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The role of Industry 4.0 in the post-crisis competitive market – The case of O.L.V.

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1. INTRODUCTION

The welfare of a community mainly depends on the goods and services it manages to produce in a unit of time, i.e. what economists call productivity. But what does productivity growth depend on? It derives essentially from the flow of innovations. And the industrial revolutions that have taken place throughout history have certainly influenced this. Industry 4.0 is the synthetic expression used to identify the fourth industrial revolution, namely the profound and irreversible digital transformation of the productive, but also socio-economic, system that will lead to accelerating exponential growth phenomena. The aim of this text is to offer a general description of the current state of industry and its relaunch after the difficult years of the global crisis that had profoundly debunked it in all sectors. A great help for the revival is undoubtedly due to the technological renewal that in recent years has produced significant changes. One of these is certainly the birth of the paradigm called Industry 4.0, whose characteristics, as well as the advantages and obstacles to its development are carefully described in the various chapters of the text. It is now up to the various companies to grasp its fundamental characteristics so as to gradually introduce them, so as to maintain an advantage over competitors that is sustainable over the years. Even in Italy something is happening too. Top management understands the importance of embarking on a real digital revolution, and the first 4.0 industries are beginning to emerge, not only in the service sector, but also in purely productive sectors, such as metallurgy. Emblematic in this sense is the case of the O.L.V., a metallurgical company that has decided to bet on new technologies to improve its production system.

2. FINDING COMPETITIVE ADVANTAGE

Today in the world there are billions of companies that compete in hundreds of sectors. Each of them follows different strategies to achieve specific results. Nevertheless, all these companies share a common goal, the pursuit of a competitive advantage.

For at least two decades, the concept of competitive advantage has been central to the practice and study of strategic management and a key element in the process of creating competitiveness of all types of businesses. The concept became perhaps the most important one in strategy after the publication of Porter’s immensely popular “Competitive Strategy” in 1980, followed by his “Competitive Advantage” in 1985. In Porter’s view, “Competitive advantage is at the heart of a firm’s performance in competitive markets”. He argued that a firm’s ability to outperform its competitors lay in its ability to translate its competitive strategy into a competitive advantage. It addresses the interplay between the types of competitive advantage (cost and differentiation) and the scope of a firm's activities. The result of this process, i.e. the competitiveness of a given entity, is a strategic feature from the point of view of its long-term functioning and development. Due to its nature, its components include efficiency, dynamism and flexibility of the studied business.

It is increasingly often indicated that the ability to create a competitive advantage is connected with a schematic, bold thinking, an extreme change in the manner business is conducted, operational speed, innovative ideas and finding revolutionary solutions (Chakravorti, 2010). All the above-presented considerations lead to the conclusion that it is a phenomenon increasingly difficult to sustain, design and effectively implement.

Competitive advantage should be seen as a given company’s ability to develop, and later on to control a special and peculiar type of resources and skills which allows it to create and implement strategies that improve its performance and efficiency. It describes its ability to consciously identify, deploy, develop, protect and enjoy the benefits of such unique resources and competences which are wanted and valued by the market, and which are not available to the same extent to other competitors. Creating unique and competitive combinations in this regard increases chances of long-term market success. The ability to identify, shape and develop exceptional competences within a company is important along with the ability to mobilize the necessary resources and skills located outside the company.

But advantage over other competitors is not gained simply by possessing rare and valuable resources but by employing and deploying those resources to address or shape environmental conditions resulting in supernormal returns. Thus, determining the presence of a competitive advantage entails examining the financial performance of a specific competitive strategy in a certain environment. This approach recognizes that competitive advantage is a result of the interaction of a firm’s competitive strategy, an internal factor, and environmental conditions, an external factor.

Changes in industry structure can therefore affect the bases on which generic strategies are built and thus alter the balance among them. For example, the advent of electronic controls and new image developing systems has greatly eroded the importance of service as a basis for differentiation in copiers. Structural change can shift the relative balance among the generic strategies in an industry, since it can alter the sustainability of a generic strategy or the size of the competitive advantage that results from it.

The automobile industry provides another good example. Early in its history, leading automobile firms followed differentiation strategies in the production of expensive touring cars. Technological and market changes created the potential for Henry Ford to change the rules of competition by adopting a classic overall cost leadership strategy, based on low-cost production of a standard model sold at low prices. The result was that Ford rapidly dominated the industry worldwide.

Based on these considerations, a question arises: is competitive advantage sustainable or merely temporary in today’s dynamic, hypercompetitive environments? Several strategy researchers (Brown & Eisenhardt, 1998; D’Aveni, 1994; Eisenhardt & Martin, 2000; Hamel, 2000) argued that at the firm level achieving and particularly sustaining competitive advantage in today’s highly dynamic (or hypercompetitive) environments was difficult if not impossible.
Because advantages are quickly copied or rendered inoperable today by the advent of new advantages, firms can only look forward to temporary or a series of temporary advantages, while long-term or sustained above-average profitability is no more feasible as before. (Beal, 2001)

3. TECHNOLOGY PROGRESS TO OVERCOME THE CRISIS

A company's stability and profitability are interdependent on its ability to quickly identify and respond to changes in the external environment. Change is inevitable and having the flexibility to deal with unexpected market mutations can mean the difference between survival and extinction for an organization. As a result, the organization must be attentive to any stimulus from the external environment, must continually adapt to it, and primarily involves adapting knowledge and information.

Therefore, a firm needs to possess dynamic capability in order to reconfigure internal and external competencies in response to the changes in the environment. In order to foster dynamic capabilities, the firm must be ambidextrous. This requires managers to manage two critical tasks—they must be able to accurately sense changes in the external environment and act on these opportunities and threats. Firms like Facebook, Tesla Motors and Whole Foods have benefitted by capitalizing on macro-environmental opportunities and exploiting trends in social, technological and ecological domains. Firms that have failed to take advantage of macro-environmental trends have ended up losing their competitive advantage.

3.1 THE GLOBAL ECONOMIC CRISIS

It is therefore necessary now to offer a general description of the context in which today's companies operate looking for competitive advantage. We are moving towards a smarter world. In Europe, the United States and Japan - the so-called advanced economies - there is a lot of talk about digitalisation and industry 4.0. A breath of fresh air in a world devastated by the crisis, whose effects have been, and still are, clearly visible.

The collapse of Lehman Brothers in September 2008 led to a major global economic crisis of a magnitude that had not been seen for at least half a century: world gross domestic production (GDP) and industrial production retracted, trade collapsed sharply, and unemployment increased in many of the world's major economies.

The financial crisis came as a great surprise to most people. What initially was seen as difficulties in the US subprime mortgage market, rapidly escalated and spilled over to financial markets all over the world. When it comes to recessions, sometimes the best definitions are the light-hearted ones. "If your neighbour gets laid off, it's a recession. If you get laid off, it's a depression," as one economist jokingly put it. However, economists officially define a recession as two consecutive quarters of negative growth in the gross domestic product (GDP). According to the National Bureau of Economic Research, the hallmark of a recession is a "significant decline in economic activity spread across the economy, lasting more than a few months."

Both definitions are accurate because they indicate the same economic results: a loss of jobs, a decline in real income, a slowdown in industrial production and manufacturing, and a slump in consumer spending. And that's exactly what happened after the 2008 collapse. Both sales revenues and profits declined, companies cut back on hiring new employees, or frozen hiring entirely (figure 1).

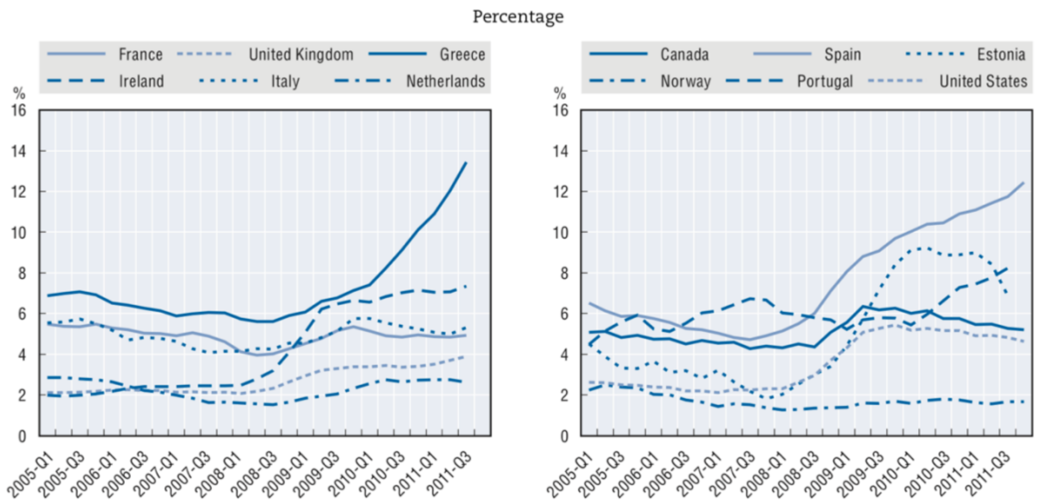

Figure 1: Quarterly unemployment rate for highly-skilled workers for selected countries, 2005-2011

In an effort to cut costs and improve the bottom line, firms stopped buying new equipment, limited research and development, and stopped new product rollouts (a factor in the growth of revenue and market share). Expenditures for marketing and advertising were also reduced. Firms' demand for bank loans decreased substantially during the recession (figure 2). In any case, access to finance appears to have been much more difficult as the global financial crisis unfolded.

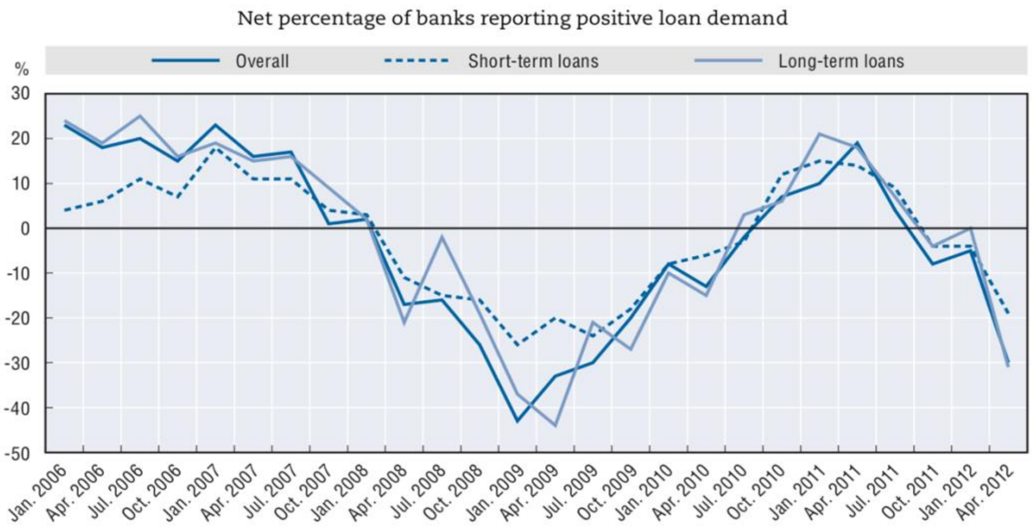

Figure 2: Changes in demand for loans and credit lines to enterprises, 2006-2012

The recession dampened companies' accounts receivable, resulting in defaults on bonds and other debt, damaging the firms' credit rating or causing bankruptcy.

According to "Insolvencies in Europe 2008/09", the total number of insolvencies increased by 11% between 2007 and 2008. That was a banner year for commercial bankruptcies and bank and brokerage-house failures in U.S. (figure 3); 136 public companies filed for bankruptcy protection, a 74 percent increase from 2007, when there were 78 public-company filings.

Figure 3: Number of bankruptcies, quarterly data, 2006-2011

As the effects of the crisis rippled through the economy, consumer confidence declined, perpetuating the recession as consumer spending drops. The national responses and other publicly available information provided some indications about the effective and expected movements in levels of sales (figure 4). Most countries reported a clear downturn in demand for goods and services, if not a demand slump, in Q4-2008, expecting a further worsening to come. (Organisation for Economic Cooperation and Development, 2009)

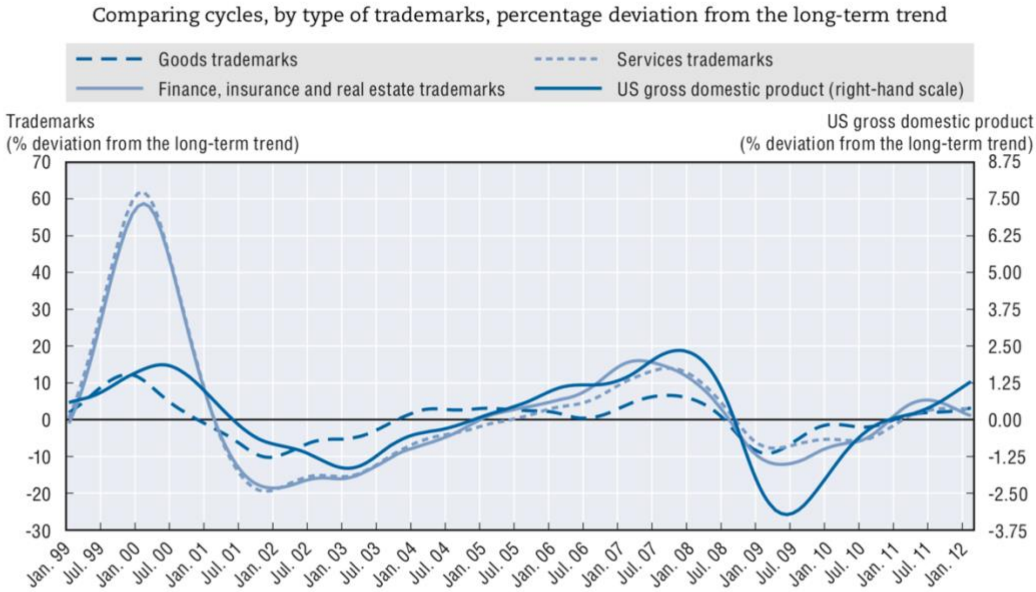

Figure 4: US gross domestic product and trademark applications, 1999-2012

Joseph Schumpeter famously argued that the process of “creative destruction”, while painful, fosters innovation and progress by discarding the old and familiar for the new and better. From this perspective, the downturn may be a source of opportunities for innovators and innovation systems. “Creative destruction” – the process whereby economic downturns force less innovative incumbents to exit and allow more innovative firms to enter – can play a powerful role in improving overall innovation performance and therefore matters substantially for growth (Philippe & Howitt, 1992). The available evidence suggests that the “creative destruction” process broke down with the onset of the global financial crisis. It was also noted that the crisis brings certain opportunities to improve firms’ legal framework and the business environment. The crisis could accelerate the redeployment of resources to new activities. Emerging firms and those redesigning their processes should be encouraged to focus on sustainability and knowledge-based outcomes.

To date, although the situation looks better than in the years immediately following the financial crisis, global economic growth remains far below the levels reached in previous decades and, above all, in the 1950s, 1960s and 1970s. After all, productivity is growing at a much lower rate than in the past, both in the United States and in the Eurozone. As stated by Robert Solow, Nobel Prize in Economics: "We see the era of computers everywhere except in productivity data". What are the reasons for this paradox?

While we agree that significant challenges lie ahead, we also see considerable reason for optimism about the potential for new and emerging technologies to raise productivity and provide widespread benefits across economies. Despite the multitude of technologies and concepts involved, a digital transformation in and of industrial enterprises is in place. And just like digital transformation it requires a strategic view and approach.

3.2 A RAPID TECHNOLOGICAL CHANGE

The other side of the coin recounts a diametrically opposite process still in progress. The negative consequences of the crisis have not yet been metabolized, while on the horizon a new revolution can be glimpsed: the technological one.

New materials, new ways of designing products, new production processes, new logistics, new marketing, new business models, new value and supply chains, new technologies, new ways of storing and using energy, new ways of working and interacting and consequently new standards and rules are revolutionizing the way of "doing" business and designing policies. All this innovations should became a stimulus for a more intense awareness of the prospects and opportunities that the fourth industrial revolution is generating especially at the country level, where new and more modern growth policies are needed, which can help the manufacturing industry and the services that operate with it to leverage on all new technologies and business models to generate product and service innovation for greater business productivity, a necessary condition for generating growth and stable and lasting employment.

Technology has come a long way, making people's personal and working lives easier and providing unprecedented convenience. As advancements in technology continue to develop, customer expectations will continue to evolve as well. It is progressing rapidly, and it is changing the way we live and work. New inventions are happening, and new paradigms are born almost every day. Conventional concepts we are used to as a human race for decades or even centuries are being disrupted by cutting edge technology. Just half a century ago, computers were only surfacing and were used for particular scientific or research work, but today they are found all around us.

The world of work is completely changing. Taking a look at some data, the top 10 in-demand jobs in 2010, did not exist in 2004. It means that students are currently preparing for jobs that don't yet exist, using technologies that haven't been invented in order to solve problems we don't even know are problem yet. Seven out of ten workers are currently in jobs where there is a great uncertainty about their future. And only one in ten workers is currently in an occupation that will grow in demand in the future. According to the experts from the Institute for the Future (IFTF), it was estimated that around 85% of the jobs of 2030 haven't even been invented yet.

The speed of "technology adoption" is another case in point (figure 5). Whereas the telephone industry took 120 years to reach more than 90 percent of the population in the USA, and the car industry 110 years to reach 75 percent, the personal computer took a little over 20 years to reach 40 percent and the cell phone less than 10 to reach 30 percent. In 38 years, the radio had reached a market audience of 50 million; to reach the same audience, television took 13 years, the Internet four, the iPod three and Facebook only two.

	Illustrative rates of technology improvement and diffusion	Illustrative groups, products, and resources that could be impacted[1]	Illustrative pools of economic value that could be impacted[1]
Mobile Internet	**$5 million vs. $400[2]** Price of the fastest supercomputer in 1975 vs. that of an iPhone 4 today, equal in performance (MFLOPS) **6x** Growth in sales of smartphones and tablets since launch of iPhone in 2007	**4.3 billion** People remaining to be connected to the Internet, potentially through mobile Internet **1 billion** Transaction and interaction workers, nearly 40% of global workforce	**$1.7 trillion** GDP related to the Internet **$25 trillion** Interaction and transaction worker employment costs, 70% of global employment costs
Automation of knowledge work	**100x** Increase in computing power from IBM's Deep Blue (chess champion in 1997) to Watson (Jeopardy winner in 2011) **400+ million** Increase in number of users of intelligent digital assistants like Siri and Google Now in past 5 years	**230+ million** Knowledge workers, 9% of global workforce **1.1 billion** Smartphone users, with potential to use automated digital assistance apps	**$9+ trillion** Knowledge worker employment costs, 27% of global employment costs
The Internet of Things	**300%** Increase in connected machine-to-machine devices over past 5 years **80–90%** Price decline in MEMS (microelectromechanical systems) sensors in past 5 years	**1 trillion** Things that could be connected to the Internet across industries such as manufacturing, health care, and mining **100 million** Global machine to machine (M2M) device connections across sectors like transportation, security, health care, and utilities	**$36 trillion** Operating costs of key affected industries (manufacturing, health care, and mining)
Cloud technology	**18 months** Time to double server performance per dollar **3x** Monthly cost of owning a server vs. renting in the cloud	**2 billion** Global users of cloud-based email services like Gmail, Yahoo, and Hotmail **80%** North American institutions hosting or planning to host critical applications on the cloud	**$1.7 trillion** GDP related to the Internet **$3 trillion** Enterprise IT spend
Advanced robotics	**75–85%** Lower price for Baxter[3] than a typical industrial robot **170%** Growth in sales of industrial robots, 2009–11	**320 million** Manufacturing workers, 12% of global workforce **250 million** Annual major surgeries	**$6 trillion** Manufacturing worker employment costs, 19% of global employment costs **$2–3 trillion** Cost of major surgeries
Autonomous and near-autonomous vehicles	**7** Miles driven by top-performing driverless car in 2004 DARPA Grand Challenge along a 150-mile route **1,540** Miles cumulatively driven by cars competing in 2005 Grand Challenge **300,000+** Miles driven by Google's autonomous cars with only 1 accident (which was human-caused)	**1 billion** Cars and trucks globally **450,000** Civilian, military, and general aviation aircraft in the world	**$4 trillion** Automobile industry revenue **$155 billion** Revenue from sales of civilian, military, and general aviation aircraft
Next-generation genomics	**10 months** Time to double sequencing speed per dollar **100x** Increase in acreage of genetically modified crops, 1996–2012	**26 million** Annual deaths from cancer, cardiovascular disease, or type 2 diabetes **2.5 billion** People employed in agriculture	**$6.5 trillion** Global health-care costs **$1.1 trillion** Global value of wheat, rice, maize, soy, and barley
Energy storage	**40%** Price decline for a lithium-ion battery pack in an electric vehicle since 2009	**1 billion** Cars and trucks globally **1.2 billion** People without access to electricity	**$2.5 trillion** Revenue from global consumption of gasoline and diesel **$100 billion** Estimated value of electricity for households currently without access
3D printing	**90%** Lower price for a home 3D printer vs. 4 years ago **4x** Increase in additive manufacturing revenue in past 10 years	**320 million** Manufacturing workers, 12% of global workforce **8 billion** Annual number of toys manufactured globally	**$11 trillion** Global manufacturing GDP **$85 billion** Revenue from global toy sales
Advanced materials	**$1,000 vs. $50** Difference in price of 1 gram of nanotubes over 10 years **115x** Strength-to-weight ratio of carbon nanotubes vs. steel	**7.6 million tons** Annual global silicon consumption **45,000 metric tons** Annual global carbon fiber consumption	**$1.2 trillion** Revenue from global semiconductor sales **$4 billion** Revenue from global carbon fiber sales
Advanced oil and gas exploration and recovery	**3x** Increase in efficiency of US gas wells, 2007–11 **2x** Increase in efficiency of US oil wells, 2007–11	**22 billion** Barrels of oil equivalent in natural gas produced globally **30 billion** Barrels of crude oil produced globally	**$800 billion** Revenue from global sales of natural gas **$3.4 trillion** Revenue from global sales of crude oil
Renewable energy	**85%** Lower price for a solar photovoltaic cell per watt since 2000 **19x** Growth in solar photovoltaic and wind generation capacity since 2000	**21,000 TWh** Annual global electricity consumption **13 billion tons** Annual CO_2 emissions from electricity generation, more than from all cars, trucks, and planes	**$3.5 trillion** Value of global electricity consumption **$80 billion** Value of global carbon market transactions

Figure 5: Speed, scope and economic value at stake of 12 potentially economically disruptive technologies.

Whilst some technological change follows a continued linear progression, many of the technological innovations we see follow a non-linear pathway. This non-linearity is observed most clearly in examples which show rapid evolution following an important enabling innovation, like the field of human genome DNA sequencing. The Human Genome Project (HGP), which aimed to determine and map the complete set of nucleotide base pairs which make up human DNA (which total more than three billion) ran over 13 years from 1990-2003. This initial discovery and determination of the human genome sequence was a crucial injection point in the field of DNA sequencing.

As reported by the NHGRI Genome Sequencing Program (GSP), the cost of sequencing DNA bases has fallen dramatically (more than 175,000-fold) since the completion of the first sequencing project. Nonetheless, this rapid decline in cost is also observed in prices for the sequencing of a complete human genome. This can also be observed in another way: in the early 2000s, we could sequence in the order of hundreds of base pairs per US$; since 2008, we have seen a dramatic decline in the cost of sequencing, allowing us to now produce more than 33 million base pairs per US$ (figure 6).

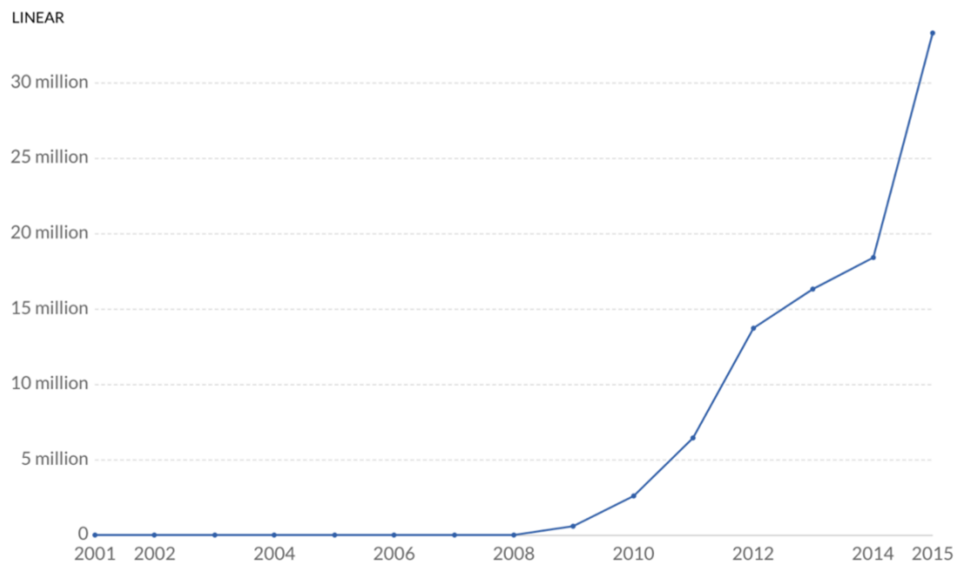

Figure 6: Number of human genome base pairs sequenced per US$

In 1965, Gordon Moore, co-founder of Intel, came up with a theory of technology progression that held true for more than 50 years. Coined "Moore's law", the theory suggested that the speed of computer processors would double every two years. The transistors inside of computer chips would continue to decline in cost and size but increase in power. Moore's law predicted that technology would continue to shrink at a rate that meant every year, twice as many transistors would be able to fit into a single computer chip (figure 7). "Half of economic growth in the U.S. and worldwide has also been attributed to this trend and the innovations it enabled throughout the economy", said Erica Fuchs, study researcher and professor of Engineering and Public Policy at Carnegie Mellon University.

Shrinking transistors have powered advances in computing for more than half a century, but soon engineers and scientists must find other ways to make computers more capable. Instead of physical processes, applications and software may help improve the speed and efficiency of computers. Cloud computing, wireless communication, the Internet of Things, and quantum physics all will play a role in the future of computer tech innovation. (Roser & Ritchie , 2013)

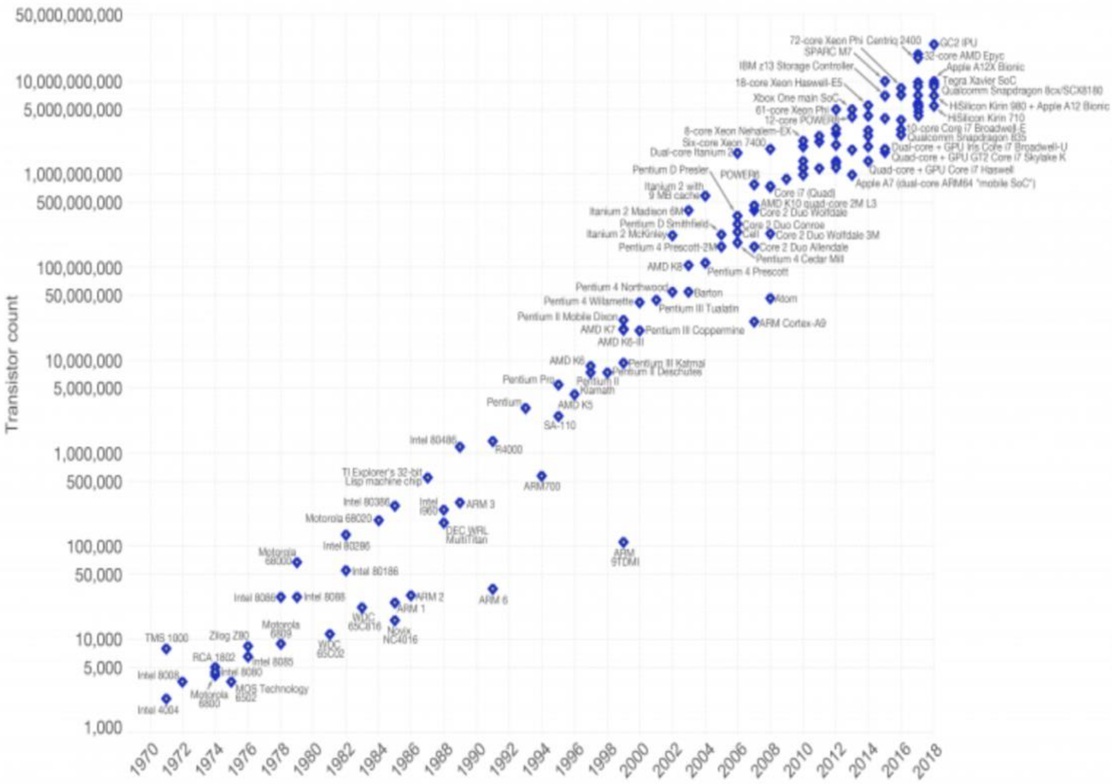

Figure 7: The number of transistors on integrated circuit chips (1971-2018)

The amount of data we produce every day is truly mind-boggling. There are 2.5 quintillion bytes of data created each day at our current pace, but that pace is only accelerating with the growth of the Internet of Things (IoT). Over the last two years alone 90 percent of the data in the world was generated. The amount of new technical information is doubling every 2 years.

Autonomous vehicle technology is a growing research field which has the capacity to revolutionize transportation. This technology which seemed like a futuristic dream, is already here to stay. Today we see self-driving cars, autonomous drones and swarms that work collaboratively to complete tasks autonomously. Other technologies like advanced robotics or 3D-printing have reached a disproportionate success and spread in recent years.

The exponential growth rates that we have observed over the last decades seem to promise more exciting technological advances in the future. For companies, not investing in innovative processes could be a strategic mistake with irreparable damage. For advanced economies, the growing automation of the manufacturing sector is an important new challenge. For emerging ones - whose economies often depend on production and high labour efficiency - technological change can even be a question of survival.

In essence, the modern global economy is at the threshold of the new industrial revolution, which is proved by a lot of actual tendencies. Firstly, large duration of the global economic crisis of the early twenty-first century and impossibility of overcoming it with the help of the existing possibilities of economic system shows depletion of the potential of the previous technological model. In the sphere of industrial production, the crisis was first manifested in overproduction of industrial goods and impossibility of selling it in domestic economic system or in the global markets—which led to massive bankruptcy of industrial companies around the world and increase of protectionist measures from governments of various countries.
Secondly, according to the modern provisions of the economic theory (in particular, the theory of economic cycles, the theory of crises, the theory of innovations, etc.), overcoming the global crisis requires starting a new wave of innovations. This tendency is supported by intensive progress of a lot of countries in formation of knowledge economy, due to which potential of the global economic system as to its future innovational development is strengthened. Innovations are a generally acknowledged global priority of socioeconomic development.

Thirdly, over the recent decades, scholars from different countries conducted research which resulted in new technologies, most of which are the leading production technologies (technological innovations)—i.e., they are oriented at the real sector of the economy. These technologies have to form and stimulate intensive development of new high-tech spheres of industry, but they have not yet been used in practice.

Lastly, at the level of separate companies and even countries, there are initiatives on revolutionary technical modernization that are aimed at achieving unprecedented innovational development. In the condition of global competition, success of economic subjects and economic systems in the global market could be ensured only by unique competitive advantages. In order to achieve and preserve them, it is necessary to use new technologies that ensure optimization of socioeconomic and business processes (Popkova, Ragulina, & Bogoviz, 2019).

4. LOOKING AT THE FUTURE WITH AN EYE ON THE PAST: THE PREVIOUS REVOLUTIONS

If the global crisis and the progress of technology represent the general context in which contemporary companies compete, the birth and progressive development of Industry 4.0 represent the direct consequence. Before going into the specifics of what are the distinctive elements of this fourth industrial revolution, it is suitable to make the necessary premises of those stages that in fact turn out to be preparatory to the revolution itself.

4.1 INDUSTRY 1.0: THE DAWN OF INNOVATION

Industrial revolutions are the most important milestones that have changed the course of human history. According to many researchers, the industrial revolution affects people’s lifestyle even more than the science revolutions.

The First Industrial Revolution does not only indicate the end of an era, the early-modern period, and the following birth of the contemporary age, but it represents a breaking point which, with its advent, at the turn of the eighteenth century, marked a historic passage from an agricultural-artisanal-commercial system to an industrial system.

The fundamental "macro-innovations" in the industrial world were essentially two: in the field of energy production, the steam machine developed for the first time by James Watt in 1775 and the subsequent application in transport and industrial production; in the field of textile manufacturing, the mechanical spinning machine introduced by Arkwright in 1779. These innovations produced in turn significant changes, mostly concentrated in two sectors: the cotton and the iron industries.

The use of steam as a driving force made the machines more efficient in terms of fuel consumption, heat loss and energy produced, allowing mass production in large factories, while the use of the mechanical spinning machine increased the productivity of work which implied an increase in the number and quality of the products produced and a decrease in production costs compared to traditional manual looms. In short, the first industrial revolution inaugurated the first age of machines, the dawn of innovation, a radical transformation that our world has ever known to the point that, to use Morris's words, it has "ridiculed all the pathos of the previous world history" (Brynjolfsson & McAfee, 2014).

4.2 INDUSTRY 2.0: THE ERA OF STANDARDIZED PRODUCTION

After the great depression of the late nineteenth century, Europe and the United States were the protagonists of an unprecedented technological development that in 1913 recorded a surprising increase in world manufacturing production of 378% compared to that of 1875.
Many historians, to refer to the set of profound transformation processes that occurred conventionally, between 1870 and 1970, used the definition of "second industrial revolution". Among the multitude of revolutionary macro-inventions that came to life in those years, the one that best sums up the turning point with respect to the previous century both for the economic and for the social impact is undoubtedly electricity. The era of the second industrial revolution was also marked by the birth of the internal combustion engine and the replacement of the oil to the coil as the main source of energy.

Overall, these inventions were able to completely revolutionize the organization of production processes. In fact, this was overwhelmed by innovations aimed at facilitating the flow of production (conveyor belts) or at increasing labour productivity (use of high precision machine tools). Among the processes of productive reorganization, the most important consists in the rational and scientific use of workers in large factories, through the application of the principles postulated by Taylor in his “The Principles of Scientific Management”. The division of labour and the centrality of the assembly line made it possible to drastically reduce unit production times and costs by guaranteeing an increase in the productivity of workers and in the volume of products produced, the maintenance of which was essential to achieve economies of scale. Thus, the second industrial revolution must be considered the era of standardized production, characterized by a market and a mass consumption in which two types of actors are identified: producers in a dominant position and consumers in a dominated position; as exemplified by the famous quote by Henry Ford, who in his biography stated: "Any customer can have a Ford T painted any colour that he wants so long as it is black“.

4.3 INDUSTRY 3.0: THE BIRTH OF COMPUTERS

Despite the fact that the third industrial revolution touches all the fields of the economic-industrial sector, it is electronics and information technology that are the masters. In fact, the birth of the computer and the transistor represent the incipit towards a continuous and rapid technological development able to determine remarkable changes in economic-social level with impacts both on the lifestyles of the population and on the organization of the industrial production. The effects of these transformations were closely linked and brought to light the increasing difficulties encountered by the mass production system in the face of saturated markets, characterized by strong fluctuations in demand and a profound transformation in consumer preferences, which have become increasingly hostile to standardization and more likely to reward quality (Battilossi, 2002).

Because of this, large companies had to abandon the rigidity of standardized mass production in favour of flexible and automated production systems (flexible machines capable of being used in numerous production lines), able to adapt volumes and production characteristics to the mutability of demand and allowing companies to reduce total costs and achieve savings not on volumes but in the collection, processing and transmission of data. This transformation implied a profound and irreversible rupture that marked the end of the Fordist era and the affirmation of the Japanese model of lean production, based on the concepts of total quality, bottom-up and just-in-time information flow.

We can thus underline how this revolution outlines a post-industrial economy, with a wide range of services and an inversion compared to the previous period in terms of dominance of the actors (producers in a dominated position, consumers in a dominant position), able to exploit resources such as information, knowledge and creativity to serve an increasingly demanding and problematic consumer.

Parameters	The industrial revolution			
	First	Second	Third	Fourth
Time frame	18th–early 19th century	Late 19th–early 20th century	Second half of the 20th century	21st century
Accumulated industrial innovations	Production of cast iron, steam engines, and textile industry	Production of high-quality steel, distribution of railroads, electricity, and chemicals	Renewable sources of energy, digital technologies, network organization of business processes	Internet of things, robototronics
Type of technological mode	Industrial production	Conveyor production	Global production on the basis of digital technologies	Fully automatized production
Required new infrastructure	Industrial equipment	Conveyor equipment, railroads	Digital equipment, global infrastructure	High-speed Internet, robotized equipment
Essence of systemic transformations in industry	Formation of industrial production	Formation of conveyor production	Formation of global production on the basis of digital technologies	Formation of fully automatized production
Efficient changes in logistics	Steam transport	Railroad transport	Buildings that generate electric energy, electric, hybrid, and other transport means	Exoskeleton, manipulators, Robototronics
Efficient changes in products	Cast iron products	Steel products	Computer products	New construction materials

Figure 8: The essence and key parameters of the three previous and the Fourth Industrial Revolution

5. INDUSTRY 4.0

The development of technology as well as the urgent crisis, with the consequent need to make a change in order not to be suffocated by an increasingly oppressive competition, have therefore facilitated the process known today as Industry 4.0. But what is Industry 4.0 actually?

While Industry 4.0 is originally a German project, and German government and economy are still the driving force behind it, however, we should keep in mind that the 4th industrial revolution are not a German phenomenon, but are global in nature, as horizontal networking in value chain networks is not limited to just one company or country. Even when companies are not consciously implementing the Industry 4.0 paradigm, the pressure from their competitors or partners will require them to do so.

5.1 THE SMART FACTORY

The analysis carried out so far let us to understand how the industrial revolutions have allowed man, through continuous disruptive innovations, to no longer have to depend on his own strength, making mass production possible and equipping millions of people with digital skills. Such changes are nothing but the prelude to the advent of a further revolution: the fourth industrial revolution. While the first three technological revolutions have indicated the development of economic systems on mass industrial production, characterized by a purely "product driven" market, today companies operate and compete in a context, that of Industry 4.0, characterized by a market that is strongly "demand driven".

The constantly changing market and customer requirements are confronting manufacturers with new challenges and affect almost every strategic decision. With the realization of the vision 'Industry 4.0' major changes will occur not only for factories but also for individuals. According to the visionary work of Schwab (2016), contrary to the previous industrial revolutions, the 4th industrial revolution is evolving at an exponential rather than linear pace and not only changing the 'what' and the 'how' of doing things, but also 'who' we are. We are witnessing profound shifts across all industries, marked by the emergence of new business models, the disruption of incumbents and the reshaping of production, consumption, transportation and delivery systems.

Accelerated industrial digitization is trying to respond to rapidly changing customer needs. Due to ever new product variants expected by customers, the product lifecycle is considerably shortened, so work on the innovation of the product, and the technology needed to produce it, has to be kept up-to-date. Not only does the product itself need to be renewed from time to time, but a production technology must also be created that can be flexibly altered along with the ever-changing customer product specifications. Due to industrial digitalization, there may be significant effects on manufacturing industries: substantial reductions in inventory, logistics and material handling costs, shorter lead times and fewer shortages during shipment. Industry 4.0's technology users at company level are expected to increase their capacity utilization and market their new products faster, in line with changing needs. The cost of value-creating processes can lead to a 3.6% annual decrease in costs in the future (reduction in lead times, improved asset utilization and improved product quality), in return for spending 5% on digital skills and tools in the next few years. (Geissbauer, Vedsø, & Schrauf, 2016).

The big upheavals that this revolution brings are the changes in the economies and jobs: by automating processes, certain jobs disappears, but at the same time new jobs are developed, which are better paid, but also require new skills that allow rapid adaptation, entrepreneurship and innovation. The unstoppable shift from simple digitization (the Third Industrial Revolution) to innovation based on combinations of technologies (the Fourth Industrial Revolution) is forcing companies to re-examine the way they do business. With the development and dissemination of technologies for universal connectivity and autonomous systems, Industry 4.0 is the driving force behind the 4th Industrial revolution.

A key point of this latest revolution is the need to create fully integrated and collaborative factory systems that respond in real time to changes in demand and to the state of the factory, the supply network and the needs of the customer, the so-called "Smart Factories". Creating a smart factory means adopting an open and interconnected infrastructure that allows to manage and monitor business processes in real time and support the definition and implementation of solutions that meet the needs of the company in the right way and at the right time, in order to create a real added value by optimizing the processes and satisfying at the same time the needs of the market, essential aspects to build a solid competitive advantage over time.

Sensors, machines, workpieces, and IT systems will be connected along the value chain beyond a single enterprise. These connected systems (also referred to as cyber physical systems) can interact with one another using standard Internet-based protocols and analysed data to predict failure, configure themselves, and adapt to changes. Industry 4.0 creates a modularly structured smart factory, a Cyber Physical System (CPS) that monitors physical processes, maps the physical world in the virtual world and decentralizes operational decision-making (autonomous machines). In simple terms, cyber-physical systems are systems which have an interface between the digital (cyber) world and the real (physical) world. A simple example is sensors with their own IP address.

Cyber-physical systems are often, however, distributed, networked ("intelligent") system elements with embedded software which use sensors and actuators to record, evaluate and store data. They are integrated in wired or wireless communication networks which enable communication between technical facilities (e.g. production plants) and/ or their performance management units. Thus, CPS represent an essential building block for networking in Industry 4.0. Often, cyber-physical systems use man-machine interfaces to ensure proper communication between users and the production plants in a networked production system environment. In this context, condition monitoring through the analysis of machine data is a good example of the use of a CPS. Industry 4.0 will make it possible to gather and analyse data across machines, enabling faster, more flexible, and more efficient processes to produce higher-quality goods at reduced costs. This in turn will increase manufacturing productivity, shift economics, foster industrial growth, and modify the profile of the workforce—ultimately changing the competitiveness of companies and regions and creating a fully integrated, automated, and optimized production flow, changing traditional production relationships among suppliers, producers, and customers—as well as between human and machine.

The progress of technological evolution will bring factories to autonomously predict the degree of production failure, to adopt the best prevention measures and to implement self-repair actions. Furthermore, in the Factory 4.0 the flexibility of the plants will be such as to allow the products to be customized according to the individual customer. Robots will work in contact with man and will learn naturally. The workflow can be reproduced in a virtual way, therefore before physically preparing it in the workshop, to verify its abstract behaviour and enhance its performance. The factory will be able to supply itself with energy without waste and at the lowest possible cost, i.e. it will be smart.

Industry 4.0 is currently more of a concept than a reality. What is certain, however, is that it requires products: industry and management software (e.g. CAD, virtual simulation tools, ERP, MES, PLM), processors (e.g. SCADA, DCS, PLC) and devices (e.g. Ethernet, robotics, RFID, motors and drives, relays, switches, sensors). These devices require specialist expertise in information and communication technology (ICT) and automation technology, which presents both a challenge and an opportunity to the educators and trainers of the future workforce.

Companies can already begin to imagine production no longer as a process, but as a real service: in the not-so-distant future it will be possible to use virtual plants (with 3D printers or next-generation CNC machines) located in positions strategically close to the target consumers (thus reducing investments in inventories) and reducing the production capacity to quickly capitalize sales results and adapt flexibly to changing market conditions.

Interoperability	The ability of communication among CPS, IoT devices, factories and human via IoT, IoS and IoE is called interoperability in Industry 4.0. It integrates the classical systems with the modern models.
Virtualization	It is the virtualization of physical processes monitored by CPS for simulation and virtual plant models.
Decentralization	The ability of CPS to take decisions independently in distributed environment without any central command.
Real-time Capability	The ability of collecting and analysing data to detect failure and find alternative solution to handle the problem for speedy production.
Service Orientation	Utilization of services of CPS, factories and human in the context of Service Oriented Architecture (SOA) to facilitate decision making man-agers, operators and customers.
Modularity	Easily addition of new machines, modules and CPS without changing the existing modules for upgradation of factories.

Figure 9: Six design principles of the Smart Factory concept

5.2 THE POTENTIAL CHANGES ON VALUE CREATION

It can be concluded that the term Industry 4.0 describes different—primarily Information Technology (IT) driven—changes in manufacturing systems. These developments not only have technological but also versatile organizational implications on today's production procedures, on work preparation, on production logistics, and also on production and plant performance management, in essence on value creation.

Until now, the high cost of tooling and the increased over-all costs strongly diminished the possibility to have individual product customization. Making production plants more flexible will let companies to get advantage from high capacity utilization in order to produce in very small batch sizes. Festo AG have already started to implement the requirements for a "resilient factory". This requires the integration of autarkic, exchangeable process modules with standardized interfaces into the production lines. Additionally, intelligent, event-driven, self-regulating production machines are joined together in the process modules. This means that products can be allocated to the appropriate machines depending on parameters such as priority, machine capacity utilization, etc., and manufactured there.

Most companies plan the production based on the current volume of orders in a defined period. For those with a high proportion in production of make-to-order, this deterministic production planning is reaching its limits as it is very complex to integrate the necessary data. However, a decentral event-driven production control and disposition system enables the company to react flexibly to such events. For example, EUCHNER GmbH & Co. KG shows that networked production (IT and production technologies) can leverage potentials for optimizing and providing the required data. In contrast to reporting on the entire batch, automatic feedback on the actual units produced is used in combination with order tracking to react flexibly to new orders, production delays or other situations.

Moreover, as multi-functional processing centres, many production machines already have several production competences today. As the trend towards greater individualization of products continues, the demand for flexible, multi-purpose production machines will also grow. The shift towards agile production systems without deterministic allocation of machines per production steps means the production organization used to date must be adapted to satisfy the changing requirements. This includes, for example, the modularization of the product architecture and of the work plans. Creating modular architectures and defined interfaces enables greater flexibility in processing and in assembly.

Furthermore, current state data on the production machines is fundamental for self-regulating production performance management. In addition to the information about current capacity utilization, this applies in particular to the already mentioned “production competences”, maintenance information and possibly even production costs. Production competences are the possible production steps which can be carried out by machines. If M2M communication is in place, this information can be collected and processed in a central production performance management system.

The possibilities for using decision-based production performance management in flexible production systems to react adaptively to the capacity utilization situation of individual machines are very high. Due to the higher diffusion of networked elements, this advantage grows exponentially with the number of machines integrated into the network. This, however, means also high capital investment costs. As a result, decisions concerning a company’s digitization and investment strategy should only be taken after an in-depth evaluation of the benefits that specific company will enjoy by increasing flexibility and after comparing those benefits with the transformation costs they would require (investments, finance plan, etc.). (Horváth & Partners, 2015)

The actual digitization of industry covers a new, fairly broad conception, and includes new technologies and concepts relating to the organization of the value chain. The use of mobile information systems for employees in production, in spare parts warehouses or in production logistics is an example of the utilization of existing technologies which, through progressive man-machine interaction, make the processes more efficient and more secure.

The VW conglomerate is experimenting with smart glasses in their spare parts warehouses to replace handheld scanners. ABB Ltd are investing in the use of tablets in their service functions in order to use augmented reality to make maintenance information on defective equipment available quickly and on the move. Trumpf GmbH & Co. KG are using technology platforms and online marketplaces for production-relevant data directly where the machine is located so that their employees always have access to the most up-to-date information. Other industry 4.0 initiatives from some German companies are included in figures 10 and 11, as well as the technologies used and developed by the companies considered.

Company	Industrie 4.0 Initiative	Enabler Technologies and Clusters
ABB Ltd	Maintenance information can be accessed as augmented reality via tablet	▪ Mobile/ online availability of relevant data ▪ Augmented reality technology ► Mobile information systems
Bayer AG	Error prediction and diagnosis via social media	▪ Comprehensive system mapping in real time ▪ System-state identification (condition monitoring) using networked sensors ► Cyber-physical systems (CPS)
BMW AG	Networked R&D and production/ work preparation	▪ Involved departments are networked ▪ Ability to simulate manufacturing processes ► Digital mapping/perf.mgmt. of real production sequences
Daimler AG	Optimization of production logistics through traceability/CPS	▪ Sensors which can be networked ad-hoc ▪ Traceability and real-time system mapping ▪ Interface to existing CPS and logistics chain ► Cyber-physical systems (CPS)
DMG Mori Seiki AG	Work planning and NC programming via virtual tool machine	▪ Virtual portrayal of real-world work environment ▪ Ability to simulate manufacturing processes ► Digital mapping/perf.mgmt. of real production sequences
EUCHNER GmbH & Co. KG	Networked production	▪ Traceability and real-time system mapping (RFID and as-is feedback (M2M)) ▪ Intercompany networking of value creation/ supply chain ► Cyber-physical systems (CPS)
Festo AG & Co. KG	Smart Factory – Flexible just-in-time production with optimal capacity utilization	▪ Interface standards for production modules ▪ Modular/ self-configuring software ▪ Simulation of order situation and production layout ► Digital mapping/perf.mgmt. of real production sequences
Fraunhofer-Institut für Produktionstechnik und Automatisierung (IPA)	Inclusion/ networking of customer in the value creation chain	▪ Big Data analysis/ handling methods ▪ Real-time portrayal/ system modelling in the planning system ► Big Data evaluation
	Enabling of up-cycling through stored material data	▪ Data storage in the product across the entire lifecycle ► Big Data evaluation
	Smart Factory – Flexible just-in-time production with optimal capacity utilization	▪ Decentral inter-disciplinary system intelligence ▪ Ability to analyze Big Data ► Big Data evaluation

Figure 10: Overview of some Industry 4.0 applications in Germany including their enabler technologies

Company	Industrie 4.0 Initiative	Enabler Technologies and Clusters
Siemens AG	Smart Data in production through fact-based basis for decision-making	▪ Comprehensive collection of production data ▪ Ability to analyze Big Data ► Big Data evaluation
	Software and automation solutions for the Smart Factory	▪ Totally integrated automation ▪ PLM software ▪ Digital mapping of the factory ► Digital mapping/perf.mgmt. of real production sequences
Trumpf GmbH & Co. KG	Networking of production systems within a value creation chain	▪ Automated adaptation of machine/ technology models ▪ Technology-specific ad-hoc materials sensors/ M2W communication capacity ► Cyber-physical systems (CPS)
	Digitization/ online market place for production-relevant information	▪ Mobile/ online availability of relevant data or the possibility to access it ► Big Data evaluation
	Online maintenance (condition monitoring)	▪ Comprehensive system mapping in real time ▪ System-state identification (condition monitoring) using networked sensors ► Cyber-physical systems (CPS)
Volkswagen AG	Use of smart glasses in parts warehouses	▪ Mobile/ online availability of relevant data ▪ Automated visual comparison with standard processes/ requirements ► Mobile information systems
Weidmüller Interface GmbH & Co. KG und Paul Hettich GmbH & Co. KG	Self-optimization of remolding processes	▪ Algorithm-based performance management ▪ Sensors for assessing current state ► Cyber-physical systems (CPS)
Weidmüller Interface GmbH & Co. KG	Intelligent automation solutions for production facilities	▪ Intelligent components such as sensor-actuator interfaces or signal converters ▪ M2M/M2W communication technologies ► Cyber-physical systems (CPS)
Wittenstein AG	Mobile production management	▪ Real-time queries for production orders/traceability and real-time modelling (DataMatrix Codes) ► Digital mapping/perf.mgmt. of real production sequences
	Distributed plant performance management in the SmartFactoryKL	▪ Semantic technology-intelligent workpieces ▪ Automatic selection of the right processing machine for the workpiece ► Digital mapping/perf.mgmt. of real production sequences

Figure 11: Overview of some Industry 4.0 applications in Germany including their enabler technologies

5.3 FUTURE IMPLICATIONS AND OBSTACLES

The creation of favourable conditions to the development of industry 4.0 encompasses many factors such as tax incentives, access to global markets, proximity to teaching and research centres, availability of capital, entrepreneurial culture, network integration, personal motivations of investors, technological infrastructures of information, business size, reluctance to change, the age of the company, financial and human resources.

We are on the threshold of a new technological age. The web network will boost the creation of intelligent processes in all phases of production, from creation, design to maintenance and recycling. The presence of educational and research institutions, capable of supporting innovative development, promotes the creation of a scientific potential necessary for the development of high technology companies. The determinants of a country's innovative capacity are conditioned by the educational system, by the greater/less integration of the population into the global environment, by the transparency of the development and selection of innovative projects and by the degree of protection of intellectual property rights. The analysis of the innovative environment of the countries reveals clear leadership from the USA, the countries of Northern Europe and Western Europe, Israel and Japan.

The innovative environment of any industrial enterprise is conditioned by macro environmental and micro environmental factors. The macroeconomic environment includes many factors: investment in infrastructures, interest rates practiced by commercial banks, and inflows and outflows, whose relationship allows an estimate of domestic investment in the country. In the microeconomic environment it is possible to identify a set of constraints, namely the economic management capacity, the level of competition, the ability to make investments, the availability of fuels, energy and material and technical resources, the specialized labour market, thus managers and workers. Finally, the presence of human resources skills. Indubitably, technological transformation requires specific skills profiles of company employees. These competences can be acquired through an internal reconversion process and/or by hiring of new employees.

Today the progressive automation of the manufacturing sector is frightening, with the increasingly massive introduction of robots. A study carried out in the 15 major industrialized countries and presented last January to the last edition of the World Economic Forum has estimated the number of employed persons at 5 million units could lose their job before 2020, due to the advent of Industry 4.0 and the technological innovations that characterize it. What is even more alarming is that, to be struck by this occupational bleeding, will not be just the traditional professions like the domestic worker or the cleaning man, replaced by robot-butlers, or drivers replaced by automatic vehicles. The greatest loss of jobs could occur between medium or medium-high level trades, which are based on a good deal of intellectual work.

The study predicts a negative employment balance of 5% (again from now until 2020) for office work, linked to administrative functions of companies. There will be a contraction of around 1.6% in the manufacturing sector and 1% in the world of media and entertainment. Even private bankers or financial advisors, who manage savers' money and have a strong personal connection with their customers, could be replaced by so-called robo-advisor, that is, by software that already today is able to automatically build portfolios of investment, through mathematical algorithms. On the other hand, according to data from the World Economic Forum, an increase in employment of between 2.5 and 3% will instead be recorded (as is obvious) in the areas of information technology, engineering and design. In short, with the advent of Industry 4.0, as usual there will be winners and losers. Especially the advanced economies hope to replace at least part of the jobs lost with others, new ones, linked to technological innovation. They are particularly focusing on hi-tech sectors, services and sharing economy. If several trades disappear, in short, many others will be born ready to replace them. It is not certain that it will be sufficient, and some countries are better prepared than others. According to a study by Roland Berger, the fourth industrial revolution can create around 6.7 million new jobs across Europe by 2035 and generate investments and profits of 420 billion euros.

The implications of digitalization for revenues, profits and opportunities have indeed a dramatic upside potential. The potential benefits for those users who the Industry 4.0 applications are aimed at can be broken down mainly into four dimensions: cost reduction, flexibility, stability/ quality assurance, and increased turnover. The main driving force for Industry 4.0 applications is the possibility of reducing costs. Three-quarters of the applications have this as their direct or indirect goal, mainly through an increase in the degree of automation and/ or improved efficiency.

Increasing flexibility is the second most common goal of the applications examined, for example through the ideal of the resilient factory, which allows companies to react optimally to fluctuations in orders and capacities. Additionally, flexible production layouts are an indispensable requirement for satisfying the customer expectation of increasingly individualized products by using reduced batch sizes.

Industry 4.0 applications often also strive to use intelligent maintenance concepts to optimize stability and quality assurance. Remote maintenance and diagnosis can be used to service the machines used at considerably lower expense and thus potentially more frequently. Constant monitoring and evaluation of the machines enables predictive maintenance. As well as increasing flexibility, applications which increase stability also indirectly lower costs.

Moreover, if we think beyond the optimization of existing structures, the changes which arise from Industry 4.0 also offer a huge, disruptive turnover potential. But these, together with the one expressed in figure 12 (McKinsey Digital, 2015), are only some of the main advantages that companies can exploit by approaching the Industry 4.0 and that will be described in detail in the next chapters.

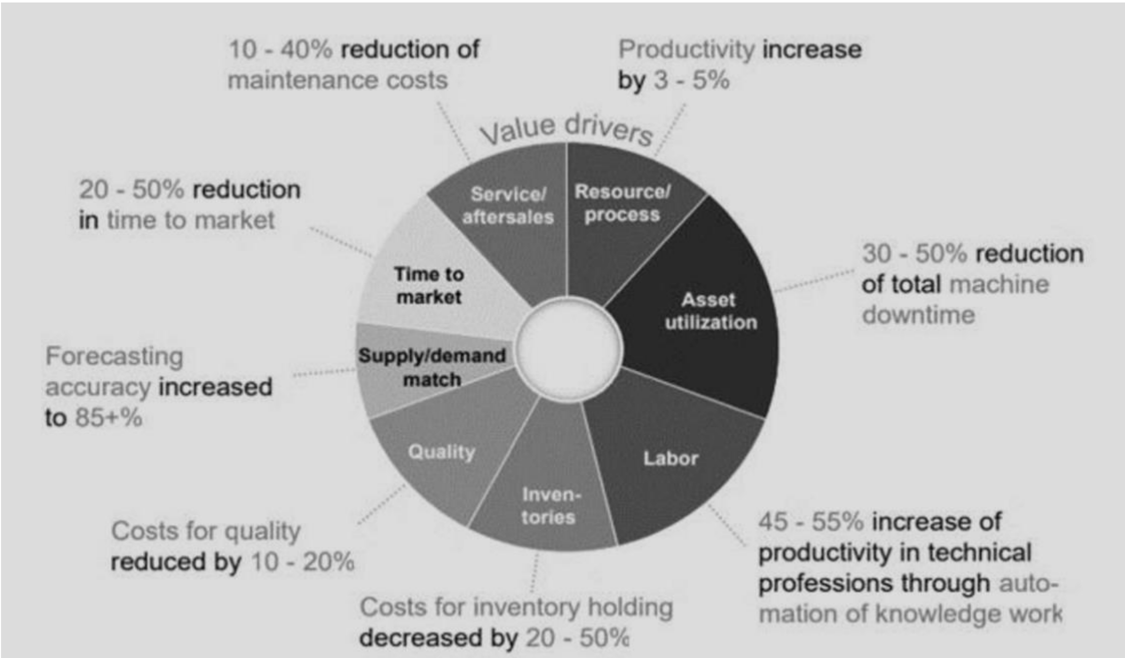

Figure 12: Opportunities for value drivers that Industry 4.0 can bring

Some factors may hold back or obstruct the spread of Industry 4.0. In 2016, PwC produced a Global Industry 4.0 survey, in which 2000 experts from 26 countries were asked about how their companies will exploit the opportunities offered by digitization. The majority of the companies surveyed (52%) said that the biggest obstacle to the implementation of Industry 4.0 is the lack of a clear digital strategy in value-creating (production and logistics) processes, and of support for corporate executives for the introduction of digital technology. Porter and Heppelmann in their "How Smart, Connected Products Are Transforming Competition" argue that companies should not address fundamental issues superficially and ignore industry signals. The digital services connected to the product must be those for which the buyer is willing to pay. It is therefore necessary to think carefully about what creates value for the buyer. Data security This is a critical point for development. Control of access must be ensured, as must the security of networks, devices, sensors, etc. and the proper encryption of information. New entrants can also appear with smart products with market-related services to implement and innovate a new type of customer-centric business model, and possibly extend the boundaries of the industry.

The big question is when to take the plunge. If a company waits too long, competitors or new entrants can tailor the market and gain an advantage in the learning process. The production of smart products requires a new kind of technology, capabilities and processes throughout the value chain. The company has to realistically see what capabilities it can develop and what it needs in order to be involved with an external partner. The progressive digitalization and robotization of productions that had been delocalized in search of savings on labour costs, will make the availability of cheap labour less important and will bring many productions closer to the final outlet markets. Thus, many developing countries will lose the current competitive advantage in labour-intensive manufacturing. A main consequence of this new paradigm is that the new automated systems can be installed near the final outlet markets and no longer have to chase the cheaper labour costs.

The example of Adidas, which is investing in automated factories to produce sports shoes in Germany and the United States, is significant. The difficult challenge for emerging economies is not to be overwhelmed by technological change but, on the contrary, to be able to ride it. This means investing in technology and human capital and focusing on increasing productivity rather than on production capacity.

Cultural Market Obstructing Factors	Labor Market Obstructing Factors	Organizational Obstructing Factors	Technological Obstructing Factors
Distrust	Inadequate quality workforce	Lack of digital strategy	Expensive technologies
Uncertainty	Shortages among workforce	Risky investment	Lack of standards
Realistic judgment of the abilities of the organization	Old-fashioned training	Fear of loss of control over intellectual property	Security of data, uncertainty regarding the level of encryption
Lack of demand for continuous learning		Partners do not have the technology	Underdeveloped data analysis
		Failure to develop data-based services	
		Lack of senior management support	

Figure 13: Factors hindering the spread of Industry 4.0

The implementation of the Industrial Internet represents a multi-year transformation process for the majority of companies, resulting in significant changes to their value chains. Due to the extent of the expected company-wide changes and the investments required in the next three to five years, it is first necessary for top management to recognise the importance of the topic, place it on the agenda and drive it to a high priority level within companies.

As dynamic and tech-savvy start-ups flood the market in almost every sector, businesses must understand the benefit of embracing Industry 4.0 in order to remain competitive and harness the plentiful opportunities that it will offer. In order to remain competitive, existing businesses must be willing to embrace technological advancements. Such developments are not limited to those within the manufacturing industry. Many businesses already have access to enormous data sets, whether it be on the functionality of their machinery, the efficacy of their workers or the behaviours of their customers. The thing that will set apart the successful businesses in the context of Industry 4.0 is their ability to harness this data effectively. Using sophisticated sensors and related software systems, businesses are granted genuine insight into their day-to-day operations which they can use to inform complex decisions they are required to make. Where previously executive level employees would have to use estimations and predictions in order to make a value judgement, emerging software offers statistical evidence to guide and support critical decisions.

What must be noted here is that the approaches to adapt and further develop the corporate performance management concepts are still only preliminary considerations. At the moment, the discussion about Industry 4.0 still focuses heavily on technical aspects, while the Industry 4.0 applications which already exist are primarily solutions for special use cases and sub-areas of value creation. There are very few real-world holistic Industry 4.0 concepts and those that do exist are still at the pilot stage (e.g. the Smart Factory). Until standards have been established, the adaptation of controlling instruments will only take place in individual companies and step-by-step. As a result, the agenda of the CFO and CIO functions in the near future will concentrate on helping to shape the digitization strategy, on evaluating strategic investment decisions, and on the successive preparation of operative performance management for the future requirements.

Achieving the full potential of promising technologies while addressing their challenges and risks will require effective leadership, but the potential is vast. As technology continues to transform our world, business leaders, policy makers, and citizens must look ahead and plan.
Policy makers and societies need to prepare for future technology. To do this well, they will need a clear understanding of how technology might shape the global economy and society over the coming decade. They will need to decide how to invest in new forms of education and infrastructure and figure out how disruptive economic change will affect comparative advantages.

Manufacturing enterprises must look in their organizations with a critical eye to drive their strategic goals. These strategic goals must then drive not only their manufacturing process (as was done traditionally) but also their business process and information process. This critical outlook will then propel and set the stage for transformation within the enterprise.

Companies can hold back for a while on the decision about whether to join the fourth industrial revolution. The development and application of new, unknown technologies is risky and expensive, but significant savings and revenue growth are achievable for early starters. There are some industries where it is essential to accept competition in development, and where adaptation is an ever-present precondition for staying competitive (the automotive and electronics industries), but there are also many industries that will only go through this kind of development if the technology also brings are turn in sectors with lower rates of profit.

Leading	Companies acting quickly while taking risks in order to use the opportunities of digitization early on: co-development of concepts of the digital revolution and possibly even creation of actual standards – however, combined with the higher risk of having to first develop and implement new and yet untested solutions.
Adapting quickly	Companies learning from the initial experience of the pioneers and quickly adjusting and implementing evidently successful concepts for themselves – however, combined with the risk of not being able to make use of the full potential any more.
Waiting	Companies waiting for a broad implementation of new technologies' solutions in order to rely solely on already-tested concepts with defined standards and established profitability analyses – however, combined with the not to be underestimated danger of having fallen behind global competition in a rapidly changing world.

Figure 14: Three different strategic approaches to the Industrial Revolution

Overall, we can conclude that Industry 4.0 penetrates the entire value chain of the corporation—although most of the value chains are interpreted as production-based, possibly supplemented with the logistics operations. The scope of Industry 4.0 can grow at the company's borders, covering the supply chain or, more broadly, the supply network. It builds on new network-linked technology (e.g., sensors, RFID), and requires new procedures (e.g., data analysis software, cloud, programming) that require new capabilities from the company (e.g., continuous innovation, life-long learning, trust, data sharing) and this may even require new business models to be developed. Industry 4.0 is thus a phenomenon that, by means of technology assets and activities, maximizes the transparency of processes by exploiting the possibilities of digitization and integrates the corporate value chain and the supply chain into a new level of customer value creation.

6. THE NINE PILLARS OF THE FOURTH REVOLUTION

Industry 4.0 includes three essential stages: Firstly, getting digital records through sensors that attached to industrial assets, which collect data by closely imitating human feelings and thoughts. This technology is known as sensor fusion; Secondly, analysing and visualizing step includes an implementation of the analytical abilities on the captured data with sensors. From signal processing to optimization, visualization, cognitive and high-performance computation, many different operations are performed with background operations. The serving system is supported by an industrial cloud to help to manage the immense volume of data; Thirdly, the stage of translating insights to action involves converting the aggregated data into meaningful outputs, such as additive manufacturing, autonomous robots and digital design and simulation. In an industrial cloud, raw data is processed with data analytics applications and then turns into practically usable knowledge.

According to a report by the multinational consulting firm McKinsey, the new digital technologies will have a profound impact in the context of four development guidelines: the first concerns the use of data, computing power and connectivity, and is declined in big data, open data, Internet of Things, machine-to-machine and cloud computing for information centralization and storage. The second is that of analytics: once the data has been collected, value must be obtained. Today only 1% of the data collected is used by companies, which could instead obtain advantages starting from "machine learning", i.e. machines that improve their performance by "learning" from the data gradually collected and analysed. The third direction of development is the interaction between man and machine, which involves increasingly widespread “touch” interfaces and augmented reality. Finally, there is the whole sector that deals with the transition from digital to “real” and which includes additive manufacturing, 3D printing, robotics, communications, machine-to-machine interactions and new technologies for storing and using energy in a targeted way, rationalizing costs and optimizing performance.

Whether they are destructive or not, the Boston Consulting Group has defined the nine main enabling technologies that represent the pillars of the 4.0 evolution, and those are: Advanced Manufacturing Solutions; Additive Manufacturing; Augmented Reality; Big Data; Cyber-Security; Horizontal and Vertical integration; Cloud; Industrial Internet of Things; Simulation. These represent the tools that, if well mixed, will allow the evolution of industry towards an intelligent model, where work tools are connected to the network and interconnected with each other.

6.1 BIG DATA AND ANALYTICS

An intelligent/smart factory operates using advanced sensors and information technologies; thus, large amounts of data are generated and collected in a smart factory, requiring big data processing technology to build an integrated environment in which the production process can be represented transparently and controlled and managed in a more efficient way. Big data is the concept of data where it is hard to collect, store, manage and process by classical tools and technologies.

Industry 4.0 is a revolution towards the digital world of digital factories and smart products and Big data is an integration of multi-disciplinary technologies, facilitating customer by bringing incredible services to a click. Data and analytics capabilities have made a leap forward in recent years. The volume of available data has grown exponentially, more sophisticated algorithms have been developed, and computational power and storage have steadily improved. The convergence of these trends is fuelling rapid technology advances and business disruptions. Most companies are capturing only a fraction of the potential value from data and analytics.

The greatest progress has occurred in location-based services and in retail, both areas with digital native competitors. In contrast, manufacturing, the public sector, and health care have captured less than 30 percent of the potential value. Further, new opportunities have arisen since 2011, making the gap between the leaders and laggards even bigger (figure 15).

	Potential impact: 2011 research	Value captured %	Major barriers
Location-based data	▪ $100 billion+ revenues for service providers ▪ Up to $700 billion value to end users	50–60	▪ Penetration of GPS-enabled smartphones globally
US retail	▪ 60%+ increase in net margin ▪ 0.5–1.0% annual productivity growth	30–40	▪ Lack of analytical talent ▪ Siloed data within companies
Manufacturing	▪ Up to 50% lower product development cost ▪ Up to 25% lower operating cost ▪ Up to 30% gross margin increase	20–30	▪ Siloed data in legacy IT systems ▪ Leadership skeptical of impact
EU public sector	▪ ~€250 billion value per year ▪ ~0.5% annual productivity growth	10–20	▪ Lack of analytical talent ▪ Siloed data within different agencies
US health care	▪ $300 billion value per year ▪ ~0.7% annual productivity growth	10–20	▪ Need to demonstrate clinical utility to gain acceptance ▪ Interoperability and data sharing

Figure 15: Potential impact and value captured from data and analytics by five main sectors

In an Industry 4.0 context, the collection and comprehensive evaluation of data from many different sources—production equipment and systems as well as enterprise and customer-management systems—will become standard to support real-time decision making. Businesses need to process data into timely and valuable information for their decision making and process optimization activities. Today's competitive business environment forces enterprises to process high speed data and integrate valuable information in production processes. For example, the concept of Industry 4.0 is expected to change production in the near future. In this concept, machines in a smart manufacturing plant interact with their environments. Ordinary machines transform into context-aware, conscious, and self-learner devices. This transformation gives these devices the capability to process real-time data to self-diagnose and prevent potential disruptions in production process. While the Internet of things connected the world of machines by adding communication capability in every device to connect to other devices or access the Internet, Big Data inflict a new horizon of opportunities in these systems.

Reliability and safety are regarded among the most crucial factors of the intelligent system, which are now challenged by the highly complex, automated and flexible industrial system. Industry big data analytics will have great benefits, such as improving system performance, achieving near zero downtime, ensuring predictive maintenance and more. Industrial big data analytics increase the productivity of enterprises. Prediction of new events from big data provides a concrete foundation for planning new projects. As it is not necessary that all the new insights will be workable and only some events are interesting out of million events, so revealing these insights are a challenge for data scientists to write suitable algorithms.

In the Big Data Analytics' field, 45% of the expenditure is dedicated to software (databases and tools for acquiring, processing, displaying and analysing data, applications for specific business processes), 34% to services (software customization, integration with company information systems, process redesign consultancy) and 21% to infrastructure resources (computing capacity, servers and storage to be used in the creation of Analytics services). Software is also the area with the highest growth (+ 37%), followed by services (+ 23%) and infrastructure resources (+ 9%). Among the commodity sectors, on the other hand, the first by market share are banks (28% of spending), manufacturing (25%) and telco - media (14%), followed by services (8%), GDO / Retail (7 %), insurance (6%), utilities (6%) and PA and healthcare (6%) (McKinsey Digital, 2016).

However, the evolution of the Big Data Analytics market goes far beyond the numbers. Methods of analysis change, with the disruptive advent of Machine Learning and Deep Learning techniques, for which around a third of large companies have already acquired the necessary skills, and real-time data analysis, already exploited by the 11%. The need for data science skills is growing: 46% of large companies have already included Data Scientist staff, 42% Data Engineer, and 56% Data Analyst. Despite a growth in the number of companies with a mature Data Science governance model (from 17% to 31%), however, more than half (55%) presents a still traditional organizational model. Exponential growth in data volume originating from Internet of Things sources and information services drives the industry to develop new models and distributed tools to handle big data. In order to achieve strategic advantages, effective use of these tools and integrating results to their business processes are critical for enterprises.

Finally, in order to exploit the potential of big data technologies as part of Industry 4.0, challenges which hinder the adoption of such technologies should be tackled. These challenges include handling large amount of unstructured data coming from IoT devices, expertise barriers, resource management, and delivery of results to appropriate channels. The biggest barriers companies face in extracting value from data and analytics are organizational; many struggles to incorporate data-driven insights into day-to-day business processes. Another challenge is attracting and retaining the right talent—not only data scientists but business translators who combine data savvy with industry and functional expertise. Data is now a critical corporate asset. It comes from the web, billions of phones, sensors, payment systems, cameras, and a huge array of other sources—and its value is tied to its ultimate use. While data itself will become increasingly commoditized, value is likely to accrue to the owners of scarce data, to players that aggregate data in unique ways, and especially to providers of valuable analytics. Recent advances in machine learning can be used to solve a tremendous variety of problems—and deep learning is pushing the boundaries even further. Systems enabled by machine learning can provide customer service, manage logistics, analyse medical records, or even write news stories.

The value potential is everywhere, even in industries that have been slow to digitize. These technologies could generate productivity gains and an improved quality of life—along with job losses and other disruptions. Data and analytics are already shaking up multiple industries, and the effects will only become more pronounced as adoption reaches critical mass. An even bigger wave of change is looming on the horizon as deep learning reaches maturity, giving machines unprecedented capabilities to think, problem-solve, and understand language. Organizations that are able to harness these capabilities effectively will be able to create significant value and differentiate themselves, while others will find themselves increasingly at a disadvantage.

Business Intelligence	Business Intelligence (BI) is a collection of tools and techniques for extraction and transformation of raw data into meaningful knowledge for escalation of business plans and strategies. Industrial big data is the precious ore of BI to help the management of the industries in achieving the goals. Industrial Big data provide a history of the customer transaction record and their purchasing behaviour of some special products which help the BI to offer some discount or promotion of products. Online analytical processing, benchmarking, data mining, performance management, predictive and prescriptive analytics are the functions of BI based on the industrial big data warehouse. The accurate BI results depend on the volume of big data used for mining. If the size is small, then the results will be not so accurate as compare to big data. Therefore, industrial big data has a valuable application in Industry 4.0 for BI.
Fault Tolerance	Mining industrial big data eliminates the delay of production due to machine failure. Having a huge amount of archive dataset of an enterprise, a smart intelligent application predicts the failure of a machine. For example, if a machine has 25 years life time and its efficiency decreased annually according to usage, then by mining the previous data we are able to estimate and predict the failure time for the other machine of the same type. If a spare machine is configured for emergency usage, then the system diverts automatically to that machine and thus the fault tolerates automatically.

Product Quality Enhancement	An industry produces different products and launches some new products time by time. Enterprises collect the response of the customer about their products and store for future usage. If the sale of a product is decreased, then the analyst takes the previous customer feedback data and analyse to detect the drawbacks of the product and enhance its quality based on the customer data. Big data helps in launching a new product by considering the customer's suggestions.
Production Planning	Big data assists in the production planning by predicting the future demand for the products in the market. By analysing the industrial big data of the previous years an enterprise predicts the future need of a specific item. If the production is going up at high speed, then the owner of the factory plan to increase some modules or systems in the factory to increase the production according to the customers need. Similarly, if there are some bad products in the production which have less demand in the market then its production will be stopped to reduce the expenses of the industry. The future planning of production depends on the availability of the big data.
Smart Cities	A smart city is the hot topic of current research where city assets are managed and integrated with ICT (Information and Communications Technology) and IoT in a secure way. The city assets are different government departments, private sector industries, and communities. The official directly communicates with the local residents and solves their problems in a smart way by using ICT. Linking of Industrial big data with smart city improves the development of a city and escalates facilities for citizens. Smart mobility, smart governance, smart grid, smart living, smart economy and smart industry are the building blocks of smart cities. Industrial big data access to citizens of a smart city changes the industrial productivity, quality, and demand of products.

Figure 16: Opportunities and applications in the Industry 4.0 perspective

6.2 AUTONOMOUS ROBOTS

In the age of Industry 4.0 computers and robotics come together in a completely new manner. The development towards smart factories goes hand in hand with higher degrees of automation. Surveys such as conducted by the VDE (Verband der Elektrotechnik, Elektronik und Informationstechnik) have shown, that in the future automation is seen to be the most important key technology for the companies interviewed. Although they have been around for some time in industrial production and assembly, robots have for decades had less attention than they receive nowadays, and they are expected to spread to other and less manufactural realms in the near future.

Robots play an important role in modern manufacturing industry. The number of multipurpose industrial robots developed by players in the Industry 4.0 in Europe alone has almost doubled since 2004. An essential face of Industry 4.0 is autonomous production methods powered by robots that can complete tasks intelligently, with the focus on safety, flexibility, versatility, and collaborative. Without the need to isolate its working area, its integration into human workspaces becomes more economical and productive and opens up many possible applications in industries.

More industrial robots are evolving with the latest technological innovation to facilitate the industrial revolution. Smart robots will not only replace humans in simply structured workflows within closed areas. In Industry 4.0, robots and humans will work hand in hand, so to speak, on interlinking tasks and using smart sensor human-machine interfaces. The use of robots is widening to include various functions: production, logistics, and office management (to distribute documents) and they can be controlled remotely. By connecting to a central server, database or programmable logic controller the actions of robots can be coordinated and automated to a greater extent than ever before. They can complete tasks intelligently, in an orchestrated manner with minimal human input. Materials can be transported across the factory floor via autonomous mobile robots (AMRs), avoiding obstacles, coordinating with fleet mates, and identifying where pickups and drop-offs are needed in real-time.

Another advantage is the possibility to have a predictive maintenance, which is an emerging theme that is being sounded at the show by injection machine suppliers and builders of auxiliary equipment. The idea is for a robot "to monitor its own internal systems and detect problems as they develop, so it can warn of a maintenance issue before a catastrophe strikes on a weekend shift," explains Dino Caparco, Yushin's engineering operations manager.
In the field of factory automation adaptive robots create new efficiencies and change how companies produce goods and organize the shop floor. For example, the process costs can be reduced as the collaboration increases the productivity and efficiency and the robot requires less space as it is not isolated from the operator.

High rates of automation are often associated with the replacement of human labour by machines. Industry 4.0 in contrast, rather aims at the support of human workers using new technologies. Therefore, automation and in this regard state of the art robot technology represent crucial elements of Industry 4.0. Previous research indicates, that robots are still the key instruments in production strategies of flexible automation. The Boston Consulting Group (BCG) estimates the global spending on industrial robotics to grow rapidly in the years to come. Statistics show a spending of 16.7 billion U.S. dollars in 2020 and a total of 24 billion U.S. dollars in the year 2025.

The new rise of robotics on one hand will doubtless provide bright prospects for the robot building sector and its companies, but on the other hand it begs the inescapable question regarding the future of those jobs still remaining today in industrial production. Assembly work in particular, which even in mass production often is still characterized by human work and hybrid or mere manual tasks, seems to be under pressure from technologically new and less expensive robotic approaches.

Nonetheless, trying to reach ever higher levels of automation the interaction between human and machines becomes a central issue. If robots are also cooperating with other activities that are distanced far away in space, then time delay problems occur. Today many researches are made to handle the problem of time delay in control.

Moreover, many of the production processes cannot be easily automated, and collaborative robots are able to fill these gaps. Indeed, recently there has been an increasing interest in those so called cobots. Traditionally a robot is defined by the IFR (International Federation of Robotics) as an automatically controlled, reprogrammable multipurpose manipulator programmable in three or more axes which may be either fixed in place or mobile. Collaborative robots enable new forms of human machine interaction. A cobot can be simply defined as a computer-controlled robot device designed to assist a person. These new collaborative robots are more flexible and are capable of learning and interact with machines and human. In contrast to traditional robots the cobots can learn new tasks through training by demonstration instead of cost-intensive programming. Unlike traditional robots, cobots need no fences around because sensors and visual systems guarantee that the robot stops before colliding with the operator. This enables robots to perform tasks as humans do and allows human workers to work closely with robots. Human workers can focus on complex tasks where intelligence and dexterity are required, in the opposite case the robots complete the tasks, which are exhausting or dangerous for the human.

Compared to traditional robots, collaborative robots show several benefits. They are smaller, smarter and safer. In addition, they are cheaper than stationary robots and can also be used as mobile units. This flexibility enables manufacturers to use the cobot on multiple lines and easily reprogram it if necessary. There are also the other side of the coin. These collaborative robots have different drawback as well. If they are compared to a conventional robot with the same capabilities their prices are much higher because of the sensorial background (sometimes even camera integration is also applied) and also the developed software background that ensures the required safety for human-robot collaboration. Their productivity is usually lagging far behind conventional robots. Robots working behind a safety area (fence) can apply their full capabilities in speed acceleration and payload. Collaborative robots cannot utilise these, to ensure that the robots stop if it collides with a human. This way they work with a much slower speed that are even reduced further if a human approach the robots. This reduces the productivity of the robot considerably.

Several robots have been introduced with the latest technology to be the pioneer in Industry 4.0. Kuka LBR iiwa (Figure 17) is a lightweight robot for industrial applications that is designed for safe close cooperation between human and robot on highly sensitive tasks. Iiwa which stands for intelligent industrial work assistant can learn from its human colleagues and can independently check, optimize, and document the results of its own work while connected to the cloud.

Bosch also introduces the APAS family robot system (Figure 18) which includes APAS assistant, APAS inspector, and APAS base for an agile and flexible production concepts based on quickly and easily retooled production systems.

Nextage robots from Kawada Industries (Figure 19) are an evolution from mere equipment to becoming a partner in parts assembly lines. Its overall design includes a “head” with two cameras, a torso, two 6-axis arms, and a mobile base, a flexible software GUI. Its advance stereo vision with image recognition system allows it to ascertain object distance and attain 3D coordinates with high precision. The accompanying open source software provides superb visibility and usability, making the operation and instruction of Nextage easy and flexible.

The dual-arm Yumi robot (Figure 20) is the first collaborative robot from ABB. It features an advanced vision system, flexible hands, parts feeding systems, sensitive force control feedback, and state-of-the-art robot control software that allows for programming through teaching. Along with the built-in Safety function, it is designed to work side-by-side with humans (Bahrin, Othman, Nor Azli, & Talib, 2016). As David Nye shows in his impressive comparative historical review of the 100-year industrial history, “America’s assembly line”, the assembly line today “in a new form is more productive than ever, thanks to robotics”.

Figure 17: German company Kuka presents the LBR iiwa opening and pour a glass of beer (Light Weight Robot) at the European Robotics Forum in Edinburgh

Figure 18: The APAS production assistant from Bosch is the world's first certified, contactless working human-robot collaboration system.

Figure 19: Kawada Industries presented a tech demo of its service robot making a Nespresso at Japan Robot Week.

Figure 20: YuMi guiding the Lucca Symphony Orchestra and famous opera vocalist Andrea Bocelli in a rendition of Verdi's popular 'La Donna e’ Mobile' from 'Rigoletto.'

6.3 SIMULATION

Since the first general engineering applications of in 1960s, simulation modelling has developed from a technology accessible to mathematical and computing experts to a standard tool in an engineer’s portfolio, used to solve a range of design and engineering problems.

In the past few decades, computer simulation has become an indispensable tool for understanding the dynamics of business systems. Many successful businesses intensively use simulation as an instrument for operational and strategic planning. However, the penetration of computer simulation into various areas of business process has resulted in the need to connect the simulation models used in different parts of an organization.

Also, the trend in simulation development has shifted from purely analytical and optimisation-oriented models to integrating simulation models into decision support tools to be used recurrently. For example, by integrating models of various parts of an organization, a joint distributed simulation system can be built to conduct large-scale business system simulations, giving an overview of the modelled organization. This development has brought changes in the requirements for simulation model design. Stand-alone models, accessible only to simulation experts are to be replaced by models that can be connected to various data sources and destinations and controlled or even modified via user-friendly front-ends or other applications. Moreover, with the increased integration of simulation modelling in the product life cycle management, the user requirements have changed considerably. Increasing product variants and customisable products require more flexible production systems.

The advent of the Industry 4.0 paradigm has brought changes to the simulation modelling paradigm as well. It requires modelling of manufacturing and other systems via the virtual factory concept and the use of advanced artificial intelligence (cognitive) for process control, which includes autonomous adjustment to the operation systems (self-organization). These simulations leverage real-time data to mirror the physical world in a virtual model, which can include machines, products, and humans. This allows operators to test and optimize the machine settings for the next product in line in the virtual world before the physical changeover, thereby driving down machine setup times and increasing quality. For example, Siemens and a German machine-tool vendor developed a virtual machine that can simulate the machining of parts using data from the physical machine. This lowers the setup time for the actual machining process by as much as 80 percent.

Due to shortened product development cycles, manufacturers have to move from traditional design processes and practices, that used a “build it and tweak it” approach and must instead take a more systems-design approach that has proven to be an essential part of the design process within the aerospace and automotive industries for many years. Through formal requirements management, and the development of high-fidelity dynamic models used in simulations of the system, manufacturers can validate the design against the requirements in the early stages of the process. The resulting high-fidelity model from this process is referred to as the Digital Twin, a concept borrowed from space programs. In space missions, any changes can be fatal, therefore all modifications of a vehicle, probe or rover on a mission, are tested on a detailed simulation model of the system to ensure the change produces the desired effect.

Individual application	Simulation tools	Simulation-based System Design	Digital Twin Concept
Simulation is limited to very specific topics by experts, e.g. mechanics. 1960+	Simulation is a standard tool to answer specific design and engineering questions, e.g. fluid dynamics. 1985+	Simulation allows a systemic approach to multi-level and multi-disciplinary systems with enhanced range of applications, e.g. model based systems engineering. 2000+	Simulation is a core functionality of systems by means of seamless assistance along entire life cycle, e.g. supporting operation and service with direct linkage to operation data. 2015+

Figure 21: The main aspects of the evolving simulation paradigm from 1960s until today

A definition of a Digital Twin, proposed by researchers of Fraunhofer IPK and TU Berlin provides a separation of usage data and models for simulation: “A Digital Twin is the digital representation of a unique asset (product, machine, service, product service system or other intangible asset), that alters its properties, condition and behaviour by means of models, information and data” (Stark, Kind, & Neumeyer, 2017). Today every instance of an individual product or production system produces a “digital shadow”, which is the name for the structured collection of data generated by operation and condition data, process data, etc. The concept of Digital Twin extends the use of simulation modelling to all phases of the product life cycle, where the products are first developed and tested in full detail in a virtual environment, and the subsequent phases use the information generated and gathered by the previous product life cycle phases. Combining the real-life data with the simulation models from design enables accurate productivity and maintenance predictions based on the realistic data.

An important aspect of the Digital Twin concept is the accumulation of knowledge - the information created in every stage of the product lifecycle is stored and made available to the following development stages. This greatly improves the knowledge management aspect of product development. A high-fidelity simulation models - Digital Twin of a process or part of process has several potential uses in an organization. An in-line Digital Twin allows an operator to train on a virtual machine until they have the skills and confidence needed to operate the real machine, without the expense of a dedicated training simulator. It accelerates the learning process and minimizes the risk of damage to the machine. Using optimal control and model-predictive control techniques, combined with advanced machine-learning capabilities, a Digital Twin can also be used to identify potential issues with its real machine counterpart. A high-fidelity physics model running in parallel with the real machine can immediately indicate a potential malfunction in the real machine by detecting a drift between the machine's performance and the behaviour of the model. The information could be used to stop and service the malfunctioning machine or use the model to provide a strategy for compensating for a decrease in performance without slowing or stopping production.

An embedded Digital Twin would provide the basis for increasing the self-awareness of the machine, allowing it to optimize its own performance for given duty cycles, diagnose and compensate for non-catastrophic faults, and coordinate operation with other machines with minimal input from the operator. The Digital Twin is the natural result of adopting a system-design approach to product development and can be readily integrated into the final product for training, in-line diagnostics, and performance optimization and beyond (Rodič, 2017).

Currently, automated model development is more common with methods that allow easier and more standardized formal description of models, e.g. Petri nets. Automation of model construction and adaptation can significantly facilitate the development of models of complex systems and generation of simulation scenarios. Optimisation through modification of model structure can be performed by constructing several versions of the model and input data (i.e. scenarios) and comparing simulation results.

6.4 HORIZONTAL AND VERTICAL SYSTEM INTEGRATION

Philipp Gerbert, in an article called "Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries" writes, "…with Industry 4.0, companies, departments, functions, and capabilities will become much more cohesive, as cross-company, universal data-integration networks evolve and enable truly automated value chains."

Industry 4.0 is a topic with a strong interdisciplinary character. This paradigm shift in the traditional manufacturing industry requires a holistic and sustainable digital reorientation of the entire corporation, especially in the field of factory organization. To realize the vision of smart factories, the holistic integration of all machines into a company-wide digital infrastructure is necessary. In smart factories manufacturing processes, but also the engineering and business processes from the 'office floor' need to be integrated in the digital infrastructure. In order to meet the vision of an open, smart manufacturing platform, the manufacturing systems need to be vertically networked and horizontally connected. Interaction between implemented systems based on highly specialized software and specialized user interface, which are integrated in digital networks, create an entire new world of the systems functionality for the horizontal and vertical integration.

The horizontal integration describes the connection of machines and production systems across company borders. All stages of the supply chain share data and communicate in a digital production network. Trough the integration of the Network IT technologies and manufacturing systems an exchange of data and information must be established between the firms and the geographically remote sites across the value chain. Therefore by "Horizontal integration" an integration of various information technology systems in the production and automated equipment for various stages of the production and planning process is understood.

Vertical integration in this context refers to the connection of business and manufacturing processes including resources such as material across all levels of the organization. Process data is collected and analysed in real-time, to react and adapt to environmental changes such as unexpected production stops or failures in the supply of material. The production lines are constantly connected and always optimally adjusted to the specific situation. The smart factory is driven and controlled by real-time data and therefore guarantees that all necessary decisions can be taken as efficiently and rapidly as possible. The "internet of things" and services grant immediate access to IT and production systems. Trough vertical integration of data and information directly from the workplace by controlling and operating on a production and corporate level, the data is processed and as a result, adequate information about the management is returned. Therefore "Vertical integration" can be understood as the integration of information technologies in IT systems in various hierarchy levels in production and automation equipment. (For example: sensors, level of management, level of production management).

The vertical and horizontal cooperation between machine and internet, machine and person and machine to machine on the chain of value, in real time, is the basis of the production cyber system.

Because of that, interoperable communication interfaces and standard protocols are required. Furthermore, the products of manufacturing are intelligent, they carry information from their own manufacturing in machine-readable form (for example RFID chips), that way they can coordinate their own manufacturing actions. In order to meet the requirements for communication in real time, and also so that the cyber-physical systems meet the requirements for high availability and for a longer life cycle they must be built with standard IT elements. In that way, in order to establish a decentralized data collection, they must be continuously integrated into IT systems – best case scenario, included in Enterprise Resource Planning (ERP), manufacturing management (MES), systems for supervision (supervisory control and data acquisition, SCADA), programmable controllers (SPS) and integrated systems for vertical and horizontal integration (Chukalov, 2017).

6.5 THE INDUSTRIAL INTERNET OF THINGS

The Internet of Things (IoT) is a new paradigm that is rapidly gaining ground in the modern wireless telecommunications landscape. The main strength of the IOT idea is the high impact it will have on various aspects of everyday life and the behaviour of potential users.
IoT is a new revolution of the Internet. It makes objects themselves recognizable, obtain intelligence, communicate information about themselves and access information that has been aggregated by other things. The Internet of Things allows people and things to be connected anytime, anyplace, with anything and anyone, ideally using any path or network and any service (Bhuvaneswari & Porkodi, 2014).

The IoT was started in the year 1998 and the term Internet of Things was first coined by Kevin Ashton in 1999. According to the IEEE Internet of Things journal, an IoT system is a network of networks where, typically, a massive number of objects, sensors and devices are connected through communications and information infrastructure to provide value-added services via intelligent data processing and management for different applications. It provides interaction among the real/physical and the digital/virtual worlds. The physical entities have digital counterparts and virtual representation and things become context aware and they can sense, communicate, interact, exchange data, information and knowledge. With the Industrial Internet of Things, more devices will be enriched with embedded computing and connected using standard technologies. This allows field devices to communicate and interact both with one another and with more centralized controllers, as necessary. It also decentralizes analytics and decision making, enabling real-time responses.

Through the use of intelligent decision-making algorithms in software applications, appropriate rapid responses can be given to physical entity based on the very latest information collected about physical entities and consideration of patterns in the historical data, either for the same entity or for similar entities. These paves new dimension of IoT concept in the domains such as supply chain management, transportation and logistics, aerospace, and automotive, smart environments (homes, buildings, infrastructure), energy, defence, agriculture, retail and more.

The Internet of Things is thus a computing concept that describes a future where every day physical objects will be connected to the Internet and will be able to identify themselves to other devices. It involves adding digital sensors and networking technologies to the devices and systems that we use every day. Some of the most well-known consumer examples are Nest and Ecobee smart thermostats and Amazon's Alexa-powered devices including the Echo smart speaker. Smart thermostats have sensors in multiple rooms and connect to your phone and the Internet to allow you extended control over the temperature. They can also be connected to algorithms to control the temperature when you're not home or based on weather patterns. They can even "detect" when you leave.

According to Gartner, by 2020 30% of our interactions with technology will be through "conversations" with smart machines. In 2020 there will be about 20 billion connected objects compared to the current 13 billion, while at the beginning of the 90's the number of connected "things" was around 1 million. Everything evolves and we are entering a phase that will mark an epochal change. According to a study by the Polytechnic University of Milan in Italy, the "Internet of Things" market is worth over € 1.55 billion and expects a remarkable growth in the field of smart cars, smart homes and smart cities.

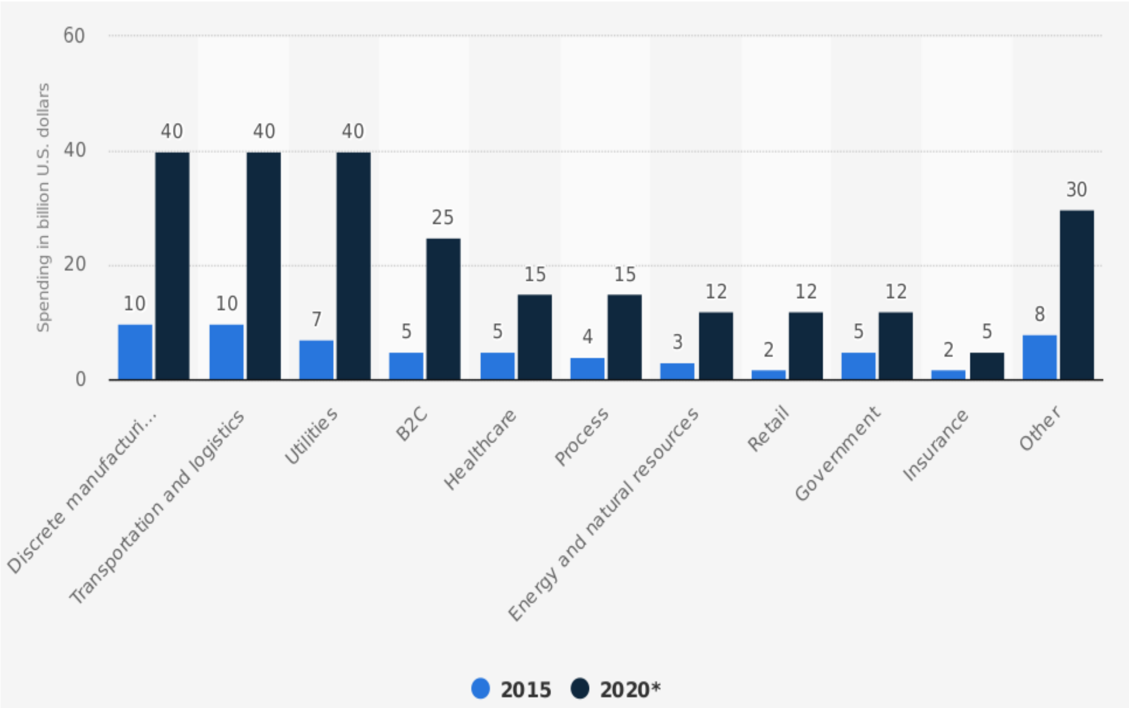

Figure 22: Spending in Internet of Things worldwide on vertical by 2015 and 2020 (in billions of U.S. dollars)

Although the IoT enabling technologies to have tremendously increased in the past decade, there are many issues to be open and addressed. Security will be a major concern, wherever network consists of many devices or things are connected. There are many ways the system could be attacked; disabling the network availability, pushing erroneous data into the network, and accessing personal information. It is impossible to impose proper privacy and security mechanism with current already existing techniques. Thus, privacy becomes a major concern and need to incorporate appropriate security measures.

Moreover, huge volumes of data will be collected from connected network of devices. According to a rough estimate, more than 2.5 trillion bytes of new data every day will be logged by these systems. Analysis of data and its context will play a key role and poses significant challenges. The data collected through IoT devices have to be stored and used intelligently for smart IoT applications. These leads to develop artificial intelligence algorithms, and machine learning methods based on evolutionary algorithms, genetic algorithms, neural networks, and other artificial intelligence techniques are necessary to achieve automated decision making.

Another hurdle for both IoT and Industry 4.0 has been the lack of standards. Having a bunch of smart devices is great, but if they all record data in their own format and require their own protocol, integrating them into an automated factory will be cost prohibitive and difficult. Manufacturing giants like Bosch, the Eclipse Foundation, and others have been working on standard communication protocols and architectures like OPC UA, MQTT, and PPMP. These all aim to help smart devices, including those on the factory floor, communicate with each other and provide common data formats. But more data formats can mean more difficulty in creating one data model (Oliver, 2018).

6.6 CYBERSECURITY

Many companies still rely on management and production systems that are unconnected or closed. With the increased connectivity and use of standard communications protocols that come with Industry 4.0, the need to protect critical industrial systems and manufacturing lines from cybersecurity threats increases dramatically. As a result, secure, reliable communications as well as sophisticated identity and access management of machines and users are essential. Cybersecurity is a synonym of computer security, that is of all those technologies useful to protect a computer or a set of computers from attacks that can lead to the loss or compromise of data and information.

The fourth industrial revolution (Industry 4.0) is closely associated with the topic of cybersecurity. It is common ground that Industry 4.0 means process, product, service and management innovation, with significant impacts on plants, products, information and of course, not least, on people. All this will be made possible thanks to the pervasiveness of ICT technologies and what is now commonly called cyberspace. Cyberspace which, as Professor Roberto Baldoni recalled, "is the most complex and articulated thing that man has ever conceived, a union of thousands of data networks and software layers that interconnect men and things around the world".

With the number of potential attackers and the growing size of the network, the tools that potential attackers can use are becoming more sophisticated, efficient and effective. A rapidly increasing number of Industry 4.0 cybersecurity incidents emerge, additionally stressing the need to strengthen cyber resilience. This is particularly true for industrial operators who are beginning to utilise the Internet of Things (IoT) and Industry 4.0 solutions. The need to improve cybersecurity of Industry 4.0 is even more important, since the potential impact of relevant threats ranges from compromising physical security to production downtimes, spoilage of products to damaging equipment as well as ensuing financial and reputational losses.

During the past year, several industrial-equipment vendors have joined forces with cybersecurity companies through partnerships or acquisitions. According Frost & Sullivan, increasing data density with Industry 4.0 and the fusion of information technology and operational technology brings newer challenges, particularly of cyber security. Increasing cyber-attacks in recent years, with victims ranging from individuals to governments around the world, continue to alarm. As seen from the general perspective, it is obvious that the cyber-attacks have caused a great deal of damage to the whole world. To prevent cyber-attacks, organizations should educate consumers about the appropriate safety procedures that should be followed while using an IoT system.

Cyber security is today the core issue that all governments follow at the highest level of importance. At the beginning of the 1980s, general cyber-attacks began with password cracking and password guessing methods. Today, directed cyber-attacks occurs with packet spooling, advance scanning, keylogger and denial of service. In future, strategic cyber-attacks are expected to damage strategic points with bots, morphing and malicious codes. Over time, the nature of cyber-attacks has been complicated and extremely sophisticated.

Cyber security efforts require protection against a broader range of challenges. It is getting harder with new technologies, trends in mobile usage, social media, well-financed and organized enemies and 24h attacks. Cyber risks can have a direct impact on everything from stock exchange price to brand reputation, with their more complicated structures. The primary security principles of an efficient IoT security are addressed from five aspects (Abomhara & Kien, 2015).

Confidentiality	Confidentiality is the ability to hide information from people who are unauthorized to access it and thus needs protection from unauthorized access. Confidentiality is an important security feature in IoT. In most situations and scenarios sensitive data for instance patient data, private trade data, and/or military data as well as security credentials and secret keys, must be hidden from unauthorized accesses.
Integrity	Integrity of information refers to protecting information from unauthorized, unanticipated or unintentional modification. Integrity is a mandatory security property in most cases in order to provide reliable services to IoT users. Different systems in IoT have diverse integrity needs.
Availability	Availability is the access to information whenever needed by a user of a device (or the device itself). Therefore, the IoT resources must be available on a timely basis to meet needs or to avoid significant losses.
Authenticity	The authenticity property allows only authorized entities to perform certain operations in the network. Different authentication needs require different solutions. Some solutions must be strong control, for example, authentication of finance systems. On the other hand, most must be international, for example, ePassport, while others have to be local.
Nonrepudiation	IoT service must provide a trusted audit trail. The property of nonrepudiation presents certain evidence in cases where the user or device cannot deny an action, for instance, payment action. – Privacy: Privacy is an entity’s right to determine the degree to which it will interact with its environment and to what extent the entity is willing to share personal information with others.

Figure 23: Five security principles to be guaranteed in an IoT system

One of the desired consequences of Industry 4.0 will be the extension to the manufacturing world (and not only) of the Always-on status that each of us is already experiencing on an individual level, that is the status of all connected, always. Enabling technologies include Cloud, Broadband and Ultra Broadband, Big Data, Robots, Drones, Artificial Intelligence, and, especially for Industry 4.0, the Internet of Things (IoT), everywhere. All these technologies have already in fact increased dramatically and will increase more and more what the experts call the surface attack, that is the opportunities to launch malicious and devastating attacks by cyber criminals, be they individuals, criminal organizations or sovereign states.

First of all, the "all connected, always" means, in practice, "more doors and more windows" towards the outside world. The direct consequence is a significant increase in the risk that attackers are able, at reduced costs, to steal information, data and fundamental know-how for companies. Then there is another risk that is undoubtedly less obvious, but just as real and with potentially equally devastating effects: that our information systems and above all our products, if not properly designed, are used by the attackers as "support bases" and "ports" from which to launch devastating attacks on others. For many companies this would be very dangerous, especially in terms of image and market share.

The cyber landscape is constantly altering and evolving due to the speed of technological change, the complexity of the attackers, the value of potential targets and the effects of attacks. With the widespread use of computer networks, hackers have taken advantage of network-based services to gain personal benefit and reputation. In a threat environment where security products need to be constantly refined or updated to identify the recent exploitation, the challenge is to find a solution that provides a future-proof defence to ensure lasting network safeguard (Chemringts, 2014).

Each organization has digital knowledge and many businesses maintain business transactions and trades with online systems. Most enterprises are open to cyber threats attacking from external and internal boundaries and so, their critical infrastructure needs to be protected. Cyber security was initially seen as a problem for the IT team, but these days it is an agenda for the entire senior executives. Cybercrime is triggered by sophisticated technologies, the use of mobility, social media, and relatively new trends in rapidly expanding connectivity—all in the hands of organized criminal networks. Under this circumstances, a smart, dynamic and evolutionary approach to cyber security is crucial to stay ahead of cybercrime and competition (Ervural & Ervural, 2018).

6.7 THE CLOUD

With the advent of Industry 4.0, more production-related enterprises will require increased data sharing across sites and company boundaries. The Cloud represents the connective tissue of Industry 4.0, the one that allows to build an innovative production strategy, more effective and efficient, exploiting sensors, artificial intelligence and robotics. According to the research evidence "Cloud: Opening Up the Road to Industry 4.0", conducted by Oracle and Intel on a sample of 1,200 managers of medium and large manufacturing companies based in EMEA (Europe, Middle East and Africa), in fact, as many as 6 companies out of 10 believe it is "necessary" to have an enterprise cloud infrastructure to capitalize on investments in innovation, declined in the main guidelines of robotics (62%) and AI (60%). The Cloud is, therefore, a real accelerator of the digital transformation in manufacturing companies.

If it is true, in fact, that AI and robotics represent the digital transformation assets in factories and Big Data and analytics are the tools on which to base both strategic and tactical choices, the 4.0 makes it clear that the most important innovation, for CIOs and business line managers, are the ways in which technologies can be used, that, thanks to the new pay-per-use and as-a-service formulas of the Cloud , are actually within the reach of any organization, large or small. The Cloud Computing infrastructures are large data centres that allow the user to have the resources he needs (storage, applications, programs, services) with the pay-as-you-go formula. In this way a new business model is born, which allows to considerably reduce the internal IT power, to be able to acquire it externally based on the actual needs.

The Cloud allows to have the computing power necessary to identify and make the most of new business opportunities, extrapolating the relevant information within the myriad of data acquired. Today many manufacturing companies are voting for new organizational and process paradigms focused on collaboration along the supply chain. The idea is to improve competitiveness on national and international scenarios by operating not as single entities, but as an element of a wider and more organic ecosystem, optimizing all production and distribution activities to obtain greater process efficiency.

Cloud Manufacturing (CMfg) is a business model that is being consolidated, which allows organizations to virtualize production resources (software, machinery ...) and offer them as a callable service, easily configurable and "consumable" via the Internet. The costs of production infrastructure and maintenance will thus be spread over the entire supply chain, ensuring greater supply capacity (and greater flexibility) and lower costs for the individual supply chain entities.

Indeed, Cloud offers up an environment for businesses to adapt to today’s rapidly changing technologies. With unprecedented compute, storage and networking capabilities, industries are now able to utilise the cloud platform to optimize their business processes, seamlessly run their applications, and ultimately gain visibility into the data and analytics that inform their next actionable insight. Additionally, the ability of innovative new applications on the cloud platform to adapt accordingly to individual needs is a great boon, boosted by its predictability and ability to perform consistently when confronted with massive amounts of data. Moreover, industry-specific application cloud is now a new blue ocean that has presented itself as a relevant market for businesses everywhere. In short, this consists of vertical Clouds tailored to the needs of specific industries, such as patient care, manufacturing, banking, retail, and so on. Though vertical cloud remains unconquered, therein exists a tremendous demand due to the growing maturity of cloud platforms today.

Reach and scalability	Cloud 4.0 is a solution spanning across different geographical regions of the world, enabling users to deploy workloads globally, optimizing reach without compromising performance.
Simplicity and flexibility	Aside from deploying and optimizing cross-region cloud applications, Cloud 4.0 is also capable of meeting the compliance, governance and regulatory requirements of varying markets.
Security	With cyberattacks random, and at times rampant, a Cloud 4.0 solution needs to leverage upon a robust globally-managed network, data centre infrastructure, and security services. It would be comprised of experts to proactively aid organizations in securing their IT infrastructure and implement cyber defence strategies.
Cost savings	This is achieved through a pay-as-you-go model, along with a slew of managed application services, thus helping businesses design and construct the most appropriate cloud architecture for optimal performance.
Expertise	Cloud 4.0 leverages the strength and expertise of a global network, whilst providing security and collaboration services.

Figure 24: The main benefits of Cloud 4.0

For instance, Lane Crawford, a leading retailer of specialty and luxury goods in Hong Kong and China, adopted a higher flexibility and scalable solution in order to accommodate changes in their business demand, influenced by seasonal shipping, sales, and promotional activities. Adopting a vertical Cloud 4.0 solution greatly enabled their business to meet the rapid growth of online shopping in massive China, better attuning themselves for the unique retail market they are in.

The same applied for Borgward Driverless Cars, a German luxury car manufacturing company, adopted a hybrid cloud deployment with an optimum solution design. This aided them in their customer globalization journey by providing speedy deployment, data sovereignty, and top-notch operational quality and performance (Loi, 2018).

Another example of Cloud Computing is the electronic invoicing, which is the digital process that allows the generation, transmission, management and storage of invoices in electronic format, definitively abandoning paper support. The advantages of electronic invoicing derive from the normalization and digitalisation of all the processes related to the life cycle of the invoice itself, with considerable efficiency gains and cost reduction.

In the near future, industries are expected to continue adopting tech automation, data analytics, and smart machines, in an attempt to improve productivity and efficiency levels. Coupled with the constant push for enterprises to expand abroad in order to remain competitive, it is an undeniable fact that there will be an increase in IT applications on the cloud, and across geographical regions. Businesses need to realise that not all cloud solutions were created equal, and it's imperative to select one that meets all their needs. Industry 4.0 and in parallel Cloud 4.0 is an eventual revolution, one that industries will have to eventually adopt to aid their transition into a new world.

6.8 ADDITIVE MANUFACTURING

In a historical moment in which the media exposure of this technology is very high, it is legitimate to ask whether such popularity is justified by a real revolutionary charge of the underlying technological innovations or if we are in the presence of a media bubble, destined to deflate as soon as it will be realized that the real innovative scope of these technologies is below expectations. As in the case of numerically controlled machines and robots, even in the case of 3D printers, manufacturing can be called "digital" since the designer must be able to use software - the CAD - that gives a virtual representation of the object to be produced, starting from its geometric parameters (its "mathematics") that are transmitted from a computer to a machine that makes it.

Companies have just begun to adopt additive manufacturing, such as 3-D printing, which they use mostly to prototype and produce individual components. With Industry 4.0, these additive-manufacturing methods will be widely used to produce small batches of customized products that offer construction advantages, such as complex, lightweight designs (Gerbert, Lorenz, Rüßmann, & Waldner, 2015). This technology, in fact, will increasingly allow, through virtualization, to anticipate the moment of functional verification of the design phases of the objects, whose real behaviour can be approximated so accurately that the physical realization of prototypes is even superfluous. Among the leading companies in this new approach is particularly interesting the case of Dallara, the manufacturer of racing cars, which has developed a simulation system capable of approximating and virtually comparing the actual behaviour, on the race circuit, of prototypes of cars made using different technical solutions.

The real novelty in the recent years, in any case, is the application of 3D printing for the realization of finished products, a circumstance made possible by a plurality of innovations, in different fields, which jointly have allowed a significant improvement in quality print output. First of all, the printers themselves, which are less expensive today and capable of processing a greater number of materials, can produce larger objects faster and with higher levels of accuracy. Secondly, the hardware systems capable of processing unimaginable amounts of data until a few years ago to support increasingly smart and specialized software (in particular in CAD simulation).

Finally, the materials: the chemical industry, although it has not yet invested significantly in this sector, has considerably improved the quality of the materials that can be used for 3D printing. This eliminates the need, the limits, the constructive implications and the costs of welding and many assembly activities. For each component made in 3D manufacturing, therefore, the designer's action processes admit the expression of greater freedom on the creative level, a circumstance that allows the conception of more pleasing aesthetic forms (think of the jewellery sector or the furnishing one) and more functional from a technical-engineering standpoint. Moreover, high-performance, decentralized additive manufacturing systems will reduce transport distances and stock on hand. 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.

From the point of view of the skills required by companies, therefore, important changes are expected: in particular, a greater weight of professions related to design, software, material chemistry and plant maintenance. In more general terms, an increase in the demand for technical and/or "creative" professions and a lower need for unskilled labour. According to this perspective, therefore, companies could not preserve the spare parts (atoms) but the files (bits) that record their geometries and thus significantly reduce the capital immobilization associated with them and the logistics costs. It is clear that in this case the 3D printed parts could also be much more expensive than similar pieces made in traditional manufacturing, but the change would be justified in any case on the basis of the reduction in these aforementioned costs that could be obtained.

It should also be noted that the possibility of printing spare parts does not only concern components born in the digital age, for which a reference file exists, but can also relate to pieces of high economic value (for example the piece of a vintage Ferrari engine). With a 3D scanner, in fact, it is possible to switch from a physical object to a file that describes its geometry: the operation can obviously also require the use of specialized software to improve the file obtained with respect to the requirements of 3D printing. With additive manufacturing, in any case, there is a drastic reduction in unit costs for small production scales. This implies a significant reduction of entry barriers in many sectors and in the cost of innovation.

6.9 AUGMENTED REALITY

Augmented Reality (AR) can be defined as a real-time direct or indirect view of a physical real-world environment that has been enhanced or augmented by adding virtual computer-generated information to it. Augmented Reality aims at simplifying the user’s life by bringing virtual information not only to his immediate surroundings, but also to any indirect view of the real-world environment, such as live-video stream. AR enhances the user’s perception of and interaction with the real world. While Virtual Reality (VR) technology or Virtual Environment, as called by Milgram, completely immerses users in a synthetic world without seeing the real world, AR technology augments the sense of reality by superimposing virtual objects and cues upon the real world in real time. It can potentially apply to all senses, augmenting smell, touch and hearing as well. AR can also be used to augment or substitute users’ missing senses by sensory substitution, such as augmenting the sight of blind users or users with poor vision by the use of audio cues, or augmenting hearing for deaf users by the use of visual cues (Carmigniani & Furht, 2011).

In the future, companies will make much broader use of augmented reality to provide workers with real-time information to improve decision making and work procedures. Virtual objects added to the real environment show information to the user that the user cannot directly detect with his senses. The information passed on by the virtual object can help the user in performing daily-tasks work, such as guiding workers through electrical wires in an aircraft by displaying digital information through a headset. For example, workers may receive repair instructions on how to replace a particular part as they are looking at the actual system needing repair. This information may be displayed directly in workers' field of sight using devices such as augmented-reality glasses.

Another application is virtual training. Siemens has developed a virtual plant-operator training module for its Comos software that uses a realistic, data-based 3-D environment with augmented-reality glasses to train plant personnel to handle emergencies. In this virtual world, operators can learn to interact with machines by clicking on a cyber representation. The information can also simply have an entertainment purpose, such as Wikitude or other mobile augmented reality.

While there are many possibilities for using augmented reality in an innovative way, four types of applications are most often being used for AR research: advertising and commercial, entertainment and education, medical, and mobile application. Augmented reality is mostly used by marketers to promote new products online. Most techniques use markers that the users present in front of their webcam either on special software or simply on the advertising company's website. For example, in December 2008, Mini, the famous car company, ran an augmented reality advertisement in several German automotive magazines. The reader simply had to go to the Mini's website, show the ad in front of their webcam, and a 3-D Mini appeared on their screen. With such a system, marketers could add a "paid" option on the software that would allow the user to access additional content, such as seeing a trailer and then being able to click on a link to view the full movie, turning the magazine into a movie ticket.

AR also offers a solution to the expensive problem of building prototypes. Indeed, industrial companies are faced with the costly need to manufacture a product before commercialization to figure out if any changes should be made and see if the product meets the expectations. If it is decided that changes should be made, and this is more often than not the case, a new prototype has to be manufactured and additional time and money are wasted. A group of the Institute of Industrial Technologies and Automation (ITIA) of the National Council of Research (CNR) of Italy in Milan works on AR and VR systems as a tool for supporting virtual prototyping. The ITIA-CNR is involved in the research for industrial contexts and application using VR, AR, real-time 3D, etc. as a support for product testing, development and evaluation.

Some examples of applied research projects where the above technologies have been applied include motorcycle prototyping, virtual layout of a factory and an office, virtual light simulation, and virtual trial of shoes with the Magic Mirror interface. With this interface, the ITIA of CNR in Milan has created a system which, combined with high-tech footwear technology for measurement, enables the user to virtually try on shoes prior to buying/ordering them. But AR is still in infancy stage, and as such, future possible applications are infinite. Advanced research in AR includes use of head-mounted displays and virtual retinal displays for visualization purposes, and construction of controlled environments containing any number of sensors and actuators.

MIT Media Lab project “Sixth Sense” is the best example of AR research. It suggests a world where people can interact with information directly without requiring the use of any intermediate device. Other current researches also include Babak Parviz AR contact lens as well as DARPA’s contact lens project, MIT Media Lab multiple research applications such as My-Shopping Guide and TaPuMa. Parviz’s contact lens opens the door to an environment where information can only be viewed by the user. Of course, this can also be done by using glasses as opposed to contact lens, but the advantage in both cases over using a cell phone, for instance, is that no one else but the user can see the information projected, making it very personal. Cisco has imagined a world where AR could be used for replacing the traditional fitting rooms by trying on virtual clothes, thus saving time and providing the ability to try on more clothes, increasing the chance for stores to sell.

Augmented reality also brings the possibility of enhancing missing senses for some users. For example, AR could be used as a sensory substitution device. Hearing-impaired users could receive visual cues informing them of missed audio signals and sightless users could receive audio cues notifying them of unknown visual events.

Even the future is not far from challenges for augmented reality, with some social acceptance issues, privacy and ethical concerns arising with the future of augmented reality applications in the industry. Social acceptance mostly arises from mobile devices with the need for the devices to be subtle, discrete and unobtrusive as well as fashionably acceptable, but also with systems that will require retraining of the personnel and staff in order to be utilized. This might be the case with some medical applications, and the health system might decide against the use of augmented reality if they consider the retraining as too costly. Privacy concerns arise not only with medical applications, but also with technologies that have the ability to detect and recognize people. When it comes to ethical concerns, the apprehension mostly comes from the fact that people tend to get carried away by these technologies.

We do not know where to put down limits for the use of technology and keep researching as we see the potential grow. However, with augmented reality, it will be very important for the developers to remember that AR aims at simplifying the user's life by enhancing, augmenting the user's senses, not interfering with them.

7. THE ROLE OF 4.0 ON THE METALLURGIC SECTOR IN ITALY

The advent of Industry 4.0 is radically transforming the labour market and the various sectors, including the manufacturing and engineering sectors. Innovation and new digital tools are gradually being added to and partly replacing traditional production systems, laying the foundations for what could be called "Factory 4.0". Metallurgy, a discipline that concerns the study and processing of metals, is still today a sector of fundamental importance in the field of industrial production. Indeed, the metallurgical industry sector plays an important role in the economies of industrialized countries, both in terms of employment and strategy, and in terms of added value and international exchange.

Even in the Italian national territory the metallurgical sector is an important economic resource. It plays an important role in the economy of the Italian-system both in terms of employment and international exchange, although only in the second post-war period did it begin to play a leading role in the national productive panorama. In this context, the state intervention of the time was essential to allow the evolution of metallurgy in Italy.

The economic crisis that began in 2007 has affected various sectors, including that of metallurgy, which nevertheless managed to resist the recession, given that it continues to contribute positively to the Italian employment rate. According to the findings of the European Confederation of Iron and Steel Industries, in the period 2005-2007 the European production of crude steel has grown at an average annual rate of 3.6%, a figure to be considered comforting given the fierce competition from some emerging countries. In the subsequent two-year period, however, there was a drop in production, particularly marked in 2009 (-29.9% compared to 2008) due to the effects of the global financial crisis which had serious repercussions on the metalworking industry and on the buildings, or on the major basins of demand for steel products. In this context, the Italian steel industry followed the same trend as the European one, but with a decrease in production in 2009 even more marked (-35.1% compared to 2008) (Informest, 2011).

Although the economic recovery in Italy is emerging in a less marked manner compared to countries like Germany, France and Spain, the data on the performance of our country reveal a favourable and encouraging framework for the development of Industry 4.0. While in the tertiary sector the digitization has already had the opportunity to show its disruptive innovative potential, the secondary sector has understandably shown fewer fast dynamics, also in light of the longer life cycle of its assets. But the time is now ripe for the fourth industrial revolution: thanks to digital technologies, industrial companies will take a leap in their competitiveness and efficiency thanks to the increased ability to interconnect and cooperate with their resources (machinery, people, information), whether they are inside the factory or distributed along the value chain.

The 4.0 revolution is contributing to the revival of the Italian metallurgic district. Strongly debated in recent years, it has now become synonymous with a gradual and incremental evolutionary process, aimed at integrating new digital technologies in industrial and manufacturing enterprises. The target? Open the way for Smart Manufacturing, towards interconnection and cooperation, in production processes, between the different corporate resources involved. Industry 4.0 will therefore mark the development of interconnected industries, more performing and competitive, decentralized, where the processes are controlled in an automated way and based on a more efficient man-machine collaboration.

Indeed, the most recent data on the state of adoption and application of 4.0 technologies in the industrial sector reveal that Italy maintains a solid position in Europe and in the world. With around 5,400 high-tech manufacturing companies, Italy is among the top four countries in Europe (along with Germany, the UK and Poland), where there are around 46,000 high-tech companies in total. From these premises derives the profile of a country rich in resources and potential, which deserve to be adequately exploited and exploited through strategies of collaboration between companies, institutions and public and private bodies. (La Fratta & Michele, 2019; La Fratta & Michele, 2019)

Given that metallurgical production appears to be growing (even if only by a few percentage points), it is extremely important that political-economic interest should be addressed to the financing of sectoral research, so as to make Italian metallurgy competitive internationally, where production it is preceded by considerable investments in the study of new technologies. The productivity of this market is strongly determined by the ability to innovate through research: from the study of new types of high-quality steel to the adoption of new technologies. The challenge of Industry 4.0 represents not only a significant opportunity for re-launching the country's economy, but also an opportunity to optimize production by making it more flexible and more in line with customer needs. A road to spreading this innovative type of industry is the adoption by companies of technological solutions capable of enabling the new paradigm and the development of digital skills that are necessary today.

In 2017 the Government decided to take an important first step towards the technological evolution of our industrial fabric, implementing a series of important measures with the "Piano Nazionale Impresa 4.0". Tax incentives and other initiatives have achieved positive results, as shown by the growth in investments in digital technologies and the purchase of new industrial machinery. Statistics show that ours is a leading country in terms of new technologies. Italian companies are embracing change, increasing investments.

However, from the I-Com report some disconcerting data still emerge: there are still many SMEs that do not understand the advantages of investing in digitalization, especially in terms of the insertion of new resources, considering that on the total of the Italian workforce the ICT specialists are only 2.5%, and the percentage of high technological skills in the workforce is among the lowest in Europe (figure 25).

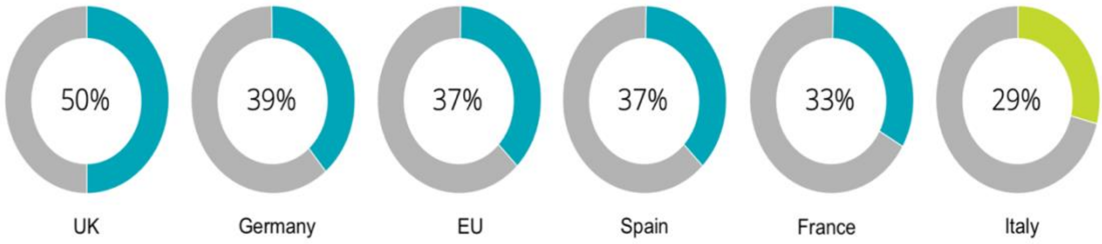

Figure 25: Percentage of high technological skills in the workforce

The road ahead for the revival of this Italian production sector is still long. In particular, the biggest stumbling block for companies that want to keep up with today's digital changes is certainly that of skills. The choice to invest in a specific technology is dictated above all by the prospect of increasing the satisfaction and involvement of end customers (43%). Slightly lower (40%) is the ability to integrate new technology with existing ones, increase ROI, support a new business model and forecast long-term impact on the organization. However, it is in the management and development of human resources that the gap with other countries appears more evident. The presence of talents and the availability of suitable skills to exploit technology is in fact extremely marginal (9%) in influencing the choice of investments in new technologies, contrary to the global data (32%) (Deloitte, 2018).

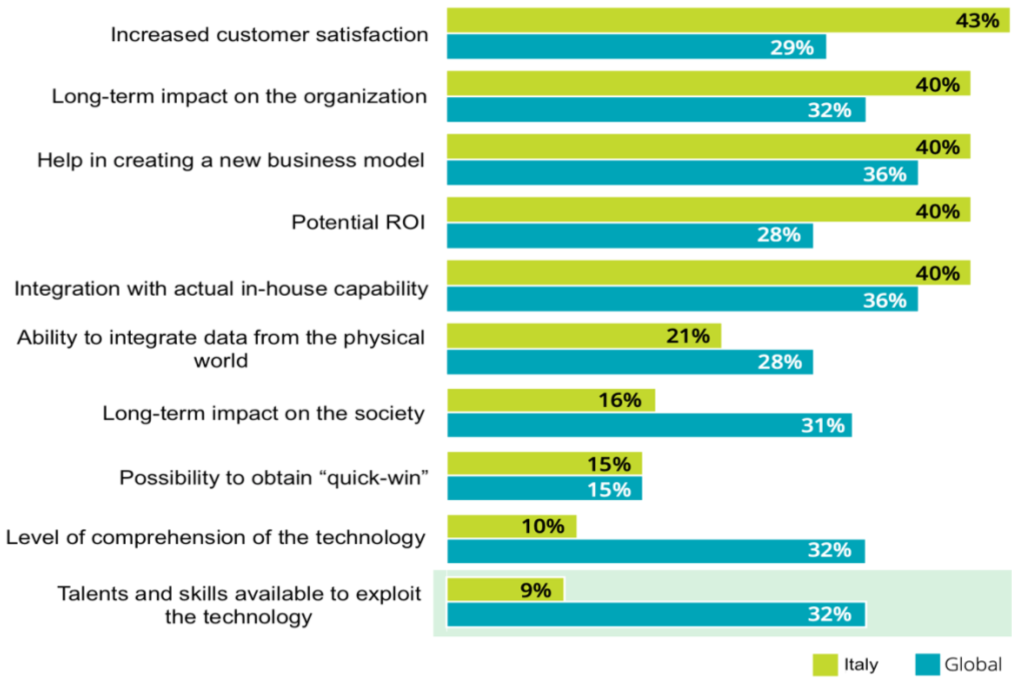

Figure 26: What influences a company in the decision to invest on a specific technology

In order for the potential of the fourth industrial revolution to be effectively translated into practice in the metallurgic sector, companies must rely on a new generation of highly skilled workers and invest in training the current workforce so that they can understand and make the most of new machines and technologies. From this point of view, the relationship between school and work will have to be renewed and ad hoc programs will be promoted that will transmit to the students the knowledge of the sector and the new digital skills. Secondly, companies will also have to invest time and resources in industrial plans and training strategies linked to the theme of innovation.

Among the innovations that have been introduced, there should be the commitment to review the current system of professional framing in the light of developments connected to Industry 4.0 and the allocation of new investments for continuous training, which allow workers to adapt their skills to the changes brought about by the digital revolution. The "new" mechanics will therefore not be mere executors but will also have to use innovative and complex technologies and will be able to have greater spaces of autonomy thus becoming "entrepreneurial workers".

“In the last two years the market of industrial digitalization has almost doubled, while the awareness of industry 4.0 and the knowledge of new technologies are now widespread in almost all the productive realities of the country", explained Alessandro Perego, Andrea Sianesi and Marco Taisch, scientific supervisors at Polytechnic of Milan. In fact, only 2.5% of companies do not know what industry 4.0 is (almost 40% two years ago), 92% know the measures of the national plan and 55% have already implemented solutions 4.0. On average, each company has already adopted 3.7 applications and one in four claims to have invested more than 3 million euros. The investments concerned for 90% industrial IoT projects (referring only to the components to connect the machinery to the network), industrial analytics and cloud manufacturing, among the first technologies for growth. (Automazione plus, 2019) And the metallurgic sector is perfectly in line with this data.

It must be considered that metallurgical production plants have extremely long service lives, which means that Industry 4.0 must be implemented gradually within the existing machinery fleet in order to maintain functional infrastructure where possible and to optimize it, where necessary. The data-driven combination of different quality characteristics of the material and of the workpiece with process parameters is a key issue for Industry 4.0, also in the metal industry. If the process can be optimised accordingly, it is possible to implement a key approach of Industry 4.0: gaining information from the smart linkage of expected performance data with adaptive characteristics. This qualified real-time information allows adaptive maintenance options to be indicated via the control system. This is a prerequisite for the dynamic control of processes in response to the individual requirements of customers, for example in the automotive industry.

Data mining links crucial empirical knowledge on the process behaviour with consistent physical data to form digitally modelled characteristics for an optimized process. A real-time control of operations can lead to cost savings, and high energy and resource efficiency. These savings can be validated and are reproducible irrespective of individual process data.

In addition to the intelligent and integrated use of data, the main focus of Industry 4.0 is on the development of new business models evolving from the smart factory, deriving from the use of the new technologies. A quick look at the growth of investments in metal additive manufacturing highlights the potential of this sector. In 2016, over 1000 machines for the metal additive manufacturing were sold worldwide. Companies like GE, UTC and Alcoa are investing heavily in technology: $ 1,300, $ 75 and $ 60 million respectively. Current forecasts suggest that the industry's CAGR (Compounded Average Growth Rate) is growing by 47% each year, with the prospect of reaching a market of $ 7 billion by 2026. (Wholers Associates, 2017)

Generally speaking, the landscape of additive metal fabrication is dominated by four main technologies. First, the Powder Bed Fusing (PBF), the most common type of additive manufacturing of metals, made possible by laser or electron beams, that offers high complexity, precision and re-use of materials. Secondly, the Direct Energy Deposition, a solution based on materials in the form of powder or wire, which offers high productivity, large parts and reduced material costs. Thirdly, the Powder Binding (BD), a technique that involves the spraying of a binder onto a layer of powdered metal to form a "green part" and generally offers reduced costs of machinery and operations, in addition to the ability to achieve high productivity. Finally, the Metal Jetting technique (MJ), which involves the deposition of drops containing metal nanoparticles by the ink jet printheads and guarantees the production of high-quality parts.

However, today, all the technologies of additive manufacturing of the metals on the market present drawbacks, which continue to weigh on their adoption. The cost of most, if not all the technologies mentioned above, is incredibly high, starting from the purchase cost up to the cost per part. Current technologies require excessive maintenance and the use of an inert environment (based on nitrogen). Furthermore, the pre and post-processing phases can be incredibly complex. Simply put, the limits and risks of technology are currently excluding the industry's move to the use of additive manufacturing for the actual production. Once these obstacles are overcome, manufacturers can begin to exploit this technology as a truly viable alternative to traditional metalworking.

Due to their complex internal processes and the increasing globalization of supply chains, metallurgic companies need real-time information exchanges at the various stages of the product lifecycle, i.e., design, prototyping, production, maintenance/repair, etc. In this scenario, AR can be of great help, due to its capability to simulate, assist and improve its processes before they are carried out. Indeed, the virtual objects display information that the user cannot directly detect with his own senses; the information conveyed by the virtual objects may help a user perform most of the product-related tasks. AR applications to the metallurgic industry have been developed for several purposes, including process monitoring and control, real-time evaluation of plant layout, plant and machinery maintenance, plant and building construction, as well as for enhancing industrial safety. Despite this, AR applications in metallurgic are perceived to be still in an exploratory stage and full-scale deployments of AR solutions have been carried out only in a limited number of cases.

The metallurgical industry is one of the most versatile sectors and therefore perfect for robotic automation solutions. It requires perfection in details and maximum performance in difficult and sometimes extreme working conditions. The requirements for precision and accuracy of details have increased. In particular, with reference to Industry 4.0, new concepts are needed for a more intelligent production. And collaborative robots are improving the quality and quantity of production in the metallurgical and mechanical processing sector. Cobots allow manufacturers who adopt subtractive production methods to adjust the production line regardless of processes, materials and products. Using a collaborative industrial robot to carry out metallurgical processes and mechanical processing boosts productivity, reducing time to market and giving definitely a decisive competitive advantage.

To this day, numerous solutions have been proposed by large companies. An example arises from the collaboration between Siemens and Comau. It involves the complete integration of Comau robotic arms into the Siemens SINUMERIK CNC system. According to Giuliano Busetto, Country Sector CEO of Samsung, “the solution guarantees the complete integration of the Comau robotic arms into the numerical control for Siemens Sinumerik machine tools. With Sinumerik Run MyRobot / DirectControl, the Sinumerik CNC can directly control the robot, without the need for dedicated external controls and, last but not least, the considerable space savings since it is able to do everything without the robot's electrical panel. With a single numerical control, Sinumerik, it is therefore possible to control robots and machine tools. The operator is thus in control of the entire diagnostics and can perform operations such as movement commands related not only to the machine tools but also to the path and functions of the robot”.

Many are the products presented by the German company with the aim of guaranteeing manufacturers and users of machine tools greater flexibility and production efficiency, drastically reducing time-to-market and, at the same time, guaranteeing them greater competitiveness on the market global. "The Digital Enterprise Suite - affirms Busetto - is certainly a protagonist in the digitalization process. It is the complete portfolio intended for companies that want to take the path of digitizing their processes. It consists of software-based systems and automation components along the entire industrial value chain. Heart of the Suite is our operating system for the cloud-based IoT, MindSphere, and the numerous possibilities offered by its connection to machine tools". (dè Francesco, 2017)

Even KUKA, a global giant (owned by the Chinese Midea) based in Augusta (Germany) presented easy-to-apply automation solutions designed for the metallurgical industry. And many more will be presented in the next BI-MU at the next appointment scheduled from 14 to 17 October 2020 in the exhibition area of Fiera Milano Rho, with a wider and updated offer that includes also digital manufacturing and enabling technologies. Dedicated to manufacturers and users of machine tools, robots, automation and auxiliary products (CN, tools, components and accessories), BI-MU has always been recognized worldwide for its ability to respond to the need to give continuity to the encounter between the demand and supply of innovation. The success of the last edition confirms the significant data on the rapid progress of automation in Italy.

It's easy to understand the clear-cut benefits– for both workers and businesses – offered by industrial robots. Thanks to robots, in fact, workers are spared the hardest, most repetitive and dangerous tasks while the company enjoys the advantage of being able to employ personnel in more skilled activities. Further robot-generated payback includes improved process performance and productivity control, with evident advantages in terms of both finished product quality and labour costs. Robots and intelligent machines allow greater production and logistics efficiency, making production processes flexible and competitive, but to sustain and guarantee the success of this transformation, which is still ongoing, it’s necessary to pursue the achievement of an adequate level of safety of workplaces and all those responsible for the control and supervision of flows. Advanced technologies can ultimately improve working conditions.

Anyway, the most common challenges that organizations face when they try to adopt new technologies are linked to budget problems and the lack of the necessary technological know-how, thus highlighting the need for up-to-date talent training with the most advanced technological developments. The new technologies of Industry 4.0, with their innovative and destabilizing scope, deeply question the routines, structures and activities now consolidated in the companies. Thus, the need arises to broaden the perspective with which corporate strategies are conceived and translated into concrete actions, as well as to change the approach to innovation, product development and market competitiveness from the depths, going well beyond traditional activities. It is necessary that each company aligns this digital maturity to its business objectives by rethinking processes and organizational models in the difficult balance between operational management, continuous improvement and radical innovation.

8. THE CASE OF O.L.V.

The new industrial revolution is interesting not only large companies but also small and medium-sized enterprises, and the case of the O.L.V. is a proof. The O.L.V. Officina Meccanica Srl is a small company in the Canavese area (San Carlo Canavese), a very active area in the steel and metallurgical industry, founded in 1988 and specialized in high precision mechanical processing. The company can boast a large number of machines that has increased year by year, up to the current 78 units, which include centre-cutters, lathes, milling machines, drilling machines, marking machines and a gear cutting machine, each of them computer numerical controlled machinery.

Over the years the company has succeeded in expanding its customer portfolios obtaining a fair visibility and keeping contact with leading companies such as Oerlikon Graziano, Metalcastello or Farinia Group, to name a few, to which it supplies products in the transmission sector: in particular gear shafts, but also power take-off shafts, transmission shafts, conical transmission pinions, grooved teeth, drive shafts and hubs. These products, on which the company has always focused on high quality, are then addressed both in the automotive sector (for models like McLaren, Lamborghini, Volkswagen) and in the agricultural machinery sector (Caterpillar). Although the sector was strongly affected by the crisis that occurred in 2008, the company was able to recover by maintaining contacts with customers and deciding to focus on innovation to gain a competitive advantage over its competitors.

In fact, companies in the Metal sector need to constantly monitor processes through the use of control tools suitable both for managing a production based on customer order and for planning and produce based on forecasts. In today's world, the custom manufacturing market is demanding like a constant head-to-head race against competitors. Globalization and innovation have made the competition ever more aggressive; customers have become more demanding, qualified staff is hard to come by. Being the first to deliver a well-pitched job quotation gives a decent head start over the competition. But to stay in the lead, high quality must be provided at a competitive price with shorter delivery times. To do this, it is necessary to control and optimize the business and production processes, managing all the resources in the best way, to recover profit margins.

On the other hand, however, in the case of SMEs, a series of contingent limits come into play, which inevitably weakens their intentions to innovate. The main obstacles encountered are the high costs - linked to the purchase of machinery, sensors and other equipment to make smart production processes, with the consequent fear of committing wrong investments, especially on technologies with no proven efficacy; the fear of changes brought about by innovative measures; the lack of information - both regarding the benefits deriving from the adoption of the principles of Industry 4.0, and the incentives made available (fiscal measures, protection of intellectual property, etc. arranged in the national plans for technological transformation). From this last point of view, the numerous conferences, as well as fairs and initiatives aimed at making the main features of new technologies known, must be exploited, especially by SMEs.

And it is precisely "through some conferences organized by trade associations, such as API-Torino", of which the OL.V. it is part, that Federico Valle, head of the Industry 4.0 project, has taken the key aspects of this new trend fully sharing it. In 2017 the Company had made some important investments in production facilities, in particular with the purchase of new machinery. Therefore, the incentive deriving from the tax relief justified an interconnection intervention on the them. In this perspective, as explained by Valle, "an Industry 4.0 plan was designed that started from new machinery and then later on also included a revamp of the machinery already present. Moreover, the system chosen has been modular. Therefore, the project is always evolving with the possibility of integrating new solutions".

The first step, started in September 2017, involved the introduction of an uninterrupted traceability system for products that run along the extended supply chain, obtained by registering all the handling functions both inside and outside the warehouse, and a Manufacturing Execution System, closely linked to the installation of the WorkPLAN software for the management of the production process from the budgeting to the realization of the mold.

WorkPLAN allow companies or departments to automate and manage the most important activities such as project costs, quotations, orders, planning, document management, analysis of 3D CAD files, bills of materials, quality, touch screen to control time and attendance and to record time spent on tasks, purchasing, stock management, key performance indicators, management overview and strategic analysis. WorkPLAN can receive jobs or task lists from other ERP systems, detailing parts and quantities of components to be produced. The software then manages the manufacturing process, including the production planning and scheduling, production performance monitoring, and recording the time spent on each task by each employee or machine in real time, using touchscreens, barcode readers or data-entry forms.

As production proceeds, data can be fed back into SAP in the form of time taken, events completed, and parts produced. Detail such as set-up times, processing times, teardown times, quantities completed, reworked or scrapped are included in the information flow. Real-time recording of this information in WorkPLAN helps keep the system up to date, producing a dynamic exchange of data, and safeguards the business information, so when it is presented to managers, it reflects the true and current status of manufacture. Already at the order entry stage, the definition of product specifications activates pricing and cost determination structures that allow an immediate comparison of margins. The same product specifications, transferred in all the production phases, make it easy to maximize the efficiency of materials and labour thanks to bundling functions, for example for cutting or heat treatment activities.

These information system solutions are not limited to managing fundamental processes but stimulating their evolution towards more streamlined and rational organizational models. In an increasingly international and competitive context, the need to rely on precise and timely information tools has become an indispensable must to support the most cost-effective business choices. They instantly provide management with the information needed for the decision-making process through complete control of the logistic scenarios, assessing in advance the consequences of each decision through a precise analysis of profitability. Business development in this way relies on the strength of the data that forms the basis for ensuring effective corporate governance.

As Valle states, "the advantages are already evident as the production process is more fluid and at any time it is possible to analyse the real time status and the history of a job order. Previously, production accounting was a manual process, slow and often inaccurate, which did not meet the needs for immediate verification of producibility. Now the company is able to give certain answers to customers thanks to on time and full information, collected directly from the production lines. And human resources are also encouraged, given that their greater performance is effectively reflected in the data precisely collected. In fact, the production personnel have been involved and have shown good cooperation in the management of the system. Furthermore, during the process audit the inspectors appreciate a working method where the registrations are automatic and reduce the margin of error. Finally, the collaboration with the Turin Polytechnic was fundamental, which allowed the company workers to get in touch with young students who brought greater mental flexibility and propensity to new things."

A further digitalization process that will soon be addressed by the company will certainly be the adoption of cloud solutions, which will make it possible to improve the internal processes of the O.L.V., making the resources accessible from any device with a connection to the network. Regardless of where the user is, it will be possible to consult documents and work files, access the common agenda, use applications and management systems otherwise available only through the office PC. Certainly, these solutions are a great advantage for a company that has a large amount of data related to the various SKUs (orders, quality checks, measurements, etc.).

By doing so, backup management will change, and there will be no more USBs or external HWs as is still the case in many companies. Cloud backup is usually less expensive, with the advantage of having data replicated in real time across multiple data centres. The transition to cloud computing, whether for a few services/servers or entirely, is therefore a source of savings for small and medium-sized businesses like the O.L.V., as well as a source of greater flexibility, given that it is no longer necessary to purchase hardware with leases and expensive operations.

A further step is already planned, with the implementation of a module dedicated to machinery maintenance. Maintenance processes must be inserted and integrated in the most effective and constructive way in the 4.0 industrial model. Surely the technology offers the possibility of gathering a lot of information: the development of the sensors allows the continuous monitoring of many characteristics of the production process, both related to the product and related to the process and therefore to the state of the machines.

Predictive maintenance, therefore, can become an essential part of a long-term model, able to create additional value in the relationship between the company and its customers. In order to achieve this, predictive maintenance needs connected machines, integration with production systems and business information systems, needs analytics and needs an infrastructure capable of securely supporting data flow. All tools on which the OL.V. wanted to bet in the last years.

And in the future the company has decided to continue on this line. While technologies such as cybersecurity or augmented reality appear to be very far away due to the financial opportunities and the actual needs of a small company like the O.L.V., Valle has already participated in various events in the field of additive manufacturing, technology that in automotive manufacture is on the rise, with big names putting the technology to use for decades and new applications developing in serial production.

In many ways 3D printers represent a further evolution of the potential of computerized numerical control machines, present in the company. Using these last some working parameters depend on the characteristics of the machine: from the CAD the "mathematics" of the object to be realized is transmitted but it is also necessary to define the "tool path" that is significantly different in the case in which, for example, the same three-dimensional project must be realized with a lathe or with a milling cutter; also the specific characteristics of the machine (of that particular lathe or of that particular cutter) are relevant in the definition of the work; furthermore, the machine must be prepared for each specific process.

On the contrary, with additive manufacturing any 3D printer receives the "mathematics" from the computer and can produce the piece without any adjustment of the working characteristics to the machine: the CAD file can be interpreted by any machine and can give rise to productions in different places and with different materials. Furthermore, unlike numerically controlled machines, the 3D printer can simultaneously produce very different objects on the same work surface.

One of the most significant limitations of 3D printers is that of the dimensions of the products they can manufacture: today, in fact, only objects with a maximum dimensions of the cubic meter in the case of productions with plastic materials and less than half a cubic meter in the case of metal productions can be made. However, the components produced by the O.L.V. fall within these parameters (the most impressive components are around one meter in length).

From a prototyping point of view, there is a drastic reduction in actual time and Valle has already given positive signals for its possible future use: there is the possibility of producing small batches to be monitored immediately, testing its effectiveness, make the necessary changes based on user feedback, and then start large-scale production.
In the field of industrial prototyping, additive technology can today count on almost three decades of history. The first applications concern the automotive sector and have certainly contributed in a decisive way to realizing a real revolution, in the past two decades, in the field of new product development; although the phenomenon has not achieved as much media coverage, thanks to the potential of additive technologies, the time needed to renew the product lines has decreased from 36/40 months to just 18.

This was possible firstly thanks to the innovation in the design and industrial design (the transition to CAD) but it had a propulsive factor the possibility to quickly realize physical prototypes with the use of 3D printers. The realization of prototypes is fundamental to eliminate design errors that can emerge only in the application phase. Furthermore, it is crucial to provide concrete tools for marketing actions (internal and external) and also on the negotiation level in the relationship with component suppliers: the availability of a physical prototype, in fact, reduces the ambiguities inherent in a constructive design (albeit CAD) and therefore the need of the supplier to protect himself with higher prices from the risk of unexpected complexity in the realization of the piece.

And Valle has already clear the advantages connected to the use of 3D printers: “First of all a strong shortening of the prototype realization times (and therefore of design times), then the elimination of any uncertainty related to the discretion and possible errors in the interpretation of the construction design and, finally, the reduction of the costs of the models.”

Another point in favour of this technology, according to Valle, concerns changes in warehouse management and logistics activities. Starting from a CAD file, in fact, additive manufacturing allows the creation of unique or small series pieces where and when desired, without the need to prepare complex processes and preliminary dedicated products (e.g. molds). The rationalization of stocks and the optimization of internal logistics - cornerstones of lean production - would therefore have a powerful ally in additive manufacturing techniques, since it can be imagined that the need to hold spare parts will be greatly reduced if they can be "printed" just in time, especially in cases where (e.g. in the aeronautical sector, but also in the automotive sector) the value of such parts is high, as is the urgency to dispose of them quickly.

These characteristics of additive technologies, therefore, are arousing great interest on the part of metallurgical companies like O.L.V., attracted by the benefits obtainable particularly in small-scale applications. In some cases, unit production costs could be higher with additive techniques than if they were made using traditional techniques, but this higher cost could be more than offset by the savings deriving from the optimization of warehouse management: both in financial terms (reduction of capital assets) and with reference to the potential reduction of warehouse space and logistics costs.

One of the reasons that explain the euphoria of those evoking the start of a fourth industrial revolution associated with the advent of additive manufacturing comes from the (almost total) absence of economies of scale in it: the cost of producing an object printed in 3D it is (almost) independent of the volumes. A 3D printer can produce in any production cycle - which, in the case of metal, can last up to ten hours - a number of pieces that vary from one to a maximum of a few tens or hundreds, depending on the dimensions of the pieces themselves and the working chamber of the printer. In this context, economies of scale are very limited: as production increases, the trend in total costs is increasing according to a substantially linear function. Some non-linearities are present, but very small on every single machine and rather limited even in the series of several machines. To date, therefore, additive manufacturing is not competitive in terms of costs in large-scale production.

The absence of economies of scale, in any case, turns into a very important strength in small series productions: the costs of the variants are essentially zero. The revision work, in fact, can take place on the construction drawing (at the CAD) without any need to intervene on the machinery; above all, it is not necessary to prepare new molds, whose manufacturing costs are typically very high and are justified only when the production to be carried out is of large numbers. In this way, therefore, additive manufacturing would challenge the traditional idea for which there would be a trade-off between cheap mass production, which exploits economies of scale, and high-cost customized production. Considering that the production of parts per month processed by the O.L.V., which in any case undergoes strong seasonal variations, reaches peaks of maximum 3000 pieces, thus returning to what can be reputed small series production, the additive manufacturing proves itself to be once again a technology to focus on.

However, other aspects have to be taken into consideration. Additive printing has a key role for high-level production and is one of the most promising aspects of the transformation of industrial processes in progress: it gives the possibility of designing with a high degree of freedom and therefore of generating complex geometries so that more efficient components can be produced, making them as unique pieces and not as the result of the merger of several parts. This aspect appears to be somewhat in conflict with the previous considerations simply because actually the pieces produced by the company do not have very complex geometric shapes (the most complex have at most 3 different processing passages in its longest cycle).

But it also allows to obtain products with superior performance compared to traditional manufacturing, with better material properties, weight reduction and therefore lower consumption costs, with reduced development times and higher production process yield. If it is true that the company has always focused on the high quality of its components, on the other hand customers have always been satisfied with the finished products and thus radically changing the production process would entail enormous risks that the company could not currently afford.

Therefore, it appears more consistent for the company to focus on another technology widespread by the 4.0 paradigm: the autonomous robots. The company has already some machines capable of working independently, namely two lathes CMT Kronos, an ABB Flexible Automation robot and a marker Automator. However, if in the future it will be decided to remove the older machines (some of those still working in the plant have more than 30 years of life), Valle has assured that he wants to focus strongly on this type of technology.

The implementation of autonomous robots could primarily drive value by reducing direct and indirect operating costs of the company and increasing its revenue potential. Autonomous robots can reduce labour costs and increase productivity by continuously working around the clock without fatigue. Even employee safety can be improved, and insurance and injury leave costs can be reduced significantly. Humans can work directly with collaborative robots, easily training them with programmable movements and then handling material and sorting packages side by side with them.

These technologies can give the O.L.V. more options for meeting capacity demands. Available labour, particularly during peak holiday months, cannot always meet seasonal demands but the company can turn to robots to improve operations and meet labour demands. Price ranges for both consumer-facing and industrial robots vary greatly, depending on the technology, level of artificial intelligence, and functional capabilities. However, as the cost of materials such as lasers, cameras, processors, and force-torque sensors continue to decrease, robots are becoming increasingly affordable. Production costs are also decreasing, bringing autonomous robots within an affordable range for hobbyists as well as large organizations, allowing for the proliferation of use cases and reducing cost barriers to autonomous robot implementation.

And among the enabling technologies 4.0 from which the major changes are expected, the autonomous robots are by far the most popular voice (in 53% of cases), preceding the solutions of the Internet of Things (21%) and, at a distance, additive manufacturing and augmented reality applications (introduced by 4% and 2% of companies respectively). (Technopolis Magazine, 2018)

In general, therefore, the scenario that is emerging is therefore positive and this is confirmed by the fact that 86% of companies in 2017 invested part of their turnover in digital transformation projects: 38% of the sample allocated between 1 % and 10% of revenues; 18% between 10% and 20%; 11% between 20% and 30% and only 6% have gone to spend between 30% and 40%. The O.L.V. not only is it following the trail, but it tries to anticipate the moves of the competitors, keeping itself always informed on new technologies and also relying on a close collaboration with the Polytechnic of Turin in order to guarantee ever more fresh resources and open to the world of innovation.

It will therefore be interesting to closely monitor the situation of the company, especially in the coming years, so as to have a broader picture of the actual results that the adoption of an industry 4.0 model may have, as well as its impact on SME growth.

The technology is advancing and techniques or instruments that were once unthinkable are now commonly used: some plants start and stop automatically, the use of cameras and thermal imaging cameras allows to monitor the production process, the tablets are increasingly widespread, methods of advanced troubleshooting allows to quickly identify fault origins and possible solutions, radio-frequency systems allow to collect technical information, drones inspect inaccessible or dangerous areas.

At this point technology will not be the winning card, but the ability to manage it in the best possible way: the competent human resource, with deep technical and managerial knowledge, information technology and statistics, will be the trump card of a company in the 4.0 paradigm. Mature economies will thus have to seize it by favouring private investments aimed at innovation and then updating the workforce, thus guaranteeing companies like O.L.V. the possibility of adapting their business model to the new industrial revolution, with obvious advantages for the entire economy.

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