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"INDUSTRY 4.0: FROM THEORY TO PRACTICE. AN EMPIRICAL ANALYSIS OF THE FACTORY OF THE FUTURE."

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INTRODUCTION

In an industrial world where change has always been present and where progress has since forever represented the humankind's ultimate goal that will never be entirely achieved, it is fundamental to keep up with times and stay aware of new, ground-breaking ways of performing manufacturing activities and conduct a successful business. After three page-turning industrial revolutions, the world has now found itself – according to many – at the edge of a fourth one also known as "Industry 4.0", that will potentially break the current status quo equilibrium once again.

This paper was written with the purpose of discussing the meaning of this innovative paradigm, as well as the opportunities and challenges that it entails.

The first chapter will therefore be introducing the subject by re-visiting the main historical steps leading up to it, and describing the technologies enabling the transformative process toward a new factory model that is believed will represent the future frame of reference for the industrial world. The notion of "Fourth Industrial Revolution" is not as recent as it may seem, in fact it has been around long enough to have pushed several countries' governments to take action and provide initiatives to grasp the benefits offered by innovation before being left behind. Chapter number two presents the three most discussed implementation programs activated in the last few years by Germany, USA and China, as well as the 2016 "Piano Nazionale Industria 4.0" through which the Italian policymakers plan to keep our country in a favorable position to compete in the global market. For each of these advanced countries, the key strategic guidelines, initiatives and objectives are drawn in order to compare how each of them is measuring up to the forthcoming challenges brought about by the development of new forward-looking technologies and organizational models. The third chapter will focus on another critical aspect regarding the direct consequences of the introduction of automated production systems on the employment of workers. Although nobody can tell what effects will actually materialize in the long term, many speculations have been made and are here reported as a review of the many opinions and attitudes that are dominating the academic world. If jobs will indeed be in jeopardy, then what kind of skills and know-how will the new workers need to have to be hired in the factory of the future? How and in what measure will they interact with each other and with the working environment? Answers to these questions are suggested in chapter number three.

The fourth and last chapter of this dissertation, looks at the empirical evidence collected by the members of the Project SID with the intention of understanding the dynamics of Industry 4.0 in

Italy and the level of pervasiveness it has reached in our country. The motivations of non-adopters are investigated and the objectives, difficulties encountered and gains of adopters are analyzed. Industry 4.0 is though still progressing day by day, and we'll need to wait and see whether or not the different perspectives presented in this paper will actually realize or if a different scenario will unfold instead.

1. AN INTRODUCTION TO INDUSTRY 4.0

"First came steam and water power; then electricity and assembly lines; then computerization… So, what comes next?"(Marr)[1]

1.1 THE INDUSTRIAL REVOLUTION TIMELINE

As Laurent Hausermann nicely put it, ever since Prometheus cunningly stole the fire of knowledge from the unsuspecting gods on Mount Olympus and conferred it to mankind, humans never stopped fidgeting with it in the attempt to create first and innovate subsequently all throughout their evolution. Over the course of centuries, the human being has always strived to find new and better ways to fulfill his needs and adapted to changes in the environment trying to benefit from upcoming opportunities, rather than falling victim of the challenges and obstacles presented before his eyes.
History has taught us how industry can be perfected through technical evolution as well as through its complete reinvention as new resources and means are created and employed in production; some of these evolutions have had an impact so strong and radical as to be labeled with the more fitting term of "revolutions".
If time travel was possible and we went back a little over two hundred years, we wouldn't be able to recognize life as we know it in the period preceding the industrial revolutions for a very simple reason: the last two centuries were the framework for the most titanic leaps forward ever recorded in human history; most of the things we see, consume and produce today were made available, easier to use or even possible on the grounds of inventions that occurred in that timespan. As a matter of fact – as portrayed in the following graph by Ian Morris (2010) – for many thousands of years, progress was so slow that it was barely even noticeable and almost non-existent, nothing succeeded in exerting much influence and humanity persisted in a state of very slow upward trajectory [Brynjolfsson, McAfee, 2014].

1 MARR, B., Why Everyone Must Get Ready For The 4th Industrial Revolution. Available: https://www.forbes.com [Sep 6, 2017].

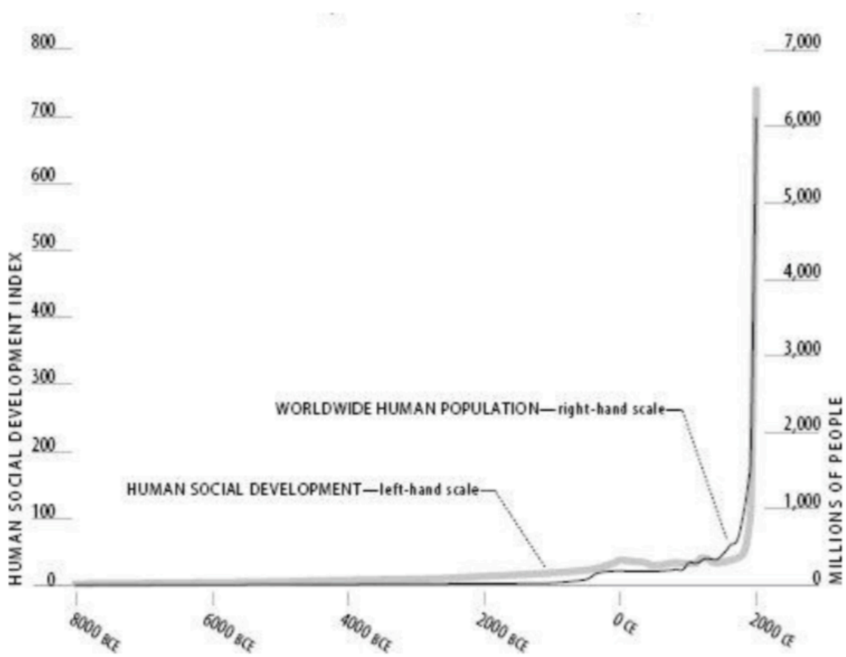


Figure 1.1: History of human social development. (Source: *Morris, 2010*)

Looking at *Figure 1*, what strikes the most is without any hesitation the recent and dizzying ninety-degree bend in the curve suddenly appeared around two hundred years ago. The cause of that jump in the late eighteenth century is, of course, to be attributed to the Industrial Revolution. Ever since then and for the past two hundred and fifty years, our civilization has undergone a series of remarkable transformations that led people to live longer and healthier lives and businesses to be more productive and deliver their promise with unprecedented efficiency. Advancements in technology and its employment across all industries have led to changes in the structures of our society, in the way we interact with each other and ultimately shaped the world we experience today.

We may trace back the beginning of this ongoing, fast-paced process of technological development to the late '700s when the First Industrial Revolution used water and steam power to mechanize production, but mass production was made possible only with the employment of electric power during the Second Industrial Revolution finally, the advent of electronics and Information technology allowed only in the past century the automation of assembly lines. Today, we find ourselves on the verge of a new era of innovation with the rise of the Industrial Internet. Some call it the Fourth Industrial Revolution (or Industry 4.0), even though others argue it represents merely the prolongation of the previous one; but whatever you name it, it represents the combination of cyber-physical systems and it is taking place by virtue of a more pervasive connectivity, low cost

sensorial devices and the power of advanced computing and analytics. The impact these innovations may have on our lives may be gigantic and most importantly – given the nature of this dissertation – disrupt our working routines.
Building on the digital revolution that has been occurring since the middle of the last century, Industry 4.0 is characterized by a fusion of technologies that are blurring the lines between the physical, digital and biological domains, bringing on a transformation that will be unlike anything humankind as ever witnessed in terms of scale, scope and complexity and bound to overturn industries all over the world [Schwab, 2016].
Directly unfolding from these considerations, the escalating interest literature has conveyed toward this topic in the last few years, represents a clear sign of how the foreseen changes are going to affect a vast spectrum of stakeholders, from the private and public sectors to academia and society as a whole, hence the urge to analyze all facets concerning the matter.
If it is indeed true that history repeats itself, and that it is good to take a look back to learn from mistakes to prevent them from happening again, then we should start from there, take a leap into the past and revisit the first three industrial revolutions in order to define the outlines of the Fourth which is unraveling right before our very eyes.

1.1.1 The First and Second Industrial Revolutions

The First and Second revolutions are often considered together in literature under the generic label of Industrial revolution, to discern it from the following Digital revolution of the late 20th century. It is described as a long period of innovation that spanned for about 150 years roughly between 1750 and the first decades of the 900s, delivering an overwhelming impression on economy, society and culture to name a few.
The first stage started in the mid 18th century after a period of slow proto-industrialization and paved the way for the remaining three revolutions; also known as the "mechanical revolution", it replaced agriculture with industry as the foundation of the economic structure of society.
The steam engine represents perhaps the most critical invention of those years, creating a new kind of energy responsible for radically changing the textile industry when used for separating cotton fibers from the seeds. This era created significant economies of scale and corresponding reductions in costs as machines grew in complexity and production volumes increased. The new power source alimented by coal allowed faster production and greater efficiency.
On the flip side of the coin though, while skilled craftsmen became perfectly superfluous and

replaceable in the new textile factory system, workers exploitation became a central issue. The factory upgrade led to a different set of skill and knowledge requirements needed by the emerging working class to adapt to the new circumstances: the specialization of skills emerged. Moreover, the industrial cities that originated from the proliferation of factories, became the emblematic representation of the public health disaster resulted from the piling up of workers and their families in slums with poor sewage systems, where epidemics spread like fire in a dry land and air was dramatically polluted by the intense use of chemicals and coal.

On the bright side, steam power fostered progress in the field of transportation significantly cutting food costs and thereby facilitating the reduction of malnutrition levels. Finally, it is during this time that, given the severe consequences of technological advances, the first trade unions and laws regulating environmental sustainability were created.

It was later, around 1870 that the second stage of the Industrial Revolution came about. This phase is also called "electrical revolution" after the main discovery that brought onto the world yet another source of power: electricity, which was soon employed in the newly conceived internal combustion engine and the nowadays ordinary lightbulbs. These were the years of the communication and transportation revolutions with the invention of the telegraph, the telephone, the automobile and the plane, all of which were made possible by the new paradigm of the "large factory", the assembly lines envisioned by Henry Ford and the scientific management of the manufacturing process proposed by Frederick W. Taylor in 1911. Mass production resulted to be the outcome of Taylor's division of labor as well as the mechanization of factories, which was also possible as a result of the construction of power stations. Another factor that drove improvements in the transportation sector was the replacement of iron with steel, which allowed the construction of rail lines, ships, skyscrapers and bridges at competitive costs. This second stage partly reduced the damage created by the first one by way of demise of child labor and resulted in a larger well-educated middle class but, on the other hand, it maintained the same pattern in terms of displacement of workers in favor of more efficient machines. Additionally, the dawn of mass production is considered to have encouraged the materialistic culture that is today our biggest setback [Vale, 2016].

All things considered, the First and Second Industrial Revolutions, not only provided us with the basic goods we consume today on a daily basis, but also laid down the groundwork for what would come next.

1.1.2 The Third Industrial Revolution: The Internet Revolution

Nearly a century later, a third wave of innovation altered the world yet again leaving an indelible mark: The Digital Revolution. Consistently with the previous revolutions, it all started with the discovery of nuclear energy, a new power source with exceptional potential. Starting from the late ‘60s, the creation of transistors and microprocessors gave way to the rise of electronics and consequently, of telecommunications and the early computers or, should we say, “mainframes”. Unfolded in just one third of the time needed to the previous two, this revolution marked the shift from mechanical and analogue electronic technology to the digital electronics we use today [Vale, 2016]. At first, room-sized mainframes, software and communicating computers, were solely the result of government-funded experiments; the Internet itself came from the military ARPANET, it was only when the two scientists Robert Cailliau and Tim Berners-Lee decided to further develop the invention, that the World Wide Web was conceived. Little did they know that not only billions of connected devices today would have created powerful new platforms for commerce and social interaction, but also that their invention would have changed the way we looked at and approached production. However, when computers and the Internet first made their appearance many were skeptical of their potential. Among them Robert Solow, who spoke in 1987 in these terms: “You can see the computer age everywhere but in the productivity statistics”, and he was right to say so. But in the mid ‘90s something unforeseeable happened, and the impressive pace of innovation drove down the prices of information and telecommunication equipment in such a way that the US labor productivity registered a sharp acceleration.

As a matter of fact, the internet, computing and the ability to transmit and receive large amounts of data, have contributed to a deeper integration of processes and more flexible operations. Decentralized decision making and more collaborative work environments also resulted as a consequence of the possibility to exchange information rapidly and cost-efficiently. Manufacturing would never be the same again, as computers became an integral part in the control of the entire process both in planning and production, defining what would later be called “Computer Integrated Manufacturing”. Early attempts at artificial intelligence led to the displacement of thousands of factory workers and caused the segregation of the job market into high-skill/high-pay and low-skill/low-pay jobs, with a void in the middle [Vale, 2016].

The automation of the assembly lines by virtue of the adoption of computer technology, transistors, industrial robots and the like, determined also a radical change in the qualifications required to work in the new factory considering that now the worker’s interactions would not be restricted to the human world, but expanded to the cyber world too. As we glimpse back at the preceding waves of innovation, we can recognize a pattern of disruptive nature in the job market every time the world gets hit by a new discovery that challenges our believes and resets the rules by which we live and operate. Whether this pattern will repeat itself in the next wave as well or not, is a question with many implications and therefore worth asking, we will hence dive into it more deeply in the next chapter hoping to at least be aware of what's to come and to make sure we won't be ill-equipped when it does.

These considerations clearly characterize this era as a knowledge and information-intensive revolution, as opposed to the previous ones which were rather resource-intensive. Moreover, here scalability does not derive from the supplement of more bodies, but results from the inclusion of more computers in the system to achieve economies of scale.

Nonetheless, we can assert with confidence that both revolutionary waves have, in the course of the past two centuries, led mankind through a path of vertiginous socio-industrial development that profoundly and irreversibly reformed the way we live, connect and perform our jobs with the perks and drawbacks that came along with it.

Here is a graphic representation of the eras we've illustrated in the first few paragraphs.

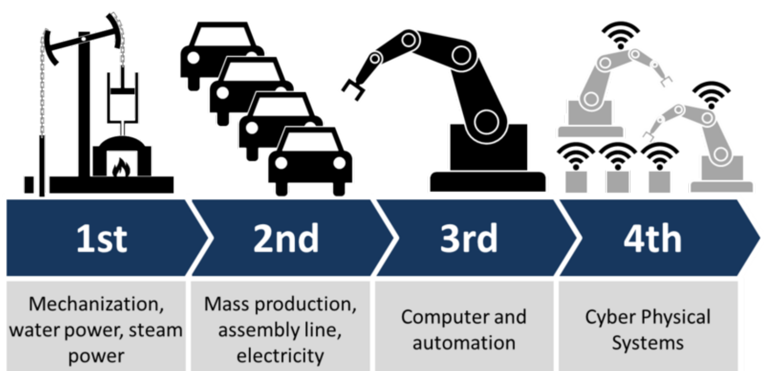


Figure 1.2: the industrial revolution timeline. (Source: *Marr, 2017*)

1.2 The Fourth Industrial Revolution: The Industrial Internet

Of course, the brief time travel itinerary explained here is a little simplified for didactic purposes; as a matter of fact, the transition from one period to the next was never this smooth and immediate, on the contrary it was more intricate and multiple paradigms would often coexist simultaneously [Brynjolfsson, McAfee, 2014]. But for some reason, the shift from craftsmanship to the big factories and again from there to the automation of assembly lines, guided us to where we are today, that is on the verge of a new reality or – as Brynjolfsson and McAfee would call it – on an inflection point bound to the right direction, one that is dictated by digitization toward a Second Machine Age. Extensively called "Industry 4.0", this industrial revolution is embodied in the existence of smart factories where web connectivity enables machines to be virtually augmented and connected to a system that can envision the entire production chain and make decisions on its own [Marr, 2016].

1.2.1 Third Or Fourth?

While some may be convinced that this is not a Fourth revolution but rather a prolongation of the previous one, the majority of literature representatives seem to believe instead that there exist many reasons why it should be considered like a new area which, indeed is originating from the Third, but has to be deemed to be something separate.

> *"We had the PC and we had a life – today our devices and sensors will become an extension of us. Facebook is an extension of us. Our phones are extensions of us. Our smart watches are extensions of who we are and what we do. This fourth revolution has the same triggers as the third revolution, but it's cyber meets human this time. It's the same in businesses. Everything gets integrated, customized and smart-automated." [Van Duüren, 2017]*[2]

According to Van Duüren, the Fourth revolution is clearly distinguishable from the Third because people and technology are not distinct anymore, they're coming together and humans are merging in harmony with the cyber world. Moreover, this is not only the first industrial revolution not rooted on the emergence of a new type of energy but rather on the new technological phenomenon of digitization but also, surprisingly, the first "invisible" one. And Mr. Duüren's remark might actually be reasonably accurate. If we think back about the inventions of the previous innovation waves, we can plainly acknowledge how "visible" they were, but so much of what's in store for us in the future, is going to be determined by what's happening inside and around the device rather than the object itself. Cloud computing, artificial intelligence, storage, algorithms, invisible processing power and much more, will be the empowering forces that will shape the industries of tomorrow.

Along the lines of Van Duüren's perspective, Virginia Heffernan – author of the book *"Magic and*

2 VAN DUÜREN, O., The Industrial Revolution 4.0. Available https://www.thedualarity.com/ [Sep 6, 2017].

Loss: The Internet as Art" – believes there are three aspects which undeniably set apart this Revolution from the prior era:

a. *Speed:* the pace by which the current breakthroughs are happening have no historical precedent;
b. *Pervasiveness:* not only technology is advancing fast, but it is also being adopted quickly by cause of its accessibility and affordability;
c. *Entirety:* as it is creating the Global shared economy.

The WEF (World Economic Forum), seems to agree with this standpoint and highlights how, when compared to the previous experiences, the Fourth Industrial Revolution is evolving at an exponential rather than linear pace, its scope is much wider and its impact far-reaching. Its force is disrupting almost every industry globally, and the depth and breadth of the changes it is carrying along with it are announcing the transformation of entire systems of production, management and governance.

1.2.2 So, What Is Industry 4.0?

The Fourth Industrial Revolution, or Industry 4.0, is the converging of the physical, digital and biological world made possible by the diffusion of technologies like cloud computing, additive manufacturing, robotics, powerful algorithms and the like. These new technologies will impact all industries, economies and disciplines and even challenge our ideas of what it means to be human [Marr, 2017]. Therefore, even though it is building upon the grounds laid down by the digital era, the further step the world is taking today aims at connecting all production means to enable their real-time interaction.
Furthermore, this may be the first industrial revolution that we have been able to announce and plan consequently, by working on the implementation of cyber-physical systems and on the integration of the IoT (Internet of Things) and Cloud computing in production facilities [Vale, 2016]. But – Bernard Marr continues – these technologies do not only have a tremendous effect on businesses efficiency, they will also help restore the natural environment through improved asset management, potentially even undoing all the damage previous industrial revolutions have produced.

1.2.3 Efficiency And Enablers Of The New Paradigm

Now that a clearer picture is drawn of what "Industry 4.0" is, it is important to try to understand what it means to apply this paradigm to the factory in order to make it "smart", what makes it possible and how this will benefit businesses in the short and long run.

To be truthful, the trend discussed in this paper is not as recent as it may seem, companies have been applying internet-based technology to industrial applications as they have become available for the last decade or so; hence we shouldn't be surprised of learning that they've been a reality for quite a while now. But we need to take account of the fact that the full potential of these technologies is yet to be realized and we currently stand at a point far below the possibility frontier [Evans, and Annunziata, 2012]. So, computers and communication have opened the gates to accelerate processes, reduce production waste and inefficiencies and enrich the human work experience, but how are entrepreneurs supposed to cross that line and attain these goals? A reform in the fundamental structure, organization, responsibility and task assignment, management and culture of the firm is needed if we want to reap the benefits offered by technology. Today's target must be to turn the factory into the place where the physical world of machines, facilities, fleets and networks merge with the digital world of connectivity and big data and the way to do that – as suggested by Evans and Annunziata – is through intelligent devices, systems and decision making. Consequently, the first step that must be taken toward the smart factory, is to provide the means for the Industrial Internet to manifest, i.e. smart devices. Ten years ago, this option would have been available only to a restricted slice of the market, but today this is not the case anymore and several forces are at play to make machines smarter and more easily accessible. Sustained efforts in IT and for the improvement of microprocessors, are yielding impressive returns in terms of computing power, making it possible for physical machines to be digitally augmented, have a "mind" of their own and communicate with the whole network. Moreover, new analytic techniques and advanced software applications for data processing, are facilitating the task of making sense out of the enormous amount of data that is collected and conveniently transferred by the machines to other devices or people in the network appointed for the evaluation, re-elaboration and understanding of the same. The possibility to harvest, store, visualize and analyze these databases taking advantage of the available analytics tools, allows the firm to engage in more informed decision-making sometimes even in a real-time fashion. Improved decision-making is also the result of collaboration efforts and the cross-functional sharing of information across machines, networks and people. Over time, these analytic tools are able to compare historical and current data flows and make predictions and estimates of performance, timing and operations that help avoid shortcomings, system glitches and minimize maintenance costs. In such a way, we're crossing a great divide and going far beyond traditional approaches with a new hybrid approach that can leverage on both historical and real-time data with industry-specific advanced analytics [Evans, Annunziata, 2012]. The good news is, that nowadays it is possible to equip and monitor industrial machines at a competitive price relative to the past; technological advances have made it easier by dramatically driving down costs for instrumentation. Therefore, what makes the widespread deployment of this intelligent instrumentation so potentially transforming, is the evidence that it is possible to reap the benefits of already existing information technology by virtue of its appliance to shop floor machinery. Endowing the factory with smart machinery though is not enough if they can't communicate well with each other. The gain that can be obtained from the interconnection of smart devices, is much more superior to the plain sum of benefits contributed by each piece of machinery on its own. Henceforth the necessity to create a networked system as an increasing number of devices joins the Industrial Internet, so that one may enjoy the synergistic effects realized. By aggregating each machine's operational experience into a unified information system, the learning process across the machine portfolio is accelerated in a way that wouldn't be possible to imagine in a single machine reality. Once the connection is set in place and the communicating system is created, the result is an endlessly self-learning environment that grows smarter day by day.

If our final destination is the possibility frontier however, a third ingredient is to be added to the recipe: intelligent decisioning. This step is necessary to tackle the intimidating complexity of interconnected facilities, fleets and networks. In settings where workers need to make an incredible amount of decisions hastily to maintain the system operating at an optimal level, intelligent decisioning comes into play by partially shifting the burden of complexity to the digital system and enabling it to perform selected operations with human consent. Applying intelligent decisioning means unlocking potential productivity gains and cost savings while allowing operators to do their jobs more efficiently.

In conclusion, always according to Evans and Annunziata, when these three elements – intelligent devices, systems and decisioning – will come together with the physical factory, only then will the full potential of the Fourth Industrial Revolution be witnessed. Of course, in the described environment workers will be required to be more flexible, the job of product developers and production workers will come closer and at some point, may even potentially merge causing the so called "vertical integration". Conversely, when literature mentions "horizontal integration" it is referring to the transversal kind of integration that occurs thanks to the data and information transfer across departments and companies of the same network.

Figure 1.3: Vertical and horizontal integration under industry 4.0 (Source: *Vdi-Wissensforum*).

Nonetheless, even following all the steps illustrated above, we couldn't rely on that alone and indefinitely for the Industrial Internet to bear its results. This is why literature experts recommend four key enablers to attain the full potential deriving from the merging of the physical and cyber worlds:

a) *Innovation:* although this Revolution itself is the result of innovation, in order for it to develop further and improve day after day, the innovation process should never stop and a learning-by-doing cycle, supported by continuous feedback flows, should be set in motion. Innovation should occur following three different trajectories:
   - Update of existing equipment and deployment of sensors and monitors into the design of new industrial equipment for a higher quality collection and transfer of information;
   - Work on a deeper records integration for a faster transformation of data into information assets for timely analysis and understanding;
   - Predisposition and application of new business practices to facilitate machine-collected data incorporation into decision-making processes and to increase flexibility in between cooperating firms.

   However, innovation does not come without investment on the part of all involved stakeholders, which are not necessarily circumscribed to businesses only, but also comprise governments and educational institutions among others.
b) *Infrastructure:* an ICT infrastructure and its further development will be crucial to properly connect machines, systems and networks within the factory and across industries and geographical constraints.
c) *Cyber-security:* the unprecedented volume of information flows and data being sent

through the cyber space, gives rise to the very delicate issue of sensitive and valuable information protection. This being the case, erecting and maintaining a protected IT infrastructure has become an essential requirement to build network trust both in B2B and B2C contexts. In order to do so, businesses have been setting into place sophisticated security regimes based on multi-layer defense mechanisms and adopting encryption measures to prevent codification of data transmitted to the cloud.

d) *Skills development:* neither of the elements listed here would be of any use if no one knew how to handle it, this is why development of talent is also key. The traditional engineering skills, although still central, won't be sufficient anymore. New, cross-discipline roles will come up blending those traditional skills with information and computing competences, proficiency in data analysis, pattern recognition and user interface expertise.

1.2.4 A GLIMPSE INTO THE BENEFITS

The unfolding of the new factory paradigm, has opened fresh perspectives and made it possible to obtain efficiencies we didn't have access to before unlocking the potential of recent technological innovations and discoveries. Industry 4.0 has started a new chapter for businesses that will help them achieve higher performance levels in a proficient way.

The networks generated across machineries, individuals, supply chains and groups of collaborating firms, have made it possible to significantly reduce time to market by shortening the innovation cycle and through the employment of an impressive amount of data gathered and processed unceasingly. In-house connectivity has likewise permitted the traceability throughout the production line of components to be assembled and semi-finished products to be transformed; while the integration of advanced technology in the manufacturing system allows for the design and assembly of more complex products. In a world where selling quality merchandise at an acceptable cost is not enough anymore, the exceptional flexibility provided by the Fourth Revolution has paved the way for high productivity and the often-mentioned: individualized mass production. The expression "mass production" has been around for a long time, it would seem a paradox to talk about it in referral to the individual, but not today; the real-time dialogue between market, suppliers, design and production, has turned extreme personalization, up to the single item, into a reality. Furthermore, enhanced flexibility helps cope with an ever-changing external environment and much volatile market demands.

Industry 4.0 has been considered "disruptive" since day one, having it changed the rules of the game and the functioning of markets and it has if we take a look at the relationship company-suppliers, for which even the concept of proximity has moved from the physical plane to the functional one. Interconnections do not only entail the supply chain or the consumer-company duo, but spread also horizontally in between entrepreneurs or consumers.

One more trend risen from the technological advances from which the society as a whole can benefit, is represented by an increased energy and resource efficiency; this might in fact be the first revolution to deviate from the energy-greed trend thanks to the ongoing efforts toward the use of alternative resources [Hausermann, 2017].

To conclude, introducing this cyber-physical structure to improve industrial and distribution practices, aids the attainment of multiple gains starting from higher efficiency and lower costs leading to the consequent drop of final prices and market demand growth, to the offering of completely new products and services. The conciliation of the two worlds is not immediate though and new, more suitable interfaces are being experimented to obtain it, but the synergies that would be drawn from it would be substantial since we would be able to take advantage of the great potential embedded in digital technologies, today only partially reaped, and take considerable steps ahead toward the improvement of production and social systems [Magone, Mazali, 2016].

1.2.5 Opportunities & Challenges

Like the revolutions that preceded it, also the Fourth has the potential to benefit the world economy raising global income levels and improving the quality of life for many individuals. Up to this day however, it seems like those who have gained the most from it are those individuals and groups who can access the digital world.

As a matter of fact, economists Brynjolfsson and McAfee are among those who believe that the Revolution could actually yield great inequality, specifically in its potential to upset the equilibrium in labor markets. According to Bernard Marr – whom we have already mentioned in this paper – by one estimate, as many as 47% of U.S. jobs are at risk from the spreading of automation. But again, this is not something we haven't witnessed before, historically industrial revolutions have started their course with greater inequality necessarily followed by periods of radical changes, both political and institutional. On the flip side of the coin – the two authors continue – in aggregate terms, the displacement of workers might even result in a net increase in safe and rewarding jobs. We may leave the first scenario up to the cynics and the latter to the hopeless optimistic, truth is that history suggests that the future outcome is likely going to be a combination of the two. Yet many literature experts seem to agree on some of the features that will characterize the future labor markets; first and foremost, the segregation of the same in the two segments “low-skill/low-pay” and “high-skill/high-pay”. A proof of it might be the fact that in high-income countries, the demand for high-skilled labor has risen instead the one for the lower skilled and less educated segment has fallen. The resulting picture of the future is a “winner-takes-all” one, where the largest beneficiaries of innovation appear to be the providers of intellectual and physical capital (investors, shareholders, innovators…).

If this is the perspective on the side of labor supply, what about businesses? Companies are probably the ones who got hit the hardest by the wave of innovation, and from different frontiers too. To face and meet the expectations of consumers “in-the-know” of about pretty much everything, businesses must redirect their operations to the ultimate goal of satisfying the customer with new and improved products and services, knowing that these will be put under their meticulous scrutiny. In the attempt to improve the way customers are served, given the impressive pace at which innovation and disruption are taking place, companies will have to rethink from scratch their business models, organizational structures, platforms and culture. Not everybody is positive that they will be able to do so. The founder of the World Economic Forum Klaus Schwab himself, expressed his concern that organizations could be incapable or reluctant to adapt to these technologies, which might not only prevent them from harvesting the benefits of Industry 4.0, but also damage their competitive power irremediably.

But major shifts on the demand side are not the only challenge companies have to cope with, as competition has never been as fierce as today. The new trend of technology-enabled platforms that combine people, assets and data creating the “sharing” and “on demand” economy, are disrupting the structure of industries as we know it.

The bottom line remains the same: it is not possible anymore for companies to stick to their business models keeping their eyes shut to what’s happening around them, because the change might come so fast and unannounced that they wouldn’t even perceive it. So, business executives need to understand their environment and challenge their current modus operandi through an unceasing innovation process, which will prevent them to stay behind.

Governments are not exempt neither, and are fighting a battle of their own. Van Duüren argues that the majority of the governments ecosystem is based on models which encompass mostly national rules, national taxes, local hiring and salary taxes to pay social security, but such an approach is no longer feasible. Governments are today being challenged to an unprecedented degree but, for the most part, they don’t seem to be managing very well.

Klaus Schwab in his book "The Fourth Industrial Revolution", warns about the possibility of governments' failure to employ or regulate these technologies properly and that inequalities could grow rather than shrink if things are not managed appropriately. The only way to come out victorious is for them to embrace an "agile" governance, meaning that regulators must continuously adapt to a new, fast-changing environment just like businesses do, and the way to accomplish that goal is for them to collaborate closely with businesses and society, as suggested by Schwab.

So, although the new path of technological innovation we have just got into is of exogenous nature, this does not mean we have no power whatsoever over it, on the contrary it is our responsibility to have it lead us to the direction we want to take and not leave it up to fate to shape our own future. This is why, the process of dehumanization brought forth by Industry 4.0, is to be tackled leveraging on the key traits that make us humans instead: creativity, empathy and stewardship [Schwab, 2017]. It is not hence acceptable for today's decision makers to keep dwelling in the past, dependent on traditional systems and paradigms, but will have to keep moving forward questioning the old ways in favor of new investment strategies and prioritizing training projects, potentially disruptive R&D investments and previously not contemplated business models.

1.3 A Short Overview Of Technological Advances

If we had to incorporate the substance of Industry 4.0, we could define it in these terms: It is simply a way to efficiently and effectively leverage new digital and robotic technologies into the manufacturing process. Such technologies include: additive manufacturing, IoT, robotics, Big Data and the Industrial Cloud, Augmented Reality and more. It seems then legit to learn at least a few things about these innovations, the gains and savings they promise to offer, their applications and future opportunities.

1.3.1 3D Printing And Additive Manufacturing

What if, with just a mouse click, one could send a digital file to an inkjet printer, except, with 3-D printing, and the machine runs off a three-dimensional product; you could, in one instant, become your own manufacturer. This is what 3D printers do, but it's actually more complicated than it sounds. As a matter of fact, what 3D printers do is build successive layers of the product starting from a computer aided design and using powder, molten plastic, or metals to create the material skeleton. This is why it is also known with the name of "additive manufacturing" to set it apart from the traditional “subtractive manufacturing,” which involves cutting down materials and then assembling them together.

According to the chief executive officer of 3D Systems Inc., a maker of 3-D printers, the technology does not require constant attention by an operator: ‘‘All you have to do is load a file and you can replicate shapes that are not possible to manufacture through traditional methods. I call it a flexible factory in a box’’ [Berman, 2012][3].

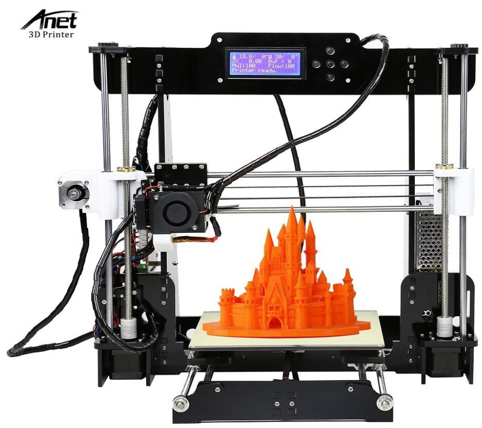


Figure 1.4: Example of a 3D printer

Although this technology has been under the spotlight only for a few years now, its patent surprisingly goes back as far as the ‘80s when Chuck Hull launched in the market the first SLA (Stereo Lithography Apparatus) printer, based on a primordial form of 3D printing technology. So, apparently a thirty years-time span has been necessary for Hull’s invention to become technically and economically valid for industrial purposes that go beyond basic prototyping.

According to Barry Berman, additive manufacturing has undergone a three-step evolution process after its conception. In the first phase, architects, artists, and designers used 3-D printing to build prototypes or mockups of new projects, even though still today most 3-D printing is represented by the manufacturing of prototypes and mockups. Later on, the technique was also used in the development of finished goods, obtaining the designation of “rapid tooling” or “direct digital manufacturing”. As stated by Terry Wohlers, manager of a market research firm specializing in 3-D printing, over 20% of the output of 3-D printers is now in final products as opposed to prototypes (‘‘3D Printing: The Printed World,’’ 2010). Wohlers predicts that this will rise to 50% by 2020 [Berman, 2012]. The next and last phase in Berman’s vision, is for 3D printers to follow on the

3 BERMAN, B. 3-D printing: The new industrial revolution. Business Horizons, 55(2), pp. 155-162. [2012]

footsteps of traditional desktop laser printers which can be easily found today in private households.
But what are, in practical terms, the advantages offered by the adoption of this new technology which, only a couple decades ago, would have sounded like good material for a sci-fi movie:

- Flexibility to design and fabricate any shape with (almost) any material;
- Reduced time-to-market;
- Lower prototyping and production costs (no waste material, no traditional sampling, less energy consumed);
- Possibility to mass customize small batches (unitary costs of customized products are not higher than mass produced units anymore);

All these reasons explain why 3D Printing has been showing promise for so many years; its use in prototyping and small-scale production is already significant, but in order for it to be fully functional in industrial manufacturing three major elements need revision: speed, quality and breadth of materials that can be used. Improvements in these fields are already starting to be perceived, but it will take time for 3D printing to get closer to mass production.
Another point in favor of 3D printers consists in that they can run unattended, and can make many things which are too complex for a traditional factory to handle, in time these amazing machines may be able to make almost anything, anywhere.

Applications

Literature identifies many varieties of 3D printing technologies but, without getting into any specifics, there’s one thing that is true for all of them and that is their ability to obtain, in a single printing session, items which are traditionally realized through the assembly of multiple separate parts even if these are movable components.
New lighter, stronger and more durable materials are replacing the old ones, like carbon fiber is replacing steel and aluminum. For instance, aerospace companies are already using additive manufacturing to apply new designs that reduce aircraft weight, lowering their expenses for raw materials such as titanium but also hearing aids and high-tech parts of military jets are being printed in customized shapes, to name a few.
The process greatly reduces the production cost, requiring as little as 10% of the raw material consumed in traditional manufacturing and employs less energy than conventional factory production systems (approximately 84% of the productivity gains in the manufacturing and service

industries are attributable to increases in thermodynamic efficiencies [Rifkin, 2012]; thus providing additive manufacturing with the potential to significantly reduce the cost of producing goods, making entry costs sufficiently lower to encourage hundreds of thousands of small manufacturers: ideally any computer may become a little factory.

As a matter of fact, the spreading of 3-D technology and the attached prospect for on site, just in time, customized manufacturing will also reduce logistics costs.

As we have mentioned earlier in this chapter, one of the key challenges of businesses today, is being able to adapt with the growing need for customization and winning the race against competitors in delivering the desired qualities. 3-D printing is the cost and time efficient heaven-sent solution to this dilemma, as it allows for products to be manufactured from concept.

There are many mass producers who would like to be able to offer more individualization, this will be possible as 3D printing increasingly brings design, manufacturing and service flexibility to many industries. As always, those who will manage to take advantage of the new possibilities will be the winners.

In the Italian context, Magone e Mazali believe that in the future smart production techniques might benefit Italian manufacturing, being it historically rooted on customization and encourage a return of craftsmanship. This is a bright perspective indeed, but the results obtained in field interviews conducted by the two authors, show how in reality additive manufacturing in our country is looked at with more caution than what may surface from literature reviews.

What appears to be for Italy the right approach to embrace the paradigm of Industry 4.0, is for our country to adapt to its own industrial configuration the technological and organizational innovations conceived abroad. By doing so we would be able to combine together the competences of traditional craftsmanship with the efficiency of new technologies. Moreover, the limits associated with the small dimension of our enterprises, could be partially overcome taking advantage of structures like business networks for instance.

Summarizing, 3D printing is perhaps one of the most “flexible” means of manufacturing, as literally each print could be unique. Currently, however, most 3D printing equipment is more or less “standalone” and provides only simple, if any, interfaces to a larger manufacturing ecosystem. As of today, 3D printers require humans to “set up” the 3D printer to unload the completed prints, refill the material mechanism and perform finishing operations, which are often done manually. A 3D printer that was fully automated and software operated is not a reality yet, but we cannot exclude that it could be in the future, given the current pace of innovation. We don’t need to wait for tomorrow to reap the benefits of additive manufacturing though, even today 3D printing brings a unique value proposition to the table. Nevertheless, it will contribute a substantial value to any manufacturer's operation only when coupled with other technologies going from new modular ERP applications to cloud computing, augmented reality, big data analytics and mobile devices.

What does the future of 3D printing look like?

Now, 3-D printing is mostly limited to products that are made to order, ordered in unique shapes and in very small quantities. The technology enables firms to quickly and cost-effectively supply these low-demand parts without the risk of carrying an unsold finished goods inventory. But there's still improvement margin and a couple adjustments still need to be made for additive manufacturing to be more widely adopted. The principal drawbacks are: material costs (due to the little pervasiveness itself), accuracy and strength of products, caused by weak bonding between layers that can lead to delamination and fracture under pressure.

Most literature experts seem to agree that the 3D printers of the future will overcome these obstacles and higher levels of precision will be achieved. The employment of additive manufacturing will expand beyond its present scope, leading to the decline in raw materials' prices. Spare parts for pretty much everything will also be more available, as it is less costly to retain old designs than excess inventories of spare parts. As more companies adopt the technology, the price of machineries itself will drop, and when it'll be low enough for a private investment, the number of printers used for home applications will also considerably grow [Berman, B., 2012].

In conclusion, it is apparent that we can positively hope for a good future for 3D printing as a technology and for its business implications.

1.3.2 Big Data

Today, millions of networked sensors are being placed in industrial machineries but also in the physical world we engage with every day, these technologies are sensing, creating and communicating gigantic quantities of data even at this very moment.

In our digitalized world, anytime we communicate, browse, shop, share information or search for it, we're leaving our own invisible trail of data.

This leads us to the definition of "big data". Not everyone agrees on what is included under this term, but it can be truly anything anyone might be interested to know that can be subjected to computer analysis. According to McKinsey (2011): "'Big data' refers to datasets whose size is beyond the ability of typical database software tools to capture, store, manage and analyze".

Therefore, the term is usually used to indicate vast, rapidly growing, diverse and often unstructured sets of digitized data that are difficult to preserve using traditional databases. It can range from anything floating around the ether, the proprietary information of companies and official government records, to name a few.

Even though the expression is relatively new, the tendency to group and store huge amounts of information for future analysis goes way back. The label however, became popular in the early 2000s when the sector analyst Doug Laney formulated the well-known 3Vs model, which has been since then used as a common framework to describe Big data:

- ✓ *Volume:* organizations collect data from different sets of sources, financial transactions, social media, sensors, machine-to-machine etc. In the past, storing and analyzing this much data wouldn't have been possible, but today new technologies facilitate these tasks;
- ✓ *Velocity:* refers to the speed at which data is generated and processed. It flows at unprecedented speed and therefore needs to be managed timely, sometimes even in real-time with technologies like RFID tags and smart metering;
- ✓ *Variety:* data comes in different formats and types (numerical, structured, unstructured, email, video, audio etc.)

The leader in analytics SAS, added another two dimensions to Laney's list:

- ✓ *Variability:* information flows can be very inconsistent and come with periodical peaks, managing daily, seasonal or event-related peaks could be challenging especially if these are represented by unstructured data;
- ✓ *Complexity:* the multiple origin of data makes it hard to connect, pair, arrange and transform transversal information despite the relevance of finding correlations and hierarchical relations between collected data.

Big data utility: how data can create value

Generally speaking, most individuals regard with suspicion to this information collection, basically considering it just one more intrusion of their privacy. But there is extensive evidence that big data can create significant value for the world economy as well as generating substantial economic surplus for consumers. As a matter of fact, consumers and citizens at large by a general pattern, are both direct and indirect beneficiaries of big data-related innovation and capture a sizeable amount of the produced economic surplus.

A McKinsey estimate shows how a retailer using big data to the full, has the potential to increase its operating margin by more than 60% [Manyika, et al., 2011][4]. This example clearly shows how today data has become equivalent in importance to the other essential factors of production: assets and human capital. The possibilities offered by big data continue to evolve rapidly, driven by technological innovation as well as analytical capabilities of data handling and consumers' behavior. So, how do governments, companies and other institutions leverage these possibilities and how do they extract value from handling this data?

Here follows a list of useful ways to apply information analytics as proposed by McKinsey [Manyika, et al., 2011]:

- Creating transparency and making data more easily accessible to relevant stakeholders in a timely-efficient manner sometimes is enough to elicit a considerable increase in value;
- Supporting testing to uncover variability, surface needs, understand causes helps improve performance and achieve higher levels;
- Segmenting the market to customize actions, tailor products and services precisely to meet each group's needs and personalize offers, coupons and communications;
- Automated algorithms can help support, if not completely replace, decision making by revealing insights that humans might not discover, minimizing risk, automatic control of inventories and pricing through real-time data transmission;
- Gathering information and analyzing consumers taste and necessities help enormously in the development of the next generation of products and to create from ground up innovative products, offer well-planned after-sales services and invent brand new business models while enhancing existing ones;

Because of all these factors, the use of big data is becoming a key strategy for leading companies to outperform their rivals at the expense of laggards. This is the time for forward-looking managers to invest effort, money and time to build their enterprises' big data capabilities. As the previously enounced McKinsey research demonstrated, a 60% margin sounds like a very profitable outcome, well worth the investment. Since in most industries both established competitors and new intimidating entrants will leverage the aforementioned potentials, it is of vital importance for all companies to take big data seriously if they want to stay competitive or to "stay" at all.

4 MANYIKA, et al., Big data: The next frontier for innovation, competition, and productivity | McKinsey & Company. [May 2011]

Issues and challenges

Because it is never as easy as it seems, capturing the full potential of big data and analytics is today's industry quest but like every quest, this too presents obstacles along the way.

The first challenge to be addressed concerns privacy and security. As for what regards the first parameter, the extensive collection of personal data is somehow always a very delicate issue for both privates and organizations, so much that sometimes we prefer not contributing this information. But it is a double-edge weapon, in the sense that if one wants to reap the benefits of big data, he/she also has to share and find a trade-off between the need for privacy and the will to gain from more efficiency/personalized offers.

In the same way, security represents a major issue and resistance in big data adoption on the part of firms is not rare [Lee 2017][5]. According to the same author, the fear of confidential information ending up on the computer screens of the wrong parties, can be overcome through the establishment of strong security protocols, encryptions, firewalls and other intrusion prevention systems. The issue of liability in the case inaccurate data leads to negative consequences is also subject to fervent debate.

Along with fear, another factor that holds back organizational leaders in adopting big data, is the lack of understanding of what it really means and how to unlock its value [Manyika et al. 2011]. The last challenge to tackle but certainly not for importance and generally acknowledged by literature, is the prospected shortage of talent, specifically of individuals with extensive statistical know-how and analysts or managers who know how to operate companies leveraging big data. In the next exhibit (*Figure 1.5*), it has been illustrated how by 2018 the demand for these skills could by much exceed the supply being produced on current trends. It will take time to train new prepared workforce, and it will be necessary to retrain the one already in place, fortunately the latter won't take as long [Manyika et al. 2011].

5 LEE, I. *Big data: Dimensions, evolution, impacts, and challenges. Business Horizons*, 60(3), pp. 293. [2017]

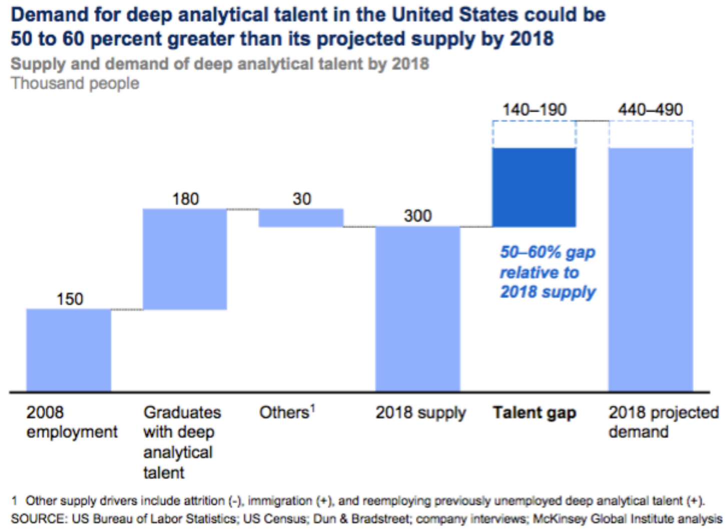


Figure 1.5: Prospected gap in analytical talent (Source: *Mckinsey, 2011*)

Concluding, big data and the elaboration of useful information, is proven to be very promising for companies, customers and society as a whole, but achieving such promises entails overcoming non-trivial challenges in pursuit of big data technology integration. The way to do that involves infrastructure development, talent encouragement, the predisposition of security and privacy protection tools as well as a little proof of courage.

1.3.3 The Cloud

Cloud computing is one of the latest technologies that are undergoing constant evolution to adjust perfectly to the new industrial paradigm. Generally speaking, with the term “cloud computing” we usually refer to the distribution of computing services like networks, servers, databases, software, data analysis and much more provided through the Internet or “cloud”[6].

Many believe the Fourth Revolution will be driven by the integration of already available resources and the new technology.

In this picture, the Cloud will participate in yielding results for success in business while pushing toward the tech frontier[7].

Cloud computing cannot have a single definition because it has many applications and being, in many instances although not always, a service provided by a third party, it is available in many models. Depending on the needs and capabilities of each company, cloud computing can be

6 Cos'è il cloud computing? Guida per principianti | Microsoft Azure. Available: https://azure.microsoft.com/ [Oct 2, 2017].

7 The Cloud in Industry 4.0: Models and Types of Service. Available: https://doky.io/blog/cloud/ [Oct 2, 2017].

delivered according to many different formats, most of these can be brought back to at least one of these three categories:

- **IaaS** (Infrastructure as a Service): this represents the basic format and the most popular solution for SMEs. This is the case where the IT infrastructure, comprehensive of server virtual machines, virtual space, network and operative systems, is leased from a cloud service provider with a consumption-based payment method. Maintenance remains a responsibility of the provider while the customer has access to the necessary virtual tools to build its own IT platforms;
- **PaaS** (Platform as a Service): through this solution, the user is provided with a virtual setting – the platform – where he can develop, test, distribute and manage software applications. Paas services are hosted on cloud and are accessible through any browser. It is a practical solution in that it allows developers to easily and quickly build their applications without having to worry also about the management and configuration of the underneath server, database and storage network needed for the job;
- **SaaS** (Software as a Service): this one is a method for the distribution of software applications through the net, usually under rental or subscription. In this case, the provider is the one to host and manage the application and the underneath infrastructure, he is also entrusted with the software's maintenance, update and security management. Users only need to log in from any browser and device to access the application.

Not only different kinds of services can be provided, but these may also be distributed following three criteria: publicly, privately, hybrid.

Public cloud services are owned by a third-party provider which offers computing and storing resources through the net. If the cloud is public, then hardware, software and the support infrastructure are all property of the service provider and managed by the same. Users access and manage their accounts directly from the browser. It is quite inexpensive and flexible, offering several options for companies and allowing each to use a cloud service customized depending on their needs. For SMEs and companies that work with sensitive data instead, it is better to use a private cloud service that seeks to protect the information and data needed for a company's production processes. In this instance, cloud computing resources would only be used by the one organization that owns them, it can be physically present in the facility's data center or at a third party's premises, paid by the company to host its private cloud. Therefore, a private cloud is a cloud where services and infrastructure are managed in a private network.

Finally, hybrid clouds combine the previous two options, allowing data and application sharing in between the two types of cloud. Thanks to the possibility of transmitting data and software from private to public and vice versa, the hybrid cloud offers organizations additional flexibility and distributive solutions.

Even though the first cloud computing services appeared only about ten years ago, already many organizations ranging from start-ups to big multinational corporations, public institutions and non-profit organizations, are all adopting this technology for different reasons. Here is a list of activities – provided by the Microsoft Azure article mentioned before – and enabled by the cloud technology:

- Creation of new services and applications;
- Filing data, backing it up and restore it;
- Host websites and blogs;
- Streaming videos and audios;
- Provide on demand software;
- Analyze data to obtain models and estimates.

These are some of the activities supported by cloud services, and the reason why cloud computing represents such an important change as compared to the traditional idea companies had of IT resources. So, why does a business decide to rely on this technology? What are its gains and advantages?

a) The first is a *cost* advantage. As a matter of fact, cloud computing cuts capital expenses associated to hardware and software purchase and configuration, the management of local data centers which require servers, a 24h electricity provision and IT specialists for infrastructure maintenance;
b) *Speed:* many cloud computing services are provided on demand, thus making it possible to obtain access to a high quantity of computing resources in a short amount of time. This grants firms extreme flexibility with no need to pre-emptively plan the necessary capacity;
c) *Global Scalability:* cloud computing services offer this IT resources flexibility anywhere and whenever is needed;
d) *Productivity:* the traditional local data center required large spaces for server racking and piling, hardware configuration, software application and many other time-costly management operations. Cloud computing eliminates many of these activities allowing IT teams to devote their time toward more important organizational goals;
e) *Performance:* the biggest cloud computing services spread over a global network of secure,

up-to-date, fast and efficient new generation hardware. Economies of scale, among other factors, allow for performance levels so much higher than in the case of a single company-owned data center;

f) *Reliability:* cloud computing also helps cutting costs for data back-up and emergency recovery operations safeguarding the company's continuity.

In conclusion, cloud technology has unprecedented computational, storage and networking capabilities and is being integrated more frequently into industry making it easier for businesses to readily change with the times without losing data. These new applications and platform services are also adaptable to individual needs and able to perform consistently when confronted with an incredible amount of data. Therefore, it appears that the cloud is and will continue to be a way for medium to large industries to surpass competition through innovation[8].

1.3.4 Industrial Internet Of Things – IIOT

The IIoT is part of the more general concept of "Internet of Things" (IoT), which can be simply defined as a network of intelligent devices, objects and computers that collect, elaborate and send extensive amount of data through a central Cloud service where it is aggregated with even more data and then shared with end-users in a valuable manner. The application of such technology in the manufacturing industry is called Industrial Internet of Things (IIoT).

Many believe that the revolutionary nature of the IIoT is and will in the future enable the acquisition and accessibility of much more data at far greater speeds and efficiency than before, thus critically changing the way we think about and relate to manufacturing. In this Industrial Internet context, data is a key asset, and analytics a necessity in the connected loop of products, resources and more[9].

The original purpose of IIoT attempts was to automate, save costs and optimize processes but now, even though these goals remain there also is a shift toward higher goals like innovation, better customer-centric service offerings, investing on building an ecosystem-wide digital transformation and value.

As a matter of fact, IIoT devices produce information and knowledge to act-upon and enable the

8 Why Cloud Computing is Crucial for Industry 4.0. Available: https://edgylabs.com/ [Oct 2, 2017].

9 Industrial Internet of Things (IIoT): definition, benefits, standards and evolutions. Available: https://www.i-scoop.eu/internet-of-things-guide [Oct 5, 2017].

creation of a data sharing ecosystem which yields revenue streams and valuable partnerships. In this ecosystem, factories are connected to each other and so are supply chains hence stretching the meaning of "connectedness" beyond the walls of the single factory to reach the entire network, which represents the new "extended enterprise".

IIoT benefits

Companies that have adopted the IIoT, are already benefitting from it through cost and time savings, operational efficiencies, scalability and much more. The era of sealed data silos is losing ground in favor of a pervasive network of connected people, data and processes from the factory floor to the management offices, allowed by the deployment of intelligent devices.

According to a Morgan Stanley research, the five main reasons why companies adopt the IIoT are:

1) To improve operational efficiency (through predictive maintenance and remote management);
2) To improve productivity (collaboration between humans and machines);
3) To create new business opportunities;
4) To reduce downtime and
5) To maximize asset utilization.

The World Economic Forum [WEF, 2015], also made some interesting remarks regarding the benefits and opportunities offered by the new paradigm of connectedness, in particular observing how the massive volumes of data provided by the connected factory, increased the ability to make automated decisions and even take actions in real time. It also predicts that as the Industrial Internet gains attention and its adoption spreads, businesses will move from products to outcome-based services and will compete against each other on their ability to deliver to customers measurable results.

Of course, in order to take advantage of the benefits of the IIoT, higher levels of collaboration across business partners belonging to the same ecosystem will be necessary, combining their products and services to accommodate customers' needs. Data collection, aggregation and sharing will be facilitated through the predisposition of more advanced software platforms. Platform owners, along with the network partners will be the winners, grasping the new value created by the network effect and the new digital business model [WEF, 2015].

Moreover, the Industrial Internet will make jobs safer, more productive, flexible and engaging, augmenting workers and presenting new opportunities for skills upgrade and the creation of completely new positions that did not exist before.

Challenges & risks

However, with opportunities also come challenges, and to achieve these efficiency levels, businesses will have to overcome a number of important barriers. Here follows a list of the major hurdles according to the World Economic Forum and a research conducted by Morgan Stanley [IIoT & the New Industrial Revolution, 2016].

- Cybersecurity and data privacy represent the first and most urgent challenge given the increasing number of attacks and data breaches driven by the augmented connectivity and sharing. Companies need to know that their data is secure and will therefore need new security frameworks that span from device-level authentication security to system-wide resiliency and assurance.
- Another barrier is the lack of interoperability among existing systems, which today work largely in silos but, in the future, a fully functional digital ecosystem will require seamless data sharing between machines even across different manufacturers. The same problem exists for data integration given the variety of data source types. However, data and more specifically information and insights in sharing ecosystems are where the future revenue opportunities reside.
- Uncertain returns on investments are also a main obstacle that refrain companies to adopt the new technology. Along with this also a heavy upfront capital investment, a need to change business processes and the rapid evolution of technologies contribute to the decision of managers to delay the investment.
- It is also true that technology is still immature and at a first stage and it is being tested. Moreover, there is not enough awareness regarding the current state of development of the same.
- The lack of data governance rules across geographical boundaries provides a further reason of skepticism and security concerns.
- There is a shortage of digital talent and of highly specific skills in general but at the same time it might also be necessary to look ‘out there’ to get access to the right abilities. If there is one thing that is clear in this age of digital transformation, it’s that no organization can do it all alone and networks, ecosystems and platforms of partners are extremely crucial to succeed.
- Inadequate infrastructure.

- High cost of sensors, even though – as we've seen earlier in this chapter – their cost is decreasing very fast.

Recommendations

To seize the opportunities offered by the Industrial Internet, the WEF research recommends the following actions:

- ✓ To establish a global security commons and share the best security practices;
- ✓ Technology adopters should begin reorienting their overall business strategy, identify their new ecosystem partners and determine whether they should join a partner's platforms or develop their own;
- ✓ Public policy-makers should re-examine and update data protection and liability policies to encourage investment and the adoption of the new digital processes;
- ✓ Industries, governments and academia should collaborate to cope with the technology challenges related to security, interoperability and management of systemic risks leveraging long-term R&D projects. Implement new training programs and encourage reskilling for high-demand job categories.

Dell Inc., one of the giants of personal computers manufacturing, suggests five steps to optimize IIoT benefits, mitigate risks and deploy projects:

1. Build partnerships;
2. Clarify business goals and ROI;
3. Start small, fail, iterate, go bigger, scale;
4. Security first: Security by design and embedded security is a must. And as in all transformational projects, involve security early on.
5. Architect for analytics: It's always all about the data which you turn into insights, action and automation in your Industrial Internet of Things project.

The future of IIOT

Businesses that have embraced the IIoT paradigm, have seen noteworthy progresses to safety, efficiency, and profitability, and it is expected that this trend will continue as IIoT technologies are more widely adopted. It is believed that it will continue to unite people and systems on the plant floor with those at the enterprise level and more largely across factories in the same network. It can also allow enterprises to get the most value from their system without being constrained by technological and economic limitations.

According to the WEF report, in the next ten years the Internet of Things revolution will fundamentally transform how people will work through new interactions between humans and machines, will bring unprecedented opportunities, along with new risks, to business and society at large. It will combine the global reach of the Internet with a new power to directly control the physical world, including the machines, factories and infrastructure. It will change the rules of competition, redraw industry borders and create a new upsurge of disruptive and innovative companies. But, to be real, today the great majority of organizations are still trying to figure out what the implications of the IIoT will be on their businesses and industries; these will need to move faster in order to keep up with times.

1.3.5 INDUSTRIAL ROBOTS & ARTIFICIAL INTELLIGENCE

Robots and artificial intelligence (hereafter referred to as AI), represent one more fundamental aspect of the smart factory. The term "robots" encompasses so many different kinds of devices, that most literature experts identify industrial robots on the basis of a universal definition provided by the ISO (International Standards Organization).
ISO 8373 (2012):

"An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications"

Which, in simple terms means that we can define as "industrial robot" any robot system used for manufacturing that is automatic, designed so that the programmed motions can be changed without physical alteration but can be adapted to a different application with an alteration of the mechanical system, and that is capable of moving in linear or rotary mode.
Robots can be used in the factory for multiple purposes, typical applications may include: welding, painting, assembly, pick and place, packaging and labeling, palletizing, product inspection, and testing. There are so many diverse applications, that these technologies must come in different sizes and shapes. They can be categorized using several parameters, but the most frequently used is the classification by mechanical configuration [*industrial robots: definition and types* (IFR[10]), 2016]:

- *Linear robots* (including Cartesian and gantry robots): robots whose arm has three prismatic joints and whose axes are coincident with a Cartesian coordinate system;

10 International Federation of Robotics

– *SCARA* (Selective Compliance Assembly Robot Arm) *robots:* robots, which have two parallel rotary joints to provide compliance in a plane;
– *Articulated robots:* robots whose arm has at least three rotary joints;
– *Parallel robots:* a robot whose arms have concurrent prismatic or rotary joints;
– *Cylindrical robots:* a robot whose axes form a cylindrical coordinate system.

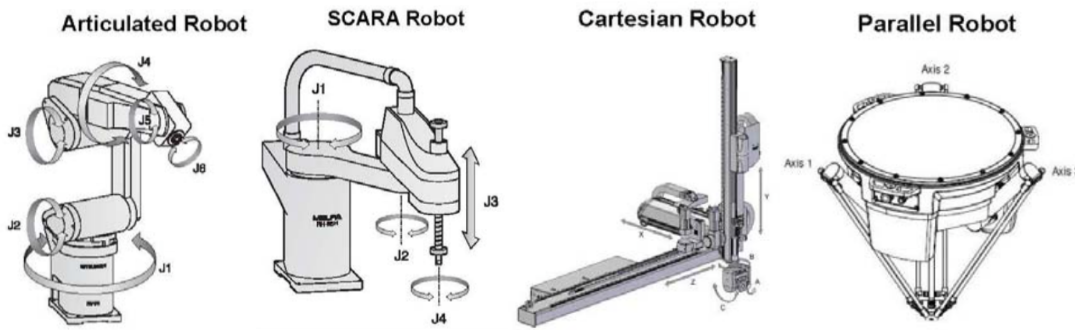


Figure 1.6: Categorization of robots by mechanical structure. *(Source:* International Federation of Robotics*)*

Another category of industrial robot that seems to be increasingly spreading on shop floors of big companies is represented by Automated Guided Vehicles (AGV), which are typically used to move materials around a manufacturing facility or warehouse. These are usually connected to a central server, allowing for coordination and automation of their actions. They can complete tasks intelligently, with minimal human input transporting materials across the factory floor avoiding obstacles, coordinating with each other to prevent collision through a digital connection, and identifying where pickups and drop-offs are needed in real-time. Their presence not only ensures punctual and efficient dispatch of material, but also allows employees to focus on actual assembly and production operations without wasting time on the minutiae of internal logistics [Melanson, 2015].

Another noteworthy robot category is the one of “cobots” (or collaborative robots). A cobot is a robot intended to physically interact with humans in a shared workspace as opposed to other robots, designed to operate autonomously or with limited guidance [Wikipedia].

Technological improvements in incidents prevention, have made it possible for cooperative robots to come out of their isolated cages and be integrated in human workspaces opening up many possible applications in industries. Consequently, in Industry 4.0, smart robots will not only replace humans, but will work “hand in hand” with them on entwining tasks using sensors and human-machine interfaces [Bahrin, et al., 2016]. This is also thanks in a large part to the nascent internet of things and big data, which are producing machines capable of “learning” if not “thinking”. The Japanese technology company Seiko Epson for instance, has created a prototype that is an example of how manufacturing will evolve in the future. Seiko Epson’s president Minoru Usui, described the robot as an “autonomous dual-arm robot that can grasp objects and has cameras for ‘eyes’ in its hands and head; this robot has the ability to recognize 3D objects and make visual inspections, but most exciting of all, he can learn” [Matthews, 2015]. Kuka LBR IIWA (Intelligent Industrial Work Assistant) is another lightweight robot designed for safe close cooperation between human and robot on highly sensitive tasks. IIWA can learn from its human colleagues and can check, optimize, and document the results of its own work while connected to the cloud. The advanced collision avoidance system makes it safe for IIWA to work together with humans. An even more sophisticated robot is the dual-arm YuMi. It features an advanced vision system, flexible hands, sensitive force control feedback and modern robot control software that allows for programming through teaching: it is therefore entirely designed to work side-by-side with humans [Bahrin, et al., 2016].

Of course, some level of human input is needed to power automation, this is why, in smart factories, supervisors are endowed with handheld technology like smartphones and tablets in order to direct robots’ activities and perform supervision using non-expensive, conventional technology, helping production managers to keep up with the factory’s fast-paced environment [Melanson, 2015]. These technological advances will allow some companies to set up “lights out” factories where automated robots continue production after the staff has gone home [Bahrin, et al., 2016].

These autonomous manufacturing methods powered by robots that can complete tasks intelligently and in a flexible and versatile way, are making production cheaper, more reliable, reducing human error, improving health and safety standards while leaving humans more time to work on creative projects. It should therefore come as no surprise that the use of robots is widening to include various functions: production, logistics, and office management.

Some statistics on robotics

In order to understand a little deeper how has the robot market behaved in the last couple years, and what are the most significant trends, here are some interesting insights from a 2017 executive summary on world robotics by the International Federation of Robotics:

- Since 2010, the demand for industrial robots has accelerated considerably due to the ongoing trend toward automation and remarkable technical improvements (an increase of about 84% as compared to the average annual supply between 2005 and 2008). In 2016, robot sales increased by 16%, a new peak for the fourth year in a row.

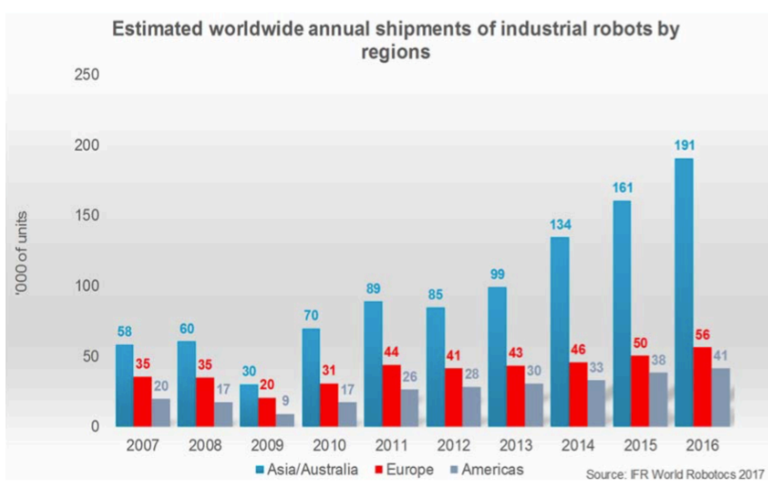


Figure 1.7: Estimated annual shipments of industrial robots by region. (Source: IFR world robotics 2017)

- As we can see from Figure 7, a continued considerable increase in all regions was registered. Asia still represents the world's strongest growth market (190,492 units sold in 2016 with a rise of 19%). Europe comes second with an increase of 12% and 56,000 units. The third place goes to the Americas (41,300 industrial robots shipped and 8% increase from the previous year).
- 74% of the global robot sales is to be attributed to the following 5 countries (ordered by sales volume):
  - *China:* keeps expanding its leading position as the biggest market with a share of 30% of the total supply (2016);
  - *The Republic of Korea:* the second biggest market saw annual sales increasing considerably in the last year due to major investments in robots of the electrical/electronics industry;
  - *Japan:* with an average increase in robot sales of 7% between 2011 and 2016;
  - *USA:* robot sales growing since 2010, driven by the trend to automate production and keep manufacturing at home or bring back manufacturing previously sent overseas;
  - *Germany:* it is the fifth largest robot market in the world
- Italy has ranked 7th since 2014 regarding the worldwide annual supply of industrial robots.
- The automotive industry is still the major customer of industrial robots with a share of 35% of the total supply in 2016. Between 2010 and 2014, it considerably increased investments

in industrial robots worldwide. Between 2011 and 2016, the registered increase was on average 12% per year. The number of robot installations rose by cause of investments in new production capacities in emerging markets as well as in production modernization in major car producing countries.

- Another important industry is the electrical/electronic one, accounting for a share of 31% of the total supply in 2016 and an increase in sales of 41% in the same year. The driving factors for the boost in sales are: the rising demand for electronic products, the need to automate production and the increasing need for batteries, chips and displays.

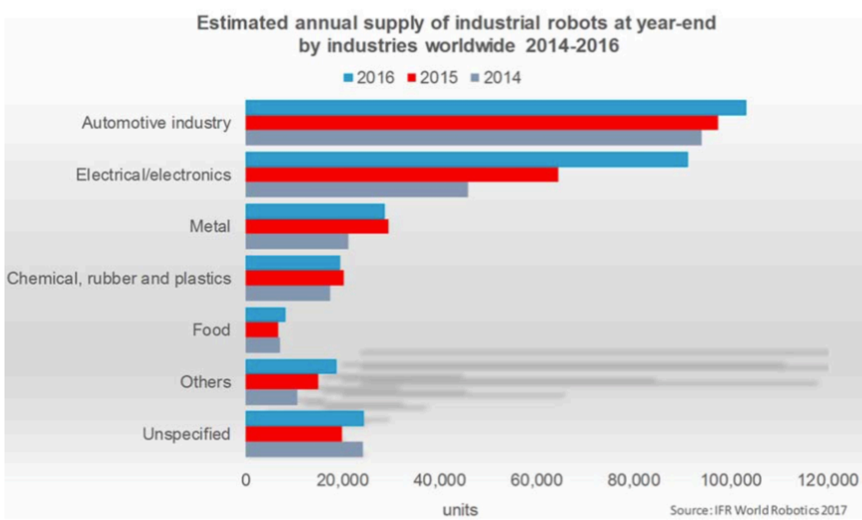


Figure 1.8: Annual supply by industry. (Source: IFR world robotics 2017)

- The average global robot density was about 74 industrial robots installed per 10,000 employees in the manufacturing industry in 2016. With the Republic of Korea being the most automated country in the world.
- Global robot installations are estimated to increase at least by 18% (to about 346,800 units) in the current year. Robot supplies in the Americas will increase by 16%, by 21% in Asia/Australia and by 8% in Europe.

Artificial intelligence (AI)

Artificial intelligence (also known as machine intelligence), is defined as intelligent behavior by machines as opposed to humans' natural intelligence. Therefore, it refers to any device that perceives its environment and takes actions that maximize its chance of success at some goal, and is applied when a machine simulates "cognitive" functions usually associated to the human mind,

such as “learning” and “problem solving” [Wikipedia].
The capabilities that are, at present, generally classified as AI include successfully understanding human speech, competing in strategic game systems (ex: chess), self-driving cars, intelligent routing, interpreting complex data and the like.
One of the fields where AI is finding an important and potentially life-saving application is healthcare, assisting doctors in cognitively intensive tasks. For example, Microsoft is working on a project to develop a machine called “Hanover” to help doctors find the right treatments for cancer. Hanover can memorize all the papers related to cancer and help predict which combinations of drugs will be the most effective for each patient, such activity would be too challenging for a person considering the existence of more than 800 medicines and vaccines to treat cancer. A study found that artificial intelligence appears to be as good as trained cancer doctors in identifying skin cancers [Gallagher, 2017]. Hanover though is not the only hero, IBM’s Watson not only won a jeopardy game against the champions, but was also able to successfully diagnose a woman suffering from leukemia. Another case of success is represented by autonomous surgery robots, which have demonstrated to be as good, if not better, than a human surgeon.
Other famous AI applications can be seen in virtual assistants like Apple’s Siri, or self-driving cars. As a matter of fact, advancements in this technology have contributed to the growth of the automotive industry through the creation of self-driven vehicles (both cars and drones). There are today over 30 companies utilizing AI for the development of driverless cars and trucks, including Tesla, Google and Apple. These vehicles incorporate systems such as braking, lane shifting, collision prevention and mapping which, together with high performance computers, constitute complex vehicles able to navigate on their own.
These and many other applications are becoming more and more popular today across all sectors, and with them also important ethical and legal controversies are rising as the boundaries between human and artificial are increasingly blurred.
To sum up:

- ✓ Robotics and AI improve the quality of work by taking over dangerous and tedious jobs that are not possible or safe for humans to perform;
- ✓ Machines will increasingly acquire new skills through learning processes and new generation robots will enable man and machine to work closely and safely together;
- ✓ IIoT, AI and collaborative robots will play an increasingly important role in global manufacturing in the coming years for several reasons:

- Competition is requiring continuous modernization and expansion of production facilities;
- Increase in the variety of products requires a more flexible automation;
- Continuous quality improvement requires more sophisticated robot systems.

✓ A global continued increase in the use of industrial robots is predicted especially in the growing Asian markets, North America and Europe.

1.3.6 AUGMENTED & VIRTUAL REALITY

Augmented reality (AR) is a live direct or indirect view of a physical, real-world environment whose elements are "augmented" by computer-generated or extracted real-world sensory input such as sound, video, graphics or GPS data. The goal of an AR system is to enhance people's perception and interaction with the real world through supplementing it with 3D virtual objects that seem to coexist in the same space. In contrast, virtual reality (VR) entirely replaces the real world with a simulated one.

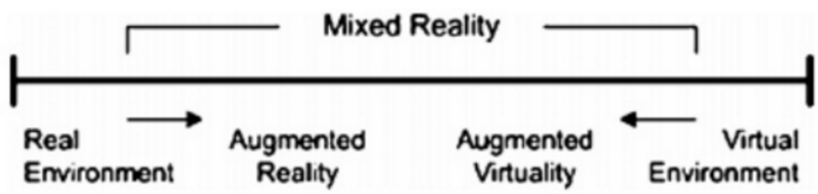


Figure 1.9: Difference between augmented and virtual reality. (Source: *Sun et al., 2015*)

These technologies conform well with the context of the smart factory, being able to contribute to the reduction of human errors, costs and inefficiencies. AR and VR are attracting more and more attention in the industrial sector, as a matter of fact their versatility allows application on all parts of the value chain:

- *Product design and prototyping:* reduces designing time and costs, ensures data is visualized with actual proportions and shows virtual data on a real model;
- *Production planning and spatial organization:* complex and time-consuming manual assembly design and planning can be replaced with an immersive and intuitive environment to evaluate the virtual prototypes or the assembly sequence, reducing re-designing and planning activities [Sun et al., 2015];

– *Training and assembly:* AR and VR could be a revolution in training and assembly, they would reduce formation time and costs as they provide direct information on the field, real time data reduces the possibility of making errors and wearable devices allows for hands-free work (no more need for manual handling);

– *Maintenance:* huge amounts are spent annually in maintenance around the world, and the process of fully training the staff takes a long time. In this context AR is extremely effective at reducing execution times, minimizing human errors and sending the relevant performance analytics to maintenance managers. There is a number of empirical studies comparing the performance of two groups of workers carrying the same assembly/maintenance activities, one operating with the aid of AR instructions, the other using a traditional manual. AR enabled the first group to perform twice better in terms of speed of completion and errors [Ferrari, 2017].

– *Logistics:* improving efficiency of warehouse management operations supporting employees during indoor navigation and picking operations.

To conclude, let's consider the following Exhibit illustrating advantages, opportunities and challenges involving these technologies.

ADVANTAGES	CHALLENGES	OPPORTUNITIES
• Visualization during design and planning • Time reduction for complex tasks • Decrease of human errors • Decrease of workers' mental load • Technical assistance during maintenance • Reduction in training time	• Sophisticated processing on a mobile device • Limits to current speed and accuracy • Immature transparent display technology • Insufficient resolution • Difficult AR content development	• AR software for glasses and head-mounted displays • Higher quality transparent displays for AR glasses • Light, non-intrusive wearable devices • User-friendly AR content development • Better object tracking and registration algorithms

Table 1.1: Advantages, challenges and opportunities for AR and VR

2 CHAPTER

2. INDUSTRY 4.0 AROUND THE WORLD: IMPLEMENTATION PROGRAMS

"Behind the scenes of the world's leading industrial and manufacturing companies, a profound digital transformation is now underway." (Geissbauer, et al., 2016)

SPREADING INTEREST, INCREASING INVESTMENTS

A global Industry 4.0 survey conducted last year engaging over two thousand companies residing in 26 different countries, showed how the paradigm of the smart factory is being embraced more and more pervasively and many businesses all over the world are taking concrete steps towards a thorough value chain transformation leading to products augmented by digital interfaces and data-based, innovative services [Geissbauer, et al., 2016]. Industrial leaders are – according to the same survey – already digitizing vertical operation processes, as well as those with their horizontal partners at every stage of the value chain. Despite the fact that at the moment only 33% of these companies define themselves as "advanced", by 2020 the rate might jump to 70% considering the intention of many respondents to dramatically increase their level of digitization by that time.

The countries that are already one step closer to the industry of the future, are the ones whose governments – in most cases – have decided to launch programs devoted to the implementation of initiatives, usually related to funding, directly focused on the transformation of factories into working environments based on the installation of cyber-physical systems (CPS).

We will therefore dedicate this chapter to a brief review of the most relevant cases of Industry 4.0 strategies, and the incentive policies undertaken by those countries who have already been developing technologies in various fields to realize Smart Manufacturing over the past few years. In particular the following pages will discuss the current German, Italian, American and Chinese initiatives.

2.1 The Case Of Germany: "Industrie 4.0"

"We must (...) deal quickly with the fusion of the online world and the world of industrial production. In Germany, we call it Industrie 4.0." – Angela Merkel, German Chancellor

The first country that will be here taken into analysis is of course Germany, being it considered the pioneer of the new paradigm, and the one to coin the definition "Industry 4.0" itself.
Germany is today one of the world's most competitive and innovative manufacturing industries and leader in technological industrial production research and development.
Its strong machinery and plant manufacturing industry, the high level of IT competences and know-how in embedded systems and automation engineering, mean that this country has a significant chance to develop a leading position in this industry and tap into the potential of a new type of industrialization presented by the Fourth Industrial Revolution [Kagermann, et al., 2013].
In the words of Professor Henning Kagermann of the National Academy of Science and Engineering, INDUSTRIE 4.0 is the German strategic initiative to take up a ground-breaking role in industrial IT, which is currently reforming the manufacturing sector. It will strengthen the country's economy intensifying international cooperation while creating new, internet-based markets and potentially making Germany a leading supplier and market for Industry 4.0 solutions.
INDUSTRIE 4.0 is one of the "Future projects" identified by the German government as part of its High-Tech Strategy 2020 Action Plan, to pursue innovation objectives over a 10 to 15-years period. Germany plans to achieve its ambitious goal of playing an active part in modeling this industrial revolution, by leveraging on its industry's traditional strengths and experienced research community skills and know-how [Kagermann, et al., 2013]:

- Market leadership in machinery and plant manufacturing;
- A globally significant cluster of IT competencies;
- A leading innovator in embedded systems and automation engineering;
- A *highly-skilled* and highly-motivated workforce;
- Proximity to and in some cases close cooperation between suppliers and users;
- Outstanding research and training facilities.

According to the Industrie 4.0 Working Group, by focusing on horizontal integration through value networks, vertical integration and networked manufacturing systems, Germany believes it can manage to obtain an optimal outcome by leveraging existing technological and economic potential

through a systematic innovation process engaging the skills and know-how of its workforce.
Already starting from August 2006, the "High-Tech Strategy" set billions of euros aside annually for the development of advanced technologies. The objectives set out by this initiative, were afterwards extended within the "High-Tech Strategy 2020" launched in 2010 with the intention to create lead markets, further intensify partnerships between science and industry and continue to improve the general conditions for innovation [MacDougall, 2014].
The action plan for the 2020 Strategy, identifies ten "Future Projects" which are considered critical to realize the current innovation policy objectives. These projects include INDUSTRIE 4.0 to which has been allocated funding of up to 200 million euros [MacDougall, 2014].
The increasing adoption of Cyber-Physical Systems (CPS) by German factories, will have two effects: on one hand, it will improve the efficiency of domestic production, on the other, the development of CPS technology will offer important opportunities for the export of such technologies and products. In order to take advantage from the market potential of Germany's manufacturing industry, the Government has opted for combining a leading market strategy with a leading supplier strategy in a main dual strategy, comprising the deployment of CPS in manufacturing as well as the marketing of CPS technology and products.

2.1.1 LEADING SUPPLIER STRATEGY

As of today, German equipment suppliers provide manufacturing industry with world leading technological solutions and are therefore the most probable candidates to become global leaders in the development, production and marketing of smart products. The way to do that, is to find smart options of combining these exceptional solutions with the new potential offered by information technology, this combination promises to enable future new market opportunities.
The following represents some fundamental steps in order to accomplish the leading supplier strategy [Kagermann, et al., 2013]:

1. Existing basic IT technologies need to be adapted to the specific requirements of manufacturing and continue to be developed. It will also be necessary to enhance the IT systems of existing facilities with CPS capabilities as part of the transition strategy to Industry 4.0, while developing models and strategies for designing and implementing CPS manufacturing structures at new locations.
2. Priority should be given to the promotion of research, technology and training initiatives in order to develop methodologies and test applications in the field of automation engineering

modelling and structure optimization.

3. Create new value networks leveraging technology and developing new business models.

2.1.2 LEADING MARKET STRATEGY

Germany's domestic manufacturing industry is known to be the leading market for Industry 4.0, in order to successfully expand this leadership, close networking of parts of businesses located at different locations will be required, as well as closer cooperation between different enterprises.

One of the main challenges Germany will have to cope with pursuing this goal, is to achieve at the same time integration into the new value networks of both large, globally operating firms and regional-level SMEs. This represents indeed a challenge, as many SMEs are not ready for the structural changes brought about by Industry 4.0 yet, either because they're missing the essential specialist staff or because of a cautious or even cynical attitude towards the unfamiliar instruments [Kagermann, et al., 2013]. The Working Group final report suggests the designing and implementation of comprehensive knowledge and technology transfer initiatives, with the intention of integrating SMEs into global value networks. The Group believes that doing so would help remove the obstacles that prevent SMEs to become acquainted with CPS methodologies incorporating and implementing them into their own businesses. To facilitate the process, the acceleration in the development and use of the technological infrastructure (high-speed, broadband data transmission etc…), the education and training of skilled workers and the planning of customized, efficient organizational designs will be paramount.

These two strategies do not work independently and the reason for calling it a "dual strategy" resides in the fact that they must be coordinated in order for their benefits to complement each other. More in detail, the strategy – as envisioned by the Working Group – should entail three fundamental features:

a) *Development of inter-company value chains and networks through horizontal integration:* companies should find a way to proficiently and sustainably integrate their strategies, value networks and business models using CPS. The choice should also consider aspects like know-how protection, sustainability and staff training initiatives.

b) Digital end-to-end engineering across the entire value chain of both the product and the associated manufacturing system: the objective is to ensure that the digital and real worlds are always integrated across a product's entire value chain and across different companies while also complying to the customer's requests. To provide end-to-end support throughout the whole value chain, from product development to manufacturing system engineering, production and service, proper IT systems will be key, and for this to be feasible, engineers will require an appropriate training.

c) *Development, implementation and vertical integration of flexible and reconfigurable manufacturing systems within businesses:* companies need to find ways to deploy CPS to create flexible and reconfigurable manufacturing systems. To facilitate the automatic building of an ad hoc structure for every situation, a set of IT configuration rules will be defined. Furthermore, it is essential to guarantee end-to-end digital integration of actuator and sensor signals across different levels right up to the ERP level and to develop modularization strategies in order to enable ad hoc networking and re-configurability of manufacturing systems. These new approaches to the manufacturing system, will have to be completely understood by foremen and operators, whom will hence need to be properly formed.

Summarizing what has been said so far, the transformation path towards Industry 4.0, will require the dedication of huge amounts of effort into R&D, research into the horizontal and vertical integration of manufacturing systems and end-to-end integration of engineering. Other matters of importance will be the new social infrastructures in the workplace as well as the continued development of CPS technologies.

Furthermore, the Industrie 4.0 Working Group believes that these research and development activities will need to be accompanied by actions in the following eight key areas [Kagermann, et al., 2013]:

1) *Standardization and reference architecture:* In order for the collaborative partnership between companies of the same value network to be successful, it'll be necessary to develop a single set of common standards together with a reference architecture which provides a technical description of the same to facilitate their implementation across the network.
2) *Managing complex systems:* When products and manufacturing systems become increasingly complex, the use of appropriate planning and explanatory models can help manage the intricacy. Consequently, engineers should be provided with the fitting tools and methods for the development of such models.
3) *A comprehensive broadband infrastructure for industry:* The broadband Internet infrastructure needs to be expanded on a massive scale, both within the country and

between Germany and its partner countries as a key requirement for a reliable, comprehensive and high-quality communication network.

4) *Safety and security:* As discussed in the previous chapter, both workplace safety and data security represent crucial concerns at the basis of Industry 4.0. It is hence important to make sure that production facilities and the products themselves don't endanger either people or the environment (sustainability issue). From here the need to safeguard facilities, products and the data and information they enclose, against misuse and/or unauthorized access and disclosure through the deployment of integrated security architectures.
5) *Work organization and design:* Industry 4.0 and smart factories have disrupted the role of employees, transforming the work content, processes and the working environment. A new approach to work organization is now required, one that is not only technical but also endows workers with the opportunity to enjoy greater responsibility and enhance their personal development, through the implementation of more participative work designs and the deployment of lifelong learning projects.
6) *Training and continuing professional development:* Appropriate training strategies should be implemented as well as a new, lifelong learning-fostering work organization. Digital learning techniques should also be investigated for future reference.
7) *Regulatory framework:* Another important action to be taken is the adaption of the existing legislation to take account of new innovations. The challenges include the protection of corporate as well as personal data, liability issues and trade restrictions. This will not only require legislative provisions, but also actions on behalf of businesses including guidelines, model contracts and company self-regulation initiatives (ex: audits).
8) *Resource efficiency:* While on one hand, Industrie 4.0 will deliver gains in terms of resource productivity and efficiency, on the other it will also be necessary to evaluate the trade-offs between these potentially generated savings and the additional resources that will need to be invested in smart factories.

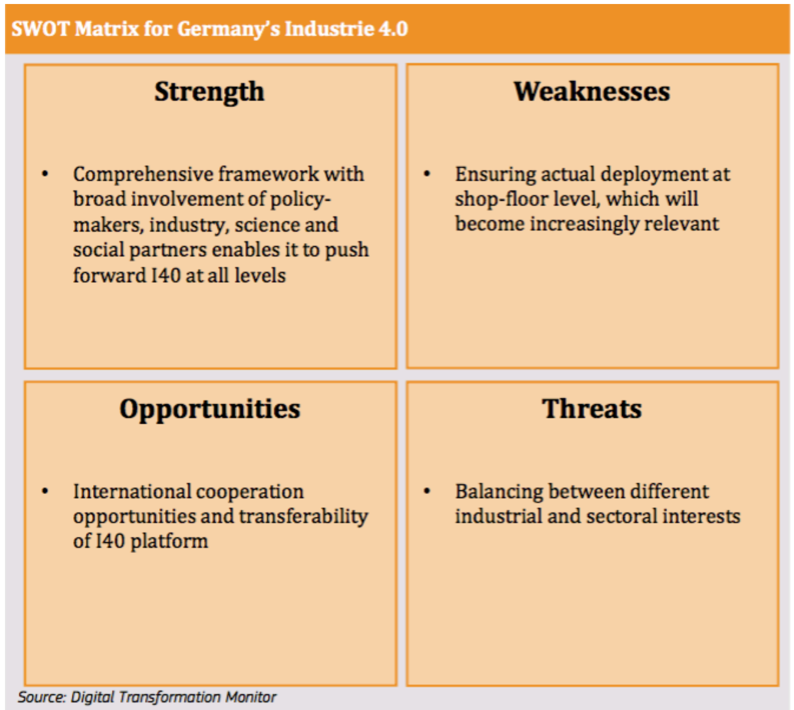


Figure 2.1: SWOT analysis for INDUSTRIE 4.0. (Source: *European Commission, 2017*)

The Boston Consulting Group expects productivity benefits to reach 90-150 billion euros over the next 5-10 years. According to the European Commission Industrie 4.0, being launched in 2011, has moved to mainstream in terms of collaboration and implementation in a very short time-span. The program has been successful in transferring research into practice for example by supporting testbeds and a reference architecture, even if it is still in stage one. Since its launch the initiative had already been considerably scaled up at the national level, in terms of transferability, the platform could also be considered by many countries as a model to follow and adapt to nation industry structures, features and workforce qualification [*Germany Industrie 4.0.,* 2017].

Germany however, is not the only country to have recognized the opportunities in deploying the new technological paradigm in manufacturing industry. Global competitors are also joining the race towards digitization and Asia does not represent the only threat to Germany anymore.

The US are also fighting de-industrialization through “advanced manufacturing” programs. But before analyzing these cases, let’s take a look at what our country is doing to keep up with the times.

2.2 The Case Of Italy: Il "Piano Nazionale Industria 4.0"

The Italian industrial system is much different from the German one, there are only a few big private industrial players to lead the manufacturing makeover, only a limited number of supply chain leaders with the ability to coordinate and guide the evolutionary process, an industrial system fundamentally characterized by SMEs, a couple key prestigious universities and research centers and a strong country of origin connotation of products[11].

The European Commission observed in the "Country Report 2016" that:

> *"[In Italy] productivity growth is stagnant mainly because of the persistent presence of structural obstacles to the efficient allocation of resources in the economy."*

The Commission also stated that:

> *"The currently underway and planned structural reforms, will help overcome the barriers to investment, and will in time have a positive effect on productivity and GDP growth."*

Highlighting however, that the total productivity growth also critically depends on human capital and on the ability to innovate. The irrelevant and uncertain fiscal incentives on R&D activities, negatively affect private investments on innovation. Moreover, the Italian system for research and Innovation is characterized by a very insufficient cooperation between academia and the business world. The Italian House of Representatives conducted in 2016 a fact-finding survey where, after having analyzed the strengths and weaknesses of the Italian industrial system in terms of digitization and the opportunities and threats deriving from the global context, five main pillars upon which to build a national Industry 4.0 strategy are described, together with some operative recommendations:

1. Creation of a governing body and the identification of the goals to be achieved;
2. Realization of the enabling infrastructures by the implementation of the broadband Internet plan, the development and diffusion of fifth generation wireless connectivity, smart electric networks, Digital Innovation Hubs and a public digital administration;
3. Planning of a training and education system – both scholastic and post-degree – focused on the development of digital competences in all fields, including humanities.
4. Research reinforcement, both in terms of academic autonomy and international research centers;

[11] CAMERA DEI DEPUTATI, Temi dell'Attività parlamentare 2017. Available: http://www.camera.it/leg17/ [Oct 13, 2017].

5. Open innovation, based on open standards, interoperability and a system promoting Made in Italy, leveraging the opportunities provided by the Internet of Things.

   The Italian Minister of Economic Development Carlo Calenda, has described the National Plan in these terms:

"The Plan provides for a wide array of consistent and complementary measures promoting investment in innovation and competitiveness - all measures that have proved their effectiveness in the past have been strengthened under a "4.0" logic, and new measures have been introduced to meet new needs. […] we have planned measures that every company can put in place automatically […] and, above all, without any restrictions in terms of its size, sector or location. As demonstrated by the considerable financial resources that have been committed to the Plan in the coming years, this Government is offering enterprises that want to grow and innovate a new deal."

On September 21st 2016, the Government has issued the "Piano Nazionale Industria 4.0 2017-2020" the details of which we will analyze hereafter. The Plan presents some key guidelines for leading the change as well as some of complementary nature.

2.2.1 KEY GUIDELINES

1) **Innovative investments** (total private (24) and public (13[12]) investment: 37 € billion)

   The first urgent actions involve the subsidization of private investments on technology and Industry 4.0 products, the intensification of private expenditure on research, development and innovation and last – but not for importance – the enforcement of the financial support directed to Industry 4.0, Venture Capital and start-ups. The objectives currently being pursued in terms of investment are the following:

   - +10 € billions: a jump from 80 to 90 billion in 2017 in private investments;
   - +11,3 € billions: in R&D&I private expenditure focused mainly on I4.0 by 2020;
   - +2,6 € billions: in early-stage private investments by 2020.

   The main initiatives being implemented are:

   1) *Hyper-depreciation:* for depreciation purposes, investments in new tangible assets, devices and technologies enabling companies' transformation to "Industria 4.0" standards will be valued at 250% of the investment value.
   2) *Super-depreciation:* for depreciation purposes, investments will be valued at 140% of the investment value.

[12] Includes also the 2018-2024 values to cover for the 2017 private investments subjected to hyper and super-depreciation initiatives and capital goods.

Both hyper and super-depreciation support and offer incentives to companies that invest in new capital goods, tangible assets and intangible assets for the technological and digital transformation of their production processes, thus investing in growth.

3) *"Nuova Sabatini":* The Nuova Sabatini initiative offers more credit to those who innovate, supporting businesses requesting bank loans to invest in new capital goods, machinery, plant, factory equipment for use in production and digital technologies. It entails a contribution partially covering interest paid by business on bank loans of between 20,000 and 2,000,000 euros, granted by banks approved by the Ministry of Economic Development, and it's available to all micro, small and medium enterprises in Italy operating in any sector.
4) *Tax credit for R&D:* The Government deems it important to encourage private investment in Research and Development for product and process innovation and to ensure the competitiveness of enterprises in the future. This is why the Plan provides for a 50% tax credit on increases in R&D costs up to an annual limit of €20 million a year per recipient, estimated on the basis of the average expenditure on Research and Development between 2012-2014, even if companies experience losses. This provision too is aimed at rewarding those who invest in the future.
5) *Patent box:* Another optional special taxation system is applicable to income from the use of intangible assets: industrial patent rights, registered trademarks, industrial designs and models, copyrighted know-how and software. The reason for its establishment resides in the need to offer an incentive for bringing back to Italy intangible assets currently held abroad by Italian or foreign companies while making the Italian market more attractive to long-term domestic and international investors by offering a special rate of taxation for incomes deriving from the use of intellectual property rights.
6) *Innovative start-ups and SMEs:* A series of funding initiatives, exclusion from the application of some regulations and other facilitations have been devoted to the support of innovative enterprises at all stages of their life cycle and to the development of Italy's startup ecosystem as well as the spreading of a new business culture based on teamwork, innovation and openness towards international markets. The initiatives apply to newly-established unlisted limited companies with

an annual value of production below 5 million euros, whose company purpose is clearly related to innovation.

2) **Competences** (total private (200) and public (700) investment 900 € million)

The lack of specific know-how and competences has called for some measures to be taken:

- The diffusion of I4.0 culture through the "Digital School" and the "Work-School Alternation" initiatives;
- The development of I4.0 competences through the provision of specific curricula and dedicated technical high school institutes (objective: 200.000 university students and 3.000 managers specialized on I4.0 subjects);
- Research financing through the empowerment of Clusters and Doctorates (1.400 PhDs with I4.0 focus);
- Establishment of Competence Centers and Digital Innovation Hubs.

2.2.2 COMPLEMENTARY GUIDELINES

Other complementary initiatives entail:

- *Broadband Internet coverage:* 100% of businesses covered at 30 Mbps and at least 50% at 100 Mbps by 2020 through both private and public investments;
- *Fondo Centrale di Garanzia:* reform and re-funding for the year 2017 with focus on I4.0 investments coverage;
- *Made in Italy:* strong investment on digital sale chains and augmented support for SMEs;
- *Development contracts:* negotiation and supply of customized funding on the basis of ad hoc requirements;

Meanwhile, the Government also expressed its willingness to:

- Guarantee private investments;
- Fund the considerable innovation investments;
- Enforce and innovate the safeguard of international markets;
- Support the salary-productivity exchange through corporate decentralized contracting.

But first and foremost, the need to spread awareness represents a top priority, and the Government intends to take action by:

- ✓ Organize presentations and showings of recent technological advances for digital manufacturing, benefits, innovation, productivity and competitiveness gains, targeting business managers for SMEs;
- ✓ Plan an I4.0 roadshow with seminars for SMEs awareness;
- ✓ Targeted assistance for high-potential SMEs to guide the design and implementation of a transition plan toward I4.0;
- ✓ And finally, a national communication plan (both web and press).

Results as of the first semester of 2017 (Data from the Ministry of Economics and Finance)

- Increase in national orders for instrumental goods (+11,6% for machinery and others);
- +10%/+15% (sample pool) businesses which will increase R&D expenditure;
- Only a limited increase in early stage investments for the first semester (+2%);
- 3,5 € billion allocated for incentives and public intervention for new broadband infrastructure;
- +10,7% devoted to the "Fondo di Garanzia";
- 53.000 jobs created and safeguarded;
- Delays in Competence Centers foundation.

2.3 The Case Of The USA: "Manufacturing USA"

The United States has been the leading producer of manufactured goods for more than 100 years, but its ability in manufacturing innovation, which has so far sustained this leadership, is now threatened by new and growing competitors abroad. In order to fight for its position, in 2011 the first Advanced Manufacturing Partnership (AMP) was called for, establishing a National Network of Manufacturing Innovation Institutes (NNMI). The NNMI represents a set of public-private partnerships inaugurated in order to create high-tech facilities and expand the Country's leadership in emerging technologies, improving community-college workforce training programs to meet the new skill requirements and ameliorating the business climate to incentivize investments through tax, regulatory, energy and other policies [The President's Council of Advisors on Science and Technology, 2014].

Manufacturing USA represents the plan for leveraging the potential of Industry 4.0 in the U.S. and it is focused on coordinating public and private investment in emerging advanced technologies for production. It does not only involve the industrial sector, but brings together also academia, and government partners to get the best out of the Country's resources, collaborating and co-investing to boost manufacturing innovation and accelerate commerce. The desirable end result for this initiative is the creation of a competitive, effective and sustainable research-to-manufacturing infrastructure for U.S. industry and academia. The now expanding network consists of multiple connected Manufacturing Innovation Institutes (MIIs) with shared goals but distinctive technological concentrations. The shared contribution from the private and public sectors and academia, promises to set in motion the development of new technologies, educational competencies, digitized production processes and products.

In particular, the institutes will provide shared facilities to help local start-ups and SMEs adopt innovation developments, scale up their businesses and accelerate technology upgrade and transformation. Moreover, they will act as "teaching factories" to build workforce skills and to strengthen business capabilities for all companies regardless of their dimension [Marton, 2015].

The hope is for this national, integrated network to create a stimulating effect on the U.S. manufacturing sector on a large scale notwithstanding the regional focus of each institute belonging to the system. As a matter of fact – always according to Cara Marton – the institutes serve as technology hubs promoting both local and national interests, they complement each other and gain from shared resources and capabilities while encouraging further investments and production in their area and across the USA.

The program is designed to address the inconsistency in the Country's economic and innovation policy residing in the fact that federal investments in R&D and tax incentives are not matched by corresponding incentives to encourage domestic manufacture of the technologies and products that result from R&D activities. As reported in Manufacturing.gov, institute activities include applied research and demonstration projects that reduce the cost and risk of commercializing new technologies or that solve generic industrial problems.

As reported in the 2016 NNMI Strategic Plan:

> *"The backbone of the NNMI Program is the understanding that America is at its strongest when we work together and make full use of our human resources. Connected through each institute and through the larger network of institutes, communities of researchers enable cutting-edge production technologies to be readied for use by industry. These talented, knowledgeable, experienced professionals provide real- world training for the next generation of our industrial workforce — who will then, in turn, gain access to high-paying advanced manufacturing jobs."*

On the base of this testimony, the four major goals set for the NNMI Program are described in these terms:

Goal 1: Increase the competitiveness of U.S. manufacturing.

Goal 2: Facilitate the transition of innovative technologies into scalable, cost-effective, and high performing domestic manufacturing capabilities.

Goal 3: Accelerate the development of an advanced manufacturing workforce.

Goal 4: Support business models that help institutes to become stable and sustainable.

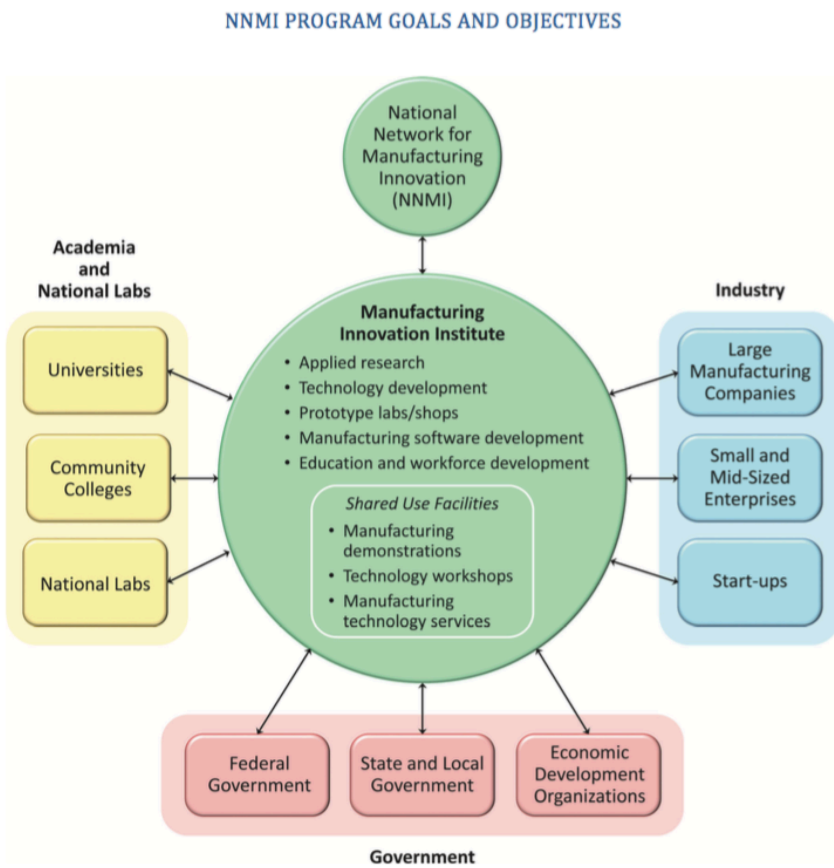


Figure 2.2: The Institute Ecosystem - Major Stakeholder Groups and their Interconnections. *(Source:* NNMI Strategic Plan, 2016)

The Advanced Manufacturing Partnership launched by the Obama administration in 2011, represents a national effort based on three fundamental pillars responsible of ensuring an ecosystem for advanced manufacturing leadership:

a) Enabling Innovation
b) Securing the Talent Pipeline and
c) Improving the Business Climate

For each of these pillars, a set of recommendations has been provided for the Plan to succeed.

Recommendations	Pillar 1: Enabling Innovation
Rec. 1)	**Establish a national strategy for securing U.S. advantage in emerging manufacturing technologies** with: ✓ coordinated initiatives across the public and private sectors and all stages of technology development ✓ leveraging the technology prioritization and analysis process developed by the AMP ✓ facilitate management of the portfolio of advanced manufacturing technology investments
Rec. 2)	**Create an Advanced Manufacturing Advisory Consortium** to provide coordinated private-sector input on national advanced manufacturing technology research and development priorities.
Rec. 3)	**Establish a new public-private manufacturing research and development infrastructure to support the innovation pipeline**, which complements Manufacturing Innovation Institutes (MII) to provide a framework that supports manufacturing innovation at different stages of maturity and allows small and medium-sized enterprises to benefit from these investments.
Rec. 4)	**Develop processes and standards** enabling: ✓ interoperability of manufacturing technologies ✓ exchange of materials and manufacturing process information ✓ certification of cybersecurity processes for developers of systems
Rec. 5)	**Create a shared National Network for Manufacturing Innovation (NNMI) governance structure** that can ensure a return on investment for the NNMI's many stakeholders

Table 2.1: recommendations to enable innovation. (*Source:* AMP 2014 final report)

Recommendations	Pillar 2: Securing the Talent Pipeline
Rec. 6)	**Launch a national campaign** to change the image of manufacturing and showcase real careers in today's manufacturing sector.
Rec. 7)	Incent private investment in the implementation of **a system of nationally recognized, portable, and stackable skill certifications** that employers utilize in hiring and promotion
Rec. 8)	**Make the development of online training and accreditation programs eligible to receive federal support**

Rec. 9)	Curate the documents, toolkits and playbooks that have been created by AMP2.0 to further **scale and replicate these important talent development opportunities**, via the Manufacturing Institute.

Table 2.2: Recommendations to secure the talent pipeline. (*Source:* AMP 2014 final report)

Recommendations	**Pillar 3: Improving the Business Climate**
Rec. 10)	**Leverage and coordinate existing federal, state, industry group and private intermediary organizations** to improve information flow about technologies, markets and supply chains to small and medium-sized manufacturers
Rec. 11)	**Reduce the risk associated with scale-up of advanced manufacturing** by improving access to capital through: ✓ the creation of a public-private scale-up investment fund ✓ the improvement in information flow between strategic partners, government and manufacturers ✓ the use of tax incentives to foster manufacturing investments

Table 2.3: Recommendations to improve the Business Climate. (*Source:* AMP 2014 final report)

The three pillars and the related recommendations are not hierarchically ordered, instead they complement and reinforce each other and they're individually important for securing the U.S. leadership in advanced manufacturing and innovation. For the Plan to operate properly though, the Advanced Manufacturing Partnership 2.0 has addressed a final recommendation to the federal government: to specify the ongoing Executive Office of the President (EOP) role in coordinating the federal government's advanced manufacturing activities and to clarify the roles and responsibilities for federal agencies and other federal bodies in implementing the above recommendations [AMP final report, 2014].

2.4 The Case of China: "Made In China 2025"

The case of China is peculiar because the need to launch an Industry 4.0 strategic plan was dictated more by the need to keep up and solve some internal issues, than the one to protect a leadership position, even though the latter certainly contributed.

As a matter of fact, the Chinese economy was growing strongly over the last decade. The manufacturing turnover between 2006-2016 was expanding in real terms at a CAGR of 10%, where the major driver of growth was the production of intermediate and high-tech goods. In comparison, today's growth pace of the manufacturing sector is slowing dramatically, decelerating to just 5% last year, against the yearly 20% of a decade ago [Lasinskas, 2017].

The main Chinese strength had been for years its low-cost labor force which yield the Country's reputation of "factory of the world", but in the last decade or so, China registered rapidly rising wages making it less convenient to foreign investors as compared to its neighbors in Southeast Asia. But as wages continue to rise, China finds itself caught between competing with low-cost developing countries and advanced economies and its low-skilled, low-cost manufacturing model is no longer sustainable. From here the necessity to find new growth opportunities to drive growth in the post-cheap costs era [Lasinskas, 2017].

China's manufacturing industry still has many strengths to capitalize on as it goes through this transition[13]:

- Well-developed infrastructure;
- Accessibility to partners in the dynamic Southeast Asian region;
- Growing demand from a domestic consumer class.

As of today though, Chinese enterprises only use an average of 49 industrial robots every 10,000 employees, which is close to the Asia average but far below the European (92) and American (86). For all these years in 2015 was announced the "Made in China 2025" (or MIC 2025) plan, a ten-year blueprint aimed at transforming China into an advanced manufacturing leader. It targets ten strategic industries that constitute about 40% of the Country's entire industrial value-added manufacturing, and aims at using state resources to create a global scale competitive advantage in those sectors [U.S. Chamber of Commerce, 2017].

According to the same source, the main goals to be achieved consist in:

- The promotion of in-house innovation;
- The development of domestic brands;
- Secure and controllable standards;
- Localization of production and data.

The underlying intention is to improve indigenous research and development in order to double self-sufficiency rates for core infrastructure components and materials and to increase the market share of domestic intellectual property for high-value equipment.

[13] INTOUCH MANUFACTURING SERVICES. Made in China 2025: China's push for Global competitiveness in advanced manufacturing. [2017]

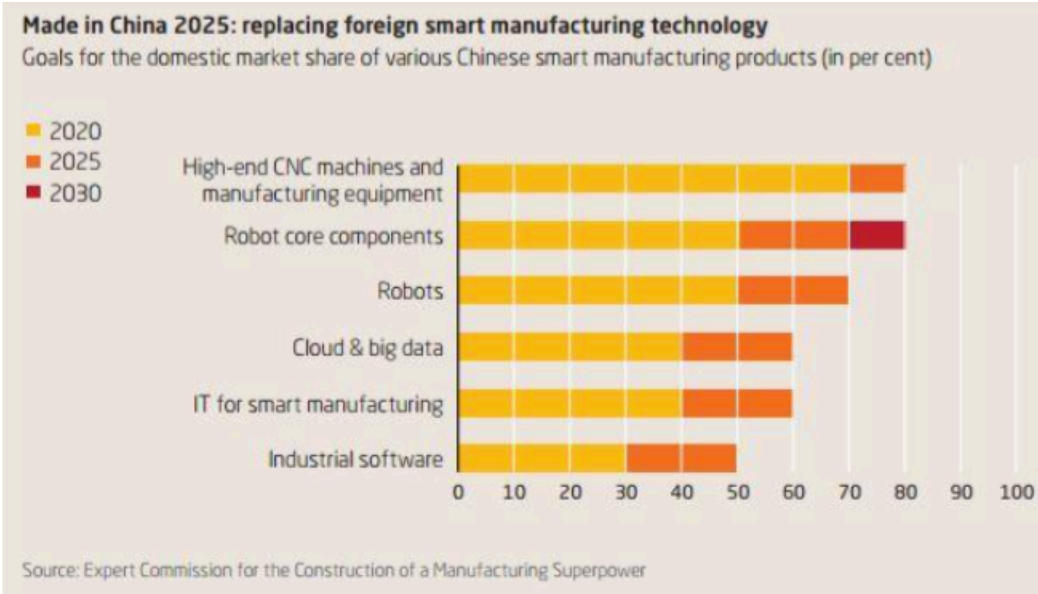


Figure 2.3: foreign smart manufacturing technology replacement. (*Source:* U.S. Chamber of Commerce, 2017)

At present, China is lacking self-sufficiency in high-end materials and relies on other countries for critical technology, this is why it is a major concern to focus on domestic innovation to cut this dependence on foreign companies.

More specifically – as reported in MIC 2025 and the related plans – China intends to become a global leader in the manufacturing of high-quality and high-tech products, and plans to achieve its goal by implementing a three-step strategy process:

I. *Localize and indigenize* strongly supporting Chinese companies in their efforts to develop indigenous intellectual property, brands and technology.

II. *Substitution* of the dependence on foreign technology with internal development and production.

III. After having developed its own technology and brands, the plan is to *capture domestic and global market share* across the targeted industries.

The instruments that the country is now utilizing are [Jost Wübbeke, et al. 2016]:

- Top-down policy campaigns with forward-looking strategic planning, which have a powerful effect on attracting widespread attention throughout the country in a short time;
- Significant government funds and subsidies: the 2.7-billion-euro Advanced Manufacturing Fund was established and it has already started to make investments. Globally, China allocated $23.1 billion for MIC 2025 ($2.9 billion for the Advanced Manufacturing Fund

and $20.2 billion for the National Integrated Circuit Fund), which greatly surpasses the budget of other big spenders like Germany ($213 M) and the U.S. ($70 M) [InTouch manufacturing services, 2017];

- Mergers and acquisitions of international high-tech companies by Chinese investors;
- Increased R&D funding: the percentage of R&D funds of large manufacturing companies should increase from 0.95% to 1.68% by 2025. From 2013 to 2015 Chinese inventors registered more than 2,500 patents for Industry 4.0-enabling technologies, even though only 30% of research is being put in practice in China (versus as much as 70% for advanced economies) [InTouch manufacturing services, 2017];
- Adoption of preferential taxation policies to stimulate further growth in the targeted sectors:
  - Extension of the Enterprise Income Tax Law policies enacted in 2007
  - Important high-tech enterprises that are deemed necessary to be supported by the state also benefit from a reduced tax rate of 15% (as compared to the standard 25%)

Summarizing, the target industries, the goals and projects all rely on technological advances, the promotion and spreading of smart manufacturing technology represent the cornerstone of the MIC 2025 plan. However, in order to gain that leading position, the long-term focus should be directed to the replacement of imports of foreign technology with domestically produced technology.

Strengths

- Mobilisation capacity of policy initiative;
- Long-term planning orientation;
- Generous funding;
- Local experimentation;
- Strong local initiatives;
- China's ability to develop innovative products.

Weaknesses

- Mismatch between political priorities and industry needs;
- Fixation on quantitative targets;
- Inefficient allocation of unding and overspending by local governments;
- Overall downward pressure on Chinese economy
- The upgrading process will likely result in job losses among low-skilled labour;
- Shortage of skilled labour;
- Chinese education system is not adequately equipped to educate high-skilled workers;
- Lack of bottom-up initiative and investment as the plan is still largely promoted from the state. Enterprises still opt for low-cost, low-risk solutions;
- Chinese enterprises rely on the state for market dominance, no market forces are pressuring them to modernize.

Challenges

- The economic slowdown affects and delays the willingness to invest and purchase new equipment;
- Need to provide a basis of high-skilled workers;
- Impending ley-offs due to automation, large-scale dismissals;
- China must overcome its current technological gap;
- Chinese suppliers will need to catch up in order to be able to meet demand for smart manufacturing technology

Figure 2.4: strengths, weaknesses and challenges of MIC 2025

The actualization of the Made in China 2025 will have widespread implications for China's economy, government and population. If the plan turns out successful, advanced economies will be forced to take into consideration one more competitor, but in the short term foreign companies will most likely benefit by filling China's technological gap. On the other hand, developing countries like India, Thailand, Vietnam and others, will probably see more opportunities as foreign firms decide to move low-cost manufacturing outside China [InTouch, 2017].

Divergent opinions on the strategy's possibility for a successful outcome

According to the U.S. report (2017) on MIC 2025, it seems likely that the Chinese strategy will succeed in raising a small front of manufacturers to a higher level of efficiency and productivity who are expected to dominate their sectors internally as well as become fierce competitors on the international markets.

On the downside, the U.S. Chamber of Commerce believes that the strategy will probably fail in realizing a broad-scale technological upgrading across the Chinese economy because of the many drawbacks it entails including the mismatch between political and industry priorities, inefficient funding allocation and campaign-style overspending, which add up to the lack of bottom-up initiative and investment. Considering also the current state of the Country's economy, an upgrade will most certainly cause the lay-off of many of the less-skilled workers while the demand for high-skilled ones will surpass the educational system's capacity of training new capable personnel in time to meet that demand. As a result, the timeframe set by the Chinese government to achieve its strategic goal, appears to be a little too ambitious.

However, all in all despite the over-mentioned weaknesses, MIC 2025 still represents an influential challenge to the leading economies which will have to cope with the Chinese move when making future decisions.

The following Exhibit summarizes the key features of the plans and initiatives discussed in this chapter:

COUNTRY	***PLAN DESCRIPTION***	***ACTIONS***	***BUDGET***
GERMANY	***"Industrie 4.0"*** is an action plan sponsored at Federal level with the involvement of big industrial and technological players. Dual strategy: ✓ Leading supplier; ✓ Leading market.	✓ Financing of business projects and applied research centers, support of testbeds; ✓ Tax benefits for investments in technological start-ups.	€200 million public investment complemented by in-kind contributions by industry. *Source:* Key lessons from national industry 4.0 policy initiatives in Europe. (2017)
ITALY	***"Piano Nazionale Industria 4.0"*** is a government initiative providing a wide array of measures to promote investment in innovation and competitiveness on the part of enterprises that want to grow no-matter their size.	✓ Hyper and super-depreciation; ✓ Nuova Sabatini (more credit allowed); ✓ Tax credit for R&D and special taxation system for industrial patent rights; ✓ Funding initiatives for innovative start-ups and SMEs;	€45 million (public investment of 34M and 11M in private funding) *Source:* Key lessons from national industry 4.0 policy initiatives in Europe. (2017)

		✓ Competences building and awareness spreading initiatives	
U.S.A.	***"Manufacturing USA"*** is a plan promoted by the government and financed by private-public partnerships to build a national network involving labs, academia and the industrial sector	✓ Public support to research projects; ✓ NNMI establishment; ✓ Talent creation and development opportunities; ✓ Improvement of business climate.	– $70-120M federal investment per institute over 5/7 years; – $481M in private funding *Source:* National Institute of Standards and Technology (2015)
CHINA	***"Made in China 2025"*** is a ten-year blueprint aimed at transforming China into an advanced manufacturing leader	✓ Government funds and subsidies; ✓ Preferential taxation policies; ✓ M&A of international high-tech companies by Chinese investors.	$23 billion of which: – $2.9 billion for the Advanced Manufacturing Fund and – $20 billion for the National Integrated Circuit Fund. *Source:* InTouch manufacturing services (2017)

Table 2.4: National plans summary

3. IMPLICATIONS FOR LABOR

"One machine can do the work of fifty men. No machine can do the work of one extraordinary man." (Elbert Hubbard)

DOES HISTORY REPEAT ITSELF?

As acknowledged in the past chapters, and endorsed by the already mentioned Brynjolfsson and McAfee (2011), the pace of technological innovation and adoption is increasing exponentially, allowing for more sophisticated software systems to disrupt labor markets by making workers redundant. Needless to say, literature has been discussing the issue of substitution of human workers and unemployment extensively in the last couple decades, raising concern for the possibility of a – maybe not too far away – future where workers might see their jobs disappear and their skills become useless. This apprehension over technological unemployment is hardly a recent phenomenon. We've seen in the first chapter how history seems to repeat itself and creative inventions and advances have created throughout history enormous wealth, but also unwanted disruptions. The limits to economic development were never in the lack of ingenious ideas but rather resided in powerful social and economic interests obstructing any change in the status quo [Schumpeter, 1962]. The "Luddite" riots between 1811 and 1816 are a good example of how innovations are more often than not followed by manifestations of fear of change and its repercussions on workers. These demonstrations of rejection though, only slowed things down but eventually, although new technologies at the time made the skills of artisans obsolete, gains from technological progress gradually benefited a growing share of the labor force [Goos and Manning, 2003]. The advent of textile machines, negatively affected many workers, but the Industrial Revolution laid the groundwork for Ford's mass production decades later.

The current equivalent of the 19th century riots can be seen in taxi drivers today demonstrating against driverless cars and Uber, or the millions of employees around the world working on assembly lines soon to be upgraded with robots and intelligent machines. As remarked by Brown and Buntz (2017), the basic fear now is the same as it was then: "Humans are making themselves obsolete". Now, how technological progress in the 21st century will impact labor markets outcomes, remains to be seen.

3.1 Impact On The Workforce

It's hard to determine what will happen in the future, and how the dynamics of the labor market will unfold, but literature is filled with opinions on the matter and estimates based on different assumptions. It's not the purpose of this paper to deliver an extensive evaluation of these opinions, nor to deliver our own, but we will discuss here the most recurrent and accredited ones.

In general, literature experts' sentiments can be roughly assigned to two broad categories: the catastrophists and the innovation militants [Magone e Mazali, 2016].

3.1.1 Catastrophists

One of the most cited works is a recent report by the McKinsey Global Institute [Manyika et al., 2017], found that automation technology will replace about 5% of all jobs globally, and 49% of all tasks currently being accomplished by workers, at all levels, can be automated by 2055 considering only the technology that exists today. Brynjolfsson and McAfee (2014) stressed that the ever so rapid development and spreading of digital technologies leads to an increasingly widening gap between technology demand and the usually slower socio-economic adaptation mechanisms. On the same line, in the early 30s John Maynard Keynes anticipated a widespread technological unemployment driven by the inability of society to find new uses for labor with the same pace at which innovative means of economizing the use of labor are discovered. Motivated by Keynes, Frey and Osborne (2013) build upon this idea analyzing the US labor market, which shows that a very significant possibility for job losses may be strongly linked with digital technologies. Focusing on potential job automatization over an unspecified period of time, according to their estimates about 47% of total US employment is in the high-risk category where "high-risk" means that they expect that they could be automated perhaps over the next decade or two. This category comprises workers in transportation and logistics, office and administrative support, and those employed in production occupations. In particular, the authors speak of two waves. The first wave consists in the substitution of primarily routinizable and at least partially non-routinized activities by technologies. As a matter of fact, over the past decades, robots have taken over the routine tasks of most workers in manufacturing, recently though even non-routine manual tasks are being jeopardized by more advanced robots equipped with enhanced sensors and manipulators.

A second wave of automation is expected to spread to activities encompassing also creative and socially interactive tasks as algorithms for big data are today able to recognize patterns and substitute human labor in a wide range of non-routine cognitive tasks. Finally, Frey and Osborne have also found that a substantial share of employment in service occupations is today highly vulnerable to computerization.

A similar analysis but for the European labor market was conducted by Bowles (2014) who calculated similar high job substitution threats, with more than 51% of activities at risk of being replaced in the long term (mainly transport and storage activities, auxiliary personnel and office jobs). However, the majority of mentioned authors, with different intensity, agree on the fact that we should not expect abrupt job losses but rather a slow substitution process that will lead eventually to the illustrated consequences.

3.1.2 INNOVATION MILITANTS

On the other hand, there is also a good part of literature that believes short-term negative employment effects due to technological advancement, are always going to be compensated in the long run with efficiency gains such as innovative or customized products, new markets and new, more complex, but also more gratifying employment opportunities [Hirsch-Kreinsen, 2016].

Among those with a brighter opinion on our future, Ingo Ruhmann – special adviser on IT systems at Germany's Federal Ministry of Education – states:

> *"Complete automation is not realistic. Technology will mainly increase productivity through physical and digital assistance systems, not the replacement of human labor."*

Staying with this view point, according to a 2015 Boston Consulting Group study, it seems like what will decrease in the future is the number of routine or physically demanding jobs, while instead we will probably witness an increasing demand for jobs requiring problem solving, customization and flexible responses [Lorenz et al. 2015]. The BCG analysis on German manufacturing found that the growth stimulated by Industry 4.0 will lead to a 6% increase in employment over the next decade. At a similar conclusion arrive Spath et al. (2013), claiming that the great majority of industrial enterprises in Germany, believe that human labor will – in the next few years – remain significant in industrial production and not be reduced. This will go hand in hand with the generally high productivity gains and economic growth rates predicted by Bauer et al. (2015). In support of this thesis, a 2014 study by Evangelista et al. concluded that it is not that easy to attribute causal effects on employment to the advent of new technologies and that the adoption of the same has little clear impact on employment.

Tullio Tollio – professor at the Politecnico di Milano and president of the scientific committee at the National Smart Factory Cluster – expressed himself in these terms [Magone and Mazali, 2016]:

> *"We have long believed that some things could be done by men and others by automation, but I believe that in the future man and automation will work together. If I think of the evolutionary factory I think of men, because only men can ensure change, machines are not able to change."*

Brynjolfsson and McAfee (2014), although having stressed the problem of a widening gap between technological adoption and socio-economic adaption, believe that as of now jobs that require emotional, creative, intellectual and problem-solving skills, remain outside machines' "domain of power". Similarly, Baldassari and Roux (2017) underline how the automation of simple activities will have the positive outcome of freeing up time for more creativity and value creation and hence don't see Industry 4.0 reducing jobs, but rather creating different ones. A recent piece in Forbes magazine by Harold Sirkin on the role of advanced manufacturing, speaks in these terms:

> *"Many people fear the new labor-saving technologies; they know only too well that jobs will be lost, particularly factory jobs. They don't seem to realize, or don't seem to care, that new jobs also will be created – and that on balance there should be more new jobs than lost jobs. But the new jobs will require different skills. And many of today's industrial workers don't have those skills."*

According to Brown and Buntz (2017) instead, the current job skillsets may just need an upgrade rather than a complete revamp, so that the challenge would be on integrating an interface into a job versus starting from scratch, adapting previous tools, infrastructure and skills to take full advantage of new technologies. Therefore, the authors suggest focusing on the upgrade of what is already at our disposal, to make the most of the new paradigm.

All things considered, although substantial empirical studies are lacking, in literature an optimistic view of the long-term employment effects of digital technologies appears to prevail [Hirsch-Kreinsen, 2016].

An equilibrated view is proposed by the BCG 2015 report where the employment of robotics will on one hand, significantly reduce the number of jobs on the shop floor, and on the other will allow manufacturers to deploy new business models that promote job creation. Current jobs will be updated and entirely new job families will be created while others become obsolete. Always according to this report, BCG found universal agreement that manufacturers will increasingly adopt robotics and other advancements but will mainly use it to assist workers.

3.2 POSSIBLE EFFECTS OF INDUSTRY 4.0 ON THE WORKFORCE

Algorithms based on historical data that identify product and process failures, flexible robots that assemble and pack, fully automated transportation systems that navigate intelligently within the factory, self-coordinating machines that organize production, 3-D printers that create complex parts in one step making assembly redundant, all these have radically changed the working environment and the role of the workforce. Many empirical studies have tried to quantify the actual effect of Industry 4.0 on employment, we'll discuss hereafter some of the results they've produced.
The already mentioned 2015 BCG study, set its objective on finding how Industry 4.0 will affect the evolution of Germany's industrial workforce from 2015 through 2025 and obtained the following insights:

- Significant productivity gains will result from the current adoption rate of technological advancements reducing the number of workers needed to achieve a given level of output. Some jobs will be lost but the intensity of cooperation between humans and machines will increase notably;
- The source suggests that German companies will welcome Industry 4.0 to generate additional growth of 1% per year with an adoption rate of 50%. If this is the case, then it will lead to a net increase of about 350,000 jobs;
- The reduction in assembly and production jobs of approximately 610,000 due to robotics and computerization, will be more than offset by the creation of about 960,000 new jobs;
- The job gains will be the result of an increase in demand for an additional 210,000 high-skilled workers in information technology, analytics and R&D as well as another 760,000 new jobs created on the basis of the cited revenue growth opportunities;
- The number of jobs in IT and data integration will nearly double (+110,000 jobs, a +96% increase for this category). The same will happen for R&D jobs.
- Industrial data scientist will be the job function experiencing the highest growth, given the

great importance of data in the context of Industry 4.0;

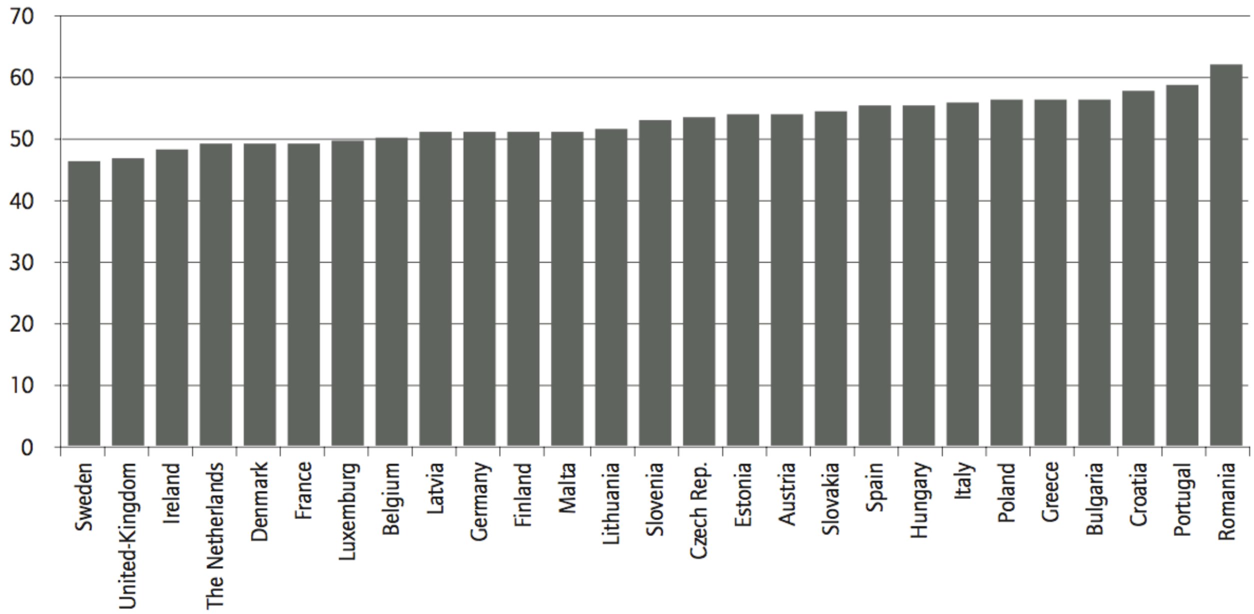
- Another new role that manufacturers will need to create is of robot coordinator accounting for an additional 40,000 jobs;
- On the flip side of the coin, workers who perform simple and repetitive tasks that can be standardized, will most certainly see themselves replaced by machines. Job losses will reach: 120,000 (4%) in production, 20,000 (8%) in quality control, and up to 10,000 (7%) in maintenance;
- Routine cognitive work will also be affected (ex: more than 20,000 jobs in production planning will be eliminated;
- The expanding market for smart machines will, on the other hand, allow manufacturers of this technology to add 70,000 jobs to their workforce.

Job Family	**Net Employment (thousands)**
Office and Administrative	-4,759
Manufacturing and Production	-1,609
Construction and Extraction	-497
Arts, Design, Entertainment, Sports and Media	-151
Legal	-109
Installation and Maintenance	-40
Business and Financial Operations	+492
Management	+416
Computer and Mathematical	+405
Architecture and Engineering	+339
Sales and Related	+303
Education and Training	+66

Table 3.1: Net employment by job family 2015-2020 (based *on "The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution", 2016)*

As of the percentage of jobs that "will be lost", we've seen how Frey and Osborne (2013) estimated a 47% high-risk share of the total US employment. Applying the same methodology to the European situation, Bowles (2014) conducted a study from which it emerged that advances in technology will impact a proportion of the EU workforce ranging from the mid-40% up to over 60%. Despite the 54% average, peripheral countries such as Romania, Bulgaria, Portugal and Greece, will be the most negatively affected, whereas Germany, Belgium, France, the UK and other countries in the center and north part of the EU would be less affected.

The following Figure by Degryse (2016) summarizes the percentages by country.



Source: Bruegel calculations based on Frey & Osborne (2013), ILO, EU Labour Force Survey

Figure 3.1: Percentage of EU jobs at risk of computerization by country (Source: *Degryse, 2016)*

The following table considers a classifications of job categories by risk of automation or digitalization as well as a list of new jobs as proposed by Degryse (2016):

Jobs at greatest risk of automation/ digitalisation	Jobs at least risk of automation/ digitalisation	New jobs
Office work and clerical tasks	Education, arts and media	**'Top of the scale'**
Sales and commerce	Legal services	Data analysts, data miners, data architects
Transport, logistics	Management, human resources management	Software and application developers
Manufacturing industry	Business	Specialists in networking, artificial intelligence, etc.
Construction	Some aspects of financial services	Designers and producers of new intelligent machines, robots and 3D printers
Some aspects of financial services	Health service providers	Digital marketing and e-commerce specialists
Some types of services (translation, tax consultancy, etc.)	Computer workers, engineers and scientists	**'Bottom of the scale'**
	Some types of services (social work, hairdressing, beauty care, etc.)	Digital 'galley slaves' (data entry or filter workers) and other 'mechanical Turks' working on the digital platforms (see below)
		Uber drivers, casual odd-jobbing (repairs, home improvement, pet care, etc.) in the 'collaborative' economy

Source: Christophe Degryse (ETUI 2016) on the basis of data from Frey & Osborne, Ford, Valsamis, Irani, Head, Babinet

Figure 3.2: Jobs in the digital economy (Source: *Degryse, 2016)*

The World Economic Forum issued last year a new report "The Future of Jobs" based on a survey of chief human resources officers and top strategy executives from companies covering fifteen of the world's largest economies. The report illustrates an overall 7.1 million-loss in jobs over the next 5 years mainly in white-collar office and administrative roles. In accordance with previously mentioned studies, also this one predicts the loss will be at least partially offset by the creation of 2.1 million new jobs (mostly in classes comprising computer, mathematical, architecture and engineering skills). It is however important to consider that the impact will differ significantly across industries and job category. The most negative repercussion – according to the WEF – is expected to hit employment in Healthcare, Energy and Financial Services and Investors, instead most jobs will be created in Information, Communication Technology, Professional Services and Media and Entertainment.

Another critical remark the study makes, specifies that although "the burden of job losses seems to fall equally on women (48%) and men (52%), [...] given that men represent a larger share of the overall job market than women, this even spread translates into a widening of the employment gender gap, with women losing five jobs for every job gained compared with men losing three jobs for every job gained." [Cann, 2016].

Concluding, there are not enough elements to agree neither with the catastrophists nor with the super-enthusiasts, it seems overall more likely that the final outcome will be somewhere in between those scenarios. What we do know now, is that the tasks attributed to workers and their education and training will look different in the future. We should therefore focus on how "traditional industry" and the digital world are coming together and, most importantly, what are going to be the effects on operators, technicians and at large on the organizational structure.

It is indeed unequivocal, that there's never been a better time to be a worker with special skills or a right education (where by 'right' we mean well-fit with the changes taking place), because these people can use technology to create and capture the value that it offers. On the other hand, there's never been a worse time to be a worker with only 'ordinary' skills to offer, because they will soon be substituted with computers, robots and other digital technologies that are acquiring those abilities at an extraordinary rate [Brynjolfsson and McAfee, 2014].

In the next paragraphs, we'll try to define a framework of the 'most wanted' skills on the labor market today and those that will be required in the future, we'll also describe the characteristics of the new augmented worker and some new roles that we'll see turn up on the shop floor.

3.3 A New Factory Concept Will Need a New Set Of Skills

As we have seen from the first two chapters, developed economies are increasingly investing in smart technologies in order to drive growth, productivity and to stay competitive in the global market. The direct consequence of the factory upgrade is the requirement of a more qualified personnel within the manufacturing industry. As a matter of fact, in order to run the new sophisticated systems and to analyze data either collected on the shop floor or received from partners and consumers, companies will need a solid base of skilled workforce. This human resource infrastructure will have to be trained in cross-functional areas and have managing and information processing abilities. A workforce responding to these credentials will never be redundant, in fact – as Gehrke, et al. (2015) put it – "the role of the human factor in the advanced manufacturing of the future is of increased significance", and the key factor of success of a highly innovative factory undeniably resides in these qualifications.

3.3.1 A Pyramidal Model To Derive Skills and Qualifications

A 2015 conference paper by Gehrke et al., produced a three-tier pyramidal model to derive recommended skills and qualifications for workers in the factory of the future. The approach consists of a bottom tier (tier no. 3), which constitutes the basis for the 2nd tier, which in turn represents the basis for the 1st one (see the following Figure for reference).

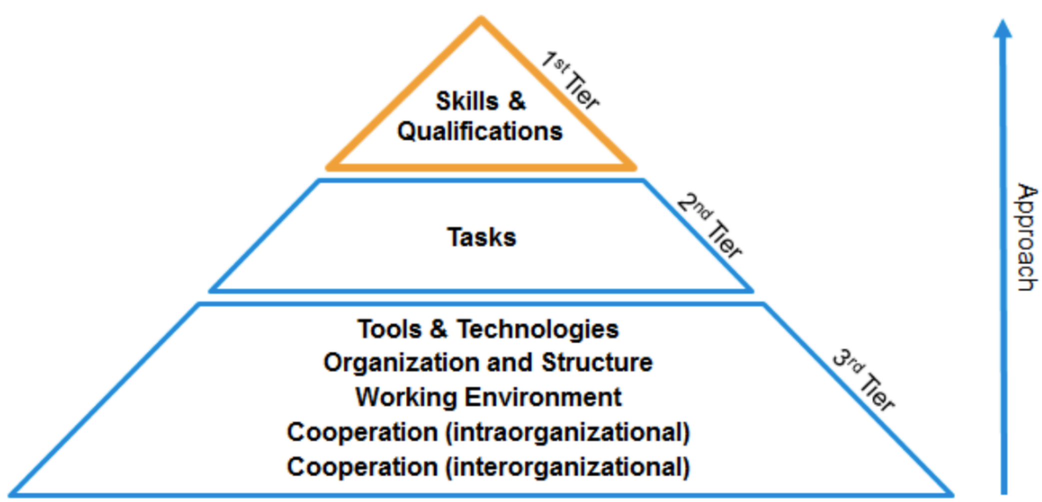


Figure 3.3:Pyramidal model for skills recommendation (Source: Lars Gehrke, et al., 2015)

TIER 3: The base of the pyramid represents four fundamental changes of the factory of the future that the authors believe will have a strong impact on the human factor:

a) *Tools and Technologies:* in the smart factory, humans will have to share the work station with robots sensitive and clever enough to be capable of collaborating with their human counterpart. They will take over easy tasks, giving workers time to focus on more qualified ones. However, the autonomy and automation of machines will not outweigh the role of the staff, in fact personnel supervision over the efficient functioning of machines will become more important than ever before;
b) *Organization and Structure:* advanced tools and technologies though won't do the trick if they're not embedded in the appropriate company structure and organization. From here the necessity to provide for a well-suited, systematic re-configuration of the enterprise environment, which contemplates a more flexible, changeable and decentralized organization. More specifically, in the factory of the future qualified workers will not be limited to a single production area anymore, the smart devices they will handle daily will enable job rotation and job enrichment with ease. Operators will also have more responsibility and decision-making power, problem solving – says Bauernhansl (2014) – will be done in collaboration with all participating parties on the shop floor without much influence of a higher hierarchy, hence making the structure of companies flatter;
c) *Working Environment:* technologies and data sharing will also enable larger shifts or working day flexibility, hence improving the work-life balance. The already popular trend of office working will be even more encouraged. Shared control rooms for the supervision of production processes by virtue of team work will also most likely become a norm. Work on the shop floor instead will be improved in terms of ergonomics making it easier, quicker and less physically demanding for employees to perform their tasks;
d) *Intra-organizational and Inter-organizational Cooperation:* the workers of the future will be utilizing smart devices capable of connecting them in real-time with their co-workers and machines whenever and wherever, all information and data will be available at their fingertips. This possibility will enable a significant step forward in intra-organizational and inter-organizational cooperation and communication both along the vertical and horizontal organization and value-chain. Pervasive connectedness will also allow for workshops, training sessions and meetings to be effectuated within the cyberspace. In Industry 4.0 factories, communication goes beyond man-to-man communication to include also man-to-

machine data exchange entailing all kinds of cyber-physical systems (such as robots, machines, or products).

TIER 2: The second tier of the approach proposed by Gehrke et al. provides an insight on **tasks**. According to the authors, the skilled workforce of the future will enjoy a greater task variety as compared to today. Most physically challenging and repetitive activities will be brought to a minimum if not entirely eliminated, leaving skilled labor more time to perform more creative/qualified tasks. They will instead be assigned work involving a great deal of data processing, as information flow will occupy a central role in the smart factory. The skilled worker will be assisted by new devices and software systems for the collection and elaboration of data flows but will also have to closely work in team with his/her peers. Interaction will not be restricted to human co-workers anymore – as already mentioned – but operators will also be able communicate with their intelligent partners with voice command, gestures as well as conventional knobs and switches.

TIER 1: On the basis of the tasks that workers will be performing, the acquisition of specific **skills** and qualifications is recommended by literature experts.

New skills do not imply the elimination of today's credentials, it means conversely that skills that will become important in the future will complement the existing set of qualifications. In particular, requirements will consist in two categories:

- *Technical skills:* IT knowledge, information and data processing and analytics understanding, the ability to interact proficiently with advanced interfaces and modern machinery and the like. Not compulsory but certainly valued are computer programming and coding abilities;
- *Soft skills:* social and communication skills will also become fundamentally useful as well as team working and self-management abilities for the reasons we've mentioned describing tier 2.

Generally speaking a trust in new technologies and assistance systems will be unavoidable together with a universally accepted mindset of continuous improvement and lifelong learning, as changes in the industrial ecosystem will become increasingly profound [Gehrke et al., 2015].

The following Table combines together the necessary, useful and accessory qualifications for a worker in the factory of the future.

	Must	Should	Could
	be included in the skillset of the skilled labor of the future.		
Technical Q&S	IT knowledge and abilities	Knowledge Management	Computer programming/coding abilities
	Data and information processing and analytics	Interdisciplinary / generic knowledge about technologies and organizations	Specialized knowledge about technologies
	Statistical knowledge	Specialized knowledge of manufacturing activities and processes	Awareness for ergonomics
	Organizational and processual understanding	Awareness for IT security and data protection	Understanding of legal affairs
	Ability to interact with modern interfaces (human-machine / human-robot)		
Personal Q&S	Self- and time management	Trust in new technologies	
	Adaptability and ability to change	Mindset for continuous improvement and lifelong learning	
	Team working abilities		
	Social skills		
	Communication skills		

Table 3.2: Qualifications and skills of the worker in the factory of the future (Source: Gehrke, et al., 2015)

Therefore, Industry 4.0 workers will have to combine specific job know-how with IT competences that go from basic familiarity with spreadsheets and interfaces, to more advanced programming and analytics skills. The before illustrated 'soft skills' will play a central role to cope with the changes taking place on the shop floor. In order to succeed in this attempt, employees will need to be even more open to change, flexible to adapt to new roles and work environments, and to continual interdisciplinary learning. They will hence require less machine and product-specific training but will need stronger capabilities to utilize digital devices and software [Rüßmann et al., 2015].

When describing the structural change in job activities due to digitization, literature defines two popular concepts: qualifications upgrade and qualifications polarization.

- *Qualifications Upgrade:* according to this model, the digitization of work brings an appreciation (or 'upgrading') of required qualifications. The winners in the process of substitution by technologies are those workers categories who already detain higher qualifications and behavioral resources [Brynjolfsson and McAfee, 2014]. In the future people will be employed less as "machine operators" than as "decision-makers and coordinators", thus increasing the variety of job content. This perspective adapts well to a holistic organization model characterized by a high degree of structural openness, a network of qualified and entitled workers, and a very limited division of labor and high flexibility. The workforce in this ecosystem is self-organized and no employee has defined tasks, activities are instead determined on a situational basis, and vary to face the problems that turn up. A general frame of action defining the basic rules and objectives, is pre-determined at management level to avoid contrasts and inefficiencies, other than that, this model leverages informal social processes of communication and support enriching the associated extra-functional skills of employees [Hirsch-Kreinsen, 2016].

- *Qualifications Polarization:* this model accounts for the increasing replacement of medium-level skills accompanied by an increasing demand for workers employed in the two extremes of the continuum, high-qualification activities on one side and the easier but not routinized – and hence not automatable – activities on the other; extremes defined by Frey and Osborne ‘Lousy and Lovely Jobs’ [Brynjolfsson and McAfee, (2014); Autor and Dorn (2009)].

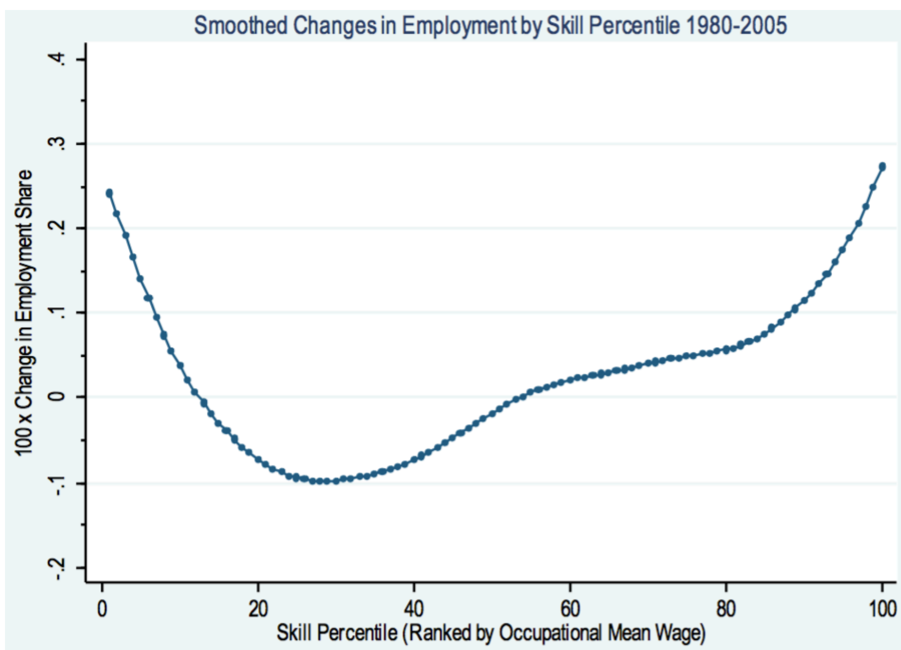


Figure 3.4: Skill Polarization (Source: Autor and Dorn, 2009)

The U-shaped graph proposed by Autor and Dorn – showing (y) changes between 1980 and 2005 in the employment share of occupations arranged by the “skill level” of the occupation (x) – well portrays the enounced concept of skill polarization. We’ve already seen how in the last couple decades, the demand for managerial, technical and professional jobs, but also less demanding occupations in the service and industrial sectors, has increased significantly. In the meantime, medium-skill jobs in areas such as sales, administration and production have either remained stable

or decreased. What we learn from Autor and Dorn's work is that not only easy, routine, low-skill activities can be substituted, but also many activities necessitating intermediate skill levels.
Hirsch-Kreinsen (2016), underlines the intrinsic contradictory combination between the principles of decentralization of the organization and task variety on one hand, and the strongly exhibited division of labor produced by skill polarization on the other.
Summarizing, work by Acemoglu and Autor (2011), suggest that all occupations can be divided into a two-by-two matrix: cognitive/manual and routine/non-routine. What they found is that demand has been dropping most severely for routine tasks, regardless of whether they are cognitive or manual, leading to job (or skill) polarization: a collapse in demand for middle-income jobs, while non-routine jobs (both manual and cognitive) have been able to hold up quite well. Therefore, even though computers outrun us in pattern recognition and computation within their frames, human workers still succeed in ideation, complex forms of communication, creativity and other cognitive areas where we're still competitive [Brynjolfsson and McAfee, 2014].

3.3.2 New Roles And Jobs Of The Future

As the cost of automation decreases, fewer people will be needed in factories for repetitive and routine tasks, whether on the shop floor or in the office. At the same time though, cyber-physical systems will need to be developed and upgraded, factory hardware will need continuous improvement and optimization in order to stay competitive etc.., this means that even the most avant-garde and automated factory left alone won't stay competitive for long, and more and more jobs will be created to fulfill the infrastructure needs. Just like with past industrial revolutions, a single factory may necessitate of fewer employees to run it, but the productivity growth should create new markets and new business opportunities [Baldassari and Roux, 2017]. Using Baldassari and Roux words: "Along with new markets and new businesses come new job categories […] Many of the most popular jobs in Industry 4.0 did not exist ten years ago […]. Our experience from past industrial revolutions indicates that humans will design new, higher-value jobs that allow people to turn their passions into greater value for the economy".
Some of the new roles that will turn up in the factory of the future include:

- *Industrial data scientist:* the person or team that will take on this role will collect and arrange data, perform advanced analytics and put into practice the findings in order to improve production processes and the final outcome as well. The job requires knowledge and understanding of both manufacturing processes and IT systems, strong causal analysis and programming skills are also a precondition to identify correlations and draw conclusions for action taking. Furthermore, Flexibility and adaptability to address both one-time requests and continuous topics are needed qualities as well as the ability to work on-site and remotely [Lorenz et al., 2015];

- *Robot coordinator:* this individual/team will overlook robots on the shop floor, identify potential malfunctions, and promptly respond. He/she is also appointed to carry out both routine and emergency maintenance activities and will replace out of service robots to avoid production downtime [Lorenz et al., 2015];

Other jobs that will be seen in the future include [Degryse, 2016]:

- Software and application developers;
- Networking and artificial intelligence specialists;
- Designers and producers of new intelligent machines, robots and 3D printers;
- Digital marketing and e-commerce specialists;
- (…)

The BCG report "Man and Machine in Industry 4.0" (2015) stresses the bright side of the new changes in industrial roles and the appearance of new jobs, arguing that their emergence promises to benefit many workers who might otherwise find themselves at a dead end for employment possibilities. Robotic assistance systems may support older operators in physically demanding jobs allowing them to extend their work life and smart interfaces might help them with a step-by-step guidance for getting acquainted with new machineries. The same technologies allow return to the workforce, under entirely new roles, for those individuals who've seen their jobs disappear and their experience become obsolete.

3.3.3 THE 'AUGMENTED BLUE COLLAR'

"The utopian worker of the factory of the future is participative and proactive, at the antipodes with respect to the defiant or reactive 20th century factory worker." [Magone and Mazali, 2016]

The definition of 'Augmented Blue Collar' may lay on two complementary connotations. On one hand the term 'augmented' refers to the always-on connectedness of Industry 4.0 workers, who exploit the benefits of cutting-edge technology made available by recent advances; on the other hand, it also denotes a set of new qualifications that he/she is required to meet. More specifically, the new factory concept demands proactivity and devotion on the part of the worker, who's given the chance to perform more interesting and self-fulfilling tasks, in exchange of a higher level of creativity, responsibility and engagement.

Given that "[…] a factory with no human resource is simply impossible"[14], the industrial sector is looking at a future where robots are freed from their cages and able to cooperate closely with their human counterpart working "hand-in-hand" in absolute environmental safety.

The objective is for both workers and machines to collect and translate data into information to apply in following production processes; the next step entails engaging also the final product into this acquisition-transmission procedure.

Many see the augmented worker as the real protagonist of this revolution, as he is living a true upgrade of competences and is learning to act conveniently on his own initiative, working in team and organizing activities with his peers leveraging his potential and his 'subjective' skills more like never before. These soft skills are becoming so important that, surprisingly, a recent graduate knowing nothing of the job, might actually be an advantage, and the most sought competence has shifted from end product knowhow, before acquired spending years at the assembly line, toward information technology. As a matter of fact, according to Nevio Di Giusto – CEO of the Fiat Research Center – people with experience often can't handle technological devices with the same confidence and ease as the younger generations, they have therefore a very strong potential but low dynamic. Conversely, younger workers have a good dynamic but extremely low potential (as measured in years of experience), hence a high probability of making mistakes. The true challenge – Mr. Di Giorno continues – "is to encapsulate know-how and experience into the tool or machine, in such a way that the next, much quicker users will manage to do more and in a shorter amount of time without making mistakes".

Following the same logic, many factories around the world are experimenting with the integration of smart devices (tablets, smartphones and the like) into the manufacturing system. These items allow for a great amount of information to be stored and readily available even for those individuals who don't have any specific competence regarding the end product. Anyone can understand their task referring to the tablet they're holding or consulting the assembly workstation touch screen and

[14] MAGONE A., MAZALI T., (2016). Industria 4.0: Uomini e macchine nella fabbrica digitale. Guerini e Associati.

learn by following step-by-step virtual simulations [Magone and Mazali, 2016]. Devices are important but dexterity and the contribution of people's intellect still play a central role in reaping the benefits of the investment in technology. In this context, the growth of competences is key and for the personnel to express its potential, managers need to work on fostering its passion and motivation in every way possible.

The new blue collar does not manually intervene in the process and does not live in reciprocity with just one machine, on the contrary he/she is aware of the entire process, he/she must be multitasking but at the same time more cooperative and forthcoming with higher hierarchical levels [Magone and Mazali, 2016]. According to the same authors, this high level of collaboration and extension of the skill set is blending together professions that were before disjointed.

In regards of the man-machine affiliation, there seem to exist two different schools of thought:

- ✓ The first suggests a supervising and controlling worker in a process made autonomous by virtue of the social knowledge incorporated in the machines;
- ✓ The second suggests a worker who is an activator, a leader, the director of a team consisting of smart devices and robots.

In summary:

- The blue collar of the future is a digital media user who combines together hard and soft skills, he/she is a good communicator and a team member who coordinates and makes decisions timely and efficiently, he/she is flexible and versatile and capable of working in a fast changing environment. The connected operator is 'augmented' in terms of readily available information and guidelines, but 'diminished' in terms of specialized work experience;
- The key competence of the future to access the labor market will be informatics alphabetization;
- Employees won't be selected only with reference to their past work experience, but on the basis of their problem-solving skills and ability to learn fast in ambiguous situations. Technical know-how and abilities are only complementary to soft skills such as values, passion and predisposition;
- The presence of blue collars and white collars will eventually even-out or even overturn.

3.4 Literature Suggested Recommendations for Action

The changing employment landscape will bring about many challenges for multiple stakeholders, not only for companies but also for education systems and governments, all of which will have to take action to adapt to the shifting environment in order to get the best out of it. The 2015 Boston Consulting Group report advances some actions ideas for implementation by these institutions:

COMPANIES

- ***Retrain current employees:*** frequent retraining of industrial workforce will be necessary to keep the pace of new advancements in technology. Training programs will have to include both on-the-job and classroom instruction; given the scope and scale of retraining and schedule conflicts, online courses access could be granted. Since many employees will be assigned a large variety of tasks, training should educate on a broad set of skills as well as imparting a positive mindset on change and adaptability. Furthermore, recruiters will need to focus more on capabilities instead of qualifications (see previous paragraph);
- ***Adopt new organization models:*** companies should consider new work models that include flexible scheduling and rethink decision-making authority. As previously seen, given the process-wide data and information flow, the introduction of a flatter organization may benefit the company by allowing for a more dispersed use and control of data. A stronger integration across departments will allow a stronger understanding of processes from different perspectives and will facilitate cooperation;
- ***Engage in strategic workforce planning:*** quantitative modelling can be applied to gather insights into employee attrition and retirements and to simulate staff requirements given forecasts on the company's Industry 4.0 technology adoption rates, productivity improvement and revenue growth.

EDUCATION SYSTEMS

- ***Provide broader skill sets:*** The new cross-functional roles that will turn up on the industrial landscape, will require both IT and production knowledge. For this reason, universities should increase the number of interdisciplinary study programs that integrate teaching of engineering and IT as well as adapt their curricula to focus more on building specific capabilities, inter-disciplinary skills and fostering inclination towards innovation, ongoing improvement and lifelong learning;

- ***Close the It skills gap:*** the current noteworthy shortfall in IT skills will have to be addressed by education systems. With this aim in mind, institutions should encourage students to pursue degrees in computer engineering or IT highlighting the future employment possibilities, meanwhile seeking to attract foreign students;
- ***Offer new formats for continuing education:*** to incentivize lifelong learning, education systems might want to provide online-learning platforms and grant admission to free courses at universities with no entry requirements, and develop new mobile applications to offer training and access to know-how.

GOVERNMENTS

- Governments will, on their part, coordinate the efforts of both business and academia trying to help the first retain as many employees as possible and create new jobs for recent graduates. Mainly the job of governments will be to promote the successful implementation of Industry 4.0 which represents the basis for manufacturing development and the creation of new occupational opportunities.

CONCLUSIONS

We could effectively summarize what we've learned in this chapter as follows:

- ✓ The increasing pace at which new technologies are being adopted in the industrial context, will lead to the unfavorable truth of a future with less jobs in traditional assembly and production. To avoid severe unemployment, companies will have to take on action to retrain their personnel, revisit and rethink their business models and organizational structures together with the adoption of a strategic approach toward staffing planning;
- ✓ A radically pessimist attitude has no reason to be, given that several studies found that the previously mentioned job losses will be more than offset by the creation of new roles and occupations (mainly in the fields of industrial IT, data mining, robot coordination, interface experts, R&D etc…);
- ✓ The substitution of the entire workforce does not seem likely at all in the near future and workers will only undergo a skill-set upgrading process. Moreover, operators will enjoy a wider variety of tasks while more physically demanding activities will be transferred to their fellow 'artificial colleagues'. In exchange, workers will be asked to meet a new set of requirements including proactivity, higher flexibility, problem-solving abilities, faster

thinking and learning;

- ✓ All in all, like for every other revolution of the past, adaptation will be most certainly challenging, but it will also bring about important gains as far as companies apply the new technological advancements proficiently and succeed in developing new products, services and business models and ultimately: employment.

4 CHAPTER

4. EMPIRICAL ANALYSIS: PROJECT SID

THE RESEARCH AND ITS OBJECTIVES

In 2017, a research group from the “Marco Fanno” Department of Economics and Business Science of the University of Padua (DSEA), has come together to test the ground of ‘Industry 4.0’ in Italy with the Project SID: “Manufacturing activities and value creation: redesigning firm's competitiveness through digital manufacturing in a circular economy framework”. In order not to anticipate information delivered further on in the chapter regarding the project’s methodology and sample description, we’ll define here the main research objectives and postpone these matters to the next couple paragraphs.

RESEARCH OBJECTIVES

- To study the adoption processes of digital technologies labeled under ‘Industry 4.0’.
- To study the implications related to the production and innovation activities.
- To analyze the approach that businesses in our country are adopting in order to cope with the current challenges and opportunities offered by these technologies both on the production side and on their interactions with the market as well as the competitive landscape.

Figure 4.1: SID Project three main objectives

4.1 METHODOLOGY AND SAMPLING

The research was structured around a survey available on the platform Surveymonkey. The selected companies were contacted via telephone to be introduced to the project, with respect to the availability of the respondents, the survey was either completed on the phone or sent by email to the redirected address and filled in at the convenience of the recipient.

The geographic scope of interest was chosen not to include the entire peninsula but to incorporate only businesses residing in the north of the country, in particular in the regions of: Piemonte, Lombardia, Veneto, Trentino-Alto Adige, Friuli-Venezia Giulia and Emilia Romagna. Two other regions were found in the final answers database that were not selected during the sampling process (Lazio and Campania) probably because two businesses moved their registered office or for other unknown reasons, these outliers will un-significantly affect our conclusions.

Ten sectors were picked for the analysis, the choice was mostly based on previous researches and other district studies. The following table classifies the selected sectors and specifies for each the corresponding ATECO code used as selection variable on the original database and the data collection period. ATECO codes refer to the classification provided by the national statistical institute ISTAT[15].

Sector	*Data collection period*
13 Textile	17th July – 30th October 2017
14 Apparel	17th July – 30th October 2017
15 Leather goods and shoes	10th October 2017 – on going
22 Rubber and plastic goods (focus on **22-22.1**)	3rd May – 15th September 2017
27 Electric equipment[16] (no 27.9)	3rd May – 15th September 2017
29 Automotive	3rd May – 15th September 2017
31 Furniture	3rd May – 15th September 2017
32.5 Glasses and Lens (**32.505-32.505**)	3rd May – 15th September 2017
32.1 Jewelry (**32.121-32.122-32.130**)	3rd May – 15th September 2017
32.3-32.9 Sport goods	3rd May – 15th September 2017

Table 4.1: Industry sectors chosen for the analysis (numbers on the left and in parenthesis represent ATECO codes for the category)

Note that data is still being collected for the category of 'leather goods and shoes', while most of the others were completed by mid-September or by the end of October. Moreover, the 'electric equipment' sector includes also electrical appliances and lighting equipment, the latter will be analyzed separately. After choosing the sectors and geographical scope to analyze, we proceeded with the extraction of the dataset from AIDA, a database available to the Department containing financial, demographic commercial and other records on more than 200.000 companies operating in Italy. The obtained dataset was furthermore restricted to consider only those companies with a 2015 turnover higher than 1 million euros. Exception was made for the categories of jewelry, glasses, sport goods and lighting equipment, for which also companies with a turnover smaller or equal to 1 million were included in the sample. This choice was made in consideration of the fact that for these sectors, industrial districts contain a large number of minor businesses calling for the

15 Available at: https://www.istat.it/it/strumenti/definizioni-e-classificazioni/ateco-2007
16 This category will, for analysis purposes, be divided between general electric equipment and lighting equipment.

necessity to include also companies with smaller dimensions as expressed in terms of turnover. Consider the following figure for indications on the original population selected on the basis of the chosen ATECO codes, the universe assigned to the research team, the number of respondents and the final sample, which will be utilized for the survey analysis.

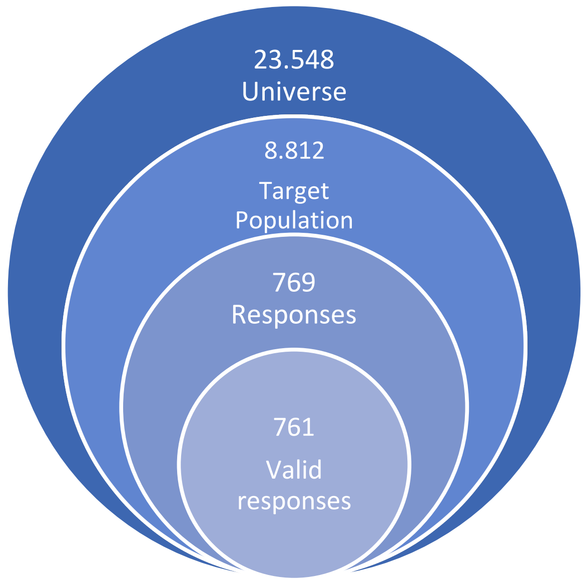


Figure 4.2: Deriving the sample from the originally considered universe.

The Universe

ATECO codes	Tot. AIDA companies	Universe <= 1 Ml	Universe > 1Ml
13 Textile	3,849	2,417	1,432
14 Apparel	5,161	3,931	1,230
15 Leather goods & shoes	1,859	1,130	729
22 Rubber & plastic goods	3,832	1,274	2,558
22-22.1 Rubber goods		*184*	*413*
22.2 Other plastic material goods		*1,090*	*2,145*
27. Electric equipment	3,641	1,609	2,032
27.0-27.5 (no 27.4) Electric equipment		*850*	*1,117*
27.4 Lighting equipment		*253*	*230*
27.9 Other electric equipment		*506*	*685*
29 Automotive	1,086	384	702
31 Furniture	3,041	1,414	1,627
32.1 Jewelry	683	377	306
32.3-32.9 Sport goods	207	98	109
32.5 Glasses	189	78	111
Total	**23,548**	**12,712**	**10,836**

Table 4.2: Universe composition

The initially considered universe was formed by choice of sectors of interest, all companies associated to the selected ATECO codes legally residing in the over-mentioned geographical regions in the north of Italy, were found on AIDA and added to the universe, for a total of 23.548

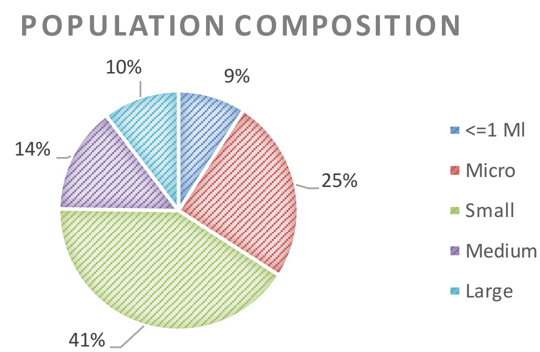
companies. These include businesses with revenues (values from the year 2015) both higher than 1 million euros (10.836) and below that threshold (12.712).

The targeted population

ATECO codes	Population assigned to team	% universe
13 Textile	1,432	16.3
14 Apparel	1,230	14.0
15 Leather goods & shoes	729	8.3
22 Rubber & plastic goods		
22-22.1 Rubber goods	413	4.7
22.2 Other plastic material goods		
27. Electric equipment		
27.0-27.5 (no 27.4) Electric equipment	1,117	12.7
27.4 Lighting equipment	483	5.5
27.9 Other electric equipment		
29 Automotive	702	8.0
31 Furniture	1,627	18.5
32.1 Jewelry	683	7.8
32.3-32.9 Sport goods	207	2.3
32.5 Glasses	189	2.1
Total	**8,812**	100.0

Population assigned to team	n.	%
<=1 Ml	806	9
Micro	2,199	25
Small	3,624	41
Medium	1,270	14
Large	913	10
Total	**8,812**	**100**

Table 4.3: Population assigned to the team and its composition.



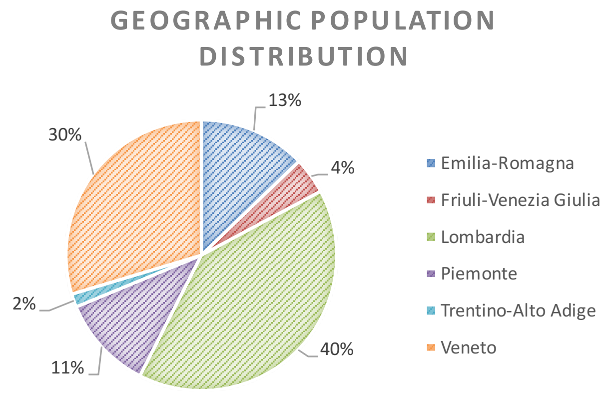
Starting from the initial universe, a further screening was performed to confine the number of companies to be included. In particular, the population that was assigned to the team members comprised in most part companies with revenues over the million, with the exception of four sectors (those marked in red on the previous table), for which it was thought appropriate to include also businesses with a revenue equal to or below that level for a total amount of 8.812 companies in the population. As we can see from the pie chart, the majority of population elements are defined as small, followed by micro companies, mediums, large and only the 9% is represented by businesses <1M euros in revenues (2015). The size classification has been conducted based on the following assumptions postulated by the European Commission[17]:

- ≤ 1M
- 1M < Micro ≤ 2M
- 2M < Small ≤ 10M
- 10M < Medium ≤ 50M
- Large > 50M

17 Available at: http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition_it

Geographic Region	Universe assigned to team	%
Emilia-Romagna	1,129	13
Friuli-Venezia Giulia	384	4
Lombardia	3,554	40
Piemonte	993	11
Trentino-Alto Adige	140	2
Veneto	2,612	30
Total	**8,812**	**100**

Table 4.4: Geographic distribution of the population



As illustrated in the chart and table, the two main regions of residence for the population companies are Lombardia and Veneto followed by Emilia-Romagna and Piemonte, only six businesses instead are to be attributed to the remaining two regions.

Respondents and final sample

ATECO codes	# of Respondents in sample	% on sample	% on sector (response rate)
13 Textile	21	2.7	1.5
14 Apparel	61	7.9	5.0
15 Leather goods & shoes	21	2.7	2.9
22 Rubber & plastic goods			
22-22.1 Rubber goods	11	1.4	2.7
22.2 Other plastic material goods			
27. Electric equipment			
27.0-27.5 (no 27.4) Electric equipment	265	34.5	23.7
27.4 Lighting equipment	72	9.4	14.9
27.9 Other electric equipment			
29 Automotive	56	7.3	8.0
31 Furniture	64	8.3	3.9
32.1 Jewelry	143	18.6	20.9
32.3-32.9 Sport goods	17	2.2	8.2
32.5 Glasses	38	4.9	20.1
Total	**769**	**100**	**8.7**

Table 4.5: Respondents by sector

This table presents the survey's raw number of respondents as produced by Surveymonkey (*response rate 8.7%*), a couple corrections were made afterwards with respect to some incoherencies. As a matter of fact, AIDA was used, after receiving the results, to download the respondents tax numbers and verify that whomever completed the questionnaire, had included the correct identification code, the same was also done for the business names. Specifically, eight companies had to be removed from the dataset mainly due to tax numbers or business names not found or non-existent. In the case of a double entry for the same company, the most complete response was kept as valid while the other was deleted from the database.

The final sample therefore, after having gotten rid of the duplicates and other inconsistencies, comprises 761 companies in total. We will define the characteristics of this group more in detail in the next paragraph before getting into the analysis of the survey's collected answers.

4.2 Sample Description

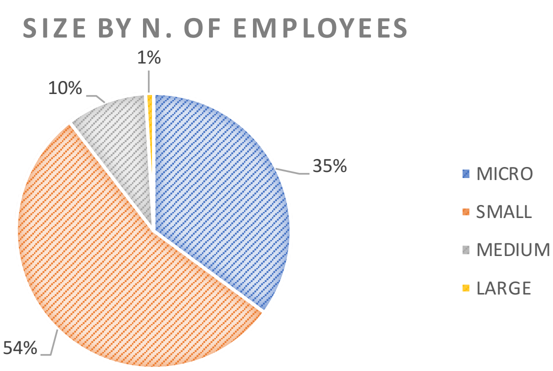
The final sample of valid responses that was derived after having made the necessary adjustments, contains 761 elements that will here be analyzed by size, geographical position and by sector of affinity. As for the size, we will consider two classifications: one based on the number of employees as of 2015 and one based on turnover (also for that year). The size groups were defined according to the standards provided by the European Commission (see previous note) and are as follows:

- Micro < 10 employees
- 10 ≤ Small < 50
- 50 ≤ Medium < 250
- Large ≥ 250

Following this grouping methodology, information on employees was extracted from the database and the following results were obtained. Note that, data was not available for all companies and therefore, the results show only the elements for which information could be found.

Size	No. of companies	%
MICRO	258	35%
SMALL	400	54%
MEDIUM	70	10%
LARGE	7	1%
TOT	**735**	100%

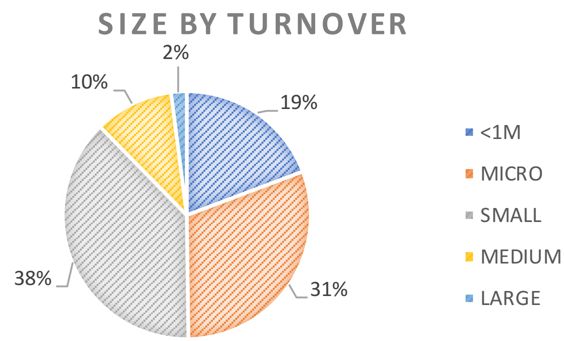
Table 4.6: Sample elements size by number of employees



Looking at the table, we see how only a small number of companies labeled as "large" have submitted the questionnaire, while the "small" companies group account for over half of the sample, followed by a 35% of "micro" businesses and a 10% of mediums. This classification will only be considered in this context. For the rest of the chapter, when size will be discussed and answers will be analyzed by size grouping, we will always be referring to dimensions defined on the basis of turnover which we consider being more representative of the real state of things. In particular we have decided to download information on turnovers referring to 2015 because we had to trade-off between the need for data availability and recency and in the end opted to attribute more importance to the first. Note that in most questions, the number of respondents will be lower when computed by dimension as compared to the one calculated by sector, this is because it was possible to retrieve from AIDA the ATECO codes of all elements of the sample, while turnover (2015) was not available for some of them.

Size	No. of companies	%
<1M	142	19%
MICRO	225	31%
SMALL	279	38%
MEDIUM	76	10%
LARGE	15	2%
TOT	**737**	100%

Table 4.7:Sample elements size by classes of turnover

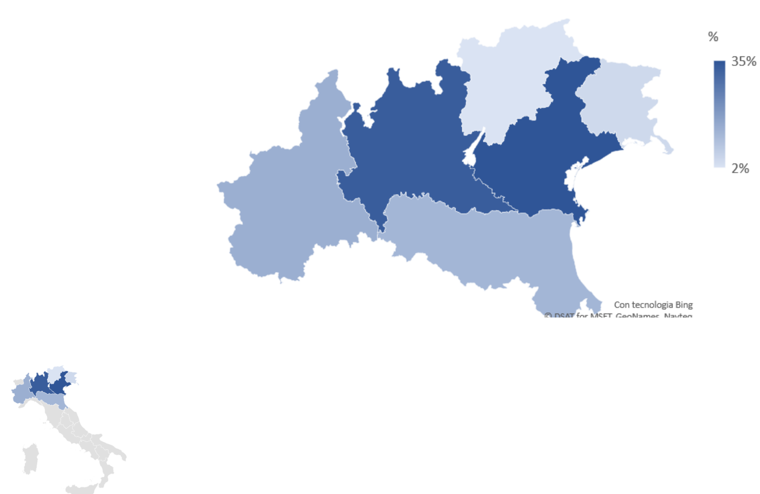


As we can see now a new class for companies with revenues lower than one million is being considered, for the assumptions explained early on in this chapter, and they represent a good 19% of our sample. The number of "large" elements has increased with respect to the previous type of classification (the one by number of employees), more than doubling from 7 to 15, the "mediums" on the contrary still account for the 10%. Due to the introduction of the new category (142 companies), the "micro" and "small" classes now own a lower share of the sample, respectively 31% and 38% (as opposed to the previous 35% and 54%).

Another important aspect to keep into consideration is the composition of the sample in terms of geographical scope. The following table and charts help in visualizing the distribution of the companies on the peninsula.

Region	No. of companies	%
Lombardia	250	33%
Emilia-Romagna	94	12%
Piemonte	106	14%
Veneto	264	35%
Friuli-Venezia Giulia	32	4%
Trentino-Alto Adige	14	2%
Other	2	0%
TOT	**762**	100%

Table 4.8: Geographical scope of sample

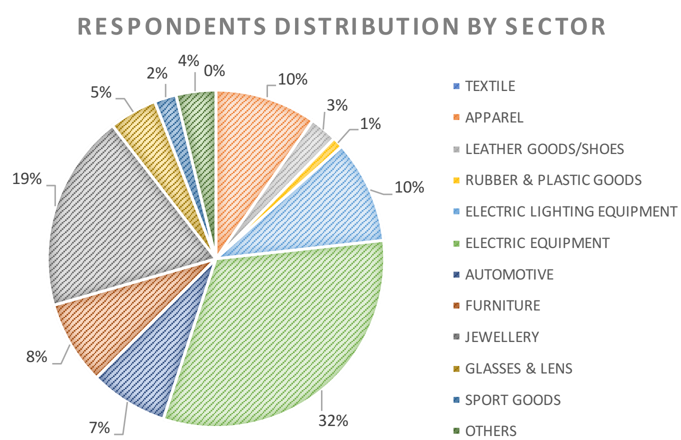


The dark blue areas on the maps indicate the regions with higher density of sample elements, in particular Veneto and Lombardia seem to be the regions where most of the respondents reside with a 35% and 33% share respectively. Piemonte and Emilia-Romagna also account together for another 26% of the companies, the rest is spread between Friuli-Venezia Giulia and Trentino-Alto Adige (32 and 14 respondents reside in these regions). An insignificant share of the sample comprising only 2 businesses must have recently moved their legal residency and seems – according to AIDA – to be located in Lazio and Campania but, for coherence reasons, we decided to mark those off.

Lastly, we propose here a distribution of responders by sector of affiliation. Note that here – as opposed to the previously illustrated sector charts – we only include responders for which correct information was provided in the survey:

Sector	No. Of companies	%
TEXTILE	0	0%
APPAREL	74	10%
LEATHER GOODS/SHOES	20	3%
RUBBER & PLASTIC GOODS	8	1%
ELECTRIC LIGHTING EQUIPMENT	75	10%
ELECTRIC EQUIPMENT	242	32%
AUTOMOTIVE	57	7%
FURNITURE	61	8%
JEWELLERY	144	19%
GLASSES & LENS	35	5%
SPORT GOODS	16	2%
OTHERS	29	4%
TOT.	**761**	100%

Table 4.9: Sample distribution by sector



First and foremost, we obtained that no respondent belongs to the textile sector, it may raise suspicion since in the paragraph "Respondents and final sample" the table counted 21 companies for that sector. The reason for this difference resides in the fact that the first table refers to the ATECO code submitted by whomever completed the survey while – with the purpose of being as objective as possible – we deemed more correct to trust the one reported on AIDA therefore, this sector will not be taken into consideration for future reference due to its numerical insignificance. Most responders belong to the electric equipment sector populated sectors are the "Electric equipment" (32%), "Jewelry" (19%), "Apparel" (10%) and "Electric lighting equipment" (10%) followed by "Furniture" and "Automotive" with a respective share of 8% and 7% of the sample.

Moreover, in "Others" we comprised all businesses which, in AIDA appeared with a different, more specific ATECO code not included in the ones initially chosen, we did not believe necessary to create additional and too specific categories for those so they were instead incorporated in a group per se.

4.3 The Survey

The survey that the contacted companies were asked to fill-in, encompassed thirty-four questions in total. Ideally, it could be divided into six groups of inquiries each associated to a main subject to be investigated. The first couple questions, are namely demographic in nature and regarded trade name and sector of affiliation, while the following two discriminate Industry 4.0 technology adopters from non-adopters and ask the latter the reasons for not implementing them. A series of queries are then devoted to extracting more information on the companies including: production specialty, employees' distribution across functions, turnover, key success factor and data on exports and R&D expenditure in the last year. Afterwards, the survey moves its focus on the technologies adoption processes, and explores the timing, nature of additional technologies, the activities involved in the change, the motivations leading up to the investment, the degree of customization of and adaptation of the technologies integrated and the parties called in for consulting and assistance. Follows a sequence of questions on impacts, obstacles, results obtained and differences in work dynamics, products, sustainability issues and innovation capabilities related to the new paradigm. Concluding the survey are inquiries aimed at gathering information on products and partners; for example, respondents were asked about the share of their first customer, the sector where their B2B partners operate if any, their product lines configuration (components, finished/semi-finished goods, standard products, partly/fully customized etc…) and the geographic derivation of their products and/or suppliers.

Q. #	Objectives
1-2	Name and sector
3-4	Discriminating adopters/non-adopters and reasons for the latter
5-11	Collecting data on sample turnover, key success factor of adopters, R&D expenditure, employees' distribution across functions and exports information
12-19	Understanding adoption processes, motivations, timing, activities involved, customization and adaptation needs, consulting and assistance partners
20-27	Exploring issues, impacts, results and changes due to I4.0 technology
28-34	Researching information on products and partners

Table 4.10: Survey cross section

4.4 THE RESULTS

Having outlined the structure of the survey in the earlier paragraph, we will discuss hereafter the results obtained considering each question starting with the discrimination between adopters and non-adopters.

➢ **Adopters and technologies adopted** (Question n.3)

It is not an easy task to define what technologies should or should not be included in the I4.0 category, some are clearly identifiable because they represent a cutting-edge, recent addition to the industrial world, others may raise some concern considering that they've been operating for quite a while now. Take as an example industrial robots or laser cutting machines, they've been around for decades – some may argue – the reason we've kept in consideration these technologies, is because the revolutionary aspect of industry 4.0 lays on the connectedness of these systems rather than the presence of the hardware itself on the shop floor.

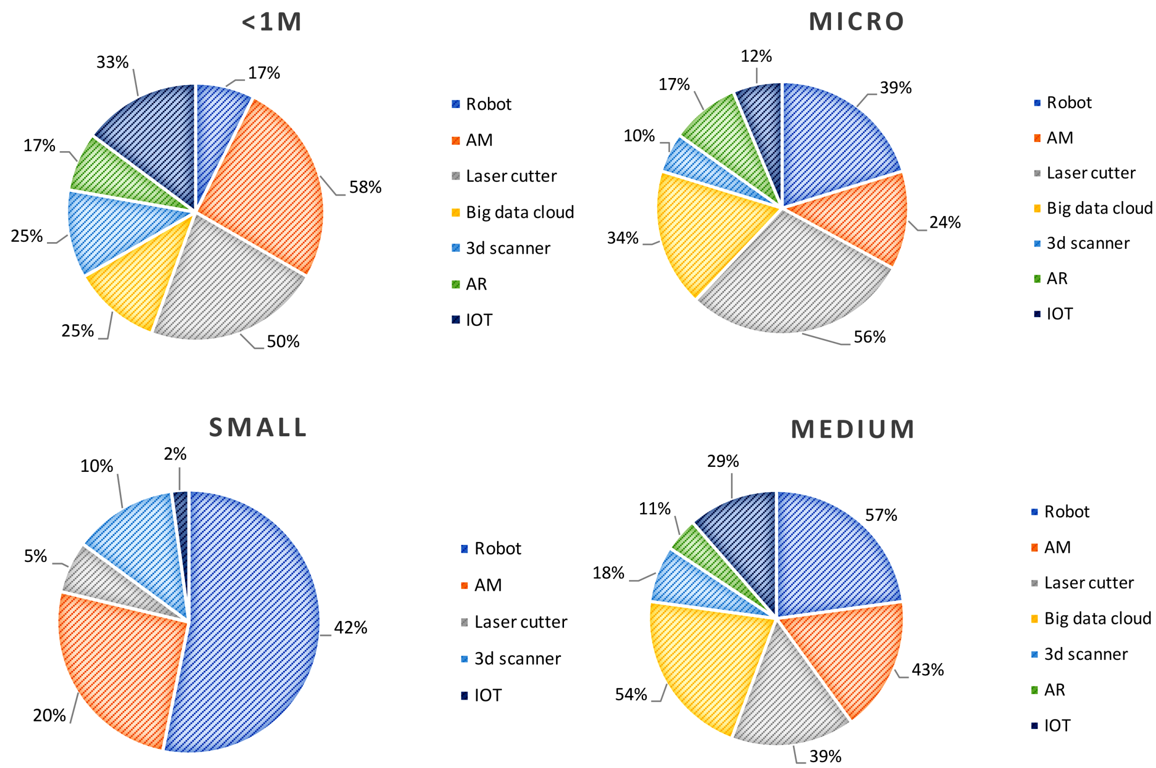
The study obtained that approximately **20%** of responders (19,89%) adopted at least one technology (of these, 42% adopted only one and 28% only two). We analyzed this 20% both by business dimension and by sector of affiliation to get a little more insight on adoption dynamics and to eventually surface differences in behavior and decision-making. The following exhibits illustrate the results by company's dimension (where the latter was computed based on 2015 turnover values).

Size	Robot	AM	Laser cutter	Big data & cloud	3d scanner	AR	IOT	TOT co. In size category	TOT adopters
<1M	2	7	6	3	3	2	4	142	12
MICRO	16	10	23	14	4	7	5	225	41
SMALL	25	12	3	0	6	0	1	279	59
MEDIUM	16	12	11	15	5	3	8	76	28
LARGE	5	4	3	4	0	1	2	15	8
								737	**148**

Table 4.11: Number of I4.0-technology-adopting companies by dimension

Size	Robot	AM	Laser cutter	Big data cloud	3d scanner	AR	IOT
<1M	17%	58%	50%	25%	25%	17%	33%
MICRO	39%	24%	56%	34%	10%	17%	12%
SMALL	42%	20%	5%	0%	10%	0%	2%
MEDIUM	57%	43%	39%	54%	18%	11%	29%
LARGE	63%	50%	38%	50%	0%	13%	25%

Table 4.12: technology adoption percentages by dimension



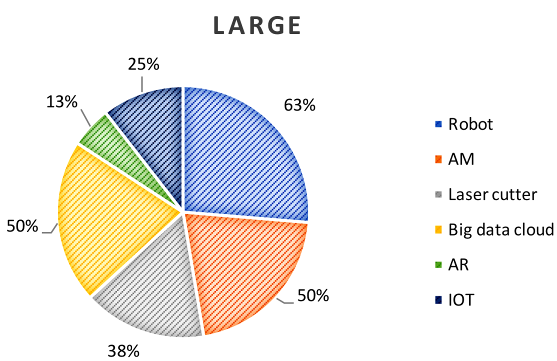


Figure 4.3: Technology adoption by dimension

The pie charts derived from the previous table, clearly tell at a glimpse that technological choice varies quite consistently across varying dimensions. Note that for each category, percentages do not sum up to 100% because more than one technology could be checked by each responder. For companies with less than one million in revenues for example, the technology adopted the most is additive manufacturing, the result may seem surprising, but as we will see examining adoption by sector, a good slice of companies belonging to the <1M category operates either in the Jewelry or the Glasses sectors and these are the ones that adopt additive manufacturing technologies the most. Laser cutting machines instead dominate the "micro" segment, probably as the result of investments made years ago, as a matter of fact it appears like these technologies are used in great part by companies with a lower economic income. On the contrary, the "small", "medium" and "large" segments seem to privilege usage of industrial robots but also experiment with additive manufacturing. As of big data and the cloud instead, medium and large businesses leverage them with some importance but none of the 59 technology-adopting small companies declared of exploiting the possibilities offered by the cloud. 3D scanners are mostly employed by the <1M and medium companies, in line with what has been said regarding additive manufacturing technologies. The results demonstrate also that Augmented Reality on one hand and Internet of Things on the other, are chosen by segments occupying the extremes of the dimension continuum. The next graph provides another visual representation of the different adoption choices by companies of different sizes.

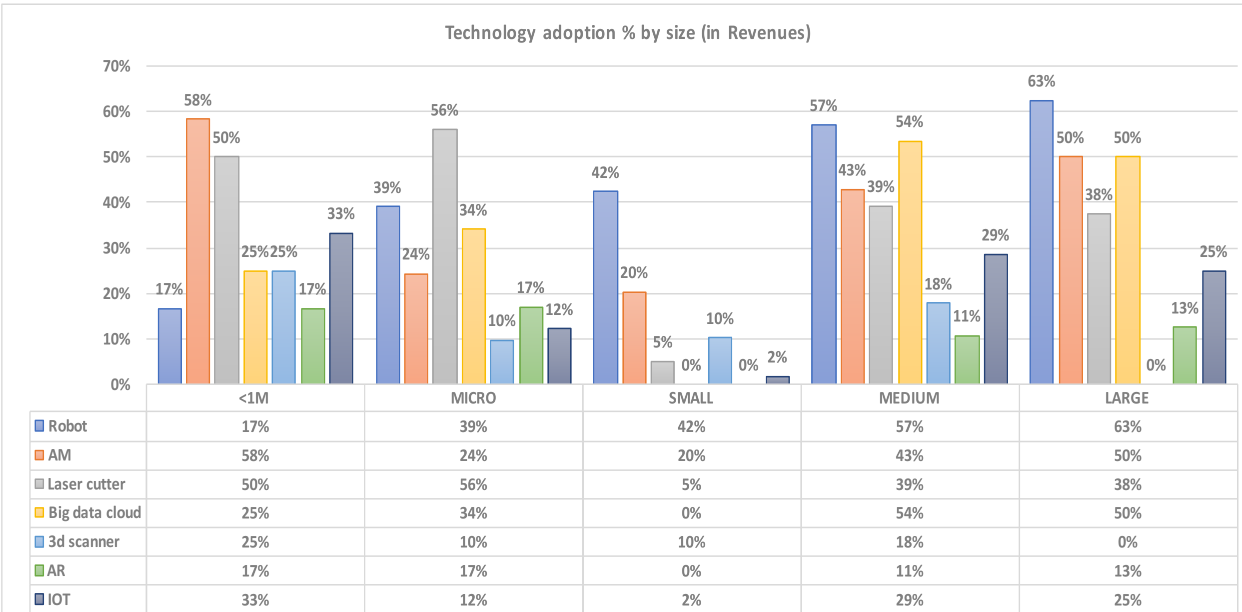
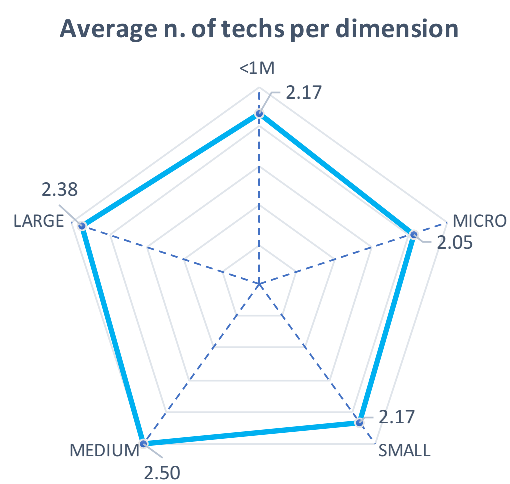


Figure 4.4: Graphic summary of technology adoption by company dimension

Another relevant information – given that respondents could check more than one technology adopted – is the average number of technologies per size category, shown in the following exhibits.

Size	Average n. of technologies per **dimension**
<1M	2.17
MICRO	2.05
SMALL	2.17
MEDIUM	2.50
LARGE	2.38

Table 4.13: Average number of technologies per size category



The table and the radar chart show interestingly how the size of companies seems to be quite irrelevant when it comes to count how many technologies businesses integrate in their processes. In fact, regardless of their dimension, on average respondents declared to possess at least two of the over mentioned technologies. Now we switch perspective and see what happens when results are analyzed by sector rather than by firm size and verify whether or not significant differences across sectors can be identified.

Sector	Robot	AM	Laser cutter	Big data & cloud	3d scanner	AR	IOT	TOT adopters by sector
APPAREL	4	3	9	13	2	3	6	26
LEATHER GOODS/SHOES	0	0	0	1	0	0	0	1
RUBBER & PLASTIC GOODS	3	0	2	3	0	0	0	6
ELECTRIC LIGHTING EQUIPMENT	4	9	7	6	2	6	10	19
ELECTRIC EQUIPMENT	6	5	3	10	1	0	6	17
AUTOMOTIVE	13	8	8	7	5	1	4	20
FURNITURE	22	9	10	0	0	0	4	30
JEWELLERY	2	9	11	2	4	3	1	13
GLASSES & LENS	8	9	10	8	4	3	4	13
SPORT GOODS	0	2	0	0	0	0	0	2
OTHERS	3	3	3	5	0	0	1	6
								153

Table 4.14:Number of I4.0-technology-adopting companies by sector

Sector	Robot	AM	Laser cutter	Big data cloud	3d scanner	AR	IOT
APPAREL	15%	12%	35%	50%	8%	12%	23%
LEATHER GOODS/SHOES	0%	0%	0%	100%	0%	0%	0%
RUBBER & PLASTIC GOODS	50%	0%	33%	50%	0%	0%	0%
ELECTRIC LIGHTING EQUIPMENT	21%	47%	37%	32%	11%	32%	53%
ELECTRIC EQUIPMENT	35%	29%	18%	59%	6%	0%	35%
AUTOMOTIVE	65%	40%	40%	35%	25%	5%	20%
FURNITURE	73%	30%	33%	0%	0%	0%	13%
JEWELLERY	15%	69%	85%	15%	31%	23%	8%
GLASSES & LENS	62%	69%	77%	62%	31%	23%	31%
SPORT GOODS	0%	100%	0%	0%	0%	0%	0%
OTHERS	50%	50%	50%	83%	0%	0%	17%

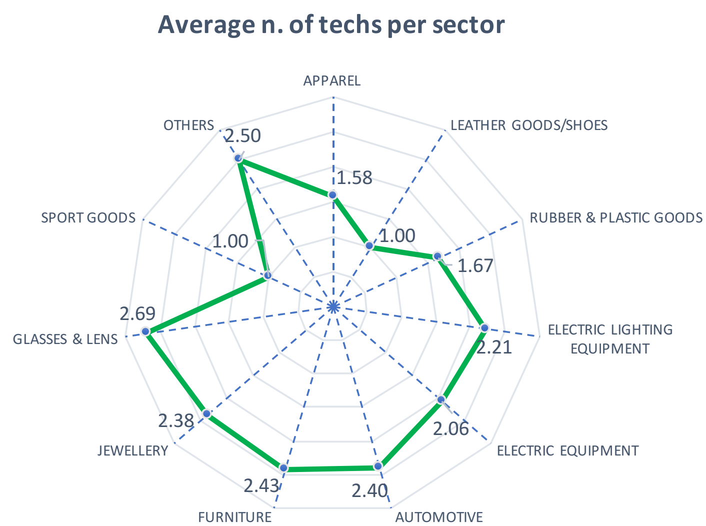
Table 4.15: Technology adoption percentages by sector

As one could have expected, different sectors require different kinds of technologies and therefore, differences in adopting behaviors across districts can be traced. In particular, even though in some cases big data and the cloud – being by nature flexible enough to be implemented by any type of business – play a fundamental role in almost all sectors considered, the other technologies seem to be more applicable to some sectors rather than others. Take for example additive manufacturing, 3D scanners and Augmented Reality, these seems to be more suited for electric lighting equipment, automotive, jewelry and glasses/lens manufacturing but less for craftsmanship activities like leather work and shoe-making. Laser cutting also covers mostly all sectors (note that those reporting 0% adoption share had a low number of respondents and therefore shouldn't be taken as highly significant), but it needs to be considered the fact that laser-cutters are not very recent and have been on the market for long. Robots are also diffused, but some sectors employ them more pervasively, like in cars, furniture, glasses/lens, rubber and plastic goods manufacturing. The IoT is also another adaptable technology which is adopted in a cross-sector fashion.

Generally speaking, each company adopts on average 2 technologies (2.18 is the exact result obtained). With regard to the average number of technologies adopted by each firm per sector, consider the following:

Sector	Average n. of technologies per **sector**
APPAREL	1.58
LEATHER GOODS/SHOES	1.00
RUBBER & PLASTIC GOODS	1.67
ELECTRIC LIGHTING EQUIPMENT	2.21
ELECTRIC EQUIPMENT	2.06
AUTOMOTIVE	2.40
FURNITURE	2.43
JEWELLERY	2.38
GLASSES & LENS	2.69
SPORT GOODS	1.00
OTHERS	2.50

Table 4.16: Average number of technologies adopted by firms per sector



In comparison with the previous analysis, where we contemplated differences among companies varying in size and found that all categories reached on average a level of two technologies, here we acknowledge more remarkable divergences between sectors. Specifically, firms manufacturing leather goods and shoes, rubber and plastic goods, apparel and sport goods, fall on average below that threshold, while all other segments exceed it, although some more significantly than others. The latter are to be re-conducted to more technology intensive industries (i.e. automotive, furniture) or industries that rely on the more precise work of machineries (as in the case of glasses, lens and jewelry manufacturing).

- **Motivation for non-adoption** (Question n.4)

Results showed how only 20% of respondents stated to own at least one of the technologies indicated in question number three, so what about the remaining 80%? The share of non-adopters is so substantial, that exploring the reasons that these companies give for not implementing I4.0 changes becomes essential for future policy-making and action-planning.

As for the previous question, also in this case we will illustrate results both under a dimension perspective and by sector.

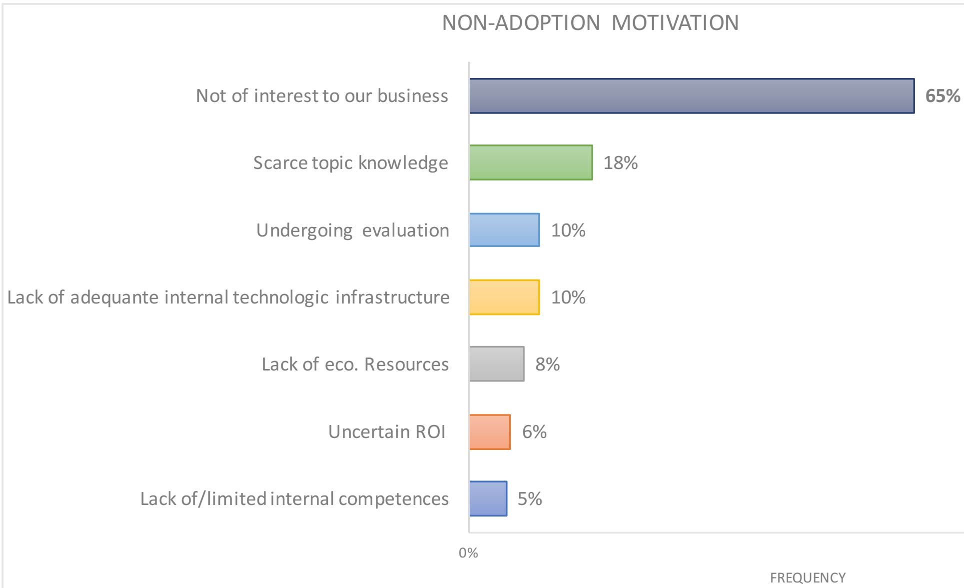


Figure 4.5: Motivation for non-adoption ordered by frequency

Motivation	N. of companies	%
Lack of/limited internal competences	31	5%
Uncertain ROI	35	6%
Lack of eco. Resources	46	8%
Lack of adequate internal technologic infrastructure	59	10%
Undergoing evaluation	59	10%
Scarce topic knowledge	103	18%
Not of interest to our business	374	65%
N. of question respondents	571	124%[18]

Table 4.17: Frequencies and percentages of motivation given by responders

Among the 571 responders of this question, as much as 374 companies stated that they do not adopt I4.0 technologies because they're not of interest to their business. This is a very important result, showing that a considerable share of the sample (a good 65%) *believes* that the innovations do not apply to their line of business, answer that may be re-conducted to the second most checked option concerning the scarce knowledge of the matter. An exemplification resides in the number of times that the research team members found themselves in the situation of having to explain to the person on the other end of the phone, what the meaning of Industry 4.0 was. Other motivations entailed a consideration of the implementation strategy, which is still at an initial evaluative stage and a lack of adequate internal technologic infrastructure suitable enough to accommodate the necessary changes. On the other hand, an uncertain return on investment, the lack or limitation of internal competences and of economic resources instead, seem to have a less meaningful weight on the respondents' decision to not adopt the new paradigm.

18 Note that the total percentage amounts to more than 100% because the respondents were given the possibility to check more than one answer.

These however, represent aggregate results, in the continuation of this discussion we will try to make comparisons between different size classes and across sectors.

Size	Lack of eco. Resources	Lack of/limited internal competences	Lack of adequate internal technologic infrastructure	Scarce topic knowledge	Uncertain ROI	Not of interest to our business	Undergoing evaluation	N. of responders
<1M	11%	9%	15%	10%	5%	68%	3%	130
MICRO	6%	6%	10%	25%	8%	68%	8%	173
SMALL	9%	5%	9%	16%	6%	63%	14%	198
MEDIUM	5%	0%	7%	23%	9%	61%	20%	44
LARGE	0%	0%	14%	14%	14%	29%	43%	7
								552

Table 4.18: Non-adoption motivation choice by size

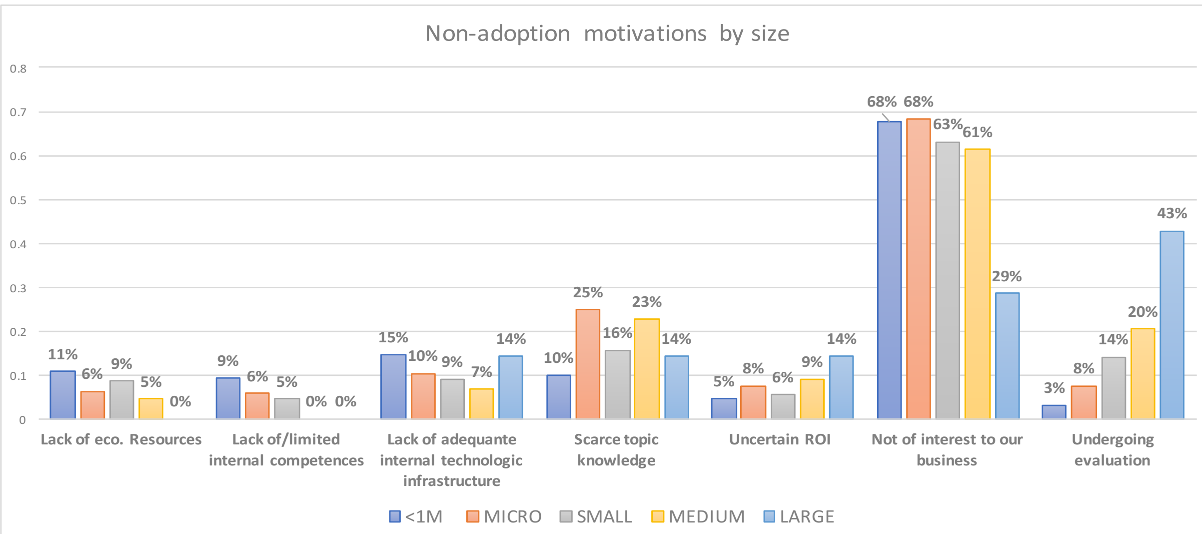


Figure 4.6: Graph of non-adoption motivation choice by size

It is very much evident from the graph above, that the great part of responders – regardless of their dimension – considers the adoption of industry 4.0 technology as something that does not concern their company. Now, starting off with businesses earning a yearly turnover lower than a million euros, for them the second most voted answer is, perhaps not surprisingly, the lack of adequate internal technologic infrastructure, followed by limited economic resources, knowledge of the topic and internal competences. Furthermore, only 3% of this group states that it is evaluating the adoption possibility. In short, the smallest category believes this type of change is either too much out of its league, or simply not of interest to its business, which is interesting considering that the results of the previous question showed that at least 8% of companies operating in this class has been able to adopt (2.17 technologies on average!). A slight difference can be perceived moving on to the next group of "micro" companies. For these, the second most checked answer was represented by scarce topic knowledge rather than the lack of a suitable infrastructure, and the same goes for small and medium companies. So, what we learn from this exhibit is that scarcity of resources is hardly the first reason for non-adoption and ignorance of the topic as well as the belief that it is not a concern for most of them, play a big role in discriminating adopters from non-adopters. This may be interpreted as both a negative and a positive result. On one hand, we perceive how our country appears to be falling behind with respect to new manufacturing and organizational approaches that developed nations around the world are already experimenting. On the other hand, the main obstacle seems to reside in the unfamiliarity with the subject matter, which is already being acted upon by the Italian government with the "Piano Nazionale Industria 4.0" and the awareness-spreading initiatives planned for the future. At the same time the program is also providing for economic incentives and financing to help companies confront the necessary investments. Consider now the last size category of large companies, for these things change a little as more responders acknowledge the matter to be of relevance to their business and most of them (43%) affirmed that, although not adopting at the moment, the project is currently undergoing evaluation. Finally, notice that at the right-hand side of the graph we can see that the chance of a respondent to be evaluating the I4.0 solution is directly proportional to the firm's size: the larger the dimension, the higher the share of respondents considering adoption.

Sector	Lack of eco. Resources	Lack of internal competences	Lack of adequate internal technologic infrastructure	Scarce topic knowledge	Uncertain ROI	Not of interest to our business	Undergoing evaluation	N. of respondents by sector
APPAREL	12%	15%	27%	9%	15%	58%	12%	33
LEATHER GOODS/SHOES [19]	0	0	0	0	0	0	0	0
RUBBER & PLASTIC GOODS	0%	0%	0%	0%	0%	100%	0%	2
ELECTRIC LIGHTING EQUIPMENT	20%	4%	4%	16%	11%	47%	16%	55
ELECTRIC EQUIPMENT	4%	0%	2%	30%	3%	68%	11%	224
AUTOMOTIVE	11%	3%	22%	14%	30%	51%	22%	37
FURNITURE	29%	42%	6%	0%	0%	0%	13%	31
JEWELLERY	2%	10%	21%	3%	0%	78%	2%	131
GLASSES & LENS	9%	5%	9%	27%	5%	64%	9%	22
SPORT GOODS	15%	15%	0%	0%	15%	46%	15%	13
OTHERS	9%	4%	4%	17%	0%	78%	9%	23
								571

Table 4.19: Non-adopting motivation by sector

Red = First choice motivation Blue = Second choice motivation

The configuration of results to question number 4 in terms of sector distribution, does not rise particular differences as of the first-choice motivation of responders, which remains "not of interest

19 The line for "Leather goods and shoes" shows zero responses because for this category only one company declared to own I4.0 technologies, the other 20 non-adopting companies, for unknown reasons, have not submitted an answer for question number 4 (a problem with Surveymonkey could have arisen).

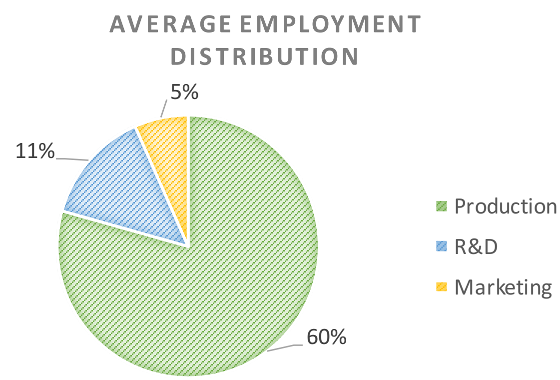
to our business" for most with the exception of the furniture sector for which none of the 31 responders checked this answer, while the 42% declared that the problem is more related to the lack of internal competences. Significant dissimilarity is instead encountered at the second level, where companies belonging to different sectors chose varying reasons obstructing the upgrade of their businesses' infrastructure. Scarce topic knowledge though still plays an important role for many.

➢ **Employment distribution across functions** (Question n. 6)

We asked responders to indicate the total number of employees and then spread this value across the functions of: production, research and development and marketing (if present). The results came in as follows.

Functions	Average employment distribution
Production	60%
R&D	11%
Marketing	5%

Table 4.20: Average employment distribution across functions



Generally speaking, a first aggregate analysis shows that more than half workers are employed in production (60%), while staff operating in R&D accounts for 11% and only 5% is attributed to Sales and Marketing.

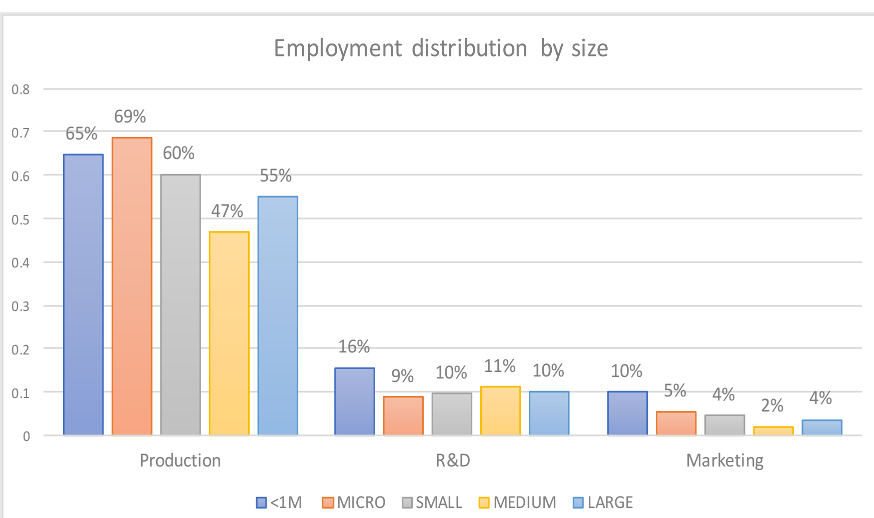


Figure 4.7: Employment distribution across functions by size

As anticipated, even discriminating by size, a very high proportion of the personnel is employed in production. Curiously, it may be noted that, for most dimensional groups, 10% of staff members are active in R&D, but for the smallest category this percentage reaches as high as 16%. Therefore, in relative terms, these devote a larger share of human resources to this function, the same happens on average in the marketing department. Also note the difference encountered moving from companies belonging to the "<1M" category to the "micro" one.

Sectors	Production	R&D	Marketing	TOT. Respondents
APPAREL	50%	10%	4%	21
LEATHER GOODS/SHOES	47%	0%	0%	1
RUBBER & PLASTIC GOODS	56%	11%	8%	5
ELECTRIC LIGHTING EQUIPMENT	53%	10%	4%	19
ELECTRIC EQUIPMENT	38%	12%	7%	15
AUTOMOTIVE	73%	20%	2%	16
FURNITURE	65%	7%	4%	30
JEWELLERY	71%	9%	10%	13
GLASSES & LENS	73%	8%	4%	12
SPORT GOODS	81%	12%	0%	2
OTHERS	48%	12%	11%	5
				139

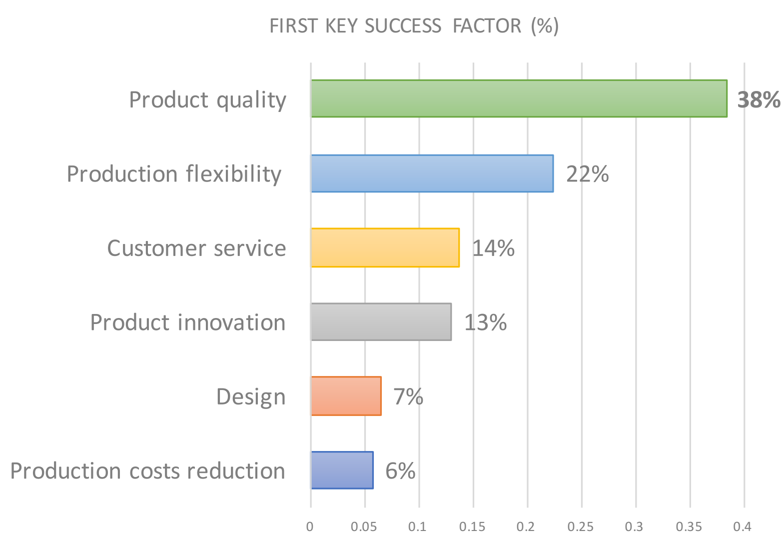
Table 4.21: Employment distribution across functions by sector

Results do not change if we control for the sector factor. As illustrated in the table, in all cases the majority of personnel are employed in production, another 10% in research and development and only a small percentage in the marketing department. Only for the Jewelry sector, marketing surpasses R&D barely by one percentile. In the other cases, marketing employs a significantly lower percentage of staff members across all sectors.

- **The company's key success factor** (Question n. 8)

Key Success Factor	Frequency	%
Production costs reduction	8	6%
Design	9	7%
Product innovation	18	13%
Customer service	19	14%
Production flexibility	31	22%
Product quality	53	38%
TOT. Respondents	**138**	

Table 4.22: Key success factor



A first analysis of results' frequency, shows a general agreement (38%) towards "product quality" as first choice of key success factor by the 138 companies that answered question number 8. 22% of responders pointed instead on the direction of production flexibility, defining it as the most important ingredient granting the success of the business over its competitors. Customer service

(14%) and product innovation (13%) follow closely and are ranked similarly for significance. On the other hand, among the elements of the sample, design and the reduction of production costs were chosen as key success factor by only 7% and 6% respectively.

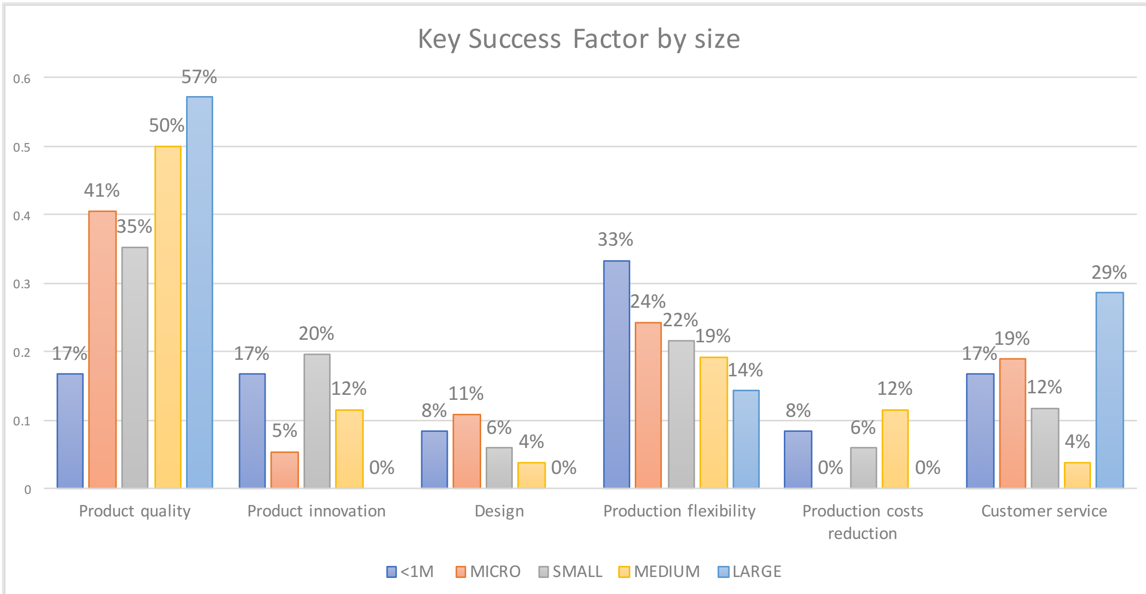


Figure 4.8: Key Success Factor by size

Size	Product quality	Product innovation	Design	Production flexibility	Production costs reduction	Customer service	TOT. Respondents by **dimension**
<1M	17%	17%	8%	33%	8%	17%	12
MICRO	41%	5%	11%	24%	0%	19%	37
SMALL	35%	20%	6%	22%	6%	12%	51
MEDIUM	50%	12%	4%	19%	12%	4%	26
LARGE	57%	0%	0%	14%	0%	29%	7
							133

Table 4.23: Key Success Factor by size

Already shifting perspective and looking at the responses by dimension, dissimilarities can be observed. Although the first key success factor remains product quality for most size classes, the smallest companies interviewed (<1M) demonstrate a stronger inclination towards production flexibility to which they attribute higher valence. The graph well portrays a declining importance attributed to production flexibility with the rising dimension of businesses. Product innovation is quoted more by small companies maybe because they're looking for a way to grow and differentiate themselves from competitors. Design on the other side is important to the first and second categories, such result could be connected to craftsmanship reasons in our country. Lastly, customer service seems to be relevant mostly for large companies (29% of responders for this category checked it as key success factor), but it is also significant for the micro (17%) and <1M (19%) segments.

Sector	Product quality	Product innovation	Design	Production flexibility	Production costs reduction	Customer service	TOT. Respondents by **sector**
APPAREL	43%	14%	10%	5%	10%	19%	21
LEATHER GOODS/SHOES	0%	0%	0%	0%	0%	100%	1
RUBBER & PLASTIC GOODS	40%	0%	0%	40%	20%	0%	5
ELECTRIC LIGHTING EQUIPMENT	39%	11%	0%	28%	11%	11%	18
ELECTRIC EQUIPMENT	40%	13%	7%	20%	0%	20%	15
AUTOMOTIVE	44%	6%	0%	33%	11%	6%	18
FURNITURE	30%	17%	17%	27%	3%	7%	30
JEWELLERY	42%	8%	8%	17%	0%	25%	12
GLASSES & LENS	55%	18%	0%	27%	0%	0%	11
SPORT GOODS	50%	50%	0%	0%	0%	50%	2
OTHERS	0%	20%	0%	20%	0%	60%	5
							138

Table 4.24: Key Success Factor by sector

From a sector point of view, everything remains quite the same. Product quality is still the first key success factor for the most part of the sample for all sectors, only the "leather and shoes", "sport goods" and "others" categories differ, but these are also the sectors with lower number of respondents therefore making the outcome less significant. As seen before, production flexibility and customer service remain the most relevant second choices.

- **Exports** (Question n. 9)

Information collected on exports on a sample of 113 respondents, display an average of 46.8% of revenues from export as a percentage of the total turnover. When asked about the first country of export, they indicated mainly European countries (France, Germany, Spain, UK, Switzerland among others) but also over the sea destinations like the U.S., Middle East countries, Australia and Asia, only a small slice cited south-American regions. To these first export countries, is directed on average 28% of total exports.

- **R&D expenditure and changes in expenditure** (Questions n. 10-11)

Sector	Average R&D expenditure (%)
APPAREL	7.44
LEATHER GOODS/SHOES	5.00
RUBBER & PLASTIC GOODS	5.88
ELECTRIC LIGHTING EQUIPMENT	6.57
ELECTRIC EQUIPMENT	8.70
AUTOMOTIVE	4.92
FURNITURE	5.50
JEWELLERY	10.38
GLASSES & LENS	5.07
SPORT GOODS	3.00
OTHERS	5.38

Size	Average R&D expenditure (%)
<1M	3.97
MICRO	7.68
SMALL	5.72
MEDIUM	6.79
LARGE	3.25
	5.48

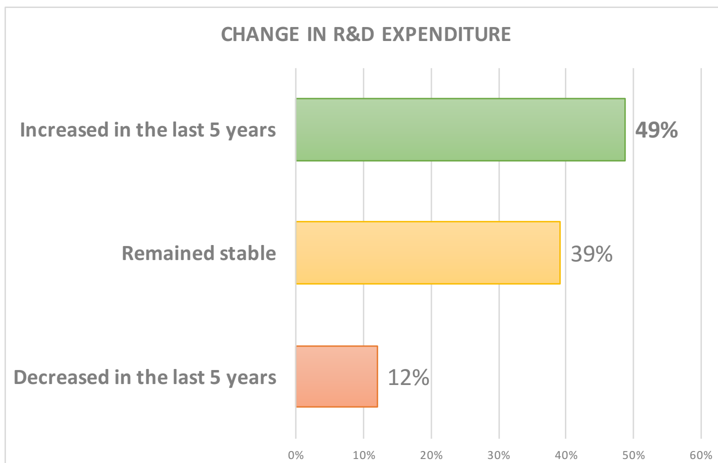
Table 4.25: Average R&D expenditure by size and sector

The values in the tables represent the average 2016 share of expenditure in research and development over the turnover for the same year. As we would expect, sectors play a significant role in defining the level of money invested in this type of activities. The electric equipment sector for example which produces also domestic appliances will need a great deal of investment in the development of new technologies. On the other hand, jewelry and clothes also need continuous research of current trends and designing of new models to meet those ongoing trends and fashions. Surprisingly enough the automotive sector does not account for a large expenditure percentage (only 4.92% is declared to be devoted to these undertakings).

On the side of dimensions, again variability can be remarked. In particular, at the extremes of the continuum little is being invested, while medium, small and especially micro firms are assigning on average up to 7.68% of their turnover to R&D. These represent stock measures, but it might be useful to see how investments in R&D have changed over the last five years given that the companies responding are now all adopters.

Variation	Frequency	%
Decreased in the last 5 years	15	12%
Remained stable	49	39%
Increased in the last 5 years	61	49%
TOT. Respondents	125	

Table 4.26: Change in R&D expenditure (last 5 years)



The cumulative results show that in the majority of cases (49%) investment in R&D has increased, for another 39% it has remained stable and for only the 12% it has decreased.

Size	Increased in the last 5 years	Remained stable	Decreased in the last 5 years	TOT. Respondents by **dimension**
<1M	36%	45%	18%	11
MICRO	48%	42%	9%	33
SMALL	44%	44%	13%	48
MEDIUM	59%	32%	9%	22
LARGE	71%	14%	14%	7
				121

Table 4.27: Change in R&D expenditure by size

Outcomes do not significantly change when considered with respect to business dimension. In fact, for most sizes expenditure has increased in the last five years, most remarkably for large companies but that may be due to the low number of responders for the category. For very small companies it has stayed constant instead in most cases, while for small businesses it was pretty much of a toss-up as 44% stated an increase and another 44% declared it remained stable.

Sector	Increased in the last 5 years	Remained stable	Decreased in the last 5 years	TOT. Respondents by **dimension**
APPAREL	47%	32%	21%	19
LEATHER GOODS/SHOES	100%	0%	0%	1
RUBBER & PLASTIC GOODS	50%	25%	25%	4
ELECTRIC LIGHTING EQUIPMENT	47%	41%	12%	17
ELECTRIC EQUIPMENT	62%	38%	0%	13
AUTOMOTIVE	53%	41%	6%	17
FURNITURE	48%	33%	19%	27
JEWELLERY	50%	50%	0%	12
GLASSES & LENS	50%	50%	0%	8
SPORT GOODS	0%	50%	50%	2
OTHERS	20%	60%	20%	5
				125

Table 4.28: Change in R&D expenditure by sector

No truly noticeable variability across sectors can be observed, in particular all of them acknowledged an increase in R&D investments, with the exception of "sport goods" and the "others" categories for which expenditure stayed for the most part stable (observe however the low number of responders for these two). In conclusion, the generally augmented interest in pursuing innovation, may be perceived positively as an effort to research and attain increasing levels of competitiveness.

- **Technologies' adoption year** (Question n. 12)

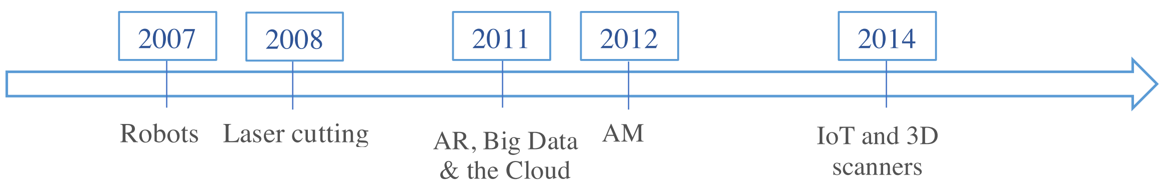


Figure 4.9: Technology adoption timeline (years represent averages of adoption years provided by respondents)

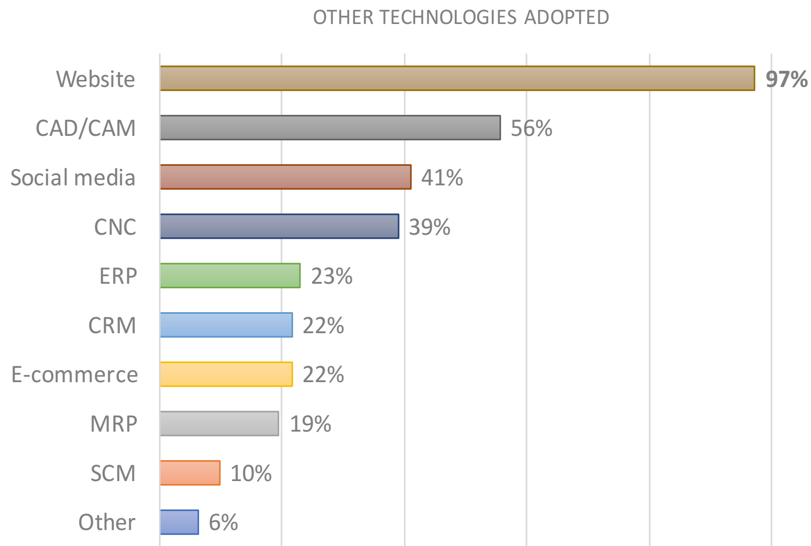
The overhead timeline describes an adoption timing that differs across technologies. Note that the years reported at the top were computed as averages of the years indicated by respondents. Even so, as presumed at the beginning of this chapter, robots and laser cutting machines were adopted on average much earlier than the other technologies around 2007 and 2008 respectively. Augmented reality, Big Data, the Cloud and additive manufacturing instead are more recent and date to approximately five years ago. On the other side, 3D scanners and the implementation of the Internet of Things, have been experimented with on average only since 2014.

Hence, as one would expect, different technologies are adopted at different times and with a considerable delay over its conception. Take for example additive manufacturing, the first 3D printing prototypes date back to the 80s, but industrial application required longer to manifest. Also observe that, according to our sample, on average all technologies were adopted before the Piano Calenda for Industry 4.0 which was announced in 2016.

- **Other technologies adopted** (Question n. 13)

Technologies	Frequency	%
SCM	14	10%
MRP	28	19%
E-commerce	31	22%
CRM	31	22%
ERP	33	23%
CNC	56	39%
Social media	59	41%
CAD/CAM	80	56%
Website	140	97%
Other	9	6%
TOT. Respondents	144	

Table 4.29: Other technologies adopted



The level of technology advancement of a company though, cannot only be limited to the ownership of Industry 4.0 technologies, others must also be taken into account. For example, older computer numerical controlled machines (CNC), or the use of software that facilitate customer relationship management, enterprise resource planning, supply chain management and material requirement planning, as well as software that accelerate designing processes (CAD/CAM) and lastly, but certainly not for importance, tools that provide for the company's online presence (websites, e-commerce activities, social media presence).

Based on the answers collected from 144 respondents, we have acknowledged that almost all of them own a website (97%) although only 22% sell online, and a good 41% is also active on social media. Hence apparently, it may seem that the online presence of Italian companies is mostly directed to "getting the brand out there" and being "reachable".

Designing programs like CAD and CAM as well as CNC machines are also among the most commonly used technologies, ERP, CRM and MRP are also quite popular, SCM on the other hand falls a little behind with only a 10% adoption score. Other technologies mentioned by responders include alternative management software applications, 3D drawing software not included among the provided options, monitoring systems for energy-savings, remote control and maintenance systems, products with remote assistance, other tools for measuring performance of prototypes, and other systems integrating orders registered on I-pads with production and accounting.

Sector	Website	Social media	E-commerce	CRM	SCM	ERP	MRP	CAD/CAM	CNC	Other	TOT. Respondents by **sector**
APPAREL	78%	61%	50%	22%	22%	28%	11%	61%	6%	6%	18
LEATHER GOODS/SHOES	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	1
RUBBER & PLASTIC GOODS	100%	0%	0%	0%	0%	0%	0%	40%	20%	20%	5
ELECTRIC LIGHTING EQUIPMENT	100%	47%	11%	32%	16%	47%	37%	53%	26%	5%	19
ELECTRIC EQUIPMENT	100%	29%	18%	12%	0%	18%	18%	47%	41%	6%	17
AUTOMOTIVE	100%	15%	10%	20%	5%	15%	20%	45%	35%	5%	20
FURNITURE	100%	60%	37%	27%	13%	17%	20%	67%	57%	7%	30
JEWELLERY	100%	38%	31%	15%	0%	0%	8%	46%	23%	15%	13
GLASSES & LENS	100%	54%	0%	23%	8%	31%	15%	69%	77%	0%	13
SPORT GOODS	100%	0%	0%	0%	0%	0%	0%	50%	50%	0%	2
OTHERS	100%	17%	0%	33%	17%	67%	33%	67%	67%	0%	6
											144

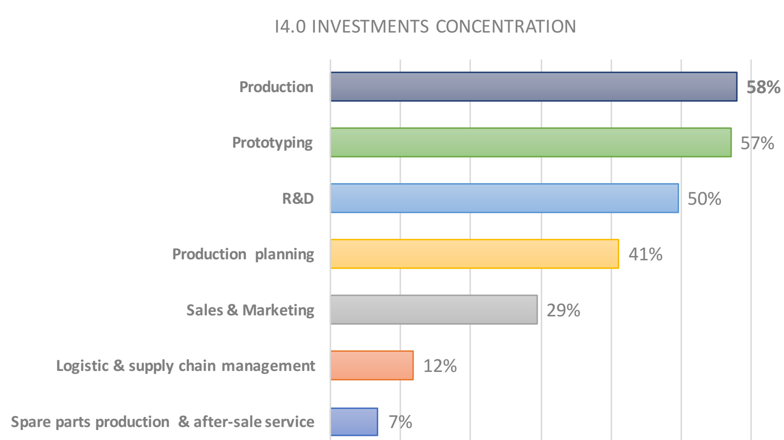
Table 4.30: Other technologies adopted by sector

The previous table portrays a similar picture to what it's already been said, where almost the entirety of the sample owns a website, and many second choices were directed towards CAD/CAM applications, which appear to be applicable to very different situations and suitable for dissimilar products. It is noteworthy to say that social medias are more employed in industries where design plays a significant role (see for reference the apparel, lighting equipment, furniture, jewelry and glasses sectors), and some of these also represent the sectors were e-commerce is most important. CNC machines on the other hand, are also adaptable to diverse necessities and are used in many instances with the exception of more craftsmanship related sectors like "apparel" and "leather goods and shoes".

- **Activities towards which investments were most directed to** (Question n. 14)

Activities	Frequency	%
Spare parts production & after-sale service	8	7%
Logistic & supply chain management	14	12%
Sales & Marketing	35	29%
Production planning	49	41%
R&D	59	50%
Prototyping	68	57%
Production	69	58%
TOT. Respondents	119	

Table 4.31: Activities where investment is concentrated



An interesting aspect regarding the implementation of the Industry 4.0 paradigm, resides in the understanding of which activities entrepreneurs are investing more on. The analysis of results produced by the survey, suggests that the main focus is on production according to 58% of responders, followed closely by prototyping activities (57%). Research and development and production planning are also subjected to significant investments, 50% and 41% respectively, so are sales and marketing but with lower intensity (29%). At the bottom of the chart, logistic management and spare parts production/after-sale services are attracting less upgrading funds.

Sector	R&D	Prototyping	Production	Production planning	Logistic & supply chain management	Sales & Marketing	Spare parts production & after-sale service	TOT. Respondents per **sector**
APPAREL	44%	50%	39%	50%	11%	28%	0%	18
LEATHER GOODS/SHOES	100%	0%	100%	100%	0%	0%	0%	1
RUBBER & PLASTIC GOODS	50%	0%	50%	50%	0%	0%	0%	4
ELECTRIC LIGHTING EQUIPMENT	53%	53%	71%	41%	24%	35%	6%	17
ELECTRIC EQUIPMENT	23%	38%	46%	46%	8%	38%	8%	13
AUTOMOTIVE	58%	75%	58%	33%	17%	0%	0%	12
FURNITURE	56%	56%	59%	41%	15%	44%	19%	27
JEWELLERY	50%	67%	50%	33%	0%	33%	0%	12
GLASSES & LENS	55%	82%	82%	36%	9%	18%	9%	11
SPORT GOODS	0%	100%	0%	100%	0%	0%	0%	1
OTHERS	67%	100%	100%	0%	0%	33%	0%	3
								119

Table 4.32: Activity focus of investments by sector

Even controlling for the sector factor, results obtained do not change. Production, prototyping, R&D and production planning are for all respondents the main functions towards which investments in innovation are directed to. Subtle changes in prioritization can be observed for the apparel, automotive and jewelry sectors, for which more companies chose to fund prototyping innovation rather than production.

- **Activity-technology association** (Question n.15)

Activity	Robots	AM	Big data/Cloud	3D scanner	AR	IoT
R&D	35%	56%	32%	47%	63%	20%
Prototyping	24%	80%	30%	87%	25%	20%
Production	84%	41%	34%	33%	31%	48%
Production planning	29%	15%	70%	7%	13%	28%
Logistic & Supply chain management	0%	5%	28%	0%	0%	16%
Sales & Marketing	4%	10%	47%	13%	38%	12%
Spare parts production & after-sale service	14%	5%	15%	0%	0%	12%
Other	0%	7%	4%	0%	0%	0%

Table 4.33: Activity-technology association

The previous question highlighted the activities over which Italian businesses are increasingly focusing their Industry 4.0 investments. Now, we investigate where each technology is being employed the most. Robots for example, are typically used for production but, according to 35% of responders, R&D activities also benefit from their use, as well as prototyping and production planning. Additive manufacturing on the contrary, is not so much found in production but twice as much in prototyping and R&D and very little in the other functions. Big data and the Cloud, not surprisingly apply to all functions although with greater intensity to production planning and sales and marketing. 3D scanners on the other hand, follow the lead of additive manufacturing appearing predominantly in prototyping, R&D and production contributing very little to the other activities. As of augmented reality, its application mainly encompasses research and development tasks but represents also the second most employed technology in sales and marketing operations. Finally, the Internet of Things finds particular utility in production and production planning but is often suitable for all business activities. The following exhibit illustrates graphically the results of the previous table and provides a more immediate picture of what has just been discussed.

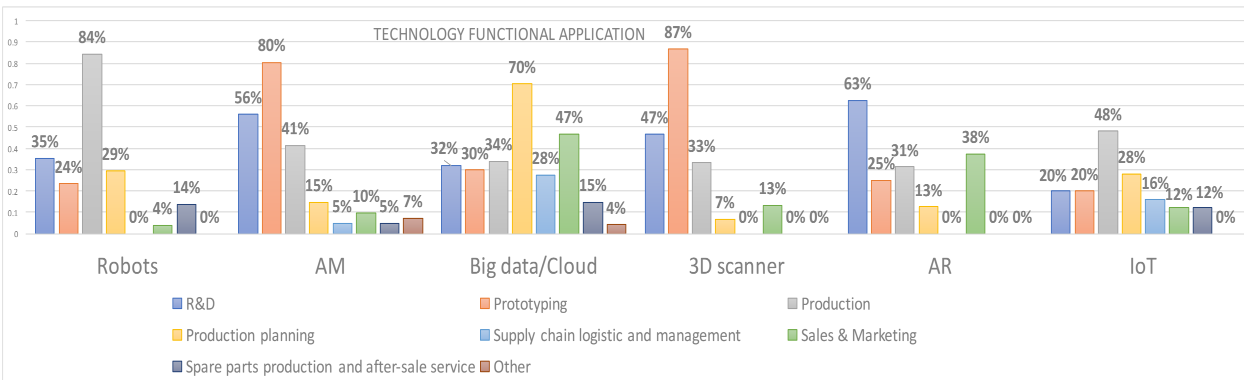


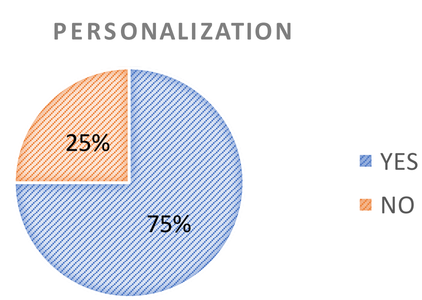
Figure 4.10: Technologies applications

➢ **Personalization of the investment** (Questions n. 16-17)

One issue when discussing the adoption of Industry 4.0 technologies raises particular concern, and that resides in the motivation of the investment. Some may argue that the recent embracement of the new industrial model may be the result of a copy-cat type behavior, for which "if my competitor does so, I should behave likewise" or the consequence of a well-received craze. The questions that we are about to consider were asked to investigate whether or not the investment made was part of a more articulated project or the manifestation of an imitation game.

	Personalization	%
YES	81	75%
NO	27	25%
Respondents	108	100%

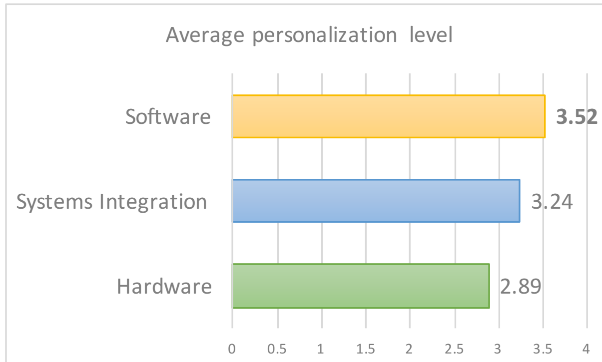
Table 4.34: Personalization of technologies



Whether or not businesses engaged in the personalization of the technological solutions adopted, may be considered as an indicator of a more comprehensive idea of the management for the implementation of the I4.0 concept. The results positively show that only one out of four companies decided not to further personalize the investment, the other 75% instead customized the acquired technologies to its processes and needs. (Check the following exhibits for information on the degree of personalization endowed to the applications)

	Average Score
Hardware	2.89
Systems Integration	3.24
Software	3.52

Table 4.35: Average personalization level of technology components

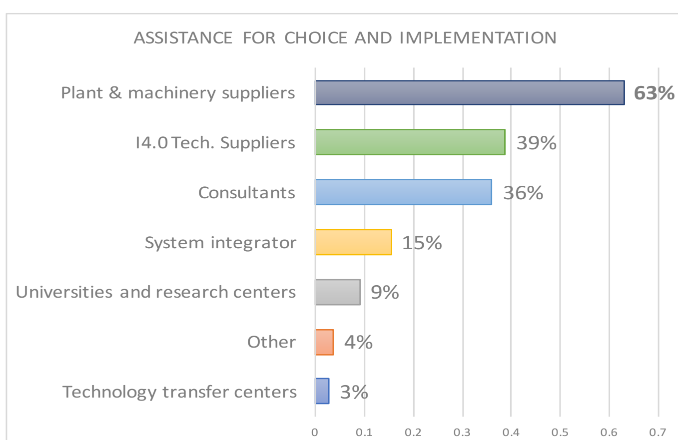


Exploring deeper, the decisions made by adopters, the survey asked them to rate on a scale from 1 to 5 (5 being the highest degree of customization), the level of personalization of three components: software, hardware and system integration. Data collected indicates that software on average is the one component where more work was done to ensure compatibility with the businesses' strategic organizational and operational purposes, this may be due to its intrinsic flexibility and easier adaptability. The second most adjusted element was the integration of systems. For last comes hardware customization, maybe because it would presumably require a more considerable effort in terms of time and money.

➢ **Assistants for choice and implementation** (Question n. 18)

	Frequency	%
Technology transfer centers	3	3%
Other	4	4%
Universities and research centers	10	9%
System integrator	17	15%
Consultants	40	36%
I4.0 Tech. Suppliers	43	39%
Plant & machinery suppliers	70	63%
TOT. Respondents	**111**	

Table 4.36: Assistants for technology choice and implementation



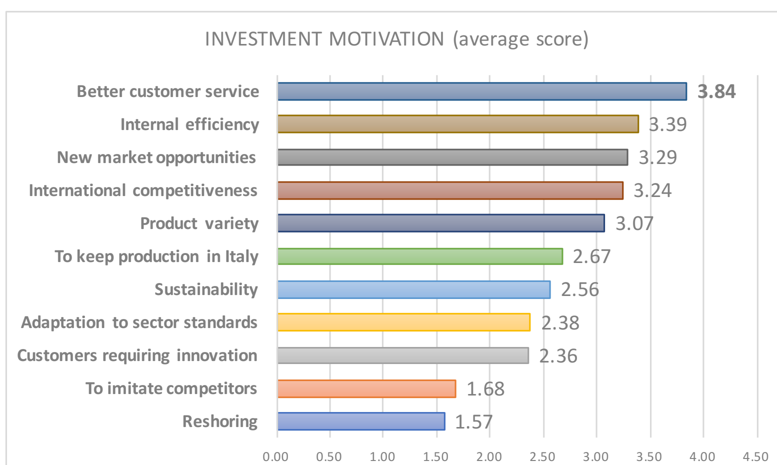
We furthermore asked our responders who assisted them in the choice, installation and implementation of the technologies adopted. Results show that in most instances, assistance was delivered by suppliers of plant and machinery (63%) or of Industry 4.0 products themselves (39%). Another significant 36% hired specialized consultants for better decision-making and 15% chose the support of system integrator figures. Only in ten cases (out of 111), companies called in universities and research centers and about 3% availed itself with the aid of technology transfer centers. A case of "other" consisted in internal consultancy, as for the rest of that 4%, it regards situations that somehow fall in the previous categories. Checking outcomes both for the dimensional and sectorial factors, results do not vary.

- **Industry 4.0 investment motivations** (Question n. 19)

The survey's question number 19 intended to further research the motivations that lead companies to invest in Industry 4.0 applications in our country. We hence asked our sample to rank from 1 to 5 (where 1 stands for "not at all important" and 5 for "very much important") a list of drivers with the purpose to identify the stronger incentives leading the process of change. From the rankings collected were consequently computed average scores for comparison and the frequencies of classes of scores were also calculated (considering 1-2-3 to be low scores communicating weak significance of the motivation under scrutiny and 4-5 to be high scores of strong significance).

Motivations	Average score
Reshoring	1.57
To imitate competitors	1.68
Customers requiring innovation	2.36
Adaptation to sector standards	2.38
Sustainability	2.56
To keep production in Italy	2.67
Product variety	3.07
International competitiveness	3.24
New market opportunities	3.29
Internal efficiency	3.39
Better customer service	3.84

Table 4.37: investment motivations ranking



The first results classification by average score – as illustrated in the above table and chart – indicate that the primary reason pushing companies to innovate is the willingness to improve customer service, as first and foremost priority. Another four dimensions though, play also a central role in promoting investment and they are, in this order: the pursuit of internal efficiency, the quest for new market opportunities, the strive to remain internationally competitive and lastly product variety. Keeping production domestic, sustainability issues, adaptation to sector standards, meeting the level of innovation required by customers are also of some relevance but are not accounted for as essential. Finally, the imitation of competitors and reshoring come in as the weakest motivations.

Motivations	Frequency of 4-5	% of 4-5	Frequency of 1-2-3	% of 1-2-3
1.Internal efficiency	63	57%	48	43%
2.Product variety	48	43%	63	57%
3.New market opportunities	59	53%	52	47%
4.To keep production in Italy	36	32%	75	68%
5.Reshoring	3	3%	108	97%
6.International competitiveness	56	50%	55	50%
7.To imitate competitors	5	5%	106	95%
8.Better customer service	76	68%	35	32%
9.Sustainability	31	28%	80	72%
10.Customers requiring innovation	29	26%	82	74%
11.Adaptation to sector standards	21	19%	90	81%
TOT responders	111			

Table 4.38: analysis by class of scores for investment motivations

The analysis by class of scores shows the same outcomes and the motivations with a higher frequency of 4-5 rankings are the first-choice drivers of change. Controlling by company size does not change the final outcome and generally, for all dimension groups, the primary motive pushing businesses to invest in innovation remains "better customer service". When considering the different sectors instead we obtain:

Sector	1	2	3	4	5	6	7	8	9	10	11	TOT
APPAREL	3.60	2.93	4.00	3.64	1.55	3.75	1.91	4.00	3.55	3.00	2.83	16
LEATHER GOODS/SHOES	3.00	2.00				3.00	1.00	5.00	2.00	1.00	4.00	1
RUBBER & PLASTIC GOODS	2.00	2.33	3.50	2.33	1.00	3.25	2.00	3.00	1.67	3.67	2.00	4
ELECTRIC LIGHTING EQUIPMENT	3.56	3.00	2.94	2.31	1.56	3.13	1.94	3.81	2.50	1.88	2.19	16
ELECTRIC EQUIPMENT	3.40	2.30	2.50	2.40	1.50	2.90	1.60	3.70	1.60	2.50	2.70	10
AUTOMOTIVE	2.92	2.83	2.92	3.00	1.75	3.00	1.42	3.92	2.42	1.75	2.00	12
FURNITURE	3.54	3.38	3.65	2.15	1.42	3.27	1.35	3.58	2.62	2.50	2.62	26
JEWELLERY	3.64	3.64	3.55	3.00	1.64	3.00	2.09	4.27	2.73	2.27	2.18	11
GLASSES & LENS	3.09	3.27	3.27	3.36	1.82	3.55	1.91	3.82	2.45	2.55	2.09	11
SPORT GOODS	5.00	4.00	4.00	1.00	2.00	4.00	1.00	5.00	5.00	1.00	1.00	1
OTHERS	3.00	3.00	2.00	2.33	1.67	3.33	1.33	4.33	2.67	2.33	2.00	3
												111

Table 4.39: investment motivations by sector

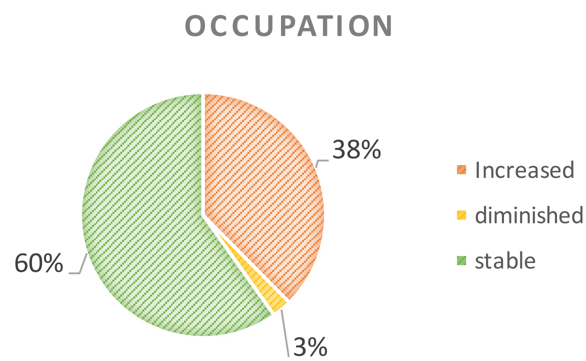
The analysis conducted by sector highlights some slight differences among sectors of affiliation. Note that for example for rubber and plastic goods manufacturing companies, the degree of innovation required by customers plays a more significant role as compared to better customer service that, although connected, places fourth in the ranking performed by businesses operating in this district. The furniture sector on the other hand, attributes greater importance to new market opportunities and only secondly to customer service. As for the other sectors under study, they pretty much conform to the first results reported in this paragraph.

- **Impact on occupation** (Question n. 20)

In chapter 3, we have made a point on the importance of the implications that technology adoption may have on the level of occupation. Now, we attempt to research the subject from an empirical perspective and ask our sample responders whether or not the level of occupation has increased, decreased or remained stable after the acquisition of I4.0 equipment.

Change in occupation	Frequency	%
Increased	44	38%
diminished	3	3%
stable	70	60%
Respondents	117	100%

Table 4.40: Change in occupational levels



Luckily enough, results obtained portray a reassuring reality: more than half of the interviewed parties, stated that the level of employment was not subject to any numerical change after the adoption of the new technology. Another important 38% on the other side, declared to have hired more personnel after the implementation decision, although they did not specify which position they were enrolled to fulfill, we can imagine they could be most likely information technology experts or skilled analysts. Fortunately, only the remaining 3% announced a decrease of the workforce, although this might not be directly a consequence of the technology adoption.

Sector	Increased	diminished	stable
APPAREL	24%	6%	71%
LEATHER GOODS/SHOES	0%	0%	100%
RUBBER & PLASTIC GOODS	0%	0%	100%
ELECTRIC LIGHTING EQUIPMENT	25%	0%	75%
ELECTRIC EQUIPMENT	23%	0%	77%
AUTOMOTIVE	38%	8%	54%
FURNITURE	58%	4%	38%
JEWELLERY	64%	0%	36%
GLASSES & LENS	42%	0%	58%
SPORT GOODS	0%	0%	100%
OTHERS	33%	0%	67%

Size	Increased	diminished	stable
<1M	20%	0%	80%
MICRO	46%	3%	51%
SMALL	36%	5%	59%
MEDIUM	40%	0%	60%
LARGE	0%	0%	100%

Table 4.41: Occupational level change by sector and size

The table on the right-hand side, displaying results by company dimension, shows no deviation from what we've just said. The by-sector classification instead, suggests that – while for all other segments in most cases levels of occupation did not vary – in the furniture and jewelry sectors the majority of companies indicated an increase in the workforce base.

- **Amount of investment and results obtained** (Questions 21-22)

Survey's answers reveal that as much as 10.3% of annual turnover was on average invested in Industry 4.0 technology, but in what consisted the results of this funding? Fortunately enough for the investing firms, it seems like the motivations that initially drove the investment, were met with matching positive results. As a matter of fact, question number 19 had acknowledged the relevance for the majority of business of an improvement in customer service and internal efficiency; these are here reported as the principal gains achieved after implementation. Immediately after came the obtainment of greater productivity followed by a turnover increase and higher diversification and product variety, while the entrance in new markets, which was one of the first drivers of change, is achieved by a modest 28% of responders. 24% was able to increase its share of customized products and only for about 9% of the sample technological upgrade was able to aid the reconfiguration of activities between Italy and abroad.

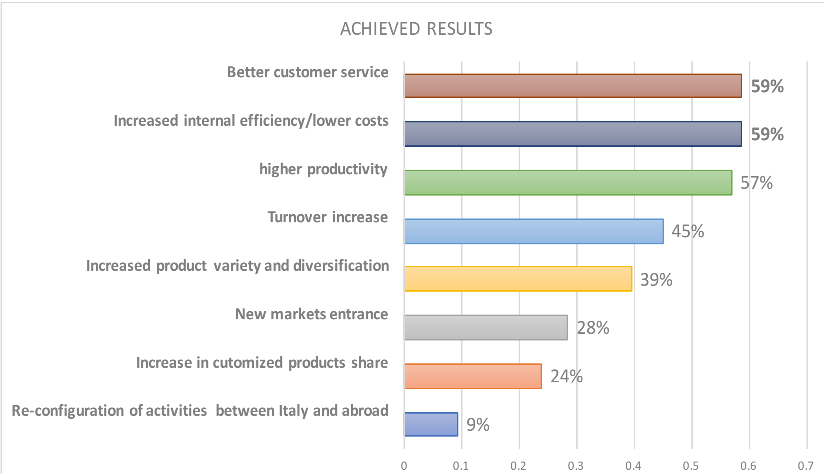


Figure 4.11: Results obtained

Results	<1M	MICRO	SMALL	MEDIUM	LARGE	
1.Turnover increase	11%	58%	43%	53%	20%	
2.Increased internal efficiency/lower costs	44%	61%	58%	53%	100%	
3.higher productivity	67%	55%	58%	53%	60%	
4.Increased product variety and diversification	44%	42%	38%	37%	40%	
5.Increase in customized products share	33%	30%	20%	21%	0%	
6.Better customer service	56%	58%	65%	47%	60%	
7.New markets entrance	11%	39%	28%	21%	0%	
8.Re-configuration of activities between Italy and abroad	0%	9%	5%	16%	20%	
TOT. Respondents by dimension	9	33	40	19	5	106

Table 4.42: Investment results by size

The above-reported table shows a little variability across different size classes. More in detail we have that companies with annual turnover lower than one million have achieved higher productivity levels through the employment of the renovated infrastructure, micro and small businesses have instead benefited more in terms of better customer service. Medium enterprises stated in equal measure to have attained a turnover increase as well as lower costs and higher productivity. Finally, all five large companies have agreed upon a greater degree of internal efficiency.

Sector	1	2	3	4	5	6	7	8	TOT. Respondents by sector
APPAREL	47%	40%	27%	40%	20%	53%	33%	13%	15
LEATHER GOODS/SHOES	0%	100%	0%	0%	0%	100%	0%	0%	1
RUBBER & PLASTIC GOODS	25%	25%	25%	0%	0%	25%	25%	0%	4
ELECTRIC LIGHTING EQUIPMENT	38%	50%	56%	44%	25%	56%	19%	13%	16
ELECTRIC EQUIPMENT	30%	90%	60%	10%	10%	60%	20%	10%	10
AUTOMOTIVE	42%	67%	67%	25%	17%	92%	33%	0%	12
FURNITURE	69%	81%	77%	62%	38%	50%	46%	12%	26
JEWELLERY	36%	55%	45%	45%	36%	73%	27%	9%	11
GLASSES & LENS	36%	18%	64%	27%	18%	45%	9%	9%	11
SPORT GOODS	0%	100%	100%	0%	0%	100%	0%	0%	1
OTHERS	50%	50%	50%	100%	0%	50%	0%	0%	2
									109

Table 4.43: Investment results by sector

The analysis by sector also highlights differences in the primary gains obtained. In the apparel, automotive and jewelry sectors, an improved customer service represents the first gain achieved, for furniture companies it is a reduction of costs and for glasses and lens manufacturers it's a higher productivity. As for the other sectors contemplated, respondents are equally divided among multiple gains.

➢ **Most frequent adoption difficulties** (Question n. 23)

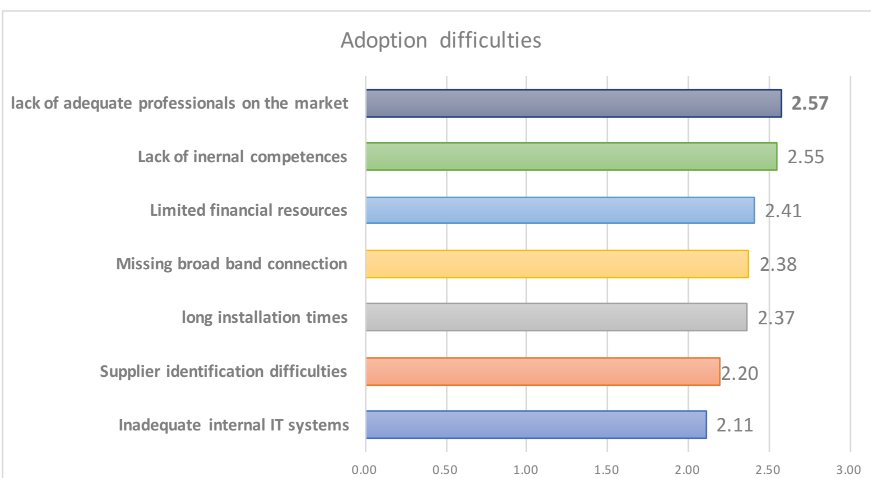


Figure 4.12: Adoption difficulties

After recognizing the gains and the benefits obtained with the embracement of the new paradigm, it is most certainly due to look also at the downsides and complications of a change of these proportions. When asked to rank on a scale from 1 to 5 the listed difficulties that could've been encountered (1 being "not at all" and 5 being "very much"), we obtained the above-reported average scores. Companies have indicated that it was hard to find adequately knowledgeable professionals on the market as well as internally. Limited financial resources, missing suitable broad band connection and long installation times have also contributed to a more problematic situation. Less challenging was instead to identify suppliers and internal IT systems in most cases measured up to the task.

Difficulties	<1M	MICRO	SMALL	MEDIUM	LARGE	
1.Lack of internal competences	2.11	2.63	2.37	2.67	3.67	
2.lack of adequate professionals on the market	2.89	2.31	2.50	2.89	2.00	
3.Limited financial resources	2.89	2.22	2.46	2.06	3.00	
4.Inadequate internal IT systems	1.78	1.88	1.94	2.67	3.00	
5.long installation times	2.22	2.09	2.40	2.61	3.00	
6.Supplier identification difficulties	2.67	1.94	2.23	2.28	1.67	
7.Missing broad band connection	2.56	2.22	2.40	2.32	2.00	
TOT Respondents per dimension	9	32	36	19	4	100

Table 4.44: Difficulties by size

From the size perspective, the smallest category – consistently with expectations – have been missing financial resources and encountered difficulties in finding professionals on the market, the latter being the primary concern for small and medium-sized businesses. Micro companies on the other hand, are mostly missing internal competences which also happened for large ones that also suffered long installation times, inadequate internal IT systems and, most unexpectedly, limited financial resources.

Sector	1	2	3	4	5	6	7	TOT Respondents per **sector**
APPAREL	2.90	2.64	3.50	2.80	3.00	2.80	2.64	13.00
LEATHER GOODS/SHOES	3.00	4.00	3.00	1.00	4.00	1.00	1.00	1.00
RUBBER & PLASTIC GOODS	2.50	3.00	4.50	1.50	1.50	3.00	4.00	2.00
ELECTRIC LIGHTING EQUIPMENT	2.56	2.69	2.19	1.94	2.25	2.44	2.88	16.00
ELECTRIC EQUIPMENT	2.44	2.78	1.67	1.56	2.11	1.89	1.44	9.00
AUTOMOTIVE	3.00	2.55	2.36	2.00	2.45	2.27	1.91	11.00
FURNITURE	2.35	2.54	2.27	2.19	2.04	2.08	2.12	26.00
JEWELLERY	1.91	2.27	2.18	2.09	2.09	2.00	2.45	11.00
GLASSES & LENS	2.64	2.55	2.55	2.18	3.00	1.82	3.18	11.00
SPORT GOODS	4.00	3.00	1.00	1.00	3.00	3.00	1.00	1.00
OTHERS	3.50	1.50	3.00	3.50	2.50	2.50	2.00	2.00
								103.00

Table 4.45: Difficulties by sector

Sectors also show considerable differences in difficulties confronted. For the apparel and rubber and plastic goods manufacturers, limited financial resources occupy an important spot. Missing professionals on the market have been an obstacle instead for the sectors of: leather goods and shoes, electric equipment and furniture. Internal competences were missing in the automotive, sport goods and other industries and the inadequate broad band connection has caused troubles for makers of electric lighting equipment, jewelry, and glasses.

- **Influence of adoption on work dynamics** (Question n. 24)

At this point of the paper, it should be clear enough that the implementation of an Industry 4.0 strategy implies a naturally disruptive change on many levels and encompassing training-upgrade necessities, a new type of human-machine interaction and between workers themselves, potentially new know-how and collaborative patterns across functions. Question number 24 was formulated with the intent of investigating these consequences and evaluating which had a stronger impact on work dynamics.

Changes	Average score
1. Higher problem complexity	2.07
2. Training & competence enhancement	2.86
3. Less interaction between man and machine	1.92
4. More cooperation between production and suppliers	2.23
5. More collaboration among workers	2.40
6. More cooperation between production and other functions	2.57
7. New know-how for production improvement	3.35
8. New know-how for product improvement	3.27

Table 4.46: changes in work dynamics

Respondents were asked to fill in a Likert scale type of question with rankings going from 1 to 5 where 1 meant that the change in consideration did not happen at all and 5 meant that the change did take place and was meaningful. Starting from the received dataset, we computed an average score for each dimension and observed that the most recurrent and significant change consisted in most cases in the creation of new know-how for production (3.35), followed closely by new expertise for product improvement (3.27). Another impact was felt on the need to upgrade and enhance competences and training programs, but the integration of I4.0 technologies also slightly increased the level of cooperation among workers and between production and other functions. Very much interestingly, the average score for dimensions number 1 and 3 was very low, indicating that the application of the new paradigm did not significantly entail a higher problem complexity, nor less interaction between man and machine (the latter result seems to line up perfectly with the expectations of literature experts on the future of work dynamics as we've seen in the previous chapter).

Sector	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	TOT. Respondents per **sector**
APPAREL	2.40	3.08	2.27	2.42	2.58	2.77	3.25	3.64	14
LEATHER GOODS/SHOES	2.00	4.00	1.00	4.00	1.00		5.00		1
RUBBER & PLASTIC GOODS	3.50	3.00	4.00	3.00	3.00	3.00	3.50	4.00	2
ELECTRIC LIGHTING EQUIPMENT	1.64	2.36	1.79	2.36	2.14	2.21	2.93	3.14	14
ELECTRIC EQUIPMENT	1.50	2.50	1.75	1.88	2.13	2.00	2.75	2.63	8
AUTOMOTIVE	2.67	2.67	2.08	2.17	2.67	2.42	3.67	3.08	12
FURNITURE	1.92	2.96	1.62	2.04	2.38	2.65	3.23	3.38	26
JEWELLERY	2.09	3.00	1.91	2.45	2.64	2.55	3.36	3.18	11
GLASSES & LENS	2.45	3.00	1.82	2.00	2.00	2.91	4.00	3.18	11
SPORT GOODS	1.00	4.00	4.00	3.00	3.00	3.00	4.00	4.00	1
OTHERS	1.00	3.50	2.50	2.50	3.50	3.50	4.00	4.00	2
									102

Table 4.47: changes in work dynamics by sector

The survey's outcomes do not change meaningfully when analyzed by sector. More specifically, we can that in most cases the highest average scores by sector are still concentrated on the last two columns representing the creation of new know-how for production and product improvement respectively. Deviations are only recognizable for sectors where only few companies responded attributing equal evaluations for more parameters.

Size	1	2	3	4	5	6	7	8	TOT. Respondents per **dimension**
<1M	2.11	2.11	1.89	2.11	2.33	2.44	3.44	3.78	9
MICRO	1.94	2.73	1.85	2.18	2.27	2.64	3.12	3.18	33
SMALL	1.91	2.91	1.79	2.31	2.56	2.39	3.41	3.18	35
MEDIUM	2.24	3.11	1.94	2.18	2.33	2.50	3.47	3.00	18
LARGE	3.00	3.50	2.67	1.00	2.33	2.75	3.00	3.67	4
									99

Table 4.48: Changes in work dynamics by size

Little changes when we consider the businesses' dimension. As a matter of fact, also in this case regardless of the size considered, the changes occurred primarily concern the development of new know-how for production and product upgrading. The two are usually attributed approximately the same evaluation, while the other factors on average scarcely or relatively influenced the traditional modus operandi. Note that in the case of medium and large companies, the second most encountered change was the enhancement of competences and training as opposed to either one of options number 7 or 8.

➢ **Impact of adoption on products and innovation capability** (Question n. 25-26)

Strictly linked to the issue of results obtained, discussed in question number 21, it is likewise critical to explore the impacts on products after adoption, given that these will determine sales and hence revenues. Respondents have shared information regarding this matter and have ranked – as always on a scale from 1 to 5 – each of the dimensions listed (refer to the underneath chart).

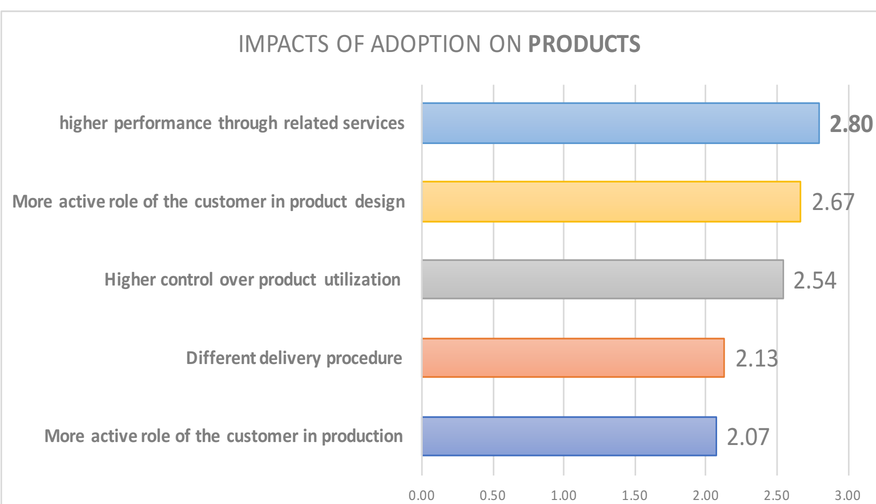


Figure 4.13: Impact on products

Attributed scores, show a considerable effect of the adoption of technology on the ability of firms to deliver to the customer a better performance through related services. Secondly, the customer also appears to have taken on a more active role in the design of products with respect to the past, although not so much in the production of the same. On average, manufacturers have also gained a fair increase in control over the utilization of the product and have on some level made changes in the delivery procedure. Data collected do not differ significantly performing an analysis by size but some variances can be noted when checking rankings by sector of affiliation.

Sector	higher performance through related services	More active role of the customer in product design	More active role of the customer in production	Higher control over product utilization	Different delivery procedure	TOT. Responders by **sector**
APPAREL	2.55	2.23	2.08	2.45	2.09	13
LEATHER GOODS/SHOES	3.00	2.00	2.00	1.00	4.00	1
RUBBER & PLASTIC GOODS	3.50	3.00	2.50	3.50	4.00	2
ELECTRIC LIGHTING EQUIPMENT	2.93	2.36	1.71	2.64	1.79	14
ELECTRIC EQUIPMENT	2.75	1.88	1.88	3.25	1.88	8
AUTOMOTIVE	3.10	2.40	2.10	2.10	1.90	10
FURNITURE	2.73	3.12	2.38	2.46	2.19	26
JEWELLERY	2.64	2.91	1.91	2.36	1.91	11
GLASSES & LENS	2.75	2.67	1.75	2.33	2.58	12
SPORT GOODS	3.00	4.00	4.00	4.00	1.00	1
OTHERS	3.00	4.50	2.50	4.00	2.50	2
						100

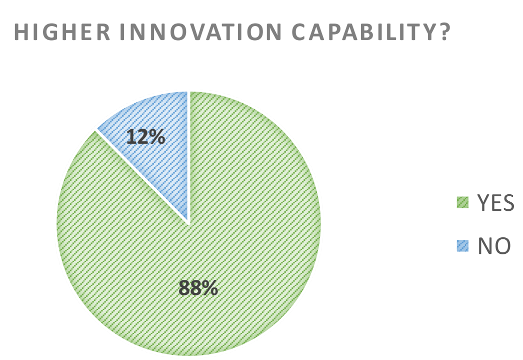
Table 4.49: Impact on product by sector

Looking at the table reported overhead, we can perceive how consequences of I4.0 technology adoption on products have manifested differently or, with different intensities, across sectors. In many cases (see for example the apparel, electric lighting equipment, automotive and glasses segments), the main effect consisted in the technology-offered possibility to improve performance by delivering additional services. For the furniture and jewelry sectors on the other hand, the biggest change has consisted in the higher degree of involvement of the customer in the product design process. Electric equipment manufacturers have been able to increase control over product utilization. The few responders in the leather goods and rubber/plastic sectors have stated that delivery procedures have undergone considerable adjustments after the introduction of the new technologies.

Therefore, responses have revealed a positive effect on the ability of companies to create and deliver improved products and services, but how does I4.0 technology adoption affect their ability to innovate? We've asked our sample to determine whether they've been able to foster this aptitude or not and obtained the following outcomes:

	YES	NO	TOT. Respondents
Frequency	92	13	**105**
%	88%	12%	

Table 4.50: Ability to innovate



Among all 105 respondents, as much as 88% has declared to have reached a higher level of innovation capability thanks to the adoption of cutting edge technology. The considerable deviation is also, if not more evident considering size and sector.

Sector	YES	NO	TOT. Respondents
APPAREL	87%	13%	15
LEATHER GOODS/SHOES	100%	0%	1
RUBBER & PLASTIC GOODS	100%	0%	2
ELECTRIC LIGHTING EQUIPMENT	93%	7%	15
ELECTRIC EQUIPMENT	78%	22%	9
AUTOMOTIVE	83%	17%	12
FURNITURE	92%	8%	26
JEWELLERY	82%	18%	11
GLASSES & LENS	82%	18%	11
SPORT GOODS	100%	0%	1
OTHERS	100%	0%	2
			105

Size	YES	NO	TOT. Respondents
<1M	89%	11%	9
MICRO	91%	9%	33
SMALL	89%	11%	37
MEDIUM	84%	16%	19
LARGE	50%	50%	4
			102

Table 4.51: Ability to innovate by sector and size

➢ **Sustainability issues** (Question n. 27)

In a world where the customer and society at large, are increasingly sensitive about issues involving waste reduction, recycling, respect for the environment, renewable sources of energy etc., these factors cannot be dodged by the management when making investment decisions. With this in mind, the research team investigated the impact of Industry 4.0 on the ability of companies to meet sustainability targets and explored the most noteworthy achievements so far attained.

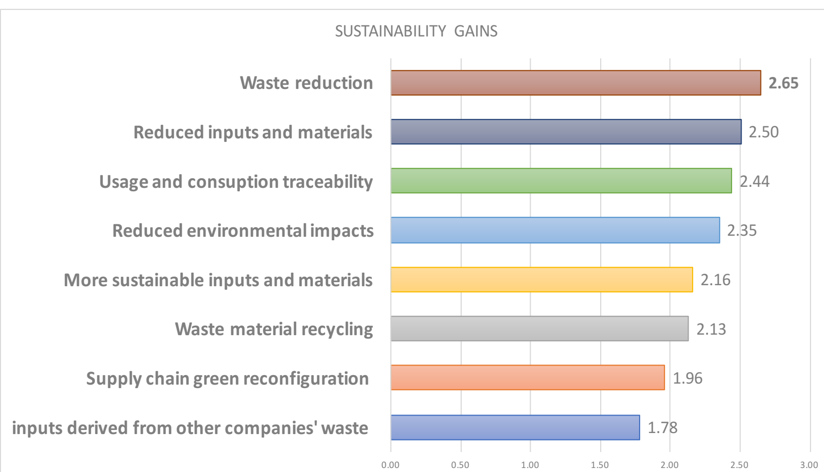


Figure 4.14: Sustainability gains

In general, the strongest impact consists in the reduction of waste produced by operations (2.65), but also of inputs and materials employed (2.50). The new paradigm is similarly allowing companies to trace usage and consumption on some level and reduce environmental impacts. Less substantial effects involve the sustainability of inputs, the recycling of waste materials, the reconfiguration of the supply chain from a "green" perspective and only in very few cases inputs are derived from other companies' waste. Results analyzed by dimension classes (see the table on next page), highlight that while for micro and small companies the biggest gain materialized in terms of waste reduction, for mediums the benefit was rather a cutback in inputs consumed. The four respondents representing large firms, declared to be in particular more able to trace usage and consumption and the same was stated by the smallest category, which have also improved in waste recycling capabilities.

Sustainability gains	<1M	MICRO	SMALL	MEDIUM	LARGE
1. Waste reduction	2.20	2.85	2.63	2.47	2.50
2. Reduced inputs and materials	2.00	2.61	2.60	2.65	1.67
3. More sustainable inputs and materials	1.90	2.33	2.12	2.06	2.00
4. Usage and consumption traceability	2.30	2.18	2.56	2.59	3.00
5. Waste material recycling	2.30	2.09	2.18	2.00	1.33
6. Reduced environmental impacts	2.20	2.39	2.29	2.53	2.33
7. Inputs derived from other companies' waste	1.80	1.70	2.00	1.65	1.33
8. Supply chain green reconfiguration	1.90	2.00	1.97	1.88	2.00
TOT. Respondents per **dimension**	10	33	36	17	4

Table 4.52: Sustainability gains by size

Sector	1	2	3	4	5	6	7	8	TOT. Respondents per **sector**
APPAREL	2.50	2.67	2.18	2.27	1.82	2.36	1.91	2.18	13
LEATHER GOODS/SHOES	4.00	4.00	2.00	4.00	4.00	3.00	1.00	2.00	1
RUBBER & PLASTIC GOODS	4.00	3.00	3.50	3.50	3.00	3.50	1.50	3.00	2
ELECTRIC LIGHTING EQUIPMENT	2.64	2.29	2.21	2.50	2.07	2.29	1.79	1.71	14
ELECTRIC EQUIPMENT	2.00	2.22	1.89	1.89	1.78	2.00	1.78	1.78	9
AUTOMOTIVE	2.50	1.55	1.36	2.64	1.55	1.73	1.55	1.55	12
FURNITURE	3.04	2.88	2.31	2.58	2.42	2.65	1.88	2.19	26
JEWELLERY	2.18	2.55	2.09	2.00	1.91	2.27	1.64	1.73	11
GLASSES & LENS	2.67	2.42	2.42	2.42	2.75	2.42	2.00	2.08	12
SPORT GOODS	3.00	4.00	3.00	3.00	1.00	1.00	1.00	1.00	1
OTHERS	2.50	3.00	2.50	3.00	1.50	3.00	1.50	2.50	2

Table 4.53: Sustainability gains by sector

Some variability can also be spotted across sectors. Among the ones which have most benefited from waste reduction and – in the case of electric equipment – also of reduced environmental impacts, we find manufacturers of: rubber and plastic goods, electric equipment and electric lighting equipment, and furniture. Industry 4.0 has moreover facilitated inputs savings for the apparel, jewelry, sport goods and the "others" sectors. Businesses operating in automotive are furthermore on average more capable of tracing usage and consumption, while those making glasses and lenses are recycling more waste material instead.

- **Products nature and origin, clientele and suppliers' location** (Questions n. 28-34)

To conclude the survey, companies were asked questions to determine the nature of their production, its location as well as the one of their suppliers, information on their customer base and other useful data for sample description. From the received answers the team gathered the following insights:

– The average first customer's share of the total turnover is of about 28%;
– Companies operating B2B also work for the following sectors:
  - Automotive: public transportation, agricultural machineries, industrial cleaning, industrial machineries, aviation, furniture and gardening tools;
  - Jewelry: eyewear, luxury and fashion accessories;
  - Sport goods: sky and trekking equipment and bicycle saddle stuffing;
  - Electric equipment: generic machineries, industrial conditioning, construction companies, automotive, automatic doors, home appliances, furniture and interior design, lighting for banks and hotels;
  - Furniture: hospital furniture, outdoor furniture and automotive;
  - Eyewear: jewelry, orthodontic and motorcycle components;
  - Apparel: stockings, automotive, umbrellas and hospitality;
  - Rubber: automotive components.
– On average, the sample elements produce, in percentage over the total production volume: 52% of finished goods for the end consumer and 29% for other companies, 10% of components and another 10% of semi-finished products. Considering the same categories but in a by-sector logic we obtained the following table.

	Finished goods for the end consumer	Finished goods for other companies	Components	Semi-finished products
	B2C	**B2B**		
APPAREL	74%	12%	0%	14%
LEATHER GOODS/SHOES	0	100%	0	0
RUBBER & PLASTIC GOODS	90%	10%	0	0
ELECTRIC LIGHTING EQUIPMENT	58%	29%	11%	2%
ELECTRIC EQUIPMENT	32%	48%	2%	19%
AUTOMOTIVE	32%	39%	24%	5%
FURNITURE	63%	27%	4%	6%
JEWELLERY	48%	24%	6%	22%
GLASSES & LENS	28%	24%	32%	16%
SPORT GOODS	0	0	100%	0
OTHERS	50%	36%	1%	13%

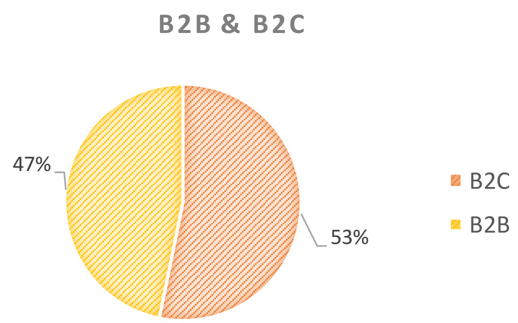
Table 4.54: production composition by sector

Results show that the apparel, rubber/plastic goods, electric lighting equipment, furniture and the jewelry sectors, mostly produce finished goods for the end consumer. Sample manufacturers of leather goods, electric equipment and automotive instead focus more on finished goods for other companies (B2B) and finally, the eyewear and sport goods sectors work on components production (note however, that for the latter group there was only one respondent).

Considering only the respondents to the just described question number 30 on production composition, and assuming as B2C only those producing finished goods for the end consumer for at least 50% of their total volume, we will obtain the following sample composition:

	B2C	B2B
N. of companies	58	51
%	**53%**	**47%**

Table 4.55: B2C and B2B sample composition



– On average products are manufactured for the 62% regionally, the 31% in our country and the 7% abroad. No significant differences are encountered across size categories, as on average for all production facilities are predominantly located inside the region of legal residence of the company, less frequently they expand outside the territory and even less abroad.

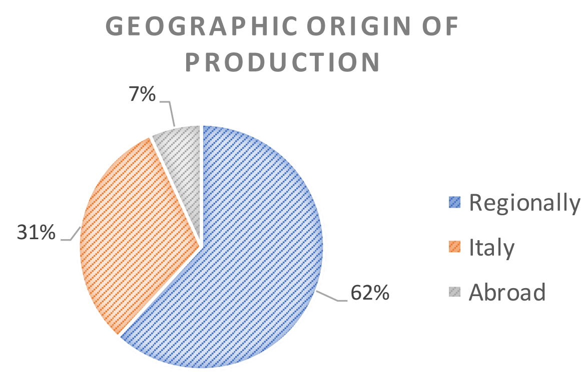


Figure 4.15: Origin of production

– Suppliers on the other hand are mostly (47%) located in the national territory, for the 38% in the same region as the producer, and for the 15% abroad. Analysis by size reveals that companies with a turnover below the one million threshold and large ones, on average keep their suppliers close (in region). Micro, small and medium-sized businesses instead have a higher share of suppliers dispersed on the entire peninsula. Those companies which either produce or receive supplies from abroad, have indicated mostly European countries like Germany, Spain, Romania, France, Belgium, Switzerland and Poland or the USA. In the case of the apparel industry in particular Asian countries like China, Vietnam and Indonesia have been cited.

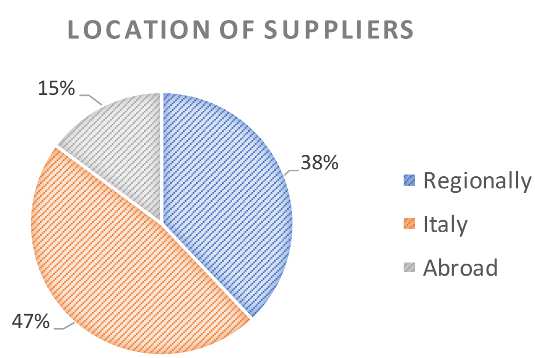


Figure 4.16: Suppliers' location

– Responders have moreover declared to produce on average 48% of the total production volume of fully customized products, 33% of standard (or catalogue) products, and standard but customizable products for 19% of the total volume. Large companies are the only ones that manufacture a majority of standard goods over customized ones, probably to take advantage of economies of scale. From a sector point of view, the manufacturers of leather goods and shoes, electric lighting equipment and jewelry are the ones who devote the great part of production to catalogue merchandise, while the remaining sectors predominantly focus on customization (see the table below for reference).

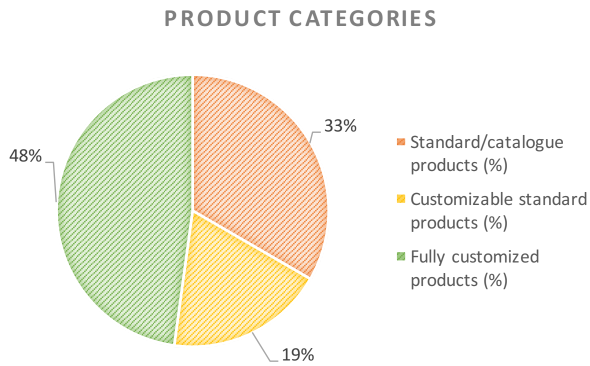


Figure 4.17: Standardized vs Customized production

	Standard/catalogue products (%)	Customizable standard products (%)	Fully customized products (%)	TOT. Respondents by **sector**
APPAREL	37	18	45	16
LEATHER GOODS/SHOES	100	0	0	1
RUBBER & PLASTIC GOODS	5	10	85	2
ELECTRIC LIGHTING EQUIPMENT	42	22	36	18
ELECTRIC EQUIPMENT	34	19	47	12
AUTOMOTIVE	25	22	53	11
FURNITURE	28	24	48	29
JEWELLERY	45	21	34	11
GLASSES & LENS	28	2	70	12
SPORT GOODS	0	0	100	1
OTHERS	34	16	50	4
				117

Table 4.56: Standardized vs Customized production by sector

➢ Considerations on financial performances

	Robot	AM	Laser cutter	Big data cloud	3d scanner	AR	IOT
Average ROE	14.02	9.19	10.51	11.13	6.29	16.09	5.21
Responders	55	39	51	52	13	18	27

Table 4.57: ROE for different adopted technologies

	Adopters	Non-adopters
Average ROE	11.79	8.55

Table 4.58: Adopters vs Non-adopters ROE

With the aim of understanding how the adoption of Industry 4.0 technologies influences the companies' return on equity, we downloaded from AIDA information on the sample ROE for the years 2014-2015-2016, computed an initial average for each company over these three years and then obtained an average for adopters and non-adopters. The previous table shows that, on average, businesses who decide to implement an Industry 4.0 strategy, have a significantly higher return on equity (11.79) as compared with their non-adopting competitors (8.55). We also checked for distinctions across type of technology acquired, and noted that the two technologies making a true difference are mainly: augmented reality and robotics. These results though, were obtained only on the basis of simple computations, they could therefore be influenced by other factors which we are not controlling for that may impact the outcomes. Manuel Polli (2017) – a SID project team member – performed several regression tests controlling for factors like the average size and age of the companies, sector of affiliation and region of residency, demonstrating that notwithstanding these considerations:

- ✓ Adopting businesses seem to obtain higher levels of financial performance as compared to non–adopting ones ceteris paribus;
- ✓ The role of robotics appears to have a higher weight on performance as compared to other technologies ceteris paribus;
- ✓ The positive effect on performance does not seem to depend on the variety of technologies adopted, as the adoption of three or more different tools does not have a significant and positive effect on performance.

- ➢ **Chi-squared test for independence: Sector → Adoption**

At the beginning of the analysis, a description of the sample discriminated elements across sectors and adopters from non-adopters, but is there an association between the sector of affiliation and the frequency of adopters? Having in mind the purpose of answering this question, we have performed a Pearson's Chi-squared test for independence. The Pearson's test is used to find out whether or not there exist a relationship between two categorical variables (which are variables with no meaningful ranking or order). It is based on the idea of comparing the frequencies we observe in certain categories – in this case of companies belonging to each sector and adopting/non-adopting – to the frequencies we might expect to get in those categories by chance [Field, 2009].
The Chi-squared test though yields only an approximate p-value which is valid when the dataset is large enough. The dimensional assumption is respected when less than 20% of the contingency cells have expected values < 5. When the assumption is violated a more appropriate test may be found in the Fisher's exact test [Deshpande, 2011].
The Pearson's test is also referred to as the "Chi-squared test of independence", because the null

hypothesis that is tested lays in the independence of the two nominal variables being considered. In our case we want to test the null hypothesis:

H_0: Sector and adoption behavior are independent;

Against the alternate hypothesis:

H_1: Dependence of adoption on sector.

On the database two variables were created: one indicating the sector of affiliation of each sample element, and a dichotomous variable assuming value 1 for adopters and 0 for non-adopters. The Pearson's test was run on the statistical software SPSS obtaining the following results:

			No adoption	Adoption	Total
SECTOR	APPAREL	Count	48	26	74
		Expected Count	59.1	14.9	74.0
	AUTOMOTIVE	Count	37	20	57
		Expected Count	45.5	11.5	57.0
	EL. EQ.	Count	225	17	242
		Expected Count	193.3	48.7	242.0
	EL. LIGHT. E.	Count	56	19	75
		Expected Count	59.9	15.1	75.0
	FURNITURE	Count	31	30	61
		Expected Count	48.7	12.3	61.0
	GLASSES	Count	22	13	35
		Expected Count	28.0	7.0	35.0
	JEWELRY	Count	131	13	144
		Expected Count	115.0	29.0	144.0
	LEATHER	Count	19	1	20
		Expected Count	16.0	4.0	20.0
	OTHERS	Count	23	6	29
		Expected Count	23.2	5.8	29.0
	RUBBER	Count	2	6	8
		Expected Count	6.4	1.6	8.0
	SPORT	Count	14	2	16
		Expected Count	12.8	3.2	16.0
Total		Count	608	153	761
		Expected Count	608.0	153.0	761.0

Table 4.59: Cross-tabulation sector-adoption

The table above reports for each sector the observed count, and the "expected count" or frequency that we would expect to observe if there was no association between the variables (i.e. the frequency that we would expect if the sector was independent from adoption). In this case we have that all expected counts are different than the observed ones. Now, looking at the second table, note that the footnote at the bottom of the chart determines that the Pearson's assumption is being respected as

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	113.286[a]	10	.000
Likelihood Ratio	109.436	10	.000
N of Valid Cases	761		

a. 3 cells (13.6%) have expected count less than 5. The

Table 4.60: Chi-squared test results

only 13.6% of the cells have an expected count < 5. This means that our sample is wide enough to consider the results provided by the Chi-squared test and that we do not need to run other tests (for example the Fisher's exact test in order to have reliable results). Being reassured by this, we can proceed to the observation of results. In particular, looking at the asymptotic significance (also known as p-value) being it zero, we know that even considering a significance value alpha equal to as little as 1%, our p-value being lower than 0.01 shows that our results are statistically significant. We can therefore accept the alternate hypothesis H_1, which says that there might be an association between sector and adoption behavior and that the registered frequencies might not be casually given.

Comments

What we take home from the study discussed in this chapter is a clearer picture of digital technologies' adoption patterns in our country, as well as of the positive and negative implications that innovation activities entail. We also gained a little more understanding of the approaches used, the competitively-relevant benefits obtained and information on the sample elements' interactions with their customers and business partners.

It must be specified though, that the project is still ongoing and data is still being collected, the sample will expand in the future and more companies will be incorporated in the analysis, increasing the significance of results obtained. Sectors that in this paper were kept into consideration but included only a few responders will be investigated more in detail when more answers will be recorded. Moreover, some of the matters discussed (for example the repercussions on employment levels) – due to the already considerable length of the survey – could not be further explored in this instance, but will certainly be more deeply researched as the project develops.

CONCLUSIONS

We've opened the first chapter of this paper with the intention of discussing the origin of the term 'Industry 4.0' and the path leading up to it. Benefits, opportunities and future challenges were pointed out and a short overview of technological advances paving the way for this Fourth Revolution was provided. Chapter number two illustrated the 'reaction' of the world's leading economies to the advent of the new paradigm. In particular, with the purpose of comparing the initiatives proposed by various institutions, we've drawn the lines of the most reviewed I4.0 implementation programs including: Germany, Italy, USA and China. Cross-country differences consist mainly in the plans' central goal, the nature of financial incentives and their focus as well as the nature of investment (public/private) and its entity. The third chapter looked at the factory of the future from the perspective of the labor force, considering the impact of the acquisition and implementation of new technologies, from a labor market point of view. Although we can't tell now what will happen in a 10 years-time frame, it is still interesting to research the opinions of both positive and negative literature experts and make assessments regarding the nature of skills and the know-how that will be required to stay competitive in the job market. In relation to this topic, the traits of the new 'augmented blue-collar' and the roles that he/she will be taking up have been described, raising concerns over the plausible need for a new type of education system increasingly focused on the development of IT-related skills and competences.

Finally, on the last chapter, the empirical study "SID project" has been introduced. The study revealed that only 20% of respondents have adopted Industry 4.0 technology and of these 42% have acquired only one. Although the embracement of the paradigm may seem to be feasible only for big size enterprises, the survey surfaced how that 20% is in fact heterogeneous in terms of dimensions and even small-sized companies can access and benefit from these technologies. The Pearson's Chi-squared test has moreover shown that adoption behavior depends on the sector and that the number of adopters for each sector considered is not given by chance, on the contrary, the two nominal variables (sector and adoption) might be associated. The number of technologies adopted also varies across sectors, the type chosen instead is different depending on the size category. Technologies have been adopted on different years depending on their typology and in general, on average before the "Piano Calenda", and employed in different activities of the value chain depending on their nature. Investments – mostly directed towards production, prototyping and R&D – have been, in 75% of cases, customized in their software and hardware components as

well as for their integration within the system. As much as 49% of sample respondents have also stated to have increased R&D expenditure over the last five years, sending a positive message regarding the eagerness to innovate of our companies.
Investigating the reasons of the other 80% of non-adopters, we understood that in most cases, respondents either believed that Industry 4.0 technologies are "not of interest to their business" or they ignored the subject itself. This result represents both a positive and negative outcome for our country as on one-hand it speaks on how far behind we are in terms of awareness with respect to other developed countries, but on the other it gives hope that the bigger problem might reside in the need to convince Italian entrepreneurs that Industry 4.0 is not un-achievable.
What has pushed adopters to invest has been the willingness to provide a better customer service, improving internal efficiency and access new market opportunities. We have acknowledged how the first two goals have been achieved in the majority of cases, as for the latter expectations might have been higher than the actual results. On the bright side, other gains have been obtained both in terms of sustainability (reduction of waste, inputs and materials), and of increased know-how for production and product improvement, as well as an augmented innovation ability in the 88% of cases considered. Generally speaking, empirical evidence seems to indicate that adoption of cutting-edge Industry 4.0 technology leads, on average, to a higher financial performance.
Another very important result resides in the fact that 60% of companies interviewed, affirmed that the level of occupation as remained stable, 38% indicated an increase and only in 3% of the cases it has dropped. Even though these results will need to be further investigated more in detail, they still give a little hope on the future of employment in an Industry 4.0 context.
On the other hand, difficulties remain for the integration of advanced technologies in today's factories, and some of them encompass: the lack of finding adequate professionals on the market, the lack of and/or insufficient internal competences and scarce financial resources. The response to some of these impediments is currently being evaluated by the government – as discussed in chapter number two – but the effectiveness of these measures will have to be assessed in light of the results that they will produce in the next couple years.

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