potenziare i servizi offerti.

Guida alla compilazione del questionario: **La compilazione la impegnerà non più di 10 minuti. Non sono necessarie competenze tecnologiche specifiche.**

Se desidera interrompere momentaneamente la compilazione, al termine di ogni pagina potrà salvare le sue risposte cliccando su "Salva". Le sue risposte saranno conservate e le verrà inviata un'email con il link per ritornare al questionario e terminarlo.

Eventuali chiarimenti in merito alla compilazione del questionario possono essere richiesti a Roberta Vadruccio (roberta.vadruccio@polimi.it – 333 9020813). Qualora preferisse è possibile rispondere alle domande del questionario tramite intervista telefonica.

Per visualizzare l'informativa privacy è possibile cliccare qui.

Questionario

1) La preghiamo di inserire i suoi dati anagrafici:

Nome azienda	
Nome e Cognome	
Ruolo professionale	
e-mail	
Contatto telefonico	
Disponibilità a intervista telefonica di approfondimento	☐ SI ☐ NO

2) Ha mai sentito parlare di soluzioni Internet of Things (IoT) per l'Industria 4.0? In che modo ne è venuto a conoscenza?

Esempio: utilizzo di tecnologie (es. RFId) in grado di tracciare i prodotti o i semi-lavorati presenti in fabbrica per ottimizzare la gestione della produzione, fornire un maggior supporto agli operatori di linea e ridurre gli errori.

Esempio: utilizzo di macchinari connessi tramite tecnologia cablata o wireless, in grado di segnalare quando sta per verificarsi un guasto e minimizzare i fermi-macchina.

Esempio: utilizzo di sensoristica e tecnologia RFId per monitorare posizione e temperatura dei prodotti (catena del freddo) lungo la supply chain.

Esempio: presenza nella fabbrica di dispositivi connessi per la gestione dei sistemi di riscaldamento, climatizzazione e illuminazione (es. sensori che attivano lo spegnimento/accensione di luci nelle stanze a seconda dell'occupazione).

Selezionare una o più alternative

- ☐ Non conosco il tema
- ☐ Ho letto articoli e/o pubblicazioni a riguardo
- ☐ Ho partecipato a eventi (es. convegni, fiere) su questo tema
- ☐ Ho osservato progetti concreti presso altre aziende
- ☐ Ho osservato progetti concreti nell'azienda dove attualmente lavoro
- ☐ Ho gestito / partecipato attivamente a progetti concreti nell'azienda dove attualmente lavoro
- ☐ Altro (specificare nelle note)

Note:

3) Come valuta il suo livello di conoscenza delle soluzioni IoT per l'Industria 4.0?

Le chiediamo di indicare il suo livello di conoscenza nella tabella sottostante (0 = non conosco il tema; 10 = conosco perfettamente il tema)

Selezionare una sola risposta

	0	1	2	3	4	5	6	7	8	9	10
Livello di conoscenza	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Note:

4) La sua azienda ha avviato progetti IoT per l'Industria 4.0 in passato, a supporto delle attività di fabbrica o logistiche?

Selezionare una o più alternative

☐ SI, nel 2020

☐ SI, nel 2019

☐ SI, nel 2018

☐ SI, prima del 2018

☐ NO, non abbiamo mai avviato progetti di questo tipo

Note:

Se è stato indicato almeno un progetto nella domanda precedente, proseguire con la domanda 5 del questionario.

Se non è stato indicato alcun progetto nella domanda precedente, proseguire con la domanda 11 del questionario.

Sezione dedicata a chi ha avviato progetti IoT per l'INDUSTRIA 4.0

A CHI HA DICHIARATO DI AVER AVVIATO ALMENO UN PROGETTO NELLA DOMANDA 4

5) La preghiamo di indicare, per ciascun progetto IoT per l'Industria 4.0 avviato dalla sua azienda, lo stato di avanzamento (analisi preliminare, progetto pilota, progetto esecutivo).

Se possibile, le chiediamo di indicare nel campo Note le tecnologie di comunicazione utilizzate nei progetti Industria 4.0 che avete avviato (es. rete cellulare, WiFi, Bluetooth, Near Field Communication - NFC, Reti Low Power Wide Area, Wireless Sensor Network).

Selezionare una o più alternative

SMART FACTORY	STATO DI AVANZAMENTO			
	Nessuna iniziativa	Analisi preliminare	Progetto pilota	Progetto esecutivo
Manutenzione preventiva (monitoraggio di uno o più parametri – es. il numero di pezzi realizzati, le ore di funzionamento della macchina - per programmare quando effettuare gli interventi di manutenzione)	☐	☐	☐	☐
Manutenzione predittiva (monitoraggio di uno o più parametri – es. la rumorosità della macchina - per stimare il tempo residuo prima che si verifichi un guasto)	☐	☐	☐	☐
Controllo qualità (monitoraggio della qualità della lavorazione effettuata, supporto agli operatori per ridurre gli errori, etc.)	☐	☐	☐	☐
Material handling (monitoraggio dei prodotti durante gli spostamenti interni alla fabbrica, monitoraggio e gestione dei mezzi di movimentazione, etc.)	☐	☐	☐	☐
Ottimizzazione della produzione (migliore preparazione del macchinario o della linea, supporto agli operatori e ottimizzazione della postazione operativa, migliore schedulazione della produzione, etc.)	☐	☐	☐	☐
Sicurezza sul lavoro (monitoraggio della posizione e degli spostamenti degli operatori all'interno della fabbrica, identificazione di condizioni ambientali di pericolo, etc.)	☐	☐	☐	☐
Energy management (monitoraggio dei consumi energetici dei macchinari, della linea, dell'impianto, etc.)	☐	☐	☐	☐
Altro (specificare nelle note)	☐	☐	☐	☐

SMART LOGISTICS & SUPPLY CHAIN	STATO DI AVANZAMENTO

	Nessuna iniziativa	Analisi preliminare	Progetto pilota	Progetto esecutivo
Tracciabilità beni lungo la supply chain (es. sistemi RFId per la tracciabilità lungo la filiera)	☐	☐	☐	☐
Monitoraggio parametri lungo la supply chain (es. sensori che consentono ai vari attori della catena del freddo di monitorare la catena del freddo)	☐	☐	☐	☐
Gestione asset logistici (es. sistemi RFId per gestione di pallet e roll container)	☐	☐	☐	☐
Tracciabilità beni all'interno del magazzino (es. tag RFId per ottimizzare l'operazione di inventario)	☐	☐	☐	☐
Gestione flotte (es. box assicurativi, tracking e monitoraggio veicoli per il trasporto merci)	☐	☐	☐	☐
Altro (specificare)	☐	☐	☐	☐

SMART LIFECYCLE		STATO DI AVANZAMENTO		
	Nessuna iniziativa	Analisi preliminare	Progetto pilota	Progetto esecutivo
Ottimizzazione del processo di **sviluppo e prodotti** (es. raccolta dati provenienti da versioni precedenti dei prodotti connessi per definire sviluppi dei prodotti esistenti o nuovi prodotti)	☐	☐	☐	☐
Gestione del **"fine vita" dei prodotti** (es. monitoraggio dei parametri per comprendere quando effettuare il ritiro del prodotto, per attivare servizi di post-vendita)	☐	☐	☐	☐
Altro (specificare nelle note)	☐	☐	☐	☐

Note:

6) Le applicazioni IoT per l'Industria 4.0 che avete avviato, indicate nella domanda precedente, hanno previsto l'attivazione di servizi aggiuntivi?

Selezionare una o più alternative

☐ NO, non è stato attivato alcun servizio

☐ SI, servizi di tipo **informativo**, basati sull'invio di notifiche in tempo reale in caso di eventi predefiniti (es. fermo della linea, valori anomali di temperatura dei prodotti durante il trasporto, fughe di gas)

☐ SI, servizi che prevedono il pagamento degli oggetti connessi (es. macchinari, asset logistici) non al momento dell'acquisto ma durante il loro ciclo di vita, sulla base dell'effettivo utilizzo (**pay-per-use**)

☐ SI, servizi di **manutenzione preventiva** (definizione anticipata dei momenti in cui effettuare la manutenzione di asset e/o macchinari)

☐ SI, servizi di **manutenzione predittiva** (ottimizzazione della scelta del momento in cui effettuare la manutenzione sulla base del reale utilizzo del macchinario o del mezzo di trasporto)

☐ SI, **coperture assicurative** degli oggetti connessi basate sul loro effettivo utilizzo

☐ SI, servizi di **energy management** che prevedono la ricezione di report/alert con l'analisi dell'andamento dei consumi energetici e consigli personalizzati su come risparmiare

☐ Altro (specificare nelle note)

☐ Non so

Note:

7) Quali sono stati i principali obiettivi che hanno portato l'azienda ad avviare progetti IoT per l'Industria 4.0?

Selezionare una o più alternative (al massimo 3 risposte)

OBIETTIVI	MAX 3 RISPOSTE
Miglioramento dell'**immagine** dell'azienda	☐
Raggiungimento dei **benefici di efficienza** (es. riduzione dei costi e/o tempi)	☐
Raggiungimento dei **benefici di efficacia** (es. miglioramento qualità dei processi produttivi)	☐
Accesso agli incentivi del **Piano Nazionale Industria 4.0**	☐
Adeguamento rispetto a vincoli di **legge** e/o obblighi normativi	☐
Necessità di allineamento rispetto all'**offerta della concorrenza**	☐
Creazione di un **database** ricco di dati resi disponibili dagli oggetti connessi (es. reale utilizzo dei macchinari, aree con maggiori inefficienze, etc.)	☐
Volontà di **sperimentare soluzioni innovative**	☐
Miglioramento della **sostenibilità ambientale** (es. riduzione CO_2, efficienza energetica)	☐
Adeguamento all'**emergenza Covid-19**	
Altro (specificare)	☐

Note:

8) Con riferimento ai progetti avviati, sono stati valutati i benefici abilitati dall'Internet of Things?

Selezionare una sola risposta

- ☐ No
- ☐ Sì, ma solo in modo qualitativo
- ☐ Sì, abbiamo quantificato i benefici prima dell'avvio del progetto (ex ante), ma non in termini monetari (es. impatto atteso su alcuni KPI quali produttività, tempo di ciclo, ...)
- ☐ Sì, abbiamo quantificato in termini monetari i benefici (ex ante), confrontandoli con i costi attesi
- ☐ Sì, ma abbiamo quantificato i benefici solo dopo aver realizzato il progetto (ex post)
- ☐ Non so

Note:

9) Avete utilizzato (ed eventualmente rielaborato) i dati che avete raccolto tramite i progetti IoT per l'Industria 4.0?

Selezionare una sola risposta

☐ I dati raccolti non sono stati utilizzati dall'azienda

☐ I dati raccolti sono stati poco utilizzati dall'azienda

☐ I dati raccolti sono stati ampiamente utilizzati in forma grezza (senza rielaborazioni) dall'azienda

☐ I dati raccolti, sia grezzi sia rielaborati, sono stati utilizzati con profitto dall'azienda

☐ Non so

Note:

10) I progetti avviati sono basati su tecnologie IoT cablate (wired) e/o senza fili (wireless)?

Selezionare una sola risposta

☐ Cablate (wired)

☐ Senza fili (wireless)

- ☐ Entrambe
- ☐ Non so

Note:

Proseguire con la domanda 11 del questionario

Sezione DEDICATA A TUTTI

11) Alla luce dell'emergenza sanitaria Covid-19, l'avvio di progetti basati su tecnologie IoT rappresenta una priorità per la sua azienda?

- ☐ Si, la situazione ha reso ancor più prioritario il tema
- ☐ No, l'emergenza sanitaria ha reso meno prioritario il tema rispetto ad altri
- ☐ Non è cambiato niente, il tema era prioritario già prima dell'emergenza sanitaria
- ☐ Non è cambiato niente, il tema non era prioritario già prima dell'emergenza sanitaria
- ☐ Non lo so

Note:

12) Alla luce dell'emergenza sanitaria Covid-19, prevede un incremento degli investimenti in progetti basati su tecnologie IoT per l'Industria 4.0 nei prossimi 12 mesi?

- ☐ Sì, aumenteranno soprattutto a seguito dell'emergenza sanitaria
- ☐ Sì, aumenteranno ma era già previsto prima dell'emergenza sanitaria
- ☐ No, rimarranno invariati
- ☐ No, diminuiranno soprattutto a seguito dell'emergenza sanitaria
- ☐ No, diminuiranno ma era già previsto prima dell'emergenza sanitaria
- ☐ Non so, dobbiamo valutare

Note:

13) Quali sono le barriere (interne ed esterne) che secondo lei possono rallentare o impedire l'avvio di progetti IoT per l'Industria 4.0?

Selezionare una o più alternative (al massimo 3 risposte)

BARRIERE	**MAX 3 RISPOSTE**
Non vi sono barriere	☐
Scarsa **conoscenza** delle tematiche relative all'Industrial IoT e/o mancanza di **competenze** interne in grado di gestire tali progetti	☐

Scarsa disponibilità di **risorse economiche**	☐
Difficoltà nell'**accesso agli incentivi** del Piano Nazionale industria 4.0	☐
Resistenze interne (es. conflitti tra IT e OT - Operation Technology, resistenze da parte dei sindacati)	☐
Mancanza di **comprensione** del reale **valore** delle soluzioni che si intendono implementare	☐
Mancanza di **prodotti/fornitori** adeguati per realizzare il progetto	☐
Tecnologie IoT **non ancora mature**	☐
Difficoltà di **integrazione** di nuovo e vecchio hardware e software	☐
Problematiche legate alle **privacy** (es. dipendenti restii al monitoraggio delle proprie attività)	☐
Problematiche legate alla **cyber security** (es. eccessiva vulnerabilità dei dati scambiati)	☐
L'emergenza sanitaria **Covid-19** ha rallentato/ostacolato l'avvio di questi progetti	
Altro (specificare)	☐

Note:

14) Se l'azienda ritiene di avere un gap di competenze relative all'avvio e gestione dei progetti IoT, come pensa di colmarlo?

Selezionare una o più alternative

☐ NO, non abbiamo un gap di competenze

☐ SI, esiste un gap di competenze ma per il momento non abbiamo intrapreso specifiche azioni per cercare di ridurlo

☐ SI, esiste un gap di competenze e infatti stiamo formando il nostro personale

☐ SI, esiste un gap di competenze e infatti stiamo assumendo nuove figure professionali dedicate

☐ SI, esiste un gap di competenze e infatti stiamo lavorando con dei consulenti esterni con competenze specifiche su questi temi

☐ SI, esiste un gap di competenze ma non riusciamo a reperire nuove figure professionali sul mercato e/o consulenti esterni

Note:

15) Con riferimento al piano di investimenti per il 2020, è stato allocato un budget per la realizzazione di progetti IoT per l'Industria 4.0? Se sì, indicare entità del budget e/o percentuale sul fatturato.

Selezionare una sola risposta

☐ Non lo so

☐ NO, non abbiamo allocato budget

☐ SI, abbiamo allocato budget (specificare nelle note l'ammontare in € e/o la % sul fatturato se possibile)

Note:

16) L'azienda di cui fa parte ha in programma di avviare progetti IoT per l'Industria 4.0 in futuro?

Nel caso si intendano avviare progetti, specificare gli ambiti applicativi di interesse.

Selezionare una o più alternative

Non abbiamo in programma l'avvio di progetti in futuro ☐

SMART FACTORY	
Manutenzione preventiva (monitoraggio di uno o più parametri – es. il numero di pezzi realizzati, le ore di funzionamento della macchina - per programmare quando effettuare gli interventi di manutenzione)	☐
Manutenzione predittiva (monitoraggio di uno o più parametri – es. la rumorosità della macchina - per stimare il tempo residuo prima che si verifichi un guasto)	☐
Controllo qualità (monitoraggio della qualità della lavorazione effettuata, supporto agli operatori per ridurre gli errori, etc.)	☐
Material handling (monitoraggio dei prodotti durante gli spostamenti interni alla fabbrica, monitoraggio e gestione dei mezzi di movimentazione, etc.)	☐
Ottimizzazione della produzione (migliore preparazione del macchinario o della linea, supporto agli operatori e ottimizzazione della postazione operativa, migliore schedulazione della produzione, etc.)	☐

Sicurezza sul lavoro (monitoraggio della posizione e degli spostamenti degli operatori all'interno della fabbrica, identificazione di condizioni ambientali di pericolo, etc.)	☐
Energy management (monitoraggio dei consumi energetici dei macchinari, della linea, dell'impianto, etc.)	☐
Altro (specificare nelle note)	☐

SMART LOGISTICS & SUPPLY CHAIN	
Tracciabilità beni lungo la supply chain (es. sistemi RFId per la tracciabilità lungo la filiera)	☐
Monitoraggio parametri lungo la supply chain (es. sensori che consentono ai vari attori della catena del freddo di monitorare la catena del freddo)	☐
Gestione asset logistici (es. sistemi RFId per gestione di pallet e roll container)	☐
Tracciabilità beni all'interno del magazzino (es. tag RFId per ottimizzare l'operazione di inventario)	☐
Gestione flotte (es. box assicurativi, tracking e monitoraggio veicoli per il trasporto merci)	☐
Altro (specificare)	☐

SMART LIFECYCLE	
Ottimizzazione del processo di **sviluppo e prodotti** (es. raccolta dati provenienti da versioni precedenti dei prodotti connessi per definire sviluppi dei prodotti esistenti o nuovi prodotti)	☐
Gestione del **"fine vita" dei prodotti** (es. monitoraggio dei parametri per comprendere quando effettuare il ritiro del prodotto, per attivare servizi di post-vendita)	☐
Altro (specificare nelle note)	☐

Note:

17) L'azienda di cui fa parte è interessata in futuro ad avviare progetti basati su tecnologie IoT cablate (wired) o senza fili (wireless)?

Selezionare una sola risposta

☐ NO, non abbiamo in programma l'avvio di progetti in futuro

☐ SI, cablate (wired)

☐ SI, senza fili (wireless)

☐ SI, entrambe

☐ Non so

Note:

18) L'azienda di cui fa parte è interessata ad attivare servizi aggiuntivi abilitati dalle tecnologie Internet of Things? Se sì, quali?

Selezionare una o più alternative (al massimo 3 risposte)

☐ NO, non è interessata

☐ SI, servizi di tipo **informativo**, basati sull'invio di notifiche in tempo reale in caso di eventi predefiniti (es. fermo della linea, valori anomali di temperatura dei prodotti durante il trasporto, fughe di gas)

☐ SI, servizi che prevedono il pagamento degli oggetti connessi (es. macchinari, asset logistici) non al momento dell'acquisto ma durante il loro ciclo di vita, sulla base dell'effettivo utilizzo (**pay-per-use**)

☐ SI, servizi di **manutenzione preventiva** (definizione anticipata dei momenti in cui effettuare la manutenzione di asset e/o macchinari)

☐ SI, servizi di **manutenzione predittiva** (ottimizzazione della scelta del momento in cui effettuare la manutenzione sulla base del reale utilizzo del macchinario o del mezzo di trasporto)

☐ SI, **coperture assicurative** degli oggetti connessi basate sul loro effettivo utilizzo

☐ SI, servizi di **energy management** che prevedono la ricezione di report/alert con l'analisi dell'andamento dei consumi energetici e consigli personalizzati su come risparmiare

☐ Altro (specificare nelle note)

☐ Non so

Note:

19) Nella sua azienda quali potrebbero essere in futuro i principali obiettivi alla base dell'avvio di eventuali progetti IoT per l'Industria 4.0?

Selezionare una o più alternative (al massimo 3 risposte)

OBIETTIVI	MAX 3 RISPOSTE
Non abbiamo in programma l'avvio di tali progetti in futuro	☐
Miglioramento dell'**immagine** dell'azienda	☐
Raggiungimento dei **benefici di efficienza** (es. riduzione dei costi e/o tempi)	☐
Raggiungimento dei **benefici di efficacia** (es. miglioramento qualità dei processi produttivi)	☐
Accesso agli incentivi del **Piano Nazionale Industria 4.0**	☐
Adeguamento rispetto a vincoli di **legge** e/o obblighi normativi	☐
Necessità di allineamento rispetto all'**offerta della concorrenza**	☐
Creazione di un **database** ricco di dati resi disponibili dagli oggetti connessi (es. reale utilizzo dei macchinari, aree con maggiori inefficienze, etc.)	☐
Volontà di **sperimentare soluzioni innovative**	☐
Miglioramento della **sostenibilità ambientale** (es. riduzione CO_2, efficienza energetica)	☐
Adeguamento all'**emergenza Covid-19**	
Altro (specificare)	☐
Non so	☐

Note:

20) Con riferimento al prodotto offerto dalla vostra azienda sul mercato, quale tra queste è l'affermazione più corretta?

- ☐ Il prodotto non è connesso
- ☐ Il prodotto è connesso e trasmette informazioni su sé stesso e/o l'ambiente che lo circonda ed è controllabile da remoto
- ☐ Il prodotto è connesso e comunica con altri dispositivi connessi della stessa azienda e/o di altre aziende
- ☐ L'azienda non vende prodotti, ma servizi

Note:

Il questionario è concluso, la ringraziamo per la collaborazione. Qualora volesse, può aggiungere ulteriori commenti sul tema.

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