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EVOLUTION OF MANUFACTURING AND ASSOCIATED COGNITIVE ISSUES

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INTRODUCTION

This work embraces the digital transformation brought by industry 4.0 and the consequent strategic, cognitive and competitive dynamics. Those changes have reshaped various organizational flows to many industries and firms are trying to readapt themselves to stay in the market.
The analysis will be moved from a managerial perspective by combining a scientific literature overview with various experts interviews from Laminazione Sottille s.p.a. and with databases aid. As it will emerge from the following research digital transformation (DT) is transforming the world at an unprecedent pace. The business environment infact is evolving very rapidly especially in the last decade, industrial boundaries are gradually blurring and unprecedent threats and opportunities are rising for firms. This trend has recently rocked up due to COVID-19 social and economic implications, which has brought firm in speeding up the transition to the new industrial revolution, especially for what concerns digital communications.
In the work the attention will be focused mainly on the manufacturing sector that after those turbulent years of digital transformation is now being called “manufacturing 4.0”.
The purpose of the research is to examine in depth the way in which digital transformation is taking place both from a technical and cognitive perspective to provide a solid framework about the new competitive scenario, the new mechanisms of strategic decision making and about the various supply chain operations implications.
In the actual industrial scenario knowledge assumes a greater role in the “equation to success”, thanks to real time information firms have now unprecedent possibilities and they are starting to become cognitive systems in order to better deal with the new industrial paradigm of industry 4.0.
The work is organized in 3 chapters.
Chapter 1 begins with the description of the historical path that have brought humankind through the various industrial revolutions. Then a deep look is given specifically to industry 4.0, the Hannover fair of 2011 and to the various private and public investments in such a field. Following, a scrupulous description of the various enabling technologies is provided

by accounting both a technical analysis of the functioning and utility of those technologies within the firm's dynamics.

The second chapter opens with a description of the industrial applications of 4.0 technologies in the manufacturing sector, specifically about the big data utility and the "data life-cycle".

A brief description of the supply chain collaboration is taken by focusing on the advantages of both horizontal and vertical collaboration. Then, in the last paragraph of the second chapter, a new analysis is conducted on the cognitive implications of the various changes previously mentioned. Cognitive biases and algorithmic biases are discussed to fulfill a literature gap on the matter since there is a big lack of discussion on those biases, especially in the actual scenario brought by the fourth industrial revolution. The cognitive bias is analyzed in relation to the various strategic decision making process giving birth toa framework of strategic decision affected by biases. This part of research was inspired by the interrogative regarding the new paradigm of the firm's cognitive dynamics after the advent of DT.

From a knowledge perspective it can be said that digitalization have brought firms to become the so-called "cognitive enterprises".

So the first 2 chapters aim to deploy a wide literature review to investigate and describe the last industrial revolution, the driving forces of DT, the new emerging strategic decision making approach and the associated possible biases.

In chapter 3 the discussion is shifted to the case study of "Laminazione Sottile s.p.a." a controlled of the homonym industrial group "Laminazione Sottile Group". The attempt of the third chapter is to investigate through a interviews the functioning of the above mentioned cognitive enterprises, of the new strategic decision making approach and the resulting biases that arise. In the final section of the third chapter a framework of the findings of this study is provided to understand how the investments in industry 4.0 technologies affect different area of the firm in their quality, quantity, flexibility and speed of production and also to analyze how those matters affect the new strategic decision making process.

CHAPTER 1- INDUSTRY 4.0 AND APPLICATION IN MANUFACTURING

Industry 4.0 has its roots in the very first years of 2010s when in Germany was held the presentation of a government project that aimed to turn the country into the global leader of manufacturing within a decade. Such a project was called "Industrie 4.0: Mit dem internet der Dinge auf dem Weg zur 4. Industriellen Revolution" (Industry 4.0: Internet of Things on the road of the fourth industrial revolution).

Industry 4.0 is an ongoing trend that is radically transforming our society and it has also been called the digital revolution.

The most involved sectors of such a paradigm shift are the industrial, the manufacturing and the social ones. In fact it is not only enhancing an unprecedented level of productivity and optimization but it is also reshaping significantly the social sphere.

In this chapter it will be analyzed the various steps of recent history that have brought our society to the actual scenario and lately there will be an in depth analysis of the various enabling technologies of the Fourth Industrial Revolution.

1.1- EVOLUTIONARY PATH TO INDUSTRY 4.0

1.1.1- INDUSTRIAL REVOLUTIONS

1.1.1.1- FIRST INDUSTRIAL REVOLUTION (1780-1830)

Among the most relevant events that brought our society to its current status we can consider, together with the French revolution, the industrial ones. Those can be considered the main enablers of capitalism and the liberal-bourgeois system.

The first industrial revolution began in the 1780 and its birth place is Great Britain; it has been defined as "*the process of change from an agrarian and handicraft economy to one dominated by industry and machine manufacturing*" (Britannica, 2021).

The birth of Industry 1.0 in England has been a spontaneous process rather than an initiative of the government. Several circumstances allowed this instance among which a socio-political revolution (1640-1688) that enabled the rose of the bourgeois class, the overcoming of the feudal system in agriculture and of course the colonial trade that allowed a massive and cheap supply of raw materials, mainly through India and the East India Company and later through America (Villari, 1993).

The cotton sector was the first experiencing an organizational transformation, the first innovation that allowed the mechanization of the sector was the flying shuttle by J. Kay (1733) that doubled the production speed of the weaving machines, then it was only a matter of time for the following upgrades, in 1764 the cotton spinning Jenny by J.Hargreaves, the frame powered with hydraulic energy (1768), the mule in 1785 and then the cotton gin in 1793 by E. Whitney.

The mechanization of the sector brought the need for speeding up the others and thanks to T. Newcomen first and then J. Watt, it became possible after the invention of the steam engine, such technology revolutionized not only the cotton sector, but also the iron sector (1780) and the transportation one with the invention of steam-ships (1807) and steam-locomotive (1814) (Villari, 1993).

Those transformations affected not only the economy but also the society with the set up of the first industrial areas that allowed to lower the labor cost, and to gain increasingly more power to the bourgeois class together with a massive population growth (Battilossi, 2002). Such a revolution was then brought in Belgium by W. Cockerill and his son that developed machine shops in Liège (1807), it was then only a matter of time for the revolution to spread in the rest of the continent until the end of the XIX century.

After Britain, industrialization developed in Belgium, France and America in a first phase and then it reached Germany, Italy and Japan.

In the continent the industrialization, unlike Great Britain, was not a spontaneous phenomenon, instead the state's interventions sustaining the private initiative had a major role (Villari, 1993).

During the second half of the XVIII century an exponential growth of the railway system occurred and, in 1870, after the implementation of the iron boat mass production the steamboats largely substituted the sailboats.
Also communication was incredibly improved thanks to the invention of the telegraph by S. Morse. For what concerned the industrial labor dynamic during those years there has been a trend of de-specialization of workers and an increase of the daily work schedules up to 14 hours a day together with low salaries and an unprecedented exploitation of the workers, especially regarding women and children.
So we can see how the first industrial revolution brought major social and economic upgrades but only to certain social classes.

1.1.1.2- SECOND INDUSTRIAL REVOLUTION (1870-1950)

The second industrial revolution happened between the middle of the XIX century and the 1950's.
Its epicenter was no longer Great Britain, instead it mostly spreaded in the United States and in Germany; then in a second phase it also got to Italy, Russia and Japan (De Simone 2014).
In those years alternative energy sources were invented, the rise of the oil industry and of the electricity gave a strong impulse to the strength of the industrial society.
In this period were projected some game changing inventions such as cars, electric trams and telephones.
Production techniques such as the Bessemer first and the Gilchrist-Thomas then, allowed the mass production of steel at a relatively low cost. Gradually the steel substituted the iron for several purposes, for example for the construction of bridges, buildings and rail tracks.
The electric turbine and the dynamo allowed the usage of hydraulic electric power.
In 1869 the Suez canal was inaugurated and this changed significantly the global trades since it enabled a direct path from the Red Sea to the Mediterranean instead of having to circumnavigate the African continent, this canal is nowadays still crucial for the global

economy so much that during the one week block of the canal of march 2021 Bloomberg estimated a daily global loss of 9.6 billion dollars (Bloomberg.com).
In 1881 Edison perfected and commercialized the incandescent light bulbs that substituted the gas lamps.
Then in 1893 the American W. Taylor theorized the principles of scientific management with the aim of strengthening the production efficiency, H. Ford was the first to apply the model in his firm, the Ford Motor Company, founded in 1903. Ford through his firm accumulated an estimated worth equivalent to 199 billions of modern dollars that put himself in the top 10 all time wealthiest persons of history.
In the Industry 2.0 we assisted in a shift of the relationship among industries and banks; those latter, through the credit control and the acquisition of stock, conquered several decision rights in the direction of the firms.
Capitalism got into a new phase, while in the first revolution was based on the free market, in the second it assumed monopolistic traits. In the United States the oil and the steel industries were the first being dominated by big production sites (Standard Oil and U.S. Steel) while in Germany the same happened for the chemistry and the electromechanical sectors (Bayern and Siemens) (Villari, 1993). Between 1870 and 1914 started a phase of economic and political subordination known as imperialism; there was an implementation of exports of capitals to less developed countries.
To give an idea, during this period (1880-1913) Great Britain spent almost 25% of its GDP on foreign investments.

1.1.1.3- THIRD INDUSTRIAL REVOLUTION (1950-2010)

The third industrial revolution took place in the second half of the XX century, soon after the end of the Second World War, those were years influenced by the political tension between the United States and URSS.
Industry 3.0 sets the stage for the modern socio-political and economical global balance and it gave birth to most of the enabling technologies of Industry 4.0.

During this period the most relevant inventions were in the technological field, such as the first microprocessor, the invention and spread of computers, the internet and lately also the ideation of social networks and smartphones.
In the third revolution humankind also managed to organize the first space mission with the soviet Sputnik 1, the first artificial satellite launched in 1957 and then under the Kennedy presidency, NASA replied with the Apollo 11 mission that brought for the first time the man on the moon.
During these years several attempts to commercialize on a large scale the computers occurred, in 1946 ENIAC was not a big success because the market wasn't ready for such an innovation, but for the states it was suddenly clear the potentiality of such an invention and thanks to this prototype the concept of hardware and Central Processing Unit (CPU) started to spread. It was then a matter of time for the electronics to become the new normality, in 1971 the email was ideated and twenty years later the invention that can be appointed as the defining of the century, the internet, first in 1990 Tim Bernard Lee introduced the Hyper Text Transfer Protocol (HTTP) that together the URL and the HTML was the main enabler of the internet.
Lately after being inspired by ARPANET, which can be considered the internet predecessor even though it only had a military utility, Lee appointed the World Wide Web (www) even though its first name was MESH .
In 1984 Apple Computers launched on the market the Macintosh that was the first popularized computer thanks to its ease of use (Hudson, 2014). In the 1990's as opposed to the Scientific Management principles applied in the Ford Motor Company we assisted in the spread of Toyota's Lean Manufacturing system that gave the Japanese company a sustainable competitive advantage over its competitors. This new trend describes a philosophy that incorporates a collection of tools and techniques into the business processes to optimize time, human resources, assets, and productivity, while improving the quality level of products and services to their customers.
During the end of the century the concept of a green economy was promoted together with the idea that a reduction of the usage of fossil fuels as an energy source was necessary. Such an idea was introduced into scientific circulation in 1989 in a report prepared by a

group of leading economists for the government of the United Kingdom (Tursunalievna, 2020). Starting from the very first years of the XXI century, thanks to miniaturization, a concept introduced by Moore's law and to the development of the lithium batteries, it became possible to build portable smart devices known as smartphones.

Smartphones were ideated as a business tool but its potential, as it's more than clear nowadays, was much more powerful.

In 1997 Six Degrees by A. Weinrech was created, the very first example of a social network, in the following years a number of competitors rose such as Friendster, Twitter, Facebook, MySpace and Instagram. Social networks have created a new market that involves billions of users and has completely reshaped the communication sector and the entertainment one.

1.1.2- FOURTH INDUSTRIAL REVOLUTION (2011- ongoing)

Differently from the previous, the fourth industrial revolution is happening globally, simultaneously and at an exponential speed rather than linear. During industry 4.0 we assist in the blurring of national boundaries and to a strong international interdependence for what concerns finance, politics and innovation technologies; this has been referred to as a systemic global economy (Schwab, 2016).

We can place the birth of Industry 4.0 in the April 2011, at the Hannover fair during which it was presented the project "Industrie 4.0" by three technical consultants of the German government: Henning Kagermann, Wolf-Dieter Lukas and Wolfgang Wahlster, respectively representatives of economy, politics and science.

Such a project aimed to turn Germany into the global leader of manufacturing by 2020 and aims to introduce a new paradigm called "Internet of Things" (IoT) in the industrial world to get to, quoting the original document, "*improvements of the production plants, of industrial systems and of daily use products through the interaction of integrated memories, communication capabilities, wireless sensors, integrated actuators and intelligent software that* [...] *permit to establish a bridge between cyberspace and tangible* *reality, allowing a fine synchronization between the digital models of the devices and the physical reality*" (Kagermann et al., 2011).

This fusion has generated the so-called cyber-physical systems (CPS) that relies on the concept of memory devices. Some automated elements were already present in the third industrial revolution but through Industry 4.0 they have been strongly implemented and interconnected thanks to various enabling technologies. The collection and analysis of massive amounts of heterogeneous information (big data) thanks to cloud computing technologies, the ongoing process of digital fabrication and programmable robotics that allow a strong speed up to the working routines. The additive manufacturing (3D printing) that reduces the distance from virtual reality and the physical one. The interaction of machines through the IoT that is based on artificial intelligence (AI) and so also on machine learning, sophisticated sensors and neural networks, this means that for the first time products and technologies have an active role in the decision making process and the faculty to intervene in operating and strategic decisions giving start to a new frontier known as data driven decision making. There has also been a significant improvement in flexibility due to a faster ability to react and to the communication machine to machine (M2M) (Kagermann et al., 2011). The growing importance of the technological side has increased the concern for cyber security (IT security) to ensure data protection and to prevent attacks that could damage the firm's software, hardware or that could mislead the service that these services provide.

After Germany, USA and France but also Italy have gone through a massive industrial revolution.

In the USA, under the Obama presidency, the USA established the Advanced Manufacturing Partnership (AMP), following the example of Germany and giving a signal about the purpose of re-industrializing the country. By convening research centers, manufacturing firms and universities the USA created a central HUB for innovation set to reaffirm the country as the leading global force and to increase the employment levels. Differently from the German model, the American one relied far less on the public funding, in fact it was mainly driven by private-public partnerships through the creation of several Manufacturing Innovation Institutes (MIIs).

The American government invested approximately 500 millions dollars through financing research projects.
Far greater is the public intervention of France that issued 10 billions euros through fiscal incentives like the super depreciation for private investors, tax credit for research and financing all the projects under the strand “Industrie du futur” and “Invest for the future”.
The French government's purpose is to modernize the manufacturing system of the country in order to stay competitive in the global market.
In Italy starting December 2016, under the premier M. Renzi and the minister of economic development C. Calenda presented the “*Piano nazionale industria 4.0*” that follows these guidance:
-to operate in a logic of technological neutrality
-to intervene with horizontal actions rather than vertical or sectoral ones
-to work on enabling factors
-to orientate existing tools for favoring the technological progress and the productivity
-to coordinate the main stakeholders without holding an oppressor role.
The Italian government has created tax benefits that came into force starting 2017 such as the super depreciation of 250% for investments in tangible assets functional to the technological and digital transformation of the country due to the plan Industry 4.0 and one of 140% for investment in structural intangible assets (Pucci et al., 2019).
The Italian cumulative investments, as reported by the MISE, in the period 2017-2020 is approximately 13 billion euros for the public sector and 24 billion euros for the private one.
In march 2017 during a conference “*digitizing manufacturing in the G20*” Germany, France and Italy declared the birth of a three year partnership to promote digitalization of the manufacturing sector, this cooperation involves the three respective implementing entities of the national strategies for industry 4.0 those are coordinated by a steering committee composed by six members for country and chaired by three general directors of the economy ministries' industrial departments.
Such a committee coordinates three different work groups with different core focus, such as standardization, involvement of SMEs and European policies support, moreover the

countries agreed to direct their efforts also for skill development and qualification of workers.

The expected benefits of the implementation of industry 4.0 are an increased flexibility and velocity from prototyping to market placing, improved productivity due to a decrease in set-up times, errors and machine down-time, and augmented quality due to innovative sensors that allow real time quality controls.

In a TED talk hosted by Oliver Scalabre in 2016, heads BCG's (Boston Consulting Group) Industrial Goods practice for Western Europe, North Africa and South America, the analysis of a growth decline was stressed out, as shown in figure 1.1 after the implementation of the Industry 3.0 the world was facing a worrying decrease in innovation for manufacturing, first the trend was to place the manufacturing factories off-shore exploiting cheap labor force but in the long term this has proven not being a sustainable strategy nor ecologically neither in terms of innovation, then the following step has been to get the factories bigger and bigger and specialize them by product, now after the appointment of industry 4.0 it has become clear that the way to enhance growth again was to combine the already existing manufacturing system with the large technology innovation. Cheap labor has to be substituted by high specialized workers and investments in domestic markets have to occur. Emerging economies like China haven’t adopted sustainable production policies and by 2015 producing in Brazil has become as costly as producing in France.

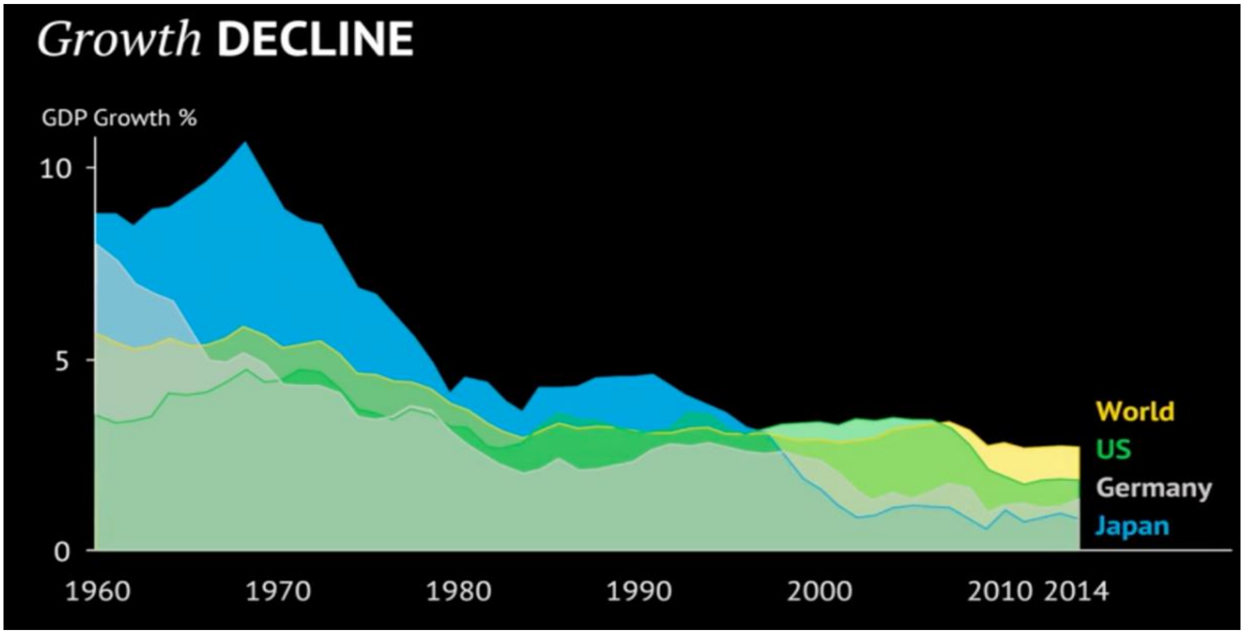

Figure 1.1: Decrease of innovation in manufacturing. Source: BCG

The new frontier of manufacturing will exploit the robotics potential, the IoT, the connectivity and the flexibility. Additive manufacturing, for example, has already changed the plastic production and now is taking on the metals sector, together metal and plastic represent the 25% of the materials used in global manufacturing so it gets clear the potentiality of such an innovation. Advanced robotics will make customized products feasible without affecting the price levels and the cost gap between mass production and personalization will gradually be reduced (Scalabre, 2021).

1.2- ENABLING TECHNOLOGIES

Industry 4.0 is not a single technology but rather appears as a cluster of different technologies that are de facto agglomerated together by technological leaders, pivotal users, system integrators and government policy makers (Martinelli et al., 2019).
As pointed out in a BCG research those technologies already existed before the birth of the fourth industrial revolution but they were never used in the manufacturing sector remaining

just applied research, what really changed is the connectivity among them and their appliance in the industrial operating activities.

The aim of industry 4.0 is to build a flexible, digital and personalized production model that provides very customer suited products and services. This has resulted in the convergence of the physical world and the virtual world (cyberspace) in the form of Cyber-Physical Systems (CPS).

As reported on the Italian Ministry of the economic development website the enabling technologies of industry 4.0 can be divided into nine groups:

-advanced manufacturing solutions (robotics)

-additive manufacturing (3D printing)

-augmented reality

-simulation

-horizontal and vertical integration

-internet of things (IoT)

-cloud

-cyber-security

-big data and analytics.

1.2.1- ADVANCED MANUFACTURING SOLUTIONS (AMS)

Advanced manufacturing solutions (AMS), commonly known as robotics, is obtained through the interaction of several disciplines such as physics, mechanics, electronics, electrotechnic, automation, informatics, software engineering and others. It’s a very technical subject that has its roots in the third industrial revolution, thanks to the development of new materials and technologies it has increased its power, speed and accurateness following a upgrading trend such as descripted in Moore’s law, it is also becoming cheaper to produce and due to this improvements it’s now essential in the manufacturing scenario.

In 1979 the Robot Institute of America defined the robos as “*a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks*”.

The very first prototype of a modern robot has been invented and patented by the american G. Devol in the first phase of the 1950s, it was a reprogrammable manipulator called “*Unimate*”, Devol tried to market his invention without having success, although his first sell was very important for industrial history, in fact in 1961 General Motors purchased such a technology to lift hot pieces of metal from a die casting machine and place them in cooling water, this represents the very first industrial use of robotics. After nearly 70 years of applied research on the subject we can say that the robotics purpose is to design sophisticated machines that can help, substitute or assist humans in the realization of expensive, complicated, repetitive, dangerous or simply boring tasks.

Some very important parameters to measure robotics degree of innovation are the sensor's accuracy, the calculation capacity, the vision systems and the auto diagnostic capability. In particular this last matter, the auto diagnostic, is fundamental for finding inefficiencies and mechanical failures in real time and with a superior analysis capacity compared to humans’.

The AMS allows the manufacturing process to be more flexible, efficient and competitive. Robots are being used in a wide range of manufacturing activities, assembly, packaging, transportations. They are also useful for dangerous activities such as space and oceans explorations, bomb defusing or war missions. Due to their reliability they are also used in the medical field for delicate operations like heart and eyes surgery.

Nowadays the most common industrial robots can be classified as follows: SCARA, Articulated, Delta, Cartesian, Dual Arm and Co-bots.

The Selective Compliance Assembly Robot Arm (SCARA) is a mechanical arm suited for fast and repetitive movements and it is used mainly in assembly lines, for example in the car manufacturing sector.

The Articulated robot is defined as a robot with rotary joints, it is the most common robot utilized in industrial manufacturing, the joints are also called axis and this particular machine can vary from a simple two jointed structure to a complex system based on ten axis, each additional joint increases the so-called degree of freedom of the machine, that increases the adaptability of the robot to multiple industrial activities.

The Delta robotics a very fast machine used in packaging and picking operations, it can run up to 300 outlets per minute and its structure is composed of three arms that jointly hold an end device oriented thanks to a parallelogram structure and the use of highly precise sensors.

The Cartesian robot is used in 3D printing and computer numerical control machines, its name is linked to its functioning based on the Cartesian coordinate system, it can move on two or three axes (x, y and eventually z) and it's a very reliable and precise machine.

The Dual arm robot is a very human-like machine, it has obviously two arms and joints in correspondence of the shoulder, elbow and wrist. This particular robot offers an unlimited approach angle and can handle multiple simultaneous tasks at a relatively high speed.

Finally Cobots (also, collaborative robots or co-robots) are designed to cooperate with humans so they share the same work environment, due to this particular matter they are integrated with skin sensors that prevent them from acting when a person is in their operating trajectory.

As reported on figure 1.2, in 2019 the world average robot density in manufacturing per 10,000 employees is 113 units, in the ranking Singapore and Korea are way more advanced than the rest of the world (respectively 918 and 868), the United States only rank at the ninth place (228) and Italy is at the eleventh (212).

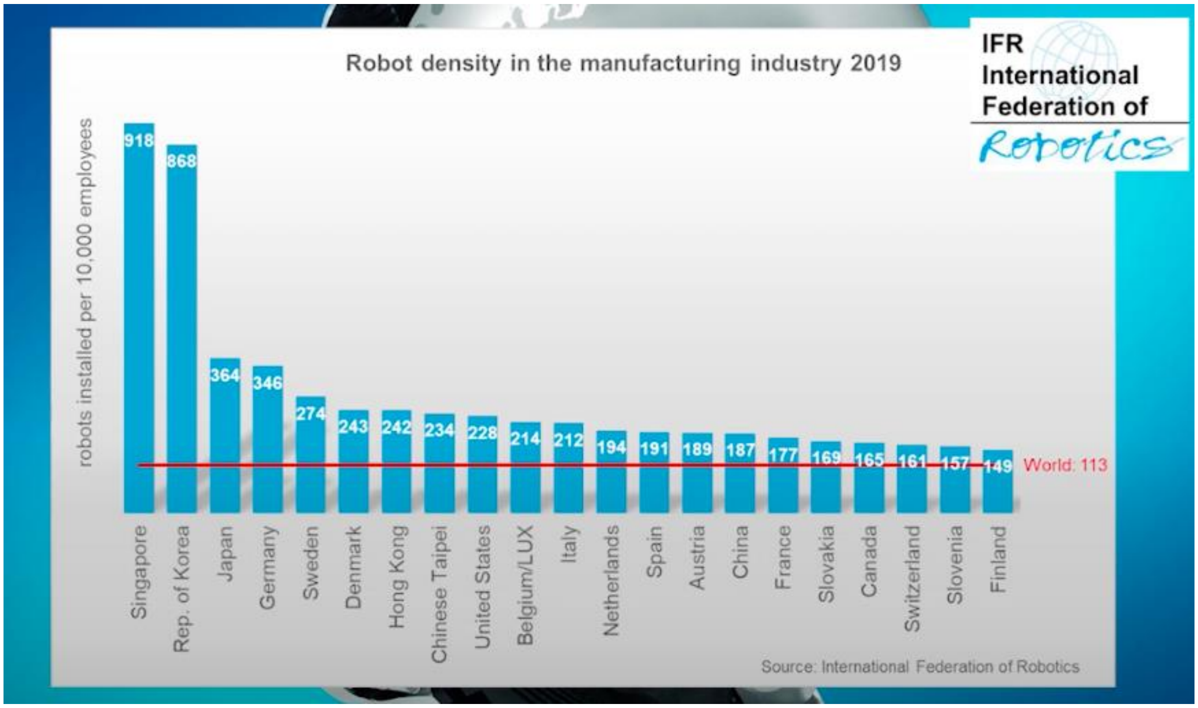

Figure 1.2: Robot density in the manufacturing industry 2019. Source: IFR

There are four degrees of human-robot interaction:

no collaboration, fenceless operation, sporadic interaction and co-working.

In the first two case there isn't any interaction but in the fenceless operation there are no construction measures to prevent contact during operation, in the sporadic intervention they only interact for non-cyclic task such as material in and out feed, while in the co-working human and robot share the same workspace and interact back to back during operations (Robotics.org).

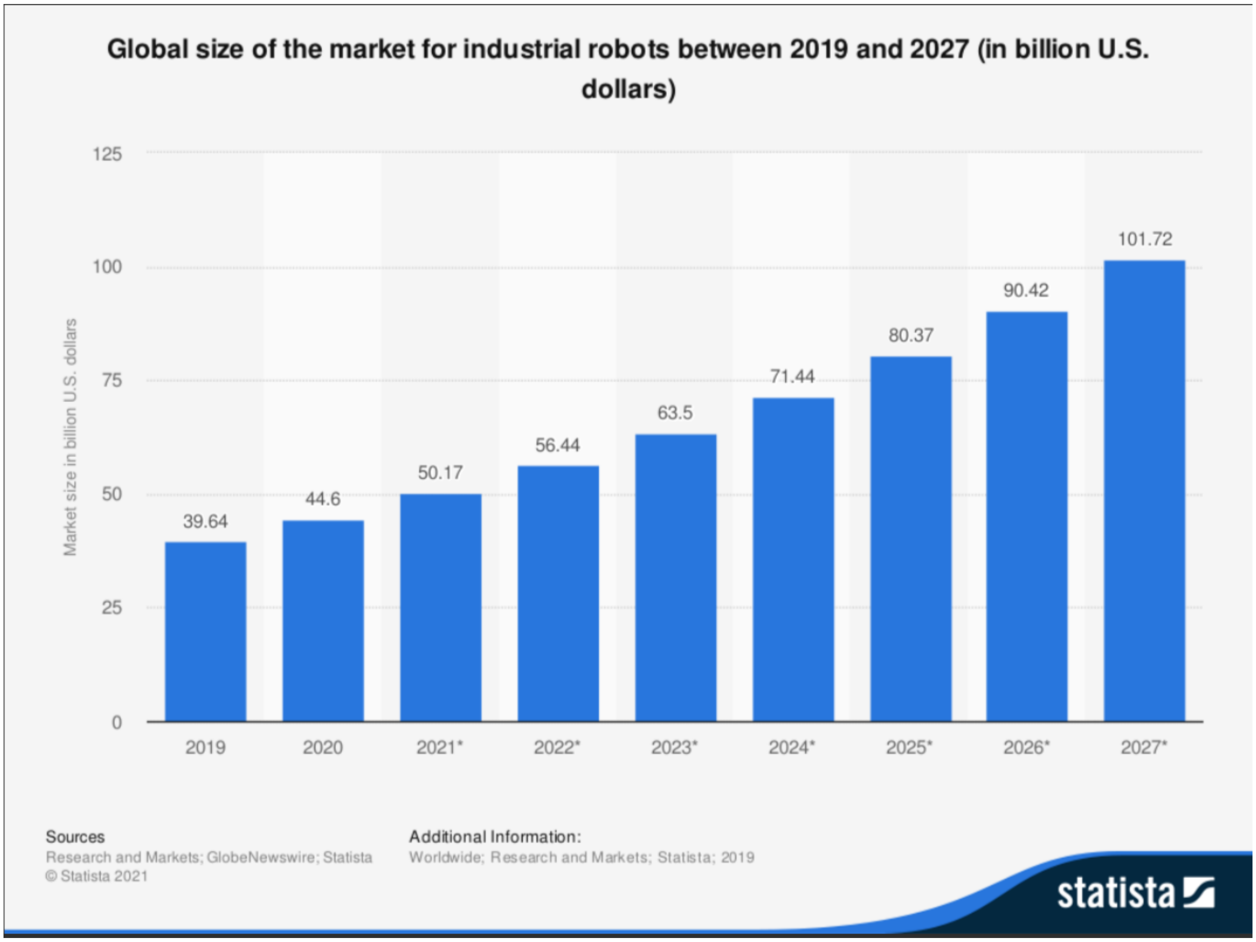

Figure 1.3: Global size of the market for industrial robots (2019-2027). Source: Statista.com

As reported on Figure 1.3, the size of the market was estimated at almost 40 billion U.S. dollars, with some 2.7 million units of industrial robots in operation worldwide. In 2027, the market size is forecast to surpass 100 billion U.S. dollars.

1.2.2- ADDITIVE MANUFACTURING

Additive manufacturing (3D printing) is a technology that consists in the construction of three-dimensional physical objects from a digital model. There are three different processes for 3D printing that are depositing, joining or solidifying materials that require three different materials such as plastic filaments, liquids or power grains.

3D printing presents a substantial difference from traditional manufacturing techniques like milling, laser cutting and turning, in fact the material is actually added rather than eliminated and this brings some consistent advantages like the minor waste of material, the possibility of working uninterruptedly 24/7 and the consequent time and cost savings. Moreover additive manufacturing enables a very flexible production, a relatively low level of inventory needed and almost zero additional cost for very personalized products.

The very first example of such a technology dates back to 1981 when the japanese Hideo Kodama ideated the rapid prototyping system, he described such invention as follows: ”*a vat of photopolymer material exposed to a UV light that hardens the part and builds up the model in layers*”.

It’s production development cycle is described as indicated in the figure 1.4.

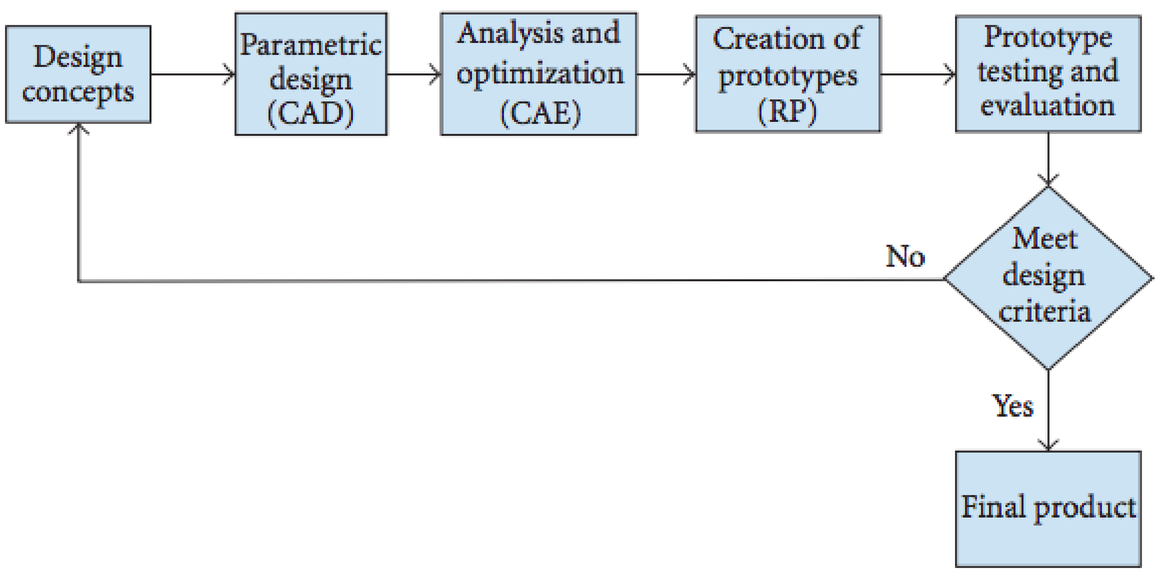

Figure 1.4: Additive manufacturing production development cycle. Source: ISRN Mechanical Engineering

Additive manufacturing results from the combination of three prior existing technologies: computer aided design (CAD), computer aided manufacturing (CAM) and computer numerical control (CNC).

Several applications for 3D stamps rose during the years, in the automotive and aerospace industry for example lightweights components for cars or aircrafts allow the production of cheap and light vehicles due to their cave structure like the so-called honeycomb cell. An other application is for architecture modeling, that can be a long and difficult process in the traditional way, but also architecture itself, in fact in city of Beckum, in Germany, the first house has been built thanks to a new material (i.tech3D) developed by the Italian firm Italcementi. After this first attempt many upgrades have been made and in 2020 the average time for building a house varies from 24 to 48 hours with a percentage of material waste of only 5% on the total used, not only it’s far faster than traditional architecture but it is also far cheaper, for giving an idea two companies, Apis Cor and Icon have declared that the manufacturing cost for it is approximately 10,000$ (Apis.com) and Icon is positive to lower it down to 4000$ (Iconbuild.com).
A very important application for additive manufacturing is the medical field, 3D printing allows the rapid and cheap prototyping of high quality bones for transplant, dental implants and custom prosthetics, also further research are being implemented for bioprinting organs a practice that could change the life expectancy of more than 100,000 people a year (Ventola, 2014) (Aido.it).

1.2.3- AUGMENTED REALITY & VIRTUAL REALITY

Augmented Reality (AR) is a technology that enriches the sensorial experience of the real world with real time digital information generated through computer devices. It is a combination of the physical and digital world and doesn’t aim to substitute reality but to provide additional information through technology. The term AR has been introduced by two scientists of the Boeing corporation in 1992, Caudell and Mizell; in 2011 Georgel introduced the idea that AR could have industrial applications for maintenance or reparations of machines, industrial plants and robotics (Industrial AR, IAR) (Bottani et al., 2018).
The AR relies on three fundamental technologies: a visualization (capturing) device, an interaction device and a tracking system.

Differently from augmented reality, the virtual reality (VR) substitutes the physical world with a digital one that can either be a reconstruction of the real or an imaginary world. VR prior applications were for simulations such as for pilots, thanks to an enhanced affordable price they are now largely diffused.
AR and VR can facilitate the ease of use of industrial machines through the high realistic representation of 3D digital models and can speed up production and maintenance times; allow the possibility of remote control, assistance and repairing of machines and this enhance a superior level of safety for operators. Other applications can be in architecture, urban design, virtual arts and industrial design.
Thanks to a supportive technology of smartphones both AR and VR are worldwide easily accessible and they are useful for a wide set of other purposes like video games and social networks.

1.2.4- SIMULATION

Simulation allows to create a digital model through which reproduces the extent of certain events on an analyzed item. It is very useful since it prevents the impossibility of reproducing determined events in a laboratory. Digital twin it's the latest available simulation modeling system and in addition to the precedent system of physical modeling allows an automated (data-based) construction and modification of the models (Rodic, 2017).
The digital twin has been defined as "*a digital representation of an asset that alters its properties, condition and behavior by means of models, information or data*" (Stark et al.,2017). Such a technology consists of a collection of data generated in the simulation (digital shadow), a unique sample of the universal model of the analyzed item (digital master) and an algorithmic correlation among the two (intelligent linking).
Simulation has several utilities such as a cost reduction and a shorter cycle of production for prototypes; allows operators to train safely until they develop the required skills for a task; increases self-awareness of machines and by combining machine learning with predictive modes it's possible to identify possible functional issues of certain design.

1.2.5- HORIZONTAL AND VERTICAL INTEGRATION

In the traditional meaning, horizontal integration is a growth strategy through which a firm starts to compete in a correlated sector of its core business in order to increase its customer base and to reach economies of scale, while vertical integration is a delicate operation through which a company incorporates an adjacent activity (up- or down-stream) of the production chain to gain a strategic competitive advantage (Chukalov, 2017).

In the industry 4.0 we refer to integration when adopting informative systems for gathering information either about clients and suppliers (vertical integration) or regarding firms that operate in the same business (horizontal integration).

This integration is enhanced through high connectivity, the IoT and artificial intelligence; it generates big volumes of data that are stored thanks to cloud computing technologies and are accessible to all the employees in real time. As Professor Gruosso says, the IoT creates a network in which operators, machines and other tools are linked in real time, while the cloud allows easy access to the various information (Ricomincioda4.it).

Both horizontal and vertical integration require breaking down data and knowledge silos, yet this is not an easy task. In fact, within the same firm different departments may adopt very different styles of communication, this can create dangerous communicative gaps and such an issue has to be resolved by meta-networks that establish a common standard. The challenge is often less about functional interoperability and more about the organizational culture (Mbtmag.com).

1.2.6- INTERNET OF THINGS

The Internet of Things (IoT) has a central role among the enabling technologies of the industry 4.0. It is an open network of objects that through sensors have the capacity to "*auto-organize, share information, data and sources, reacting and acting in face of situations and changes in the environment*" (Madakam et al., 2017).

Thanks to sensors, computer based real time monitoring and the centralization of information through the cloud, the IoT creates a global network in which everything is connected and every object, tool or machine has a unique identity.

In other words the IoT refers to the coding and networking of various machines and tools in order to make them computer-readable, traceable and computable.

Such a technology is not only applied to electronic devices but to a wide range of living and non-living objects, such as trees, animals, house furniture and appliances, industrial apparatus or landmarks.

The IoT is based on the combination of computer science, communication, electronics and information technology. The technologies involved are semiconductors technologies, internet, sensor technologies and microelectromechanical systems but also bluetooth, low consumption battery technologies, laser technologies, smart cameras, smart meters and sensors (Martinelli, 2019). Normally the IoT was distinguished by the Industrial Internet of Things (IIoT) to stress the technological differences between consumer goods and the industrial ones, but more recently this distinction has lost most of its relevance since the two categories are converging and the separation line is increasingly blurred.

The very first concept of IoT was introduced in the 1980s when at the university Carnegie Mellon in Pennsylvania a Coke dispenser was modified and connected to the internet in order to allow students to check whether cold drinks were available.

The term Internet of Things became popular in 1999 thanks to Kevin Auston, the executive director of Auto-IT labs of MIT, at a presentation held for Procter & Gamble. The Auto-IT lab developed the very first example of a universal identifier called the Electronic Product Code (EPC) with the aim of substituting the UPC bar coding system.

The IoT technology was adopted by several companies like Olivetti, IBM and Xerox but it was Siemens that introduced the first machine-to-machine (M2M) GMS connected system in 1995.

In 2003 an open source standard became very common, the JXYA, which was a peer-to-peer standard to connect electronic devices.

Between 2003 and 2004 the term became more familiar to the world after some main-stream journals like the Guardian and the Boston Globe started publishing some articles about it. In those years Walmart applied such a technology to their stores. Then, in 2005 the nabaztag was manufactured, it consisted of a robot with sensors applied to the stock market that after hitting a certain configurable threshold would alert the user about the dangers. In 2008 there was the official recognition of the IoT by the European Union and the first European conference about IoT was held. In the same year the US National Intelligence Council listed the IoT as one of the six major potential disruptive technologies (Postscapes.com).

The growing diffusion of the IoT was allowed by a trend of miniaturization of technologies such as gps, sensors and communication tools, thanks to which it was possible to place them in almost every physical object (embedded systems) used for data gathering and sharing. Together with miniaturization it was also crucial the increasing diffusion of wireless networks like wifi and bluetooth that allow a faster collection and connection of data.

In 2016, the US Senate unanimously passed the "*Developing Innovation and Growing the Internet of Things (DIGIT) Act.*" Under this act, a committee of federal and private sector representatives has to plan a regulatory environment for things such as privacy, protection, and security. This act further opened the lines of communication between the private and public sector to capitalize on developing the technology (Marketsandmarkets.com).

In 2017 IBM identified the 5 main industrial uses of IoT; the first is predictive maintenance, through sensors, cameras and data analytics, managers can determine when a piece of equipment will fail before a problem occurs; another is smart metering, for monitoring the consumption of water, gas or energy within a building or a facility; the third is asset tracking to optimize logistics, maintain inventory levels, prevent quality issues and detect theft; fleet management for enhancing maximum efficiency for transportation firms; and connected vehicles, like the self-driving cars (Ibm.com).

The IoT market is growing at an exponential rate, Fortune Business Insights has reported that its market cap reached USD 250.72 billion in 2019 and is expected to reach 1,463.19 billion by the end of 2027, with a growth of 24.9% CAGR in the forecasted period (2019-2027) (Fortunebusinessinsights.com).

The growth of IoT is driven by factors such as high rate of cloud adoption, low cost of business operations, and highly skilled workforce.

The investments on such a technology are driven by the private sector among which we have some predominant players like: Intel Corporation (US), SAP SE (Walldorf, Germany), Cisco Systems, Inc. (US), Microsoft Corporation (US), Oracle Corporation (US), International Business Machine (IBM) Corporation (US), PTC Inc. (US), Google Inc. (US), Hewlett-Packard Enterprise (US), Amazon Web Services Inc. (US), Bosch Software Innovation GmbH (Stuttgart, Germany), and General Electric (US) (Marketsandmarkets.com).

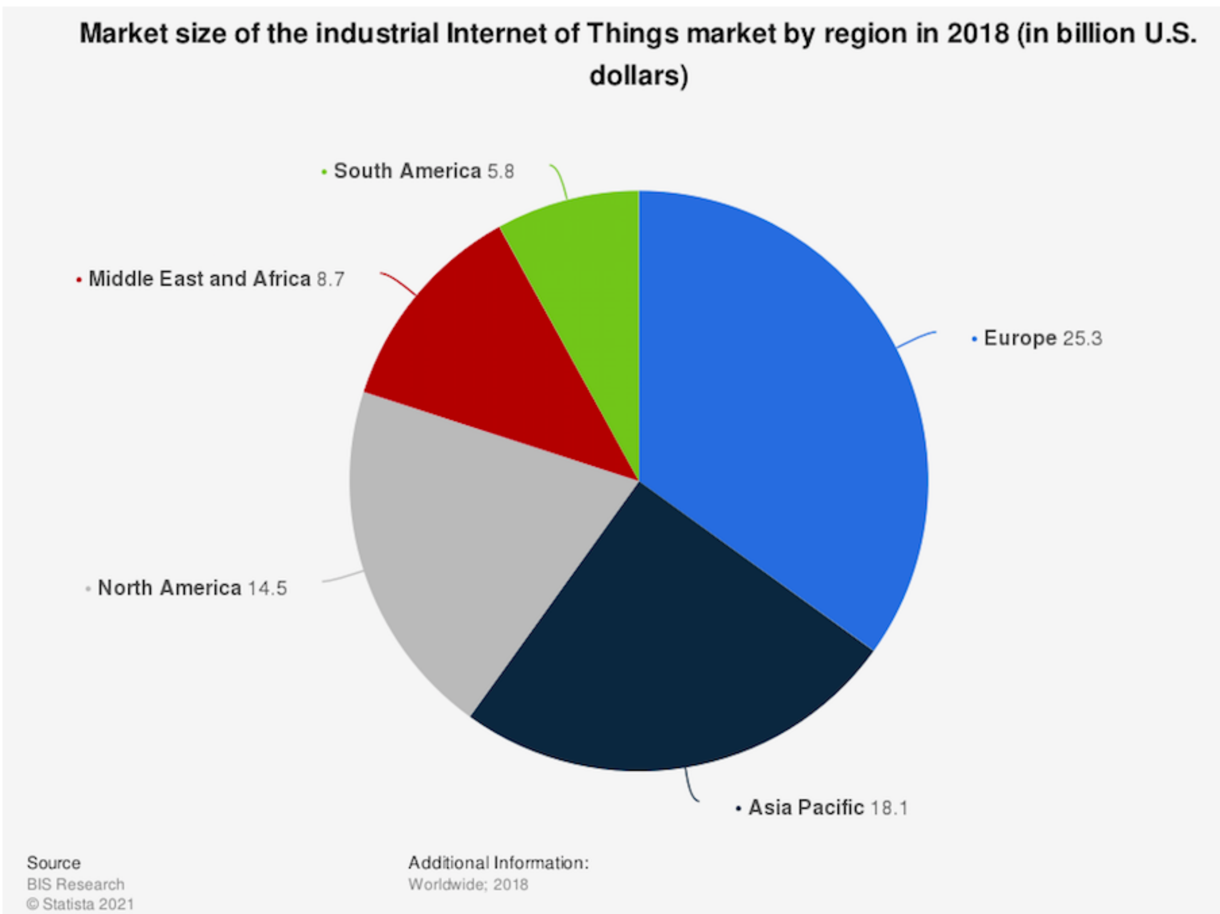

Figure 1.5: Market size of the IIoT market by region in 2018. Source: Statista.com

As pictured in figure 1.5 the global industrial IoT market had a value of more than 72 billion U.S. dollars in 2018. Europe was the largest market for industrial Internet of Things in terms of revenue, accounting for more than 30 percent of the market with total revenues of 25.3 billion U.S. dollars.

1.2.7- CLOUD

The cloud is an on-demand service that provides the users additional computer system resources like the storage of data and computing power.

It is a centralized system whose scope is to allow the storage, computation and transmission of information virtually and in real time.

While in the past the data were managed through paper systems, in the actual scenario it is, if not impossible, very inconvenient. The physical storage of data is a very long process and requires avoidable expenses for infrastructures for the conservation of documents, moreover it makes it very difficult to reach certain information fast. Such a problem was already present during the third industrial revolution but it is only with the advent of Industry 4.0 that those on-demand systems have become predominant in the industrial scenario.

The cloud is a data storage virtual system that provides on-demand services through the internet, it has a remarkable ease of use that guarantees much organizational flexibility since the usage is granted simply by rental contracts between the user and the provider (Beltrametti et al., 2016).

The term cloud refers to the intangibility of such a technology that is completely virtual with no physical infrastructure needed.

Cloud computing can be divided into three major typologies: SaaS, PaaS and IaaS.

Software as a Service (SaaS) is an everyday reality for private companies and consists of web browsers or apps that are supported by the server provided by a third party but are accessible by users through smartphone or PCs, examples are web-mails, search engines or Google Maps. SaaS are online services that organize and define the interaction of the various network infrastructure like data partitioning, security or backup through Application Programming Interfaces (APIs).

The Platform as a Service (PaaS) provides the user with software and hardware to allow additional services, may be by installing local hardware.
Specifically PaaS allows users to provision, instantiate or manage a group of modules into single files in the correct order without the complexity of building and managing the infrastructure. Examples are IBM Bluemix or Microsoft Azure.
The Infrastructure as a Service (IaaS) provides servers for additional data storage and computing power, in this last case it is the user that has to install the software, manage the hardware and control that everything works. So the IaaS ensures a higher level of manageability of resources and allows the user to integrate eventual pre-existing company software with the ones of the provider.
In all the three cases (SaaS, PaaS and IaaS) the user utilizes a software, a platform, or a virtual infrastructure provided by a third party (Ricomincioda4.it).
Cloud computing allows a complete digitalization of the business processes and a wider data collection thanks to a higher storage capacity and computing power. The resulting increase of efficiency allows both a better service for the customer but also simpler working conditions. Moreover the ease of access through the internet allows managers to access information from various personal digital devices at anytime and anyplace.
The applications of the cloud are multiple, in particular cloud computing is changing significantly the manufacturing industry, the cloud in fact is creating for firms new solutions and opportunities; it allows managers to assist the production cycle and the supply chain management through on-demand services (Xu, 2012).
The so-called cloud manufacturing basically consists in the application in manufacturing of the various cloud technologies and this brings several benefits to the firm, one is that the IT team is lightened of various tasks such as technical support, hardware or software maintenance and data security. So it is very useful for enterprises with small (or none) IT departments; it can help reduce several costs that are handled by the provider and it reduces the need for heavy capital expenditures since its only cost is a monthly fee. Another major advance is that it reduces the time between manufacturing and accounting. Moreover cloud manufacturing is useful for the virtualization of resources needed for operations so it makes material requirement planning (MRP) more smooth (Erpsoftwareblog.com).

The cloud has gradually reshaped business, it is only in recent years that investments in cloud infrastructure services have been taking on the investments on data center hardware and software; in particular the pandemic in 2020 has speeded up such a trend as shown in the figure 1.6, as worldwide firms had to setup “smart-work” environments to allow employees to work virtually from home. In particular in 2020 it has been estimated by Statista.com a global spending on cloud infrastructures of almost 130 billion USD (Statista.com).

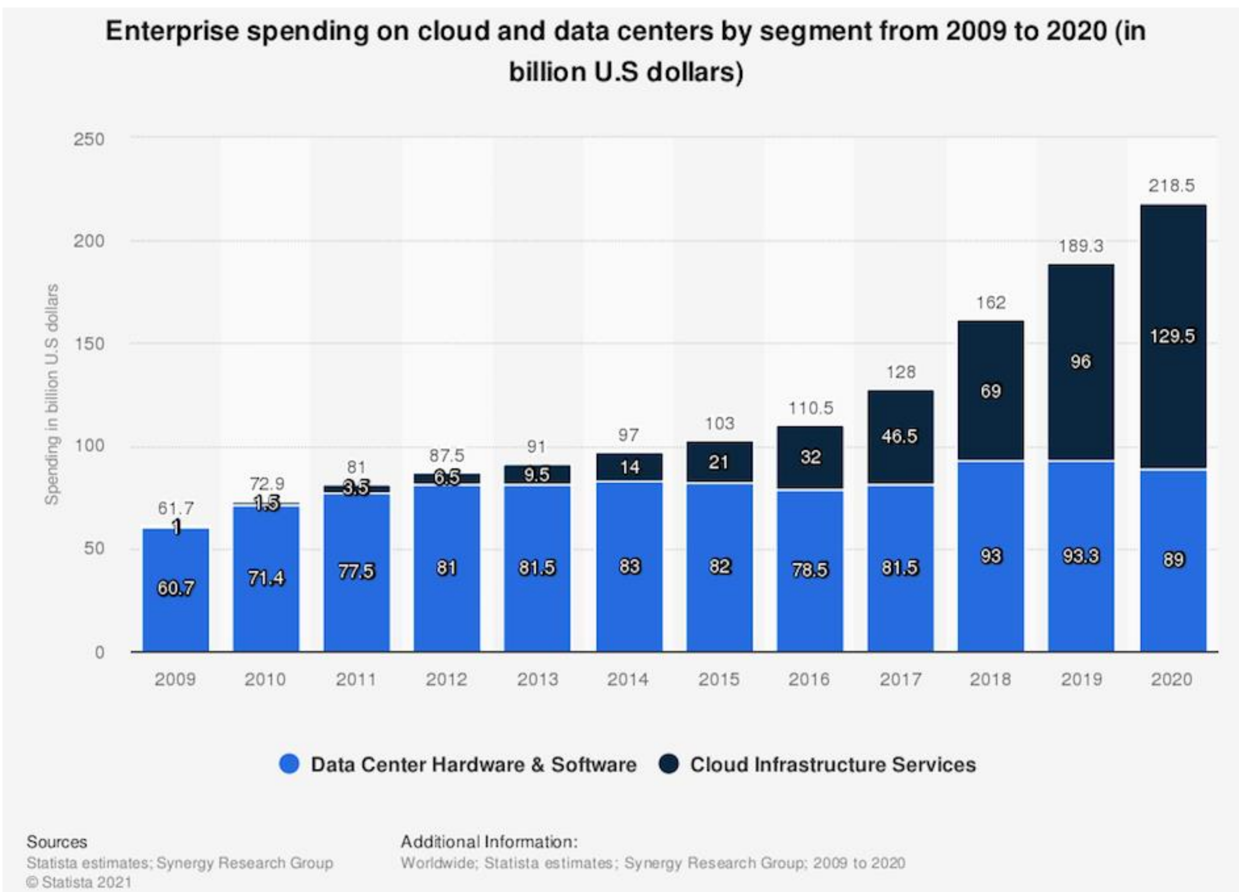

Figure 1.6: Enterprise spending on cloud and data centers by segment (2009-2020). Source: Statista.com

1.2.8- CYBER-SECURITY

Having seen how much industry 4.0 relies on a huge amount of information exchanged every day among people and various devices, it seems clear that protecting those data must be a number one priority for firms.

In fact the attempts to steal or hack those data are a real issue for IT departments or server providers that are called to protect the firm from eventual external attacks.

It is very important for firms to enhance their data with advanced cyber-security systems to ensure a high level of data protection.

As Cisco Systems (holding of the more famous Cisco WebEx) reported on their website "*cyber-security is the practice of protecting systems, networks and programs from digital attacks. These cyber threats are usually aimed at accessing, transforming or destroying sensitive information, as well as extorting money from users or disrupting normal business processes"* (Cisco.com). Nowadays cyber security assumes an increasing relevance since it is applied to several elements and not only to computers. In fact in industry 4.0 the word computer has a wider meaning, from embedded systems to communication networks but also personal devices or manufacturing machines (Ricomincioda4.it).

With the spread of smart manufacturing, characterized by an ecosystem of connected machines, digital processes are extended to the whole operational chain and everything is shared or through the cloud or through other networks, even the most sensible information. As a consequence the traditional security systems for data protection are no longer sufficient for a digital firm to prevent hacks. Investments in technology improvement for this instance are increasing in the actual industrial scenario. Three main elements are the object of protection of cyber-security and those are the endpoint devices (e.g. computers, smart devices and routers), networks and the cloud. The technologies applied for the protection of those entities are next-generation firewalls, DNS filtering, malware protection, antivirus software and email security solutions (Cisco.com).

As reported by CNBC on December 2019 the biggest hack of history is the one that Yahoo suffered in 2013 during which 3 billion users' sensitive data were exposed (names, email addresses, telephone numbers and dates of birth) (Cisco.com) (CNBC.com).

After the acquisition of Yahoo by Verizon in 2017 such a number was disclosed and the company eventually agreed to pay 117.5 million USD to settle a class-action lawsuit in April 2019 (Yahoodatabreachsettlement.com).

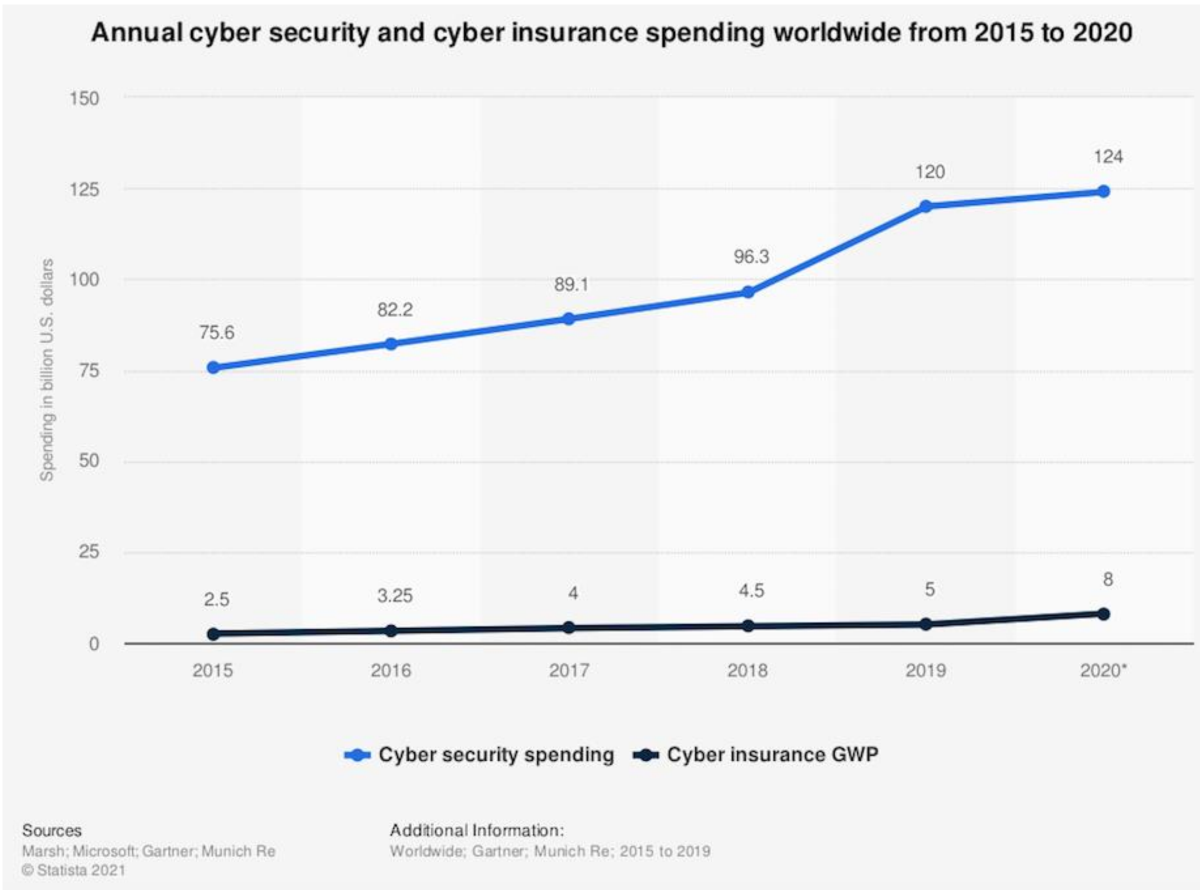

Figure 1.7: Annual cyber security and cyber insurance spending worldwide (2015-2020). Source: Statista.com

As pictured in figure 1.7 Statista.com published in 2019 the global spending for cyber-security and cyber-insurance. As it can be seen in 2019 it has globally been spent 120 billion USD for cyber-security technologies (Statista.com).

1.2.9- BIG DATA & ANALYTICS

Nowadays the number of electronic devices has overcome the number of people. Almost every interaction with smart devices generates data and the sum of that information is the so-called big data.

Big data is a term that refers to large volumes of data either structured or unstructured. Still the relevance of big data is not linked to the volume but to the usage that the firm can do with those. The concept of big data is not new for the industrial scenario, such a term was first used in the 1990s referring to the trend of increasing volume of data being generated; it gained much more relevance with the advent of the XXI century. In 2001 precisely, the market analyst Doug Laney introduced the idea of defining big data through 3Vs: volume, velocity and variety.

The volume refers to the size of internal and external data generated. Organizations gain data through various sources such as commercial transactions, smart devices, industrial machines, social media and others.

Velocity measures the speed at which data is generated from the various sources. Nowadays it is possible to manage data in real time.

Variety refers to the data types since they can be very heterogeneous (e.g. mails, images, videos, audio). Heterogeneity can be either of format or of source.

To those variants several have been added over the years; one is variability that implies the rate at which the data changes over time, understanding variability is useful for example for the firms that exploit market trends. Another is veracity that implies the level of truthfulness and quality of certain information, in fact it is important to verify the sources of data in order to avoid misleading esteems linked to fake or imprecise news (Matthew, 2021).

The main value of data is linked to the capability of analyzing them and the ability to extrapolate valuable insights, hidden paths, various correlated dynamics, customer preferences and market trends.

So talking about data without considering big data analytics is very reductive.

Big data analytics refers to the way it can be extracted, validated, translated, and utilized big data as a new currency of information transactions. It is an emerging field that is aimed at creating empirical predictions. Data-driven organizations use analytics to guide decisions at all levels (Kotteti et al., 2018).

The increase of volumes, velocity and variety of data disenables the possibility of manually computing information. Software and hardware capacity upgrades allow firms to overcome the limits of traditional systems thanks to augmented stored capacity, speed and computing power. As G. Gruosso affirms "the key point is that these data- precisely because they are collected by heterogeneous systems- is that they cannot be processed with traditional relational database management techniques used for the management of structured data". It becomes clear that it is necessary to ideate and invest in unstructured smart database systems.

Data analytics has its roots in the analytic process known as data mining, a process that applies scientific and mathematics tools to extract valuable information from data. Data analytics overcome traditional methods and apply artificial intelligence (AI) systems, generating the phenomenon known as machine learning.

Now, it is important to avoid confusion among AI and machine learning. AI refers to the capability of machines to do in autonomy various non-repetitive tasks applying logical-mathematical models. Here for machines we both refer to industrial machines and computers. The AI systems allowed the development of the so-called machine learning. Machine learning is a system of continuous improvement that applies statistical tools to large volumes of data, creating various models to optimize tasks and solving problems. Those models are continuously upgraded with trial and error methods, specifically with the implementation of increasingly sophisticated algorithms.

Big data analytics interests almost every sector in the actual economic scenario and it has become a standard to face competition. Some very popular examples are digital platforms (social media, e-commerce or streaming) such as Netflix, Instagram, Amazon or Facebook. Those platforms are highly customized in a specific way for every single user; films, news, product or contents in general, even memes are displayed differently according to individual preferences with the purpose of maximizing the time that users spend on such platforms.

The extent of data analytics is constantly growing and it has become an everyday reality also for the manufacturing industry. Manufacturing is using analytics for some essential purpose: exploiting and better controlling available data, to increase productivity and elasticity and to enhance a data based decision making process (Matthew, 2021).

The application of big data in manufacturing assumes different applications, including: preventive maintenance, product design, product management automation, customer experience and supply chain improvement. But those applications will be analyzed in depth in the next chapter.

CHAPTER 2- MANUFACTURING 4.0 AND COGNITIVE ISSUES

Having analyzed the historical path and the latest technologies that enabled the advent of industry 4.0 the focus will now be shifted to the relative implications of progress into the manufacturing industry and the consequences regarding the cognitive human processes.

2.1- SMART MANUFACTURING

2.1.1- APPLICATION OF BIG DATA IN MANUFACTURING

“Data has long been the lifeblood of manufacturing”, the generators of big data in the manufacturing field are various and those arise from everyday production and process, from machines, meters, sensors, controllers, conveyors and so on (Matthew, 2021). By analyzing big data firms can have a wide range of opportunities for identifying and fixing problems, boost efficiency, eliminate bottlenecks and levigate starving issues within the operations. Moreover data is very useful to achieve an increased customization of the products functionality and design, they help the firm to raise their quality assurance, to better manage the supply chain and to handle eventual risks linked or with the market or with the production process.

Big data analytics can help businesses in taking timely and informed decisions minimizing the need for “*visionary management*” in favor of the much more secure “*prescriptive decision making*” (Bell et al., 1988). Other benefits can be found within the process flow since data analysis can help managers to improve the assembly line efficiencies. They are also useful to increase customer services and to achieve better forecasting. For all those reasons it is nowadays more than clear that big data analytics are a must to achieve competitive advantage within the market (Delgado, 2016). On the other hand, big data analytics brings several challenges. First of all it involves a tangible complexity both for the huge volumes of information to be managed but also because of the inner complexity of manufacturing it is not easy to continuously change operations routines.

Some issues are also linked to regulatory issues since being an ongoing technology there is a level of uncertainty linked to the future development of regulations on such a matter. Last, there is a risk in digitizing core information of the firm since it exposes valuable information to possible cyber-attacks that could harm the firm.

Data is a key enabler of smart manufacturing but data without being transformed into useful insights have almost no value. There are various steps to follow to achieve such a valuable transformation: data collecting, transmission, storage, preprocessing, filtering, analysis, mining, visualization and application. These steps together can be considered the "*data life-cycle for manufacturing*" (Taoa et al., 2018). The first step is data collection, from various sources data is collected through the IoT, smart sensors, radio frequency identification (RFID) and other technologies making it possible to monitor equipment, product and the production flow in real time (Zhang et al., 2015). Examples of data collection are built-in sensors that make it possible to continuously measure, monitor, and report the ongoing operational status of manufacturing equipment and products, such as temperature, pressure, frequency and vibration (Tao, 2017). Through RFID it is possible to identify and track pieces of equipment and products automatically. Another example of data collection are smart terminals (e.g. smartphones and PCs) that allow user data collection. While web crawling is a widely used collecting method to analyze public data in an automatic and efficient way. Moreover data can be acquired from database systems (Guerriero, 2010). The second step is data storage, it is important that the large volume of data being collected is stored in a secure way and effectively integrated. Types of manufacturing data are generally grouped in 3 categories: structured (tables, digit and symbols), unstructured (media and entertainment data, surveillance data, geo-spatial data, audio, weather data, logos and images) and semi-structured (graphs, documents) (Gandomi, 2015). Unstructured data are the most difficult to collect while structured data are the one on which firms concentrate their focus. Through the cloud data are stored in a very efficient way and shared at various levels of the organization (Agrawal et al., 2010). The third phase of the data life-cycle of manufacturing is data processing, this step consists in the conversion of data into information that allows manufacturers to operate in a more informed way. During such a process it is important to remove redundancies, misleads, duplicates or inconsistency of information; those activities are also known as "*data cleaning*" and "*data reduction*" (Huang, 2015). Data processing is achieved through machine learning, various forecasting models and large-scale computing. Once the data has been processed the next step is data visualization that consists in the translation of information to graphical and statistical tools such as diagrams, charts and virtual reality. This form enables users to better understand and utilize data for operative and strategic purposes (lee, 2003). Through the IoT and the cloud data can be visualized in real time with users end-devices like smartphones and tablets.

The following step is data transmission that is the way information is communicated and spreaded through the organization. Thanks to the increasing trend of reliability that involves networks and software, information can now be shared in real time with a reliable and relatively secure transmission. The last step of the data life-cycle for management is data application. Data has affected the manufacturing process at all levels. It gives insights for designers that can get closer to customers' needs and expectations, infact through data analytics it is possible to translate the customer preferences in details and features of the product. Data allows manufacturers to adapt to market trends in a more agile way. Moreover it permits to raise the quality standard of production because it is possible to identify in advance potential dysfunctionality of products and operate precautionary actions like preventive maintenance, fault prediction and automatic upgrades (Kusiak, 2012).

As mentioned in the final part of the first chapter, the application of big data in manufacturing regards: preventive maintenance, product design, product management automation, customer experience and supply chain improvement (Lee, 2021).

Preventive maintenance is a regularly set up and check of a machine or piece of equipment to minimize the likelihood of it failing. It is applied when machines still work in order to avoid unexpected dysfunctionality of the operating process. It is a hybrid form of maintenance between the reactive and the predictive maintenance. Since the operational efficiency is given also by the availability of machinery, it has a crucial importance. Thanks to big data manufacturers can display the status of machines and the various components and by using sophisticated software determine whether it is needed for maintenance (Wan, 2017).

Product design is lightened by costly research through the use of big data analytics since it can help to identify trends and market shifts that can alter the perception of determinate design or colors of established or new products.

For what concerns production management automation it can be said that is both potentially one of the most useful applications due to cost cutting and efficiency boosting but at the same time is also one of the most complex applications of big data in manufacturing. Thanks to sensors, robotics and IoT it is now possible to give autonomy to several smart devices that can effectively produce relatively without any human help (Frohm, 2006). A useful example can be given by the firm "GE renewable energy" that produces smart wind turbines that through sensors analyzes data regarding the amount of energy generated and the direction of the wind according to which the speed and blade pitch are rearranged in order to optimize the turbine's efficiency (Ge.com).

Big data analytics are fundamental to enhance a superior customer experience, through the collection of data firms can draw a very precise picture of customers preferences and tastes. This allows firms to produce goods with a lower risk of market refusal and allows them to invest with a higher level of assurance in research and development projects.

Last, the application on big data analytics for supply chain improvement. Big data can help manufacturers to track the exact location of products in real time through the supply chain. The increasing complexity of the structure of the supply chain makes it difficult to be managed but thanks to those tracking technologies it has become easier for managers to predict whether the product will be delivered on time to customers. This makes the key supply chain information visible at any time, increasing transparency and reducing uncertainty.

2.1.2- SUPPLY CHAIN COLLABORATIVE

Supply chain collaboration consists in two or more firms that work together in order to achieve mutual benefits (Cao, 2011). Supply chain collaborative advantage is not based on Porter's *competitive advantage* (1985) but rather it refers to the paradigm of *collaborative advantage* (Kantner, 1994 and Dyer, 2000). The most relevant definition of collaborative advantage is given by Jap (2001) and lately completed by Vangen and Huxham (2003) as follows: ” *supply chain collaborative advantage refers to strategic benefits gained over competitors in the marketplace through supply chain partnering and partner enabled knowledge creation, and such synergistic benefits could not be attained by acting independently*” (Mei et al., 2010).

Collaborative relationships help firms to share risks, to combine complementary assets and skills, to avoid useless transaction costs, to enhance an increased quality and productivity, moreover it allows to create and maintain a competitive advantage over time.

Supply chain collaboration can be categorized in two different ways: vertical and horizontal collaboration. Vertical collaboration arises when 2 or more organizations from different levels of the supply chain start to cooperate by sharing assets, resources, know-hows and efforts to serve the same end-users. Horizontal collaboration is an inter-organizational relationship between 2 or more firms at the same level of the supply chain that pursue the same objective and share their efforts to achieve a common goal (Chan, 2012). Mei and Zhang (2011) conceptualized a framework of 5 dimensions on which the advantages of collaboration are reflected: process efficiency, offering flexibility, business synergy, quality and innovation (Vachon, 2008). Process efficiency refers to the level of cost competitiveness of a collaboration with respect to closest competitors. Process efficiency could refer to information sharing, common logistic process, product development operations or joint decision making process. When achieving a good process efficiency firms can achieve lower inventory levels and better delivery performance (Bowersox, 1990). Offering flexibility refers to the degree that a firm’s manufacturing division can support rapid shifts in the speed, volume or features of its offerings. In today's market firms are increasingly concerned with customer’s preference changes so it is very important to perform on such a dimension (Bagchi, 2005). Business synergy refers to the extent to which supply chain partners combine their resources, skills and social capital to achieve results that together are greater than the sum of individual parts (*spill-over benefits*). Business synergy arises from a better use of resources within the supply chain thanks to the maximization of asset utilization (Min et al., 2005). Synergies work as long as firms operate in the best common interest rather than their own.

The quality dimension regards the way collaboration of firms can enhance a higher level of product reliability and durability that can better-off customers. Moreover the quality dimension can also refer to the level of customer service and allow some substantial benefits to the firms such as customer loyalty, the possibility to position the brand as premium price and a possible increase in market share.

Garvin (1988) proposes eight dimensions of quality: performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality.

The last dimension on which collaboration reflects its advantages is innovation and it involves the speed at which firms introduce new products, services or processes. By combining the creativity capacity of two or more firms can exploit several advantages such as shorter production cycles and an improved absorptive capacity. Supply chain collaboration can assume various forms and approaches: collaborative communication, collaborative execution, coordinating contract, information sharing, joint decision making, joint knowledge creation and resource sharing (Goffin et al, 2006). Collaborative communication arises between supply chain partners when they work back to back in order to reach a common goal. The term collaboration is often used as a synonym of cooperation and coordination, yet collaboration has a stronger meaning (Cao et al., 2010). A good collaborative communication arises when two or more firms operate jointly in an open way, frequently, on a two-way basis and on different levels of the supply chain. Differently from collaborative communication, collaborative execution refers to more applicative aspects. Partners work jointly for correct and efficient execution of the various operations. Coordinating contract is a contract that coordinates the mechanism of decentralized supply chains in order to reach agreements on fundamental aspects of the partnership in terms of deadlines, quality standards, prices and quantities.

Information sharing as the extent to which partners disclosed relevant, delicate, confidential and core information overtime. It is important to understand the level of reliability of the partner.

Joint decision making is the way in which the decisions are undertaken, it can be a completely democratic approach or there can be some power asymmetries that favor one specific partner in the decision process. Joint knowledge creation is the better understanding of markets, competitors, techniques or technologies reached thanks to the combination of R&D departments or specific know-hows and the consequent synergies that arise. Resource sharing is the way in which partners combine their assets and investing capacities in order to reach a mutual advantage.

2.2- COGNITIVE ISSUES

2.2.1- COGNITIVE BIAS AND STRATEGIC DECISION MAKING

As suggested by Haselton we have cognitive biases in the "*cases in which human cognition reliably produces representations that are systematically distorted compared to some aspect of objective reality*" (Haselton et al., 2015).
Cognitive biases are "*mental shortcuts used to make judgments*" (Simon et al., 2000).
In everyday operation managers interpret the environmental transformation according to their experience, values and perception. So cognitive biases can also be interpreted as overconfidence and illusion of control, moreover it can influence the decision making process.
Lately, decision making is moving from an intuitive activity to a more scientific and analytic operation. Specifically it can be said that strategic decision making is now more oriented to a data driven process (Merendino et al., 2018).
Consequently the role of cognitive bias in this strategic decision making process is shifting, yet there is an important literature gap on how this transformation is taking form.
There are several classification of cognitive biases given by the scientific literature, the most diffused is given by Das and Teng in 1999, they divided human biases in 4 categories:
-prior hypothesis with a focus on limited targets
-exposure to limited alternatives
-insensitivity to outcome probabilities
- illusion of manageability.

The first group refers to the fact that decision makers often bring their prior bias in the final decisions and their attention may be too focused on a limited set of variables that confirm their initial hypothesis with the low attention to other information that could be valuable.
The second group focuses on the fact that decision makers expose themselves to a limited set of alternatives aimed at achieving a goal. Limiting alternatives is a two phase strategy, it can both be a way to concentrate the strength of the organization in a bright direction, or on the other hand it can be a horse blinder.
The third group represents a tendency of managers to give more relevance to the value of possible outcomes rather than the magnitude of their probabilities (Shapira, 1995).
The last group stands for managers that may underestimate the risk of certain outcomes by relying too much on their expertise and professional skills. In other words there may be a gap between the perceived risk and the objective one.
For what concerns strategic decision making it is a process through which managers take high profile decisions. For this instance is important to consider a classification based on three paradigms:
-the rationality and bounded rationality
-politics and power
-garbage can (Eisenhardt and Zbaracki, 1992).
For what concerns rationality and bounded rationality it refers to the degree to which decision makers have purposes. Decision makers start with known objectives, then collect info, analyze alternatives, probabilities and payoffs and finally identify an ideal course of action (Simon et al., 2000). Meanwhile politics and power involve emergence, competition, conflict of interests and bargaining power. Last, in the garbage can paradigm, decision makers don't know their objectives ex ante but they actively and continuously look for decisions to take.
Lyles and Thomas in 1988 proposed a five point model of strategic decision making, four of which are similar to Eisenherdt's classification. Those are the rational model, avoidance, logical incrementalism, political and garbage can.
Since different decision processes tend to accentuate particular types of cognitive bias and to understand how cognitive bias influences strategic decision making it is important to

analyze all the possible relationships among these cognitive biases with the various models of decision making. This analysis generates a matrix in which it is possible to point out nine different propositions.

Cognitive biases	Strategic decision process modes: Rational	Avoidance	Logical incrementalist	Political	Garbage can
Prior hypotheses and focusing on limited targets	1 P1	5 P3	9	13 P7	17
Exposure to limited alternatives	2	6 P4	10	14	18 P8
Insensitivity to outcome probabilities	3	7 P5	11	15	19 P9
Illusion of manageability	4 P2	8	12 P6	16	20

Note:
P = Proposition

Figure 2.1: relationship between cognitive biases and decision making models. Source: Das and Teng, 1999

Different models of strategic decision making will attract different combinations of the basic types of cognitive bias. Rational mode is widely used as a benchmark since it is based on the common assumption that human behavior is boundedly rational. In such a mode decision makers evaluate alternatives and both the internal and external environment. When managers adopt the rational mode they still can avoid cognitive biases, for example prior hypotheses let decision makers focus on a particular aspect of one problem (Bourgeois and Eisenhardt, 1988).

“The more rational and synthetic the strategic decision process, the more likely the managers will bring prior apotheosis to decisions” (Das and Teng, 1999).

Due to a systemic prevention of rational decision making in evaluating alternatives and developing the best ones, in such a case the exposure to a limited set of alternatives is very unlikely.

Another unlikely bias for the rational mode is the outcome of probabilities since managers are not only concerned with the values of probabilities but also with their magnitudes.

On the other hand the illusion of manageability is likely to happen, Thomas (1988) suggests that rationalization, self-confidence and wishful approach are possible cognitive biases that can affect the rational approach. “The more rational and systemic this strategic decision process the more likely the managers will have an illusion of manageability”(Das and Teng, 1999).

The avoidance strategic decision making refers to an intrinsic tendency of organizations to resist changes. As said from Cyret and March (1963) organizations fear the unknown and that they desire to maintain their status quo in uncertain environments.

In the avoidance approach the risk for cognitive bias is very high, moreover managers that tend to ignore problems until they get inevitable, deeply harm their firms.

The cognitive bias of maintaining prior hypotheses and such a decision making approach refers to the starting belief that changes are dangerous and therefore maintaining the status quo is a safer path. “The more emphasis on maintaining the status quo in a strategic decision making process, the more likely the managers will bring prior hypotheses to decisions” (Das and Teng, 1999).

Another bias that could be associated with the avoidance approach is a limited set of alternatives.

Managers with low levels of creativity may be stuck in the status quo because they are unable in developing bright alternatives. “The more emphasis on maintaining the status quo in a strategic decision making process, the more likely the managers will be exposed to limited alternatives”(Das and Teng, 1999).

Furthermore the avoidance decision making can fall in the cognitive bias of being insensitive to the magnitude of the various probability being stuck in the idea of “one best way”. “The more emphasis on maintaining the status quo in his strategic decision making process, the more likely that managers will be insensitive to the outcome of probabilities” (Das and Teng, 1999).

On the other hand the cognitive bias illusion of manageability is less likely to happen since the high avoidance mood charts from an incapability of managers of foreseeing what is going to happen.

In the logical incrementalist mode strategic decision making is interpreted as a step by step process. In this instance managers reject the idea of drafting one big plan but rather they prefer to take small decisions and adjust them with continuous improvements.

In such a mode the idea is to take the smallest possible adjustments and such a technique perfectly matches the bounded rationality of strategic decision making that are incapable of perfectly forecasting ex ante the various competitive scenarios (Hrebiniak and Joyce, 1985).

The logical incrementalist mode shares many aspects with the rational mode with one main difference, in the first one managers don't take binding decisions in early stages but rather prefer to maintain an agile and flexible organization that is able to rapidly follow market shifts.

Consequently the biases of focusing on limited targets and of being stuck in prior hypotheses won’t be plausible. In the incremental mode managers evaluate alternatives in two different ways: one is drafting the decision tree that involves the various decision nodes that will involve a choice by the manager in order to have a wider vision of the scenario. The other option is to continuously evaluate every single alternative that pops up. The cognitive bias of not considering the outcome of probabilities in the logical mode is not possible since such a decision making approach is completely based on analyzing alternatives, possible payoffs and probabilities of success. On the other hand it is possible that logical incrementalism can encourage the cognitive bias of illusion of manageability. Both the concept of logic and incrementalism can lead managers to the incorrect idea that everything is easily manageable. “The more logical incrementalist the strategic decision process, the more likely the managers will have an illusion of manageability”(Das and Teng, 1999).

In the political mode different people or parties fight over decisions to take. The political mood rises when decision makers are unable to reach an agreement. In such a mode the final decision is taken by the most powerful coalition.

As said by Eisenhardt and Zbaracki (1992) “people are individually rational but not collectively so”. In the strategic decision process there are two types of conflicts: the cognitive conflict, that embraces the judgmental differences, and the affective conflict that regards personal disputes.

In the political mode decision makers fall into the cognitive bias of bringing prior hypotheses to the decision node. Decision makers evaluate a limited set of targets that reflect their own interest.

“The more political the strategic decision process, the more likely the managers will bring prior hypotheses to decisions”(Das and Teng, 1999).

For what concerns both the exposure to limited alternatives and the insensitivity to outcome of probabilities the scientific literature applies two keys of interpretation.

On the one hand the decision process is seen as static since decision makers won’t change options since their prior hypothesis matches their personal interests.

Browne (1992) argues that in the political mode, decision makers consider a small number of both alternatives and consequences. So it appears that the various coalitions would not consider a sufficiently wide range of alternatives. On the other hand the decision process can be seen as fluid because decision makers will easily shift their position when it would be convenient.

Eisenhardt and Zbaracki (1992) share this second interpretation arguing that actors in the political mode are required to be flexible, able in reaching compromises, in shifting position and in horse trading. Following this last interpretation it results as highly unlikely that decision makers could fall into the cognitive bias of being exposed to a small number of alternatives.

For what concerns the outcome of probable is it is possible for decision makers to not consider them.

Decision makers frequently shift their position with regard to their estimates of the magnitude of probabilities, doing otherwise would make them more vulnerable in a political environment.

Also very unlikely for managers to fall in the bias of illusion of manageability since the political mood is characterized by a high level of uncertainty within time.

In the garbage can mode the decision making process is very uncertain and fluid (Padgett, 1980).

In such a mode the decision making is conceived in terms of problems looking for opportunities, solutions looking for problems, and decision makers looking for a job (Cohen et al., 1972).

Here the decision process can be divided into 4 components: choice opportunities, solutions, participants, and problems. In such a mode the bias of prior apotheosis it's not likely to occur since managers aren't committed to any objective and consequently don't develop any binding prior hypothesis on the matter.

In the garbage can mode instead, managers limit themselves to a limited set of alternatives. In this mode decisions are reached only after that managers find an existing solution to be applied to a new problem. “The more disorderly and anarchical the strategic decision process, the more likely the managers will be exposed to limited alternatives”(Das and Teng, 1999).

Another bias that may occur is the insensitivity of managers to outcome probabilities since in this mode managers are only looking for dishes and take with a low level of predictability of the consequences.

“The more disorderly and anarchical this strategic decision process, the more likely the managers will be insensitive to outcome probabilities” (Das and Teng, 1999).

For what concerns the illusion of manageability, in the garbage can mode it is hardly impossible to happen. In this instance the outcome of decision making is unpredictable and for managers is difficult even to know what could be a desirable outcome (Cohen et al., 1972).

Generally it can be said that this last model of strategic decision making is the one in which the rule of the season makers is cut to the bone.

After the analysis based on the matrix cognitive bias x strategic decision modes and the possible 9 propositions it seems clear that each of the four most common cognitive biases has a specific role in the various modes of strategic decision making.

By looking closer at the differences of the company biases among the various strategic decision making models an additional analysis can be made.

On one end had results that the rational and the garbage can modes complement each other. Such a complementarity arises from the fact that these two models are completely opposite for what concerns the levels of control and rationality applied by decision makers .

While the first mode appears to be rigid, rational and with a high level of control, the garbage can mode refuses strict control in favor of an increased flexibility.

As a result of such differences in the first case Top Gun devises more likely to happen is the overconfidence, while in the last case both inadequate alternatives and insensitivity to help calm probabilities are the most concrete risks.

On the other hand the overconfidence mode and the incrementalist mode both present similarities and differences. Both of them have in common to refuse drastic changes.

The only difference is that while the incrementalist mode moves slowly, the avoidance mode presents itself as a completely static mode with no movements at all.

These two last models, due to their similarity, mutually shared the four basic types of biases.

From the previous analysis true important assumptions can be taken for what concerns the relationship among cognitive biases and strategic decision modes.

First, each strategic decision making mode presents at least one cognitive bias, but cognitive bias is not the only determining factor, other important factors are the role of individuals together with the organizational, environmental and cultural variables.

Secondly the managers involved in different decision processes will present different combinations of cognitive biases. So for a bright management decision makers have to be keenly aware of the possible biases in which they can occur in order to avoid costly systematic errors.

Nowadays digital transformation is disrupting the traditional way of organizational management, of course one big driver of such a transformation is big data as pointed out previously (Janssen, Van der Voort, & Wahyudi, 2017).

In the analysis conducted by Merendino et al. (2018) an important question is addressed: “whether or not big data has changed the process of board level decision making and, if so, how and to what extent”. Following a tree level analysis is utilized to understand such an interrogative: first, implications of big data for individuals (or directors), secondly the influence of big data on the way the board works and lastly the impact of big data for external stakeholders. Organizations, due to the consequences of digital transformation, have moved from a condition of uncertainty and lack of information to an abundance of data (Tihanyi, Graffin, 2015). The advent of big data has also triggered changes in structure and dynamics of the board, in fact new professional roles have emerged such as Chief Data Officers (CDO), Chief Information Officers (CIO) and Chief Analytics Officers (CAO).

The increasing complexity of decisions being made is pushing organizations to abandon top down planning (Camillus, 2008). An emerging problem for firms is the development of increasingly complex models that can't be faced in a traditional approach (one best way).

As Camillus points out there is a strict correlation between “big problems and big data”.

In the knowledge based view (KBV) data is viewed as a key resource of strategic decision-making since it provides additional knowledge at the various levels of the organization.

In the Merendino analysis the concept of knowledge is divided into three different levels: director/individual level (managerial cognitive capabilities), board level (behavioral factors) and stakeholders level (dynamic capabilities). For Grant (1996) these three levels are strictly related, in his view organizations are bodies in which individuals (directors) with specialized knowledge integrate their know-hows “to form organizational level or group level knowledge that can in turn lead to sustainable competitive advantage”.

Helfat & Peteraf (2015) documented that managerial cognitive capabilities (at individual level), behavioral factors (at board level) and dynamic capabilities (at the stake holders level) all affect the quality of decisions since these capabilities facilitate the recognition of both environmental threats and opportunities. Therefore a focus on such a taxonomy will help to understand if and how big data are fundamental aspects on which companies have to rely.

Helfat & Peteraf (2015) argue that at the individual level people need to develop the mental models and skills, or managerial cognitive capabilities, to perceive, analyze and process changes in the environment. Such a process, as defined by Schneier (1979), has cognitive complexity and could lead managers to develop cognitive biases such as anchoring (i.e. old way of thinking) and cognitive dissonance (i.e. holding conflicting beliefs or ideas), or also organizational inertia.

At the board level the concept of knowledge has to be interpreted as routine, so in behavior deeply embedded into individuals as “tacit knowledge” (Winter, 2003).

When the board analyzes big data cognitive bias can arise and the following decision making situation can be affected. As the behavioral economist Kahneman (2011) points out “no matter how complex, refined or available data can be, decision makers are unlikely to fully consider it”.

At the stockholder level organizations are expected to anticipate environmental changes to proactively satisfy stakeholders' needs (Wang et al., 2015).

These dynamic capabilities require continuous knowledge acquisition and reshaping. Big data is very useful in providing new insights about the various environmental changes (Erevelles, 2016). The use of external knowledge together with the firm absorptive capacity and sure flexibility for such a dynamic environment. To understand how big data impact decision making three assumptions are fundamental for the analysis: first is to consider big data has a knowledge asset for the board, then to propose big data as necessary but not sufficient and therefore to be complemented by cognitive and dynamic capabilities, and last to introduce behavioral factors to the study of decision making activities.

Moreover a double taxonomy can be utilized, a first one of three core categories (cognitive capabilities, board cohesion and responsibility and control) and another one of eight sub-categories (shortfall in cognitive capability, cognitive biases, cognitive overload, decision-making disruption, temporal issues, board composition issues, organizational impact of sub-groups and external stakeholders).

For the first category (cognitive capabilities) the sub categories involved are tree: the shortfall in cognitive capabilities, cognitive biases as consequences, and the cognitive overload that can arise. Those three sub-categories are strictly linked together in a cause-effect relationship.

For what concerns this shortfall in cognitive capabilities often in the industrial scenario decision makers lack the required competence is to use the data.

Even if the amount of available data is increasing exponentially, the ability to analyze them is growing at a lower rate. This difference of speed is generating an efficiency gap that prevents decision makers to fully manage organization in an efficient way.

Speaking of cognitive bias several are threats that can arise, of course the four bases proposed by Das and Teng (1999) but also anchoring (an old way of thinking) that together with the poor and stranding of big data can undermine the validity of data based information.

In fact in the organizations there is still a certain degree of uncertainty linked with the plausibility of data. Referring to cognitive overload, it is a phenomenon of course when individuals have to manage more information than they are able to (Bawden and Robinson, 2009).

The increasing amount of data does not necessarily improve the quality of information, moreover managing big amounts of data can be hard, costly and misleading.

Even though more data often is a useful additional tool for decision makers that can take more informed decisions.

The second core category is board cohesion. Big data is disrupting the board dynamics of decision-making by changing the ways of working and interacting within the organization. This shift of organizational dynamics leads to continuous adaptation to new environmental requirements.

The gap between the old and the new way of working generates stress and tension.

The three sub-category associated with board cohesion are decision making disruption, temporal issues and board composition issues.

The first refers to the gap between the piece of big data and the lower speed of strategic decision-making.

The second focuses on the difference in the approach between big data, which are linked to the present and the past, and strategic decision-making that is future oriented.
Lastly, board composition issues arise since the ability of dealing with data and new technologies is typical of the young generations but in the decision making scenario hazard for young girls to have decisive roles.
So board composition is suffering several shifts such as the creation of new roles, new directorships, the recruitment of tech experts, restrictions during the board processes and the outsourcing of data to ensure both that resources and analytical skills.
The third core category is strictly linked with the second. words are trying to reconfigure dear structure and processes in order to better deal with stakeholders and to better apply big data insights into decision making situations.
Yet that is not an easy task and therefore many firms are failing in doing such a transformation.
This inability raises doubts regarding the board's responsibility and degree of control.
Both the degree of control and responsibility are associated with the shoe sub category organizational impact of subgroup formulation and external stakeholders.
So few companies are creating departments to adapt to the management of data by hiring specialized workers that can support the firm with conscious choices.
The second subcategory embraces the increasing trend about searching some of its tasks and resources to external stakeholders.

2.2.2- ALGORITHMIC BIAS

To the Merendino et al. (2018) analysis, that embraces the various biases associated with cognitive issues and user activities, it is important to pair the study conducted by Danks and London (2017) that analyzes in depth the issues associated with autonomous systems, semi-autonomous and the so-called algorithmic biases. Autonomous systems work thanks to algorithms. The scientific literature has raised the doubts of possible biases associated with those algorithmics. It is first of all important to specify that not only those kinds of biases are necessarily negative and moreover underlying that algorithmic bias, when it arises, it is often wanted and calculated by decision makers.

In order to work, computational systems, particularly autonomous ones, need not only hardware and software, but also learning capacity in order to adapt to new scenarios and evolving systems. This learning capacity is given by algorithmics.

In many instances autonomous systems are substituting human labor, this trend is of course increasing since machines avoid many of the flaws and shortcoming that humans have, for example they can't get distracted or sleepy. If we can consider the autonomous system as an improved version of humanity (at least for some instances) it is important to arrange the most possible unbiased algorithm. Nonetheless avoiding algorithmic bias is inevitable and this requires autonomous and semi-autonomous systems to be assisted by operators that can detect and compensate for the various biases (Barocas et al., 2016).Yet this is not an easy task, in fact autonomous systems can be very complex and the outcome of their analysis can be very difficult to be understood. So we can compute the taxonomy that distinguishes between natural and objective algorithmic bias, and those that are problematic. It is in fact important to analyze a possible meaning of the term bias, not only as a negative implication (i.e. error), but more in general as a deviation from standard.

In such a taxonomy the cognitive bias can be a teacher's statistical bias or a moral bias but also a legal, social or psychological bias.

One possible algorithmic bias that can arise from his true vision and the training or input data provided to the algorithm. So a “neutral” (not biased) algorithm can yield at a deviated model due to a bias in the input data. Often this type of bias (as said before whether statistical, moral, legal and so on) is hard to be revealed since the organization hardly ever disclosed the input data utilized.

Another bias that can arise is the algorithmic focus bias which happens “trough the differential usage of information and the input or training data”. In other words it may be plausible to think that certain types of data won't be compounded in the analysis if those information are not relevant.

Another case can be the decision of a firm in using or not legally protected information to assess a decision making situation. So the focus bias can present itself in two typical situations that can be called points of “first choice”: on the one hand we have a legal standard that could be violated or not, while on the other hand one that regards the use of apparently unnecessary additional data.

A third possible algorithmic bias regards the processing capacity of an algorithm that can itself be biased in some ways. One common example can be the use of a statistically biased estimator in the algorithm. Yet this is not necessarily an error, in some instances it can be a choice of operators. In fact, in order to reduce some bias, sometimes it can be useful to correct such a standard deviation with another different bias.

Those three types of biases regard technical and computational “errors“. Of course this also arises from the usage of those technical tools.

A possible mistake can arise from the usage of a model outside its proper applicative area, yet this is not the poor algorithmic bias but more an “user bias”.

The line of separation between the transfer context bias and the training data bias is fine and blurred. Yet the difference lies between learning scenarios from biased data and improperly using an algorithm outside its proper context. Finally, an ulterior source of algorithmic bias can be linked to the misinterpretation of the algorithm’s output that can happen because of an incorrect user interpretation or because the border autonomous system embraced the algorithm’s output in a wrong way.

As said by Danks and London (2017) “Algorithms with autonomous systems present many “surfaces” through which different types of bias may enter the system”.

It is important to understand the particular types of bias because decision makers can face both sudden issues (problematic bias) by the old son specified filters to better analyze some instances (desired bias).

Often desired biases are used to correct other inner biases that can be due to social instances, religion, discriminations and others. But even if operators find a way to correct and neutralize a bias it is not sure that it will result in a positive outcome. One very actual and discussed example nowadays is the moral standard that should be used for self-driving vehicles when they face life-death situations. Obviously it is difficult to establish one worldwide common standard for what concerns the distribution of the risk between the car passenger-driver and the people outside the car. On the other hand, even if some buyers can be neutral or even desirable, most of the biases are just problematic and it's important for organizations to analyze and manage them.

An important relation to understand for facing such a problem is the one between autonomous systems and the ethical and legal norms in force.

At the more general level it is important to correct the bias or by neutralizing it or by creating an opposite bias, or by creating a novel algorithm that avoids such a bias.

Of course there are cases in which the bias can't be corrected, neither technologically, nor morally, socially or psychologically. Barcocas and Selbst (2016) make this point vivid in the domain of employment discrimination. In cases like that it is hardly impossible to eliminate the generated biases but decision makers have to choose between different algorithms to choose the one that leads to the minor, or less harmful, one.

Another tricky case can be when operators can avoid a certain bias but only by using sensitive information (legal or moral), in this case the outcome will depend on the propension of operators in crossing some lines. So, in the end, for both cognitive and algorithmic biases it is important to differentiate harmful from desirable biases and to correctly please them in the various steps of data lifecycle management.

CHAPTER 3 - CASE STUDY: LAMINAZIONE SOTTILE s.p.a.

3.1- INTRODUCTION TO THE FIRM

Several interviews were conducted in order to assess the theoretical framework proposed in the first two chapters. Interviewers asked to remain unknown and a privacy agreement was undertaken, therefore the responders will not be specified.

The four interviewed represent three different divisions of the same firm, Laminazione Sottile group, from the commercial area (responder B and D), the logistic (responder C) area and the R&D department (responder A). Laminazione Sottile is an Italian manufacturing group composed of eight companies working in an integrated supply chain: Laminazione Sottile, Italcoat, Contital and IPS Industrial Packaging Solution in Italy, while i2r is in the UK and in South Korea, PLLANA GmbH is in Germany and Contital LM Turkey is in Turkey.

The group revenue in 2020 reached almost 490 million euro, 270 of which only by the firm Laminazione Sottile. Such a firm has a very competitive and solid structure that, together with the nature of the market which is structural for the economy, allowed the revenues to stay in the average without being impacted by the pandemic, precisely by analyzing revenues from 2018 to the end of 2020 we have an average revenue per year of 268.543.757€ not distant from the values of the last years alone 270.555.166€.

The firm counts almost 500 employees and has an organizational design arranged in a matrix structure (function X nation) as shown in the figure 3.1. Such a structure implies that cooperation and communication are essential for the firm since it moves organically through the repetitive interaction of different departments.

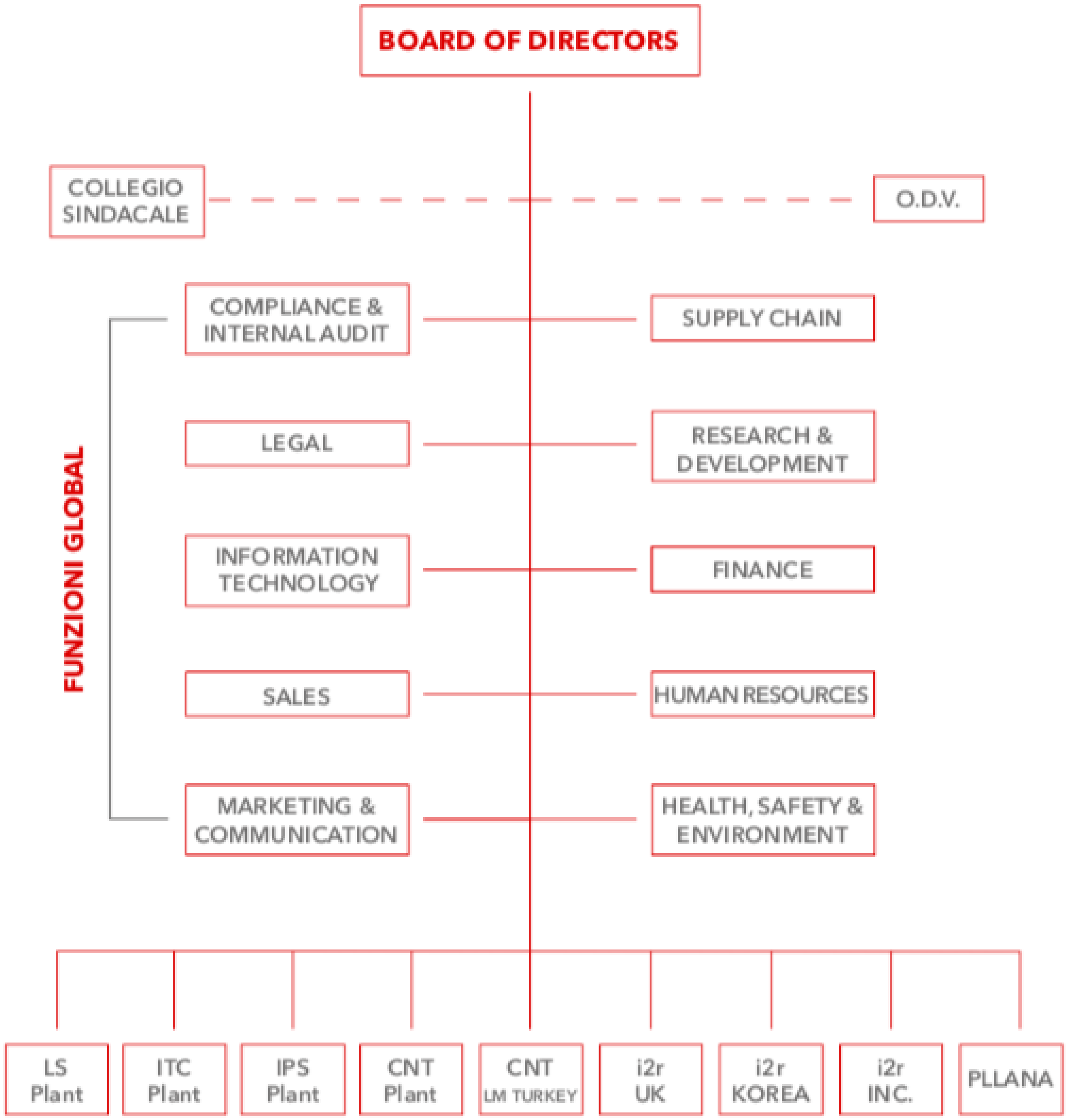

Figure 3.1: Laminazione Sottile group's organizational design. Source: Laminazione Sottile

Laminazione Sottile manufactures rolled aluminum products, in different alloys, dimensions and superficial treatments, including lacquering and printing, and aluminum food trays for a wide range of applications. The firm's performance is partially defined in the Italian market at 30% while the other 70% is linked with foreign countries. In fact the

Laminazione Sottile group is a global reality that operates in more than 70 different countries.

3.2- INVESTMENTS IN 4.0 TECHNOLOGIES

Having the firm always been very careful to the world economy's performance the very first investments in industrial technologies 4.0 were made as soon as it was clear that the fourth industrial revolution was started, even before the Hannover fair of 2011.
As said by responder B it was between 2008 and 2009 that the firm opened to such investments even though at the time the human role was still crucial because the logistics wasn't yet integrated. So it was soon clear for the firm the importance of pursuing such a transformation for the sake of the firm. As declared by responder D: "It may have seemed a risk at the beginning, as most of the radical changes, but looking back it has been a very successful move that has brought a lot of returns for the group".
Then during 2013 and 2014 the main investments were made on the first two phases of the operation flow: the foundry and the rolling mills. Those investments rocked up when the economic incentives and tax benefits were applied by the Italian government during December 2016 with the "Piano nazionale industria 4.0".
The firm has invested in various enabling technologies of the industry 4.0, in particular investments were made in the acquisition and update of machinery and plants but also in the creation of open networks (IoT) that through computers and sensors allow a real time interaction among the various assets of the plant. So where possible it was upgraded the informative system in order to get the machinery linked one another and with a central computer. While, where this upgrade wasn't possible the machines have been substituted with new ones compatible with the 4.0 paradigm that allowed such an integration. Those investments allowed to create both an horizontal and vertical integration of the supply chain within the production flow.
The main difference on the new plant is the introduction of PLC (programmable logic controller) and CNC (computer with numerical control) that are both interconnected with the firm's informative systems (as400). The PLC allows to monitor in real time various

production aspects as the working conditions and the compliance with the parameters, while the CNC allows to integrate virtually the physical machine with the plant. This creates an automated integration of all the production flow both horizontally and vertically. Specifically, reporting the responder A: “investments were made in various aspects of the 4.0 paradigm, particularly more complex plants in which the operative instructions that allow the machine to work are centralized on a computer based system. Internally those instructions are redistributed for setting the machine depending on customer requests, and moreover they are communicated to the downstream plant. So the firm informative system as400 has been linked with the “plant computer” to let the information drive the production requirement, i.e. the as400 communicates to the plant that the output needed is a laminate with specified characteristics (type of material, weight, thickness, width). Those characteristics then are translated by the computer in key research items to find out the various production “recipes” needed. So the required production phases needed to produce the output. On the other way around the plant communicates to the computer about the status of production, through a tracking sensor, so that the integrated logistic system and the master production schedule follow in real time the production flow”.

Those investments were made in various areas of the firm such as foundry, rolling mills, degreasing plants, thermal treatments furnace and in the cutting stage.

From the various interviews emerged that the drivers of the various investments in industry 4.0 technologies were linked to four key aspects of the supply chain: quality, quantity, flexibility and speed. Specifically, the aim of improving the quality of output and a product with superior performances, the upgrade of the production process in terms of waste reduction (death time and materials) and a smoother decision process since these technologies allow to deal with a wider amount of data in a much more flexible way and consequently it permits the firm to take more informed decisions in real time.

In general terms investments in new technology based machinery at the time (2008/09) could seem risky but is nowadays a commonly accepted path to global competition or, even more, the only way to survive in the market.

3.3- THE NEW INDUSTRIAL PARADIGM

Speaking of the changes that those investments brought to the firm responder A argued that the operational process didn't suffer any particular transformation in practical terms, each of the production phases has stayed unchanged. What has switched is the quality of the production flow and the role that operators have within the supply chain. In particular the operators are required to have a set of new skills and there is the rise of a new working role known as "augmented blue collar". While in the past an operator with relatively low scholastic education could get through experience to the top level of production responsibility, nowadays is required to have technical knowledge and engineering understanding of the machinery, ability in reading and analyzing data and moreover informatic skills to deal with the interface.

It is nowadays crucial for the firm that the strategic decision process is supported by data, decisions undertaken rely on a solid set of information based either on external and internal information. As suggested by responder C this managerial trend is very common and it is known as "prescriptive decision making" which has taken on the so-called "visionary management".

So the various information such as the length of the raw material and the speed of the machines are easily accessible through a database.

The increased level of information allows much more informed decisions regarding the optimal production mix. Responder B says that this increased awareness enables the commercial division to better understand on which levers move in order to increase sales and profitability. So the strategic decisions are undertaken by analyzing the production capacity and eventual starving issues or bottlenecks.

Infact by having a complete picture of the supply chain it is easier for managers to understand at which step of production there are inefficiencies.

As pointed out by responder B "the standardization of working recipes and the centralization of data through IoT systems bring to a decrease in the uncertainties of the working routines".

Among the main issues that big data analytics didn't solve is the time orientation of the firm's targets, because even if we found a computer based optimal solution in the medium-short term we might have some trouble in the long term. Is always important to find the firm best equilibrium among the two by giving an eye both on the firm capacity but also to the market threats and opportunities. Moreover this equilibrium has to be projected to the future since the setup time for a new plant can be of 15/18 months, so it's important for the firm to always have a clear idea of the volume of affairs at least for the following 2 years. For capturing those information in advance the data based market forecast is a very useful tool. Another technique used to make commercial strategies as reported by responder C are the informatic extractions (data mining), "we extract data for each client order we deal with, we centralize all the related information as timing, material and measures. Once you have everything on the as400 you will have a clear draw of all the supply chain paths, bottlenecks or starving issues" this pictures in a precise way all the journey that the raw material undertake within the manufacturing process and allow managers to draft a precise cost analysis of each product, each machine or each process.

It is clearly easier to assess cost opportunity balances but above all that information is achieved in a much more agile way, often in real time. This increased speed allows the commercial division to plan for the future in a much safer and informed way.

From the interviews we understand that there is a need for upgrading the Das and Teng (1999) "9 proposition theory" since nowadays at least one of the two vectors of the matrix has changed.

Strategic decision making in fact is now far from the predictive model, in favor of a more scientific approach: the prescriptive decision making.

Of course the cognitive bias will always be present until at least one step of the firm processes are handled by human force, but it's relevance within the company dynamics is decreasing.

It is more proper to talk about the biases that can emerge by human-computer interaction. So by implementing the matrix with another item on the horizontal axes (scientific or data-based approach) as a new paradigm of strategic decision making we can see how the already known cognitive biases are no longer the only threat.

The discussion should be shifted on the algorithms on which this new prescriptive decision making bases its working mechanism. Of course machine can avoid much of human defects or their intrinsic limitation, still there are important constriction to consider such as the subjective interpretation. While for quantitative capabilities computers outpace humans, for subjective thinking they still have various defects. So even if it is important to use those tools, it is more important is to maintain a critical perspective on data and to make strategic decisions considering both data and inner rationality since algorithms for some aspects still lack of capacities. So in the current scenario and probably also in the future human interaction can't be avoided.

Another bias that can occur within the firm operations is the "confirmation one", respondents described such a bias as an attempt of operators in forcing the data analysis in order to obtain the desired result. This is a tendency of workers in focusing too much on prior hypotheses with a low predisposition in analyzing the reality with objectivity. Internal data have confirmed that such a behavior is more likely to happen when operators have a strong confidence in their capacity and especially when those employees have a strong sense of leadership. Respondent C described the confirmation bias as follows "instead of verifying hypotheses with data objectively, decision makers sometimes focus only on information that confirm their hypotheses instead of practicing an objective data analysis". On the other hand responder B said that a very luckily bias is the "status quo bias" that is translated in a low tendency of decision makers in escaping the comfort zone for example by modifying some initial constrain of a computer base optimal solution. Specifically respondent B argues "people tend to consider computers as infallible smart entities and maybe for some aspects they are right, but when dealing with machines and computers is very important to consider that they are nothing without the human hand, they are set to work as required by operators and sometimes in the setting phase some error or some inefficiencies may be there. It is important to always think about alternatives and avoiding to think inside the box".

The status quo bias is more likely to happen for lack of vision, it is linked with the tendency of decision makers to underestimate the validity of some alternatives or it may be due to a lack of vision.

Responder B, summing up the argument concluded that “negative biases are to be avoided, still not all biases are negative since some can be desired to contrast other irreducible biases. Most of the negative biases are linked with a psychological condition of the worker that bring him or her in being alienated, distracted and therefore more likely to fall into errors”. Lately the two biggest source of alienation for workers are the pandemic and the progressive reduction of their importance within the firm dynamics due to the rise of industrial technologies, AI, sensors and so on.

For what concerns the possible frictions that those changes may have caused the three respondents agreed that it was a fully accepted change, perceived as necessary and useful with no resistance at all, neither internal or external. Indeed those changes have significantly improved the quality of work within the facility both for operators of the core business and for strategic decision makers.

When being asked about the main benefits responder C pointed out that within the last 4 years the firm increased their productivity up to 25% thanks to those investments and that nowadays such an improvement allows the firm to face with no fear the global competition. Other important benefits are linked with reduced costs due to eventual human errors in the transcription and set-up of machine requirements since the process is now computerized. Of course the tax benefit associated with such investments helped us to undertake such a choice, otherwise it could be very risky from a financial perspective in terms of liquidity. The various financial and economic benefits permitted the firm to invest in such technologies without neglecting the ordinary investments. This helped especially medium and small firms that would have been forced to choose on which direction to focus their financial liquidity. Responder A argued that the Italian and European contributions were very helpful for the firm, specifically “we exploit various tools that were provided by those political bodies, such as subsidized financing, tax relief, non-repayable contributions and other various tax benefits” (as super depreciation and curtailments).

The main issue that slows down a complete passage to industry 4.0 is of course the cyber security and the associated risk of losing control on sensible information such as know-hows. Responder B declared that the firm is currently undertaking an investment to acquire from an external provider a cyber security system that will allow the firm to upload on a cloud all the data with a lower risk of being hacked.

When been asked about the necessary skills to compete in the 4.0 industrial scenario responder A argued that it is very important to develop analytic skills to avoid potential biases such as algorithmic one, specifically he said “algorithm and cognitive biases are a tricky field, operators still can fall into distraction or data misinterpretation, therefore it will be very important to implement artificial intelligence and machine learning technologies to let the computer deal each other and limit the human role to strategic and subjective decisions”.

Artificial intelligence has to be applied in a systematic way both for structured and unstructured data analyses able to follow not only the single machine (as of today) but also to link the various plants of the facility in order to have a clear picture of the various steps (and their links) that are involved in the process of transformation of the input in output.

Another important aspect that emerged from the interviews is the necessity of centralizing the various know-hows that for many aspects are still embedded in operators, a must to achieve is to have centralized and easy access to every single detail linked with the firm in real time such as info concerned with the various processes, technologies and problems.

As a conclusion of the interview respondents were asked about their beliefs for what concerns the areas in which the next big investments will be made, this was where the responders were the most torn. All the responders declared that cloud and cyber security are the most relevant issues to be solved so the firm is already pursuing major investments in such an area. Responder A added that he also considers as priority the investments in simulation and predictive models to create increasingly more realistic digital tween of the industrial reality. On the other hand, responders B and C were more keen about the perspective of investing in AI and machine learning and about the possibility to launch by 2023 a prototype of a hot rolling machine that exploited those technologies relegating the human role to a simple supervisor.

What is commonly accepted for sure is that the firm will not stop in pursuing investments in industry 4.0 not only for the advantages that they already gave but also because by not doing so even the best player of the market risks in the near future to lose its competitiveness.

3.4- RESULT AND DISCUSSIONS

In the following section I point out and discuss the evidence of the qualitative research. To do so I will consider how the 3 area of expertise of the interviewed (commercial, logistic and R&D) have changed due to investments in 4.0 technologies. Moreover an analysis will be moved to understand the strategic decision making implication of those investments.
A framework to explain the various changes brought by digital transformation can be built on those that within the interviews emerged as the main drivers of 4.0 investments: quality, quantity, flexibility and speed.
By cross-checking the interviewed area with those 4 aspects of innovation we can make a matrix that will generate 7 different prepositions (Figure 3.2).

	Commercial	Logistic	R&D
Quality	P1	P3	P6
Quantity		P4	
Flexibility	P2		
Speed		P5	P7

Figure 3.2: 7 preposition

As reported by responder B “the commercial division has benefited of the new investments in 4.0 technologies as it is now able to pursue a more informed and qualitative strategy especially for medium and short time horizon”. The new computational capacity allows decision makers to have a clear picture of the competitive and internal scenario and this brings to the possibility of drafting safer strategic decisions.

“The more the investments in 4.0 based technologies the higher it will be the qualitative level of the commercial division” (preposition 1).

From interviews emerged that the commercial division has now the possibility of setting production and price levels almost in real time. Investments on algorithms and informative systems have permitted the firm to operate in a much more agile way. Responder D argued that Laminazione has now a very flexible structure that allows to compete in the global market and “thanks to the upgrading of the market forecast tools we can now make strategies with real time data”

“The more the investments in 4.0 based technologies the higher it will be the level of flexibility of the commercial division” (preposition 2).

For what concerns the implication of those investments in the logistics responder C argued that thanks to sensors, tracking systems, CNC, as400 and PLC the logistic is now integrated with the rest of the firm operations and with the master production schedule so “it has achieved a more flexible and qualitative level thanks to the possibility of having real time information”.

An increased qualitative level is possible thanks to the avoidance of the main source of errors: the data setting. Infact, now machines deals one-another through the as400 informative system and so they have a clue of their role within the production phase and of the materials timing within the transformation process. This communication as previously explained is allowed by introduction of the CNC that are linked to a central plant-computer, those investments allowed to create both an horizontal and vertical integration of the supply chain within the production flow.

“The more the investments in 4.0 based technologies the higher it will be the qualitative level of the logistic area” (preposition 3).

The new level of competitiveness of the firm can also be translated in terms of production. Precisely thank to the complete integration of such a division and the consequent waste reduction of time also quantitative level have been growing in the past years, infact “Laminazione was able to double its productivity level in only 3 years thanks to the new working conditions” (responder C). The new productive level allows now the firm to “compete in the global market without any more fear for Asian competitors”.

“The more the investments in 4.0 based technologies the more it will be the quantitative level of the logistic area” (preposition 4).
In the phase of inefficiencies tracking, logistic is now far more rapid in founding out bottlenecks, source of errors or eventual starving issues since is a lot easier to point out those cost source through simulation models and monitors. More over the process of errors tracking is now very changed since decision makers previously “had to find out where numbers came from” while now the link between consequence and source is easily traceable thanks to computers intelligence and centralized information.
“The more the investments in 4.0 based technologies the higher it will be the speed of logistic area” (preposition 5).
Finally for what implies R&D side the benefits were linked to qualitative matters since it is now a more oriented process and to the speed because thanks to digital twin and simulation it is nowadays far easier and cheaper to predict the outcome of projects without having to physically replicate them. So we can say that the quality of research and development benefited the online models of simulation since it reduces the number of attempts that were previously made to introduce new technologies.
“The more the investments in 4.0 based technologies the higher it will be the quality of R&D department” (preposition 6).
For the same matter also the speed of introducing new technologies in the organization is now improved. The reduction of attempts of physically recreating the various intuition led to a tangible reduction of time waste and costs.
“The more the investments in 4.0 based technologies the higher it will be the speed of R&D department” (preposition 7).
As it results from the study the common aspect of the various divisions is the new paradigm of strategic decision making. During interviews infact emerged that all the analyzed divisions of the firms have now less space for subjectivity since data have fulfill a very ambiguous gap of knowledge that previously made the strategic decision making a visionary process. Now thanks to a great step of digitalization decision making is a much more informed process, still there is some room for subjective interpretation and probably, even if reduced there always be, but now it can be said that the new paradigm of strategic

decision making is the prescriptive management rather than the visionary one. Data infact have made it possible to move decisions from a much informed and safer perspective.

The increased levels of quality, quantity, flexibility and speed can be translated in terms of augmented competitiveness so to sum up the various propositions identified it can be said that “the more the investments in 4.0 based technologies the higher it will be the level of competitiveness of a firm”.

CONCLUSION

The aim of this work was to analyze the firms' digital transformation process from a managerial standpoint providing a body of knowledge regarding the implication of industrial 4.0 investments for what concerns strategic decision making dynamics, supply chain operations, organizational matters, algorithmic and cognitive biases.

The research work was conducted by combining a traditional literature overview, database support and interview to experts from Laminazione Sottile s.p.a.

The qualitative methodology was adopted to analyze an evolutionary and fluid path, still in continuous development, that couldn't have been captured only with statistical tools; while the literature review was undertaken to provide a body of knowledge on which building the basis for the successive development of the thesis.

I interviewed 4 experts from 3 different area of the same firm in order to have different opinion of a single phenomenon and also to understand how this was reflected on the very different department that a firm have.

As a conclusion of the research work it can be said that there is almost a complete match between the literature review findings and the qualitative methodology (i.e., experts interview) especially for what concerns the applicative area of the 4.0 technologies and the various advantage that firm can gain from those investments. Experts confirmed that the main advantages of the discussed investments were reflected on different aspect of production not always in the same proportion. Generally the advantages were found in terms of quality, quantity, flexibility and speed. But what was interesting is that the drivers of those final benefit were linked with the new possibilities that real time information and centralization of data have brought to the firm.

The operations of the supply chain didn't suffer any particular changes unlike the theoretical framework was suggesting but this could be linked to the intrinsic characteristic of the manufacturing sector. On the other hand strategic decision making has changed a lot, there are unprecedent opportunity and threats in the nowadays industrial scenario and decision makers have to speed up in mastering the matter in order to overperform the competition.

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SUMMARY

This work embraces the digital transformation brought by industry 4.0 and the consequent strategic, cognitive and competitive dynamics. Those changes have reshaped various organizational flows to many industries and firms are trying to readapt themselves to stay in the market.
The analysis will be moved from a managerial perspective by combining a scientific literature overview with various experts interviews from Laminazione Sottille s.p.a. and with databases aid. As it will emerge from the following research digital transformation (DT) is transforming the world at an unprecedent pace, moreover this trend has recently rocked up due to COVID-19 social and economic implications.
The purpose of the research is to examinate the way in which digital transformation is taking place both from a technical and cognitive perspective to provide a solid framework about the new competitive scenario, the new mechanisms of strategic decision making and about the various supply chain operations implications.
Industry 4.0 has its roots in the very first years of 2010s when in Germany was held the presentation of a government project that aimed to turn the country into the global leader of manufacturing within a decade. Such a project was called "Industrie 4.0: Mit dem internet der Dinge auf dem Weg zur 4. Industriellen Revolution" (Industry 4.0: Internet of Things on the road of the fourth industrial revolution).
The most involved sectors of such a paradigm shift are the industrial, the manufacturing and the social ones. Differently from the previous 3 industrial revolutions, the fourth is happening globally, simultaneously and at an exponential speed rather than linear. During industry 4.0 we assist in the blurring of national boundaries and to a strong international interdependence for what concerns finance, politics and innovation technologies; this has been referred to as a systemic global economy (Schwab, 2016).
The fourth industrial revolution was born with the aim of reshaping the role of Germany in the global economy, quoting the original document, "*improvements of the production plants, of industrial systems and of daily use products through the interaction of integrated memories, communication capabilities, wireless sensors, integrated actuators and*

intelligent software that [...] *permit to establish a bridge between cyberspace and tangible reality, allowing a fine synchronization between the digital models of the devices and the physical reality*" (Kagermann et al., 2011). This fusion has generated the so-called cyber-physical systems (CPS) that relies on the concept of memory devices. Some automated elements were already present in the third industrial revolution but through Industry 4.0 they have been strongly implemented and interconnected thanks to various enabling technologies.

The collection and analysis of massive amounts of heterogeneous information (big data) thanks to cloud computing technologies, the ongoing process of digital fabrication and programmable robotics that allow a strong speed up to the working routines. The additive manufacturing (3D printing) that reduces the distance from virtual reality and the physical one. The interaction of machines through the IoT that is based on artificial intelligence (AI) and so also on machine learning, sophisticated sensors and neural networks, this means that for the first time products and technologies have an active role in the decision making process and the faculty to intervene in operating and strategic decisions giving start to a new frontier known as data driven decision making. There has also been a significant improvement in flexibility due to a faster ability to react and to the communication machine to machine (M2M) (Kagermann et al., 2011). The growing importance of the technological side has increased the concern for cyber security (IT security) to ensure data protection and to prevent attacks that could damage the firm's software, hardware or that could mislead the service that these services provide.

After Germany, USA and France but also Italy have gone through a massive industrial revolution.

In the USA, under the Obama presidency, it was established the Advanced Manufacturing Partnership (AMP), following the example of Germany and giving a signal about the purpose of re-industrializing the country. By convening research centers, manufacturing firms and universities the USA created a central HUB for innovation set to reaffirm the country as the leading global force and to increase the employment levels. Differently from the German model, the American one relied far less on the public funding, in fact it was mainly driven by private-public partnerships through the creation of several Manufacturing

Innovation Institutes (MIIs). The American government invested approximately 500 millions dollars through financing research projects.
Far greater is the public intervention of France that issued 10 billions euros through fiscal incentives like the super depreciation for private investors, tax credit for research and financing all the projects under the strand “Industrie du futur” and “Invest for the future”. The French government's purpose is to modernize the manufacturing system of the country in order to stay competitive in the global market.
In Italy starting December 2016, under the premier M. Renzi and the minister of economic development C. Calenda presented the “*Piano nazionale industria 4.0*” that follows these guidance:
-to operate in a logic of technological neutrality
-to intervene with horizontal actions rather than vertical or sectoral ones
-to work on enabling factors
-to orientate existing tools for favoring the technological progress and the productivity
-to coordinate the main stakeholders without holding an oppressor role.
The Italian government has created tax benefits that came into force starting 2017 such as the super depreciation of 250% for investments in tangible assets functional to the technological and digital transformation of the country due to the plan Industry 4.0 and one of 140% for investment in structural intangible assets (Pucci et al., 2019).
The Italian cumulative investments, as reported by the MISE, in the period 2017-2020 is approximately 13 billion euros for the public sector and 24 billion euros for the private one.
In march 2017 during a conference “*digitizing manufacturing in the G20*” Germany, France and Italy declared the birth of a three year partnership to promote digitalization of the manufacturing sector, this cooperation involves the three respective implementing entities of the national strategies for industry 4.0 those are coordinated by a steering committee composed by six members for country and chaired by three general directors of the economy ministries' industrial departments.
At the time, the expected benefits of the implementation of industry 4.0 are an increased flexibility and velocity from prototyping to market placing, improved productivity due to a

decrease in set-up times, errors and machine down-time, and augmented quality due to innovative sensors that allow real time quality controls.

As many scholars retain industry 4.0 is not a single technology but rather appears as a cluster of different technologies that are de facto agglomerated together by technological leaders, pivotal users, system integrators and government policy makers (Martinelli et al., 2019).

As pointed out in a BCG research those technologies already existed before the birth of the fourth industrial revolution but they were never used in the manufacturing sector remaining just applied research, what really changed is the connectivity among them and their appliance in the industrial operating activities.

The aim of industry 4.0 is to build a flexible, digital and personalized production model that provides very customer suited products and services. This has resulted in the convergence of the physical world and the virtual world (cyberspace) in the form of Cyber-Physical Systems (CPS).

As reported on the Italian Ministry of the economic development website the enabling technologies of industry 4.0 can be divided into nine groups.

1) Advanced manufacturing solutions (AMS), commonly known as robotics, is a very technical subject that has its roots in the third industrial revolution, thanks to the development of new materials and technologies it has increased its power, speed and accurateness following a upgrading trend such as descripted in Moore’s law, it is also becoming cheaper to produce and due to this improvements it’s now essential in the manufacturing scenario. The AMS allows the manufacturing process to be more flexible, efficient and competitive.
2) Additive manufacturing (3D printing) is a technology that consists in the construction of three-dimensional physical objects from a digital model. There are three different processes for 3D printing that are depositing, joining or solidifying materials that require three different materials such as plastic filaments, liquids or power grains.

   3D printing brings some consistent advantages like the minor waste of material, the possibility of working uninterruptedly 24/7 and the consequent time and cost savings.

Moreover additive manufacturing enables a very flexible production, a relatively low level of inventory needed and almost zero additional cost for very personalized products.

3) Augmented Reality (AR) is a technology that enriches the sensorial experience of the real world with real time digital information generated through computer devices. It is a combination of the physical and digital world and doesn't aim to substitute reality but to provide additional information through technology.
   Differently from augmented reality, the virtual reality (VR) substitutes the physical world with a digital one that can either be a reconstruction of the real or an imaginary world.
   AR and VR can facilitate the ease of use of industrial machines through the high realistic representation of 3D digital models and can speed up production and maintenance times; allow the possibility of remote control, assistance and repairing of machines and this enhance a superior level of safety for operators.
4) Simulation allows to create a digital model through which reproduces the extent of certain events on an analyzed item. It is very useful since it prevents the impossibility of reproducing determined events in a laboratory. Digital twin it's the latest available simulation modeling system and in addition to the precedent system of physical modeling allows an automated (data-based) construction and modification of the models (Rodic, 2017).
5) In the industry 4.0 we refer to integration when adopting informative systems for gathering information either about clients and suppliers (vertical integration) or regarding firms that operate in the same business (horizontal integration).
6) The Internet of Things (IoT) has a central role among the enabling technologies of the industry 4.0. It is an open network of objects that through sensors have the capacity to "*auto-organize, share information, data and sources, reacting and acting in face of situations and changes in the environment*" (Madakam et al., 2017).
7) The cloud is an on-demand service that provides the users additional computer system resources like the storage of data and computing power. It is a centralized system whose scope is to allow the storage, computation and transmission of information virtually and in real time.

8) It is very important for firms to enhance their data with advanced cyber-security systems to ensure a high level of data protection.

   As Cisco Systems (holding of the more famous Cisco WebEx) reported on their website "*cyber-security is the practice of protecting systems, networks and programs from digital attacks. These cyber threats are usually aimed at accessing, transforming or destroying sensitive information, as well as extorting money from users or disrupting normal business processes"* (Cisco.com).

9) Big data is a term that refers to large volumes of data either structured or unstructured. Still the relevance of big data is not linked to the volume but to the usage that the firm can do with those. The main value of data is linked to the capability of analyzing them and the ability to extrapolate valuable insights, hidden paths, various correlated dynamics, customer preferences and market trends.

   By analyzing big data firms can have a wide range of opportunities for identifying and fixing problems, boost efficiency, eliminate bottlenecks and levigate starving issues within the operations. Big data analytics can help businesses in taking timely and informed decisions minimizing the need for "*visionary management*" in favor of the much more secure "*prescriptive decision making*" (Bell et al., 1988). Other benefits can be found within the process flow since data analysis can help managers to improve the assembly line efficiencies. They are also useful to increase customer services and to achieve better forecasting.

   Data is a key enabler of smart manufacturing but data without being transformed into useful insights have almost no value. There are various steps to follow to achieve such a valuable transformation: data collecting, transmission, storage, preprocessing, filtering, analysis, mining, visualization and application. These steps together can be considered the "*data life-cycle for manufacturing*" (Taoa et al., 2018).

   The applications of big data in manufacturing regard: preventive maintenance, product design, product management automation, customer experience and supply chain improvement (Lee, 2021).

Preventive maintenance is a regularly set up and check of a machine or piece of equipment to minimize the likelihood of it failing.
Product design is lightened by costly research through the use of big data analytics since it can help to identify trends and market shifts that can alter the perception of determinate design or colors of established or new products.
For what concerns production management automation it can be said that thanks to sensors, robotics and IoT it is now possible to give autonomy to several smart devices that can effectively produce relatively without any human help (Frohm, 2006).
Big data analytics are fundamental to enhance a superior customer experience, through the collection of data firms can draw a very precise picture of customers preferences and tastes.
The application on big data analytics for supply chain improvement can help manufacturers to track the exact location of products in real time through the supply chain, as a consequence it has become easier for managers to predict whether the product will be delivered on time to customers.

In everyday operation managers interpret the environmental transformation according to their experience, values and perception. This leads to various types of biases. As suggested by Haselton we have cognitive biases in the "*cases in which human cognition reliably produces representations that are systematically distorted compared to some aspect of objective reality*" (Haselton et al., 2015).
Lately, decision making is moving from an intuitive activity to a more scientific and analytic operation. Consequently the role of cognitive bias in this strategic decision making process is shifting, yet there is an important literature gap on how this transformation is taking form. There are several classification of cognitive biases given by the scientific literature, the most diffused is given by Das and Teng in 1999, they divided human biases in 4 categories: prior hypothesis with a focus on limited targets, exposure to limited alternatives, insensitivity to outcome probabilities and illusion of manageability.
The first group refers to the fact that decision makers often bring their prior bias in the final decisions and their attention may be too focused on a limited set of variables that confirm their initial hypothesis

The second group focuses on the fact that decision makers expose themselves to a limited set of alternatives aimed at achieving a goal. Limiting alternatives is a two phase strategy, it can both be a way to concentrate the strength of the organization in a bright direction, or on the other hand it can be a horse blinder.

The third group represents a tendency of managers to give more relevance to the value of possible outcomes rather than the magnitude of their probabilities (Shapira, 1995).

The last group stands for managers that may underestimate the risk of certain outcomes by relying too much on their expertise and professional skills.

Lyles and Thomas in 1988 proposed a five point model of strategic decision making. Those are the rational model, avoidance, logical incrementalism, political and garbage can. Since different decision processes tend to accentuate particular types of cognitive bias and to understand how cognitive bias influences strategic decision making it is important to analyze all the possible relationships among these cognitive biases with the various models of decision making.

Cognitive biases are not the only kind of biases that can occur, in a study conducted by Danks and London (2017) they analyze in depth the issues associated with autonomous systems, semi-autonomous and the so-called algorithmic biases. Autonomous systems work thanks to algorithms. The scientific literature has raised the doubts of possible biases associated with those algorithmics. It is first of all important to specify that not only those kinds of biases are necessarily negative and moreover underlying that algorithmic bias, when it arises, it is often wanted and calculated by decision makers.

In order to work, computational systems, particularly autonomous ones, need not only hardware and software, but also learning capacity in order to adapt to new scenarios and evolving systems. This learning capacity is given by algorithmics. In many instances autonomous systems are substituting human labor because they tend to be more reliable under many aspects. Still, avoiding algorithmic bias is inevitable and this requires autonomous and semi-autonomous systems to be assisted by operators that can detect and compensate for the various biases (Barocas et al., 2016). Yet this is not an easy task, in fact autonomous systems can be very complex and the outcome of their analysis can be very difficult to be understood. A bias that can arise is the algorithmic focus bias which happens “trough the differential usage of information and the input or training data”. In other words it may be plausible to think that certain types of data won't be compounded in the analysis if those information are not relevant. Another case can be the decision of a firm in using or not legally protected information to assess a decision making situation. So the focus bias can present itself in two typical situations that can be called points of “first choice”: on the one hand we have a legal standard that could be violated or not, while on the other hand one that regards the use of apparently unnecessary additional data. A third possible algorithmic bias regards the processing capacity of an algorithm that can itself be biased in some ways. Those three types of biases regard technical and computational “errors“. Of course this also arises from the usage of those technical tools. A possible mistake can arise from the usage of a model outside its proper applicative area, yet this is not the poor algorithmic bias but more an “user bias”.

As said by Danks and London (2017) “Algorithms with autonomous systems present many “surfaces” through which different types of bias may enter the system”.

It is important to understand the particular types of bias because decision makers can face both sudden issues (problematic bias) by the old son specified filters to better analyze some instances (desired bias). Often desired biases are used to correct other inner biases that can be due to social instances, religion, discriminations and others. But even if operators find a way to correct and neutralize a bias it is not sure that it will result in a positive outcome.

Of course there are cases in which the bias can't be corrected, neither technologically, nor morally, socially or psychologically. Barcocas and Selbst (2016) make this point vivid in the domain of employment discrimination. In cases like that it is hardly impossible to eliminate the generated biases but decision makers have to choose between different algorithms to choose the one that leads to the minor, or less harmful, one.

Several interviews were conducted in order to assess the theoretical framework proposed in the first two chapters. Interviewers asked to remain unknown and a privacy agreement was undertaken, therefore the responders will not be specified.

The four interviewed represent three different divisions of the same firm, Laminazione Sottile group, from the commercial area (responder B and D), the logistic (responder C) area and the R&D department (responder A). From interviews emerged various interesting aspects. Having the firm always been very careful to the world economy's performance the very first investments in industrial technologies 4.0 were made as soon as it was clear that the fourth industrial revolution was started, even before the Hannover fair of 2011. As said by responder B it was between 2008 and 2009 that the firm opened to such investments even though at the time the human role was still crucial because the logistics wasn't yet integrated. Those investments rocked up when the economic incentives and tax benefits were applied by the Italian government during December 2016 with the "Piano nazionale industria 4.0".

The firm has invested in various enabling technologies of the industry 4.0, in particular investments were made in the acquisition and update of machinery and plants but also in the creation of open networks (IoT) that through computers and sensors allow a real time interaction among the various assets of the plant. The main difference on the new plant is the introduction of PLC (programmable logic controller) and CNC (computer with numerical control) that are both interconnected with the firm's informative systems (as400). The PLC allows to monitor in real time various production aspects as the working conditions and the compliance with the parameters, while the CNC allows to integrate virtually the physical machine with the plant. This creates an automated integration of all the production flow both horizontally and vertically.

From the various interviews emerged that the drivers of the various investments in industry 4.0 technologies were linked to four key aspects of the supply chain: quality, quantity, flexibility and speed. Specifically, the aim of improving the quality of output and a product with superior performances, the upgrade of the production process in terms of waste reduction (death time and materials) and a smoother decision process since these technologies allow to deal with a wider amount of data in a much more flexible way and consequently it permits the firm to take more informed decisions in real time.

Speaking of the changes that those investments brought to the firm responder A argued that the operational process didn't suffer any particular transformation in practical terms, each of the production phases has stayed unchanged. What has switched is the quality of the production flow and the role that operators have within the supply chain.

The increased level of information allows much more informed decisions regarding the optimal production mix. Responder B says that this increased awareness enables the commercial division to better understand on which levers move in order to increase sales and profitability. So the strategic decisions are undertaken by analyzing the production capacity and eventual starving issues or bottlenecks. As pointed out by responder B “the standardization of working recipes and the centralization of data through IoT systems bring to a decrease in the uncertainties of the working routines”.

From the interviews we understand that there is a need for upgrading the Das and Teng (1999) “9 proposition theory” since nowadays at least one of the two vectors of the matrix has changed. Strategic decision making in fact is now far from the predictive model, in favor of a more scientific approach: the prescriptive decision making.

It is more proper to talk about the biases that can emerge by human-computer interaction. So by implementing the matrix with another item on the horizontal axes (scientific or data-based approach) as a new paradigm of strategic decision making we can see how the already known cognitive biases are no longer the only threat.

The discussion should be shifted on the algorithms on which this new prescriptive decision making bases its working mechanism. While for quantitative capabilities computers outpace humans, for subjective thinking they still have various defects. So even if it is important to use those tools, it is more important is to maintain a critical perspective on data and to make strategic decisions considering both data and inner rationality since algorithms for some aspects still lack of capacities. So in the current scenario and probably also in the future human interaction can’t be avoided.

Interviewers, when being asked about the main benefits responder C pointed out that within the last 4 years the firm increased their productivity up to 25% thanks to those investments and that nowadays such an improvement allows the firm to face with no fear the global competition. Other important benefits are linked with reduced costs due to eventual human errors in the transcription and set-up of machine requirements since the process is now computerized. When been asked about the necessary skills to compete in the 4.0 industrial scenario responder A argued that it is very important to develop analytic skills to avoid potential biases such as algorithmic one, specifically he said “algorithm and cognitive biases are a tricky field, operators still can fall into distraction or data misinterpretation, therefore it will be very important to implement artificial intelligence and machine learning technologies to let the computer deal each other and limit the human role to strategic and subjective decisions".

For research purpose we will analyze how the 3 area of expertise of the interviewed (commercial, logistic and R&D) have changed due to investments in 4.0 technologies.

A framework to explain the various changes brought by digital transformation can be built on those that within the interviews emerged as the main drivers of 4.0 investments: quality, quantity, flexibility and speed.

By cross-checking the interviewed area with those 4 aspects of innovation we can make a matrix that will generate 7 different prepositions (Figure 3.2).

As reported by responder B "the commercial division has benefited of the new investments in 4.0 technologies as it is now able to pursue a more informed and qualitative strategy especially for medium and short time horizon". The new computational capacity allows decision makers to have a clear picture of the competitive and internal scenario and this brings to the possibility of drafting safer strategic decisions.

"The more the investments in 4.0 based technologies the higher it will be the qualitative level of the commercial division" (preposition 1).

From interviews emerged that the commercial division has now the possibility of setting production and price levels almost in real time. Investments on algorithms and informative systems have permitted the firm to operate in a much more agile way. Responder D argued that Laminazione has now a very flexible structure that allows to compete in the global market and "thanks to the upgrading of the market forecast tools we can now make strategies with real time data"

"The more the investments in 4.0 based technologies the higher it will be the level of flexibility of the commercial division" (preposition 2).

For what concerns the implication of those investments in the logistics responder C argued that thanks to sensors, tracking systems, CNC, as400 and PLC the logistic is now integrated with the rest of the firm operations and with the master production schedule so "it has achieved a more flexible and qualitative level thanks to the possibility of having real time information".

An increased qualitative level is possible thanks to the avoidance of the main source of errors: the data setting. Infact, now machines deals one-another through the as400 informative system and so they have a clue of their role within the production phase and of the materials timing within the transformation process. This communication as previously explained is allowed by introduction of the CNC that are linked to a central plant-computer, those investments allowed to create both an horizontal and vertical integration of the supply chain within the production flow.

"The more the investments in 4.0 based technologies the higher it will be the qualitative level of the logistic area" (preposition 3).

The new level of competitiveness of the firm can also be translated in terms of production. Precisely thank to the complete integration of such a division and the consequent waste reduction of time also quantitative level have been growing in the past years, infact "Laminazione was able to double its productivity level in only 3 years thanks to the new working conditions" (responder C). The new productive level allows now the firm to "compete in the global market without any more fear for Asian competitors".

"The more the investments in 4.0 based technologies the more it will be the quantitative level of the logistic area" (preposition 4).

In the phase of inefficiencies tracking, logistic is now far more rapid in founding out bottlenecks, source of errors or eventual starving issues since is a lot easier to point out those cost source through simulation models and monitors. More over the process of errors tracking is now very changed since decision makers previously "had to find out where numbers came from" while now the link between consequence and source is easily traceable thanks to computers intelligence and centralized information.

"The more the investments in 4.0 based technologies the higher it will be the speed of logistic area" (preposition 5).

Finally for what implies R&D side the benefits were linked to qualitative matters since it is now a more oriented process and to the speed because thanks to digital twin and simulation it is nowadays far easier and cheaper to predict the outcome of projects without having to physically replicate them. So we can say that the quality of research and development benefited the online models of simulation since it reduces the number of attempts that were previously made to introduce new technologies.

"The more the investments in 4.0 based technologies the higher it will be the quality of R&D department" (preposition 6).

For the same matter also the speed of introducing new technologies in the organization is now improved. The reduction of attempts of physically recreating the various intuition led to a tangible reduction of time waste and costs.

"The more the investments in 4.0 based technologies the higher it will be the speed of R&D department" (preposition 7).

As it results from the study the common aspect of the various divisions is the new paradigm of strategic decision making. During interviews infact emerged that all the analyzed divisions of the firms have now less space for subjectivity since data have fulfill a very ambiguous gap of knowledge that previously made the strategic decision making a visionary process. Now thanks to a great step of digitalization decision making is a much more informed process, still there is some room for subjective interpretation and probably, even if reduced there always be, but now it can be said that the new paradigm of strategic decision making is the prescriptive management rather than the visionary one. Data infact have made it possible to move decisions from a much informed and safer perspective.

The increased levels of quality, quantity, flexibility and speed can be translated in terms of augmented competitiveness so to sum up the various propositions identified it can be said that "the more the investments in 4.0 based technologies the higher it will be the level of competitiveness of a firm".

The aim of this work was to analyze the firms' digital transformation process from a managerial standpoint providing a body of knowledge regarding the implication of industrial 4.0 investments for what concerns strategic decision making dynamics, supply chain operations, organizational matters, algorithmic and cognitive biases.

The research work was conducted by combining a traditional literature overview, database support and interview to experts from Laminazione Sottile s.p.a.

The qualitative methodology was adopted to analyze an evolutionary and fluid path, still in continuous development, that couldn't have been captured only with statistical tools; while the literature review was undertaken to provide a body of knowledge on which building the basis for the successive development of the thesis.

I interviewed 4 experts from 3 different area of the same firm in order to have different opinion of a single phenomenon and also to understand how this was reflected on the very different department that a firm have.

As a conclusion of the research work it can be said that there is almost a complete match between the literature review findings and the qualitative methodology (i.e., experts interview) especially for what concerns the applicative area of the 4.0 technologies and the various advantage that firm can gain from those investments. Experts confirmed that the main advantages of the discussed investments were reflected on different aspect of production not always in the same proportion. Generally the advantages were found in terms of quality, quantity, flexibility and speed. But what was interesting is that the drivers of those final benefit were linked with the new possibilities that real time information and centralization of data have brought to the firm.

The operations of the supply chain didn't suffer any particular changes unlike the theoretical framework was suggesting but this could be linked to the intrinsic characteristic of the manufacturing sector. On the other hand strategic decision making has changed a lot, there are unprecedent opportunity and threats in the nowadays industrial scenario and decision makers have to speed up in mastering the matter in order to overperform the competition.