Università
Ca'Foscari
Venezia

Master's Degree programme in

Global Development and Entrepreneurship

Final Thesis

The Digitalization of the Supply Chain

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Matriculation Number: 882949

Academic Year: 2020/2021

SUMMARY

CHAPTER III: THE IMPACT OF SUPPLY CHAIN 4.0

CHAPTER IV: SUPPLY CHAIN 4.0 RISKS: THE PROBLEM OF CYBERSECURITY

INTRODUCTION

Economic and industrial transformations are key processes that for centuries have characterized the economic scenario, driving radical changes that contributed to shape our modern society, not only under a productive point of view but also hugely influencing people culture and every day lives.

As an ongoing process, technological innovation is still the main push factor for industrial growth and progress and it currently expresses itself in the massive phenomenon of digitalization.

Digital transformation is one of the most important and complex issues that companies' management are facing nowadays.

Its disruptive pace is forcing them to model and reprogram their structures and processes in order to be able not to be left behind by competitors and taking the risk of being excluded from the market.

This thesis investigates this phenomenon by focusing on how it is affecting and changing supply chains, with the objective of emphasising the great benefits that it can guarantee to business efficiency, performance and therefore profitability, still without forgetting about difficulties that such a big transformation brings up.

The discussion starts with an overview of Industry 4.0 as the fourth phase of a complex economic progress started in the mid 1700 that gradually contributed to shape our current business world.

Throughout this brief historical presentation it is possible to realize the great difference between the past transformations and the current one, which differentiate itself from the previous for the incredibly high pace at which it is happening and the gap that those who decide to adopt these new technologies enjoy with respect to those who do not.

The second part of chapter one is dedicated to the outlining of the main enabling technologies of Industry 4.0, taking into consideration especially those that are mostly deployed in supply chain activities.

After this first chapter of introduction to the theme, the second one goes deeper into the study of the supply chain by analyzing how each of its most important stages, namely planning, procurement, warehousing, production and transport are affected by these technological changes.

The third chapter will be dedicated to the examination of how these transformations of supply chain activities affect different economic actors and measures.
In particular the attention will be paid to firms' competitive advantage, consumers, workers and global value chains.
The revolutionary trait that characterizes this phenomenon implies that, together with many benefits, also certain issues may arise.
The increasing reliance of firms on digital solutions expose them to the serious threat of cyber attacks aimed at stealing data and information about production porcesses, suppliers and costumers.
Therefore it is becoming always more urgent for companies to provide themselves with advanced protection systems against cyber threats that may cause severe harms in the business functioning.
This problem is presented in chapter four by rapidly defining the emerging issue and its features and then focusing on the characteristics and structure of supply chain attacks, together with a presentation of some guiding principles that enterprises should adopt when managing the cybersecurity problem.

CHAPTER I: INDUSTRY 4.0: A NEW ECONOMIC TRANSFORMATION

1.1. FROM THE FIRST TO THE FOURTH INDUSTRIAL REVOLUTION

Before going deep into the study of the features of industry 4.0's enabling technologies and their impact on shaping a new form of supply chain, it is important to analyze the historical development, from a technological, economic and social point of view, that preceded this "new industrialization".

In fact all the technologies that are currently being adopted by manufacturing firms all over the world are the results of centuries of studies in various fields.

This process started in the midst of 18th century and consisted in four phases, which have been identified by historians as first, second, third and fourth industrial revolution.

1.1.1 THE FIRST INDUSTRIAL REVOLUTION

The first industrial revolution is a process which was initially localized in Great Britain but then became a continental and global phenomenon.

It opened the way to the period, also known as Great Transformation, that consists in the First and Second Industrial Revolution and goes from mid 1700s to mid 1900s.

It brought disruptive innovations, expecially in the manufacturing process, which drove economic transformation from an agrarian to an industrial economy both in Europe and in North America.[1]

It is not easy to set a date for its beginning, because the innovations that characterize it are the result of many years of researches, however we can position it between 1750 and 1840 approximately.[2]

Listing all the things that were critical in triggering this transformation is very complex, although we can clarify it by trying to simplify and focus on the main features, which

[1]O'Brien P., (2006) *Provincializing the First Industrial Revolution,* Working Papers of the Global Economic History Network (GEHN), No. 17/06.

[2] Ashton T.S., (1948), *The Industrial Revolution (1760–1830),* Oxford University Press, London and New York.

were steam technology and its impact on productivity , labour market and living standards of the population.

The steam technology represented the biggest driver to mechanization and industrialization, initially only in the biggest industries of the time, such as coal, textiles and iron, but then it spreaded also in other sectors over the decades.

The steam engine first appeared in 1712 and was created by Newcomen. His prototype completely changed the production processes and was continously improved.

In fact, over the years, it became stronger, lighter and more fuel efficient, till the introduction of the Watt's model.

This invention can be considered as one of the greatest of all time in terms of impact on the economy, because, thanks to the fact that it was easily controllable and reproducable, it launched, what Richard Baldwin in his masterpiece "The Globotics Upheaval calls "happy helix", that is a «self-fueling rising spiral where innovation drove industrialization; industrialization drove innovation; and both of them boosted incomes, which, in turn, fostered innovation and industrialization».[3]

This self-fueling spiral had huge impact on machine tools' production, in fact it allowed to lower the cost of making the machine helping automate production in general.

Automation led to faster and cheaper processes, partly because lower-wage and less skilled workers could handle the work.

Therefore it is clear how the revolution had huge consequences on the labour market, which has been shocked by many sets of push-pull factors that changed the labour demand and supply for good.

These effects depend on the type of sector we are considering; in fact, taking into account the agriculture sector , mechanization and new farming techniques were a strong push factors because they reduced the number of farmers needed.

But, on the contrary, the mechanization of manufacturing was a pull factor, because it made both the output per worker and the industrial output rise steeply.

Another set of push and pull factors are related to the demand side. This dynamic is mostly related to the fact that people tend to change their purchasing criteria as they get

[3]Baldwin R., *The Globotics Upheaval: Globalization, Robotics and the future of work,* Weidenfeld&Nicolson, London, 2019, p.22 e ss

richer. As income rose, people started to spend on new goods, and this extra demand created extra manufacturing jobs.[4]

This concept can be refered to as Say's Law, according to whom «As each of us can only purchase the production of others with his own production, as the value we can buy is equal to the value we can produce, the more men produce, the more they will purchase»[5].

Moreover the Industrial Revolution greatly affected also people living standards.

Cities grew rapidly with no sanitary, building and development plans and worker's very low incomes forced them to live in dark, dirty shelters with terrible hygenic conditions.

This social degradation was connected with the terrible working conditions to which labourers were undergone.

The huge increase of companies' production pointed out the need for capitalists to hire always more and more workers, many of which were children, forcing them to work at terrible and degrading working conditions.

During these decades workers started to unionize and form trade unions, which are associations of workers demanding for more benefits and reform.

Through unions they asked for improved conditions including for women and children, fewer hours and higher wages.

Even though trade unions started to proliferate and workers eventually won their battles, these forms of representation remained illegal until 1825 and even after that year strikes were banned.[6]

Therefore we can define these years as the starting point for labour rights' recognition and protection, although it was all at the very early stages.

Taking all these aspects into consideration we can state that the Great Transformation represented the start of modern globalization and growth.

From the early 1800s, due to the applications of the great innovations brought by the Transformation, the volume of international trade started to rise enormously and countries' economies became more and more interconnected.

The relationship between globalization, innovation and growth is quite simple.

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[4] Baldwin R., *cit*, p.25

[5] Jean Baptiste Say, (1834) *A Treaties on political economy*, Grigg and Elliot; this translation from Guy Routh, (1989) *The Origin of Economics Ideas,* Springer,

[6] Mohajan H.K., (2019) *The First Industrial Revolution: Creation of a New Global Human Era*, Journal of Social Sciences and Humanities Vol. 5, No. 4, pp. 377-387

Exports reduced the constraints imposed by the domestic market and this boosted the demand for innovation and, consequently, also the supply of innovative ideas.
So, international trade made innovation easier and sales more profitable.
This growth process kept accelerating to such an extent that, in the latter part of 1800s, it has been given a name: the Second Industrial Revolution.[7]

1.1.2. THE SECOND INDUSTRIAL REVOLUTION

The "happy helix" mentioned above reached a new peak in the second half of the 1800s. This phase is called Second Industrial Revolution and lasted from 1870 to 1914.
Like the first one it started in the United Kingdom, Germany and the United States and then it spreaded both to other european countries such as France and Italy and worldwide, for example in Japan.
This Second Revolution was founded on the innovations introduced during the previuos years, in fact as machinery got more sophisticated, power got cheaper and science was increasingly applied to industrial matters
A whole new group of industries emerged, such as railroads, telecommunications, electric lighting, internal combustion engines, road vehicles, aircrafts and industrial chemicals.
However the innovation not only brought these new industries to life but also improved the functioning and efficiency of exsisting ones.
For what concerns the latters the main improvements are related to the adoption of innovative models that allowed capitalists to increase the scale and speed of production and at the same time decrease its costs and work force requirements.
On the other hand when analyzing the formers we witness a different path, in fact these sectors evolved themselves during these years, and for this reason, we do not see the development of an already existing model, but rather the creation of a brand new industry.
One of the main examples of this is electricity.
The basis for its practical use in technology are represented by Michael Faraday's research on the magnetic field, which paved the way to the definition of the concept of the electromagnetic field in physics.

[7] Baldwin R., *cit*, p.29

It is, by many, considered as the most important technological and industrial achievement of the 20th century, because it dramatically changed both production processes and people lives.

Before 1870 electricity was not available in houses and offices and the population was forced to live in dark and smoky dwellings.

However this phenomenon rapidly expanded and by the end of 1880s it reached almost all houses, factories and means of trasport and communication. [8]

The other important innovations affected the transportation and communication sectors, forever changing the way in which people, both phisically and emotionally, reached others.

For what concerns transportation the main modernisations were related to automobile, railroads and airplane construction.

Development of steel and oil industries allowed to create more sophisticated engine systems, which guaranteed higher efficiency and security, such as the Diesel one invented by Rudolph Diesel in 1897.

This, together with the reduction of automobiles prices due to the introduction of Ford's mass production system, increased the diffusion of car usage which became affordable by most of the population.

Other huge changes affected also the train and and airplane transportation, which, as well as automobile, started to spread always more.

During these years railroad became safer, faster and more comfortable due to the great improvements in steel, which was cheaper and strenghter at the same time.

These new characteristics made it possible to use it to construct railroads which covered a much longer distance than iron rails.

For example, data show that by 1850, about 14,000 km, in 1870, about 17,700 km, and by 1880 about 120,675 km of rail lines had been built in the USA.[9]

Moreover we can date in these decades also the invention of the first airplane, by Oliver and Wilbur Wright who are generally credited with inventing, building and flying the first successful airplane.

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[8]Smil V., (2005). *Creating the Twentieth Century: Technical Innovations of 1867–1914 and their Lasting Impact.* Oxford; New York: Oxford University Press.

[9]Chandler A.D., (1981). *The Railroads, the Nation's First Big Business: Source and Readings*. Ayer Company Publishers, Inc., New York.

This very raw model was then developed over the years and by 1919 engineers were able to construct the first vehicle capable to offer the first regular passenger air service.
On the other hand, for what concerns communication, the invention of the telegraph and the telephone allowed businesses to establish long distance relationships very quickly and send informations to governments, clients and private citizens.[10]
All these innovations driven by automation and globalization, fueled a sustained economic growth, which did great things to companies' preformances and efficiency people lives.
However at the same time, growth does not bring exclusively benefits with it.
In fact growth means change, and change means pain.
The main routes of change outlined by growth were four: shift of workers out of agriculture to industry, shift of population from countryside to cities, a rise in inequality and a shift of the anchor of value from land to capital.
These changes were so radical that they drastically transformed long defined social traditions.
The main result of the disintegration of the existing social structure were backlashes.
Starting from the mid of 1800s a series of revolts took place all over Europe, most of which are dated 1848.
Despite these violent riots little changed concretely in States' governance.
The year was considered, as Richard Baldwin recalls, «the turning point at which modern history failed to turn».[11]
To see the real backlashes to this transformation we need to wait until 1920s instead; meaning communism, fascism and Franklin Delano Roosvelt's New Deal which paved the way to the creation of our current modern society.

[10] Haradhan K., *The Second Industrial Revolution has Brought Modern Social and Economic Developments*, in "Journal of Social Science and Humanities, January 2020
[11] Baldwin R., *cit*, p.30-40

1.1.3. THE THIRD INDUSTRIAL REVOLUTION

The Third Industrial Revolution set off the beginning of the so called Second Great Transformation, which includes also the current new phase known as Fourth Industrial Revolution.

It started after World War II and ended approximately around 2012 when the first prototypes of industry 4.0 technologies were introduced.

This new transformation was not as radical as the first one but it reshaped the economic and social realities in what we call “post-industrial society”.

The causes that triggered the beginning of this new economic era are mainly related to the increase, development and accumulation of scientific and technical knowledge that started with World Wars and continued during the Cold War.

Moreover these decades were distinguished by a condition of peace between super powers, at least in Western countries, and this encouraged the proliferation of technological innovations.

The most remarkable innovation introduced by this Revolution is Information Communicaton Technology.

ICT refers to three sectors that started developing during these years:

- Electronics: focuses itself on using electricity to process informations through machines. The biggest milestones of this science are the invention of radio, television and personal computer;
- Telematics: this science deals with the broadcasting of information to more users using media and telecommunications. Its development promoted the introduction of modern communication netwroks, including the Internet;
- Information Technology (IT): refers to the exploitation of technology to elaborate, analyze and process informations.

These innovations have been employed both to empower existing industrial sectors and to develop new ones.

In factories these technologies made machinery more flexible, meaning that, by programming them, they could have been used to perform more than just one task, especially those purely manual and repetitve.

This had a dramatic impact on factory employment.

In fact these new technologies pushed workers out of manufacturing and pulled them into offices, triggering a rapid growth of the service sector and launching into the tertiarization process.[12]

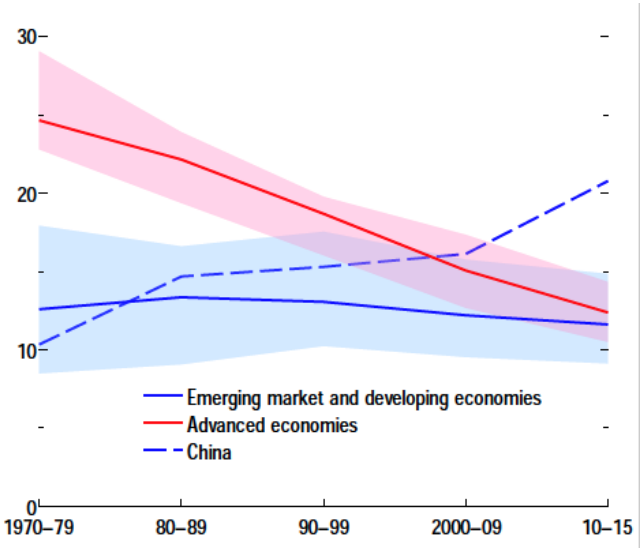

Figure 1. Manufacturing employment share (https://voxeu.org/article/declining-share-manufacturing-jobs)

Together with this set of industrial and technological innovations, from these years on, the environmental and climate issues become key to people and institutions.

This concern materialized in the formation of protest movements supporting environmental awareness and demanding governments to take action on these matter.

As for the previous Revolutions its consequences were not only beneficial for people; in fact these years saw a dramatic increase in income inequality, especially in the United Kingdom and USA, where the difference between riches and poors has become very pronounced.

The earning power has been decreasing since the 1970s in both countries; in particular the average US man working full-time earned $53.000 in 1973 and only $50.000 in 2014 inflation-adjusted, while in Britain the share of the national income going to the top bracket more than doubled from 6% to 14%.

The causes are many and complex but technology surely played a role.

[12] Baldwin R., *cit*, p.58-61

The job polarization meant that people with higher levels of education started with higher incomes and saw them increase esponencially.
While for lower educated people this process was reversed and they saw their income go even lower.
Since there are a lot of people in the low education category this pattern created a enormous gap between high and low income bracket.
So the combination of income stagnation, distruction of industrial jobs and decimation of those communities which were built around manufacturing hubs led to very bad backlashes.
The main ones are to be identified in the Trump election in 2016 in United States and in the Brexit.
They can be both traced down to a common feeling of injustice and betrayal that pushed people to desperately search for change, which, for Americans meant going for a man who based his campaign on patriotic and combative slogans promising strength, order and economic growth built on free markets and private entreprenership, while for Britains meant deciding to leave the European Union.[13]

1.1.4. THE FOURTH INDUSTRIAL REVOLUTION

In the last decade we are witnessing the emergence of a new era called Fourth Industrial Revolution.
Even if the innovations that characterize it are still in the field of digitization and IT, this period can not be considered as a mere prolongation of the Third Industrial Revolution but rather the beginning of a Fourth one.
This can be explained by three reasons:

- Velocity: it is evolving at an exponential pace with a speed that has no precedent;
- Scope: it is affecting and disrupting every industry in every country;

[13] Baldwin R., *cit*, p.72-79

- Systems impact: the breadth and depth of its changes lead to the trasnformation of entire systems of production, management and governance.[14]

This Revolution, as for the previous ones, takes advantage from the innovations introduced during the preceding centuries, which are used as a sort of raw model to be further developed.

The innovations that distinguishes it can be grouped into three main clusters of megatrends, all of which share a great dependence on digital power and degree of interrelation thanks to which the various technologies benefit from each other based on the discoveries and progress each makes.

These clusters are:

- Physical: refers to the physical manifestation of the adoption of these technologies such as robotics, 3D printing and automation in general;
- Digital: one of the main examples of the digital application of 4.0 technologies is Internet of Things, which represents a connection between physical and digital employment enabled by the Fourth Industrial Revolution. Moreover we can include in this category also Cloud Computing and Big Data Analytics;
- Biological: refers to those set of innovations applied to biology and genetics in particular, that has made considerable progress in increasing the efficiency by reducing costs and improving outcomes.[15]

These innovations have the potential to influence and dramatically change not only people lives but also business.

In fact these technologies not only widen the range of products and accuracy a company can offer but also transform costumers' expectations.

While for the first implication it is more straightforward to understand the linkage and impact that, for example, Additive Manufacturing can have on the production capacity of a company, enabling cost reduction and more precision, the same does not happen when analyzing the second one.

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[14] Schwab K., *The Fourth Industrial Revolution: what it means, how to respond*, in World Economic Forum <https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/> (2016)

[15] Schwab K., *The Fourth Industrial Revolution*, World Economic Forum, <https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/> 2016

In fact these technologies have the power to enable a real experience for costumers, who can benefit from personalized and more valuable products.

It is therefore key for companies to exploit the whole range of opportunities offered by these innovation, focusing not only on the mere production phase but also to other collateral aspects such as costumers, who represent the real "heart" of a firm.[16]

Like precedent Revolutions also this one brings both opportunities and challenges.

For what concerns the former they can be summerized by referring to its potential to increase income levels and improve life conditions of people all over the world.

As for the latter instead, as economists Erik Brynjolfsson and Andrew McAfee have pointed out, the Revolution could cause greater inequality, particularly due to its potential to disrupt labor markets.

Even if it is still unclear whether the disruption of the labor market will have positive or negative implications, it will certainly lead to a segregation of the market into "low-skill/low-pay" and "high-skill/high-pay" segments.[17]

As well as being a crucial economic concern, inequality is also the greatest social concern related to the Fourth Industrial Revolution.[18]

Even though it is still not clear which form will it have or who will the target be, it appears to be evident that social tensions and discontent generated by the challenges that these technologies introduce will lead to some kind of backlash.

[16]McGinnis D., *What is the Fourth Industrial Revolution?*, in Salesforce, <https://www.salesforce.com/blog/what-is-the-fourth-industrial-revolution-4ir/> (2020)

[17]Brynjolfsson E., McAfee A., *Race Against the Machine, Lexington-Massachustess*, Digital Frontier Press, 2011

[18] Schwab K., *The Fourth Industrial Revolution: what it means, how to respond*, in World Economic Forum <https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/> (2016)

1.2. DEFINITION OF INDUSTRY 4.0

The term Industry 4.0 is used as a synonym for the Fourth Industrial Revolution and it has been introduced in 2011.

It was coined at the Hannover Fair, in Germany, as a proposal by a team of experts, which has been further developed in the upcoming years and presented to the Federal Government in 2012.

This paved the way to the implementation of the Industry 4.0 Plan, that has been disclosed at the same Fair the following year together with a report that explains all the necessary forcast investments on infrastructures, education and energy systems, businesses and research in order to modernize the german productive system.[19]

Therefore we can say that Germany is considered to be a kind of pioneer in this transformation however this concept spreaded rapidly and inspired the majority of the countries around the world.

In fact most of them, especially the industrialized ones, have adopted a similar plan themselves.

In particular we can mention United States, France and Italy.

All of them have drafted plans which are focused on granting public support to business research programms as well as fiscal and financial incentives to push private investments on technological start-up and R&D innovation.

This term identifies a tendency towards industrial automation that integrates some new technologies in order to improve working conditions and increase productivity.

They key aspect of Industry 4.0 are, therefore, Cyber-Physical Systems (CPS) which are physical systems strongly connected with IT ones and able to cooperate with other CPS.[20]

The collaborative trait of these systems is, in fact, one of the most important aspects to be underlined when discussing the disruptive and winning potential of this transformation.

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[19]Zanotti L., *Industria 4.0: storia, significato ed evoluzioni tecnologiche a vantaggio del business*, in Digital4, <https://www.digital4.biz/executive/industria-40-storia-significato-ed-evoluzioni-tecnologiche-a-vantaggio-del-business/> 13 March 2021

[20]https://www.industry-4.it/cos-%C3%A8-industria-4-0/#:~:text=Il%20termine%20Industria%204.0%20%C3%A8,implementazione%20del%20Piano%20Industria%204.0

As defined by experts from Boston Consulting Group and McKinsey Institute, when talking about smart manufacturing this collaboration generates great changes in three different scopes that are: Smart lifecycle management, Smart supply chain and Smart factory.

The Smart life cycle management refers the whole product's development process, including the management of its life cycle that can be carried out using these advanced technologies.

The Smart supply chain refers to applying CPS to supply chain management and will be further analyzed throughout this thesis.

The Smart factory is a more general perspective that embraces the whole governance related to services and infrastructures instead.[21]

Specifically it can be grouped in three different levels:

- Smart Production: new productive technologies that allow all the elements involved in the production process, i.e. machines, tools and operator, to collaborate with one another;
- Smart Services: IT infrastructures that enable companies to work together with external structures, such as hubs, waste management and roads;
- Smart Energy: refers to the attention payed to make sure that these new cooperative systems are more environmentally friendly and have a higher performance at the same time.[22]

The great potential of Industry 4.0 can be summarized in five main characteristics:

- Flexibility: greater flexibility through the production of small batches at large scale costs;
- Speed: the process that allows the transformation of the prototype to the final product becomes quicker thanks to these technologies;
- Productivity: higher productivity due to shorter set-up times and fewer mistakes;
- Quality: higher quality guaranteed by sensors that monitor the production in real time;

[21]Zanotti L., *Industria 4.0: storia, significato ed evoluzioni tecnologiche a vantaggio del business*, in Digital4, <https://www.digital4.biz/executive/industria-40-storia-significato-ed-evoluzioni-tecnologiche-a-vantaggio-del-business/> 13 March 2021

[22]https://www.industry-4.it/cos-%C3%A8-industria-4-0/#:~:text=Il%20termine%20Industria%204.0%20%C3%A8,implementazione%20del%20Piano%20Industria%204.0

- Competitiveness: the product becomes more competitive due to the enhanced functionality brought by digitized processes.

These properties make this transformation one of the most impactful breakthorugh of the last decades, disrupting and improving business processes for good.

1.3.INDUSTRY 4.0 ENABLING TECHNOLOGIES

Industry 4.0 is not represented by a single set of technologies rather it is the result of the cooperation among different CPS.

In fact many kind of advanced technologies are utilized to reach the concept of smart factory analyzed above.

The Boston Consulting Group have identified eight technolgies that are: Big Data, Internet of Things, Cloud Computing, Robotics, Additive Manufacturing, augmented reality, Cybersecurity and simulation.

Below the first five of those listed above will be in-depth investigated.

1.3.1. BIG DATA AND ANALYTICS

IT systems have become broadly incorporated in our daily life and all of them, included software and devices generate a certain amount of data.

Examples of data are for instance for what concerns mobile technologies phone call registry, messaging and location sampling, while speaking about the business world we can get prices moves, bids and offers and costumer preferences.

In general, Big Data have been defined by many authors, first of all by Garnter in 2001 and later updated in 2012, as « high-volume, -velocity and -variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making»[23]

This definition can ben splitted into three main dimensions.

The first one is related to the so called "3 V's", which refers to Data Quantification.

The 3Vs are:

- Volume: it represents physical volume of data, which is constantly growing in latest years. They are generated by heterogeneous sources such as sensors, logs, social media, e-mails and traditional databases;
- Velocity: refers to the speed at which these data are generated and need to be analyzed. This characteristic is also about the rate of data change. Some data in fact can change right after being created, so it is important that they are promptly

[23]Beyer M., Laney D., *The Importance of Big Data: A Definition*, in Gartner < https://www.gartner.com/en/documents/2057415/the-importance-of-big-data-a-definition#:~:text=%22Big%20data%22%20warrants%20innovative%20processing,Published%3A%2021%20June%202012 > 21 June 2012

processed through real-time analytics in order to extract the correct information. For this reason this dimension is also known as "Volatility";

- Variety: refers to the different types (textual, numeric), structures (structured, semi-structured and unstructured) and formats of data that are generated, gathered and processed. This great diversity requires companies to adopt sophisticated analytical systems which have an architecture and technologies that allow them to capture this heterogeneity. Within this dimension we can include also variability. It refers to the fact that there may be inconsistency in data flow since they can vary over time.[24]

Later on, after further research on the topic, other two V's have been added to the aforementioned list, that are:

- Value: it refers to the worth of the data extracted. Since embarking on a Big Data initiative requires huge investments, it is important to understand costs and benefits of the process and ensure that the data that is reaped can be monetized;[25]
- Veracity: refers to data quality and its reliability. In fact Big Data can represent a powerful tool for companies to improve their performance provided that they are of a considerable volume and value.

The second dimension is related to the ability of Big Data analytics to guarantee an innovative and cost-effective form of data processing.

This result is achievable thanks to its capability to store and process unstructured data, link various types of data and to perform comprehensive analysis.

Last, the third dimension refers to the fact that analyzing data allows companies to extract information and use them to make reasonable and efficient decisions.

Therefore, this dimension is the most relevant for business value creation.[26]

The benefits that this phenomenon brings to businesses can be summarized in three main categories:

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[24]Sicular S., *Gartner's Big Data Definition Consists of Three Parts, Not to be Confused with Three V's,* in Forbes, < https://www.forbes.com/sites/gartnergroup/2013/03/27/gartners-big-data-definition-consists-of-three-parts-not-to-be-confused-with-three-vs/?sh=3e27099342f6 > 27 March 2013

[25]Cano J., *The V's of Big Data: Velocity, Volume, Value, Variety, and Veracity*, < https://www.xsnet.com/blog/bid/205405/the-v-s-of-big-data-velocity-volume-value-variety-and-veracity> 2014

[26] Sicular S,, *Gartner's Big Data Definition Consists of Three Parts, Not to be Confused with Three V's*, in Forbes, < https://www.forbes.com/sites/gartnergroup/2013/03/27/gartners-big-data-definition-consists-of-three-parts-not-to-be-confused-with-three-vs/?sh=3e27099342f6 > 27 March 2013

- Cost reduction: new technological developments of Big Data allow for significant cost advantages for both the expense and ability to store large quantities of data;
- Improved decision making: due to the increased processes, data can be speedily investigated and internalised and all businesses have the tools to immediately understand both the state of the overall industries and competitors. Moreover these prompt informations can be used to make more accurate and consistent future projections, enabling for a better risk handling;
- New products and services: these advanced research and analytical methods are able to isolate cosumers' wants and needs while combining them with their expected satisfaction level so that the company is able to aknowledge what is the excat right product for a certain client. Thanks to Big Data, always more companies were able to innovate and create new products on a constant basis.[27]

It is therefore crucial for companies to adopt advanced technological processes to analyze and process data, so that to be able to extract the greatest value possible from the huge amount of data produced everyday.

1.3.2. INTERNET OF THINGS

The Internet of Things concept refers to a set of technologies that allows physical devices to connect to the internet.

This connection enables them to exchange information in order to improve their effectiveness and productivity.

Many definitions have been given of this phenomenon, two of the most famous are the following.

According to Gartner IoT is «the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment.»[28]

[27] *Why is Big Data so Important?*, in European Business Magazine, <https://europeanbusinessmagazine.com/editors-choice/big-data-important/> (4 November 2020)
[28] Gartner Glossary, <https://www.gartner.com/en/information-technology/glossary/internet-of-things>

Instead the European Research Cluster on the Internet of Things provides a more complex definition that states that the IoT is «A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network.»[29]

Some common characterstics can ben identified in both of these views:

- Interconnectivity: Iot allows to interconnect anything with the global information and communication infrastructure;
- Things-related services: this technology is able to provide «things-related services within the constraints of things». An example might be privacy protection;
- Heterogeneity: IoT devices are heteregenous because they are based on different hardware platforms that interact with each other through different networks;
- Dynamic changes: both the state and the number of devices can change dynamically, i.e. connected and/or disconnected ;
- Enormous scale: the number of devices that need to be managed is huge. Since all of them generate a certain amount of data, data management and interpretation becomes critical for the success of IoT systems' application. Therefore it is obvious that IoT and Big Data are strongly interconnected.[30]

Worldwide spending on IoT has been expected to rise for the last couple of years, even if it has been significantly impacted by the economic effects of the COVID-19 pandemic in 2020, which forced many organisations to pause their IoT development.

Most of them operate in those industries which have experienced the most severe downturn casued by the pandemic, i.e. the tourism industry such as hotels, restaurants and park which were the only one to register a decline in IoT investments of 0.1%.

However despite the struggles of the aforementioned sector, in general, studies have showed that IoT spending has kept growing.

[29] IERC, *Internet of Things – From Research and Innovation to Market Development*, River Publishers, 2014

[30] IERC, *Internet of Things – From Research and Innovation to Market Development*, River Publishers, 2014

In particular, IDC research has showed that investments in IoT have been growing 8.2% year over year reaching 742$ billion in 2020 and is expected to achieve a compound annual growth rate of 11.3% by 2024.[31]

Similar studies have been carried out also by Statista predicting the IoT market to reach $1.6 trillion by 2025.[32]

The main characterstic of this tendancy is that it is not focused exclusively on a single industry or user, but it is permeating many business sectors and homes.

The many IoT applications can ben divided into the following categories:

- Connected vehicles: refers both to self-driving vehicles and traditional ones which have been updated through the installation of connected devices that allow to monitor the performance and manage the system itself;
- Traffic management: roadway infrastructure has become more and more coonnected in the last decade. Sensors, cameras and smartphone apps have been introduced in order to manage the traffic and also monitor the state of the structural health of bridges and roads, helping ensure a safe travel to drivers;
- Smart grids: IoT technologies can also bring efficiency and resiliency to to energy grids. Utilities can analyze real-time data transmitted by connected devices in order to prevent blackouts and, at the same time, individual costumers and businesses can use these systems to identify their consumption pattern and identify ways to improve the efficiency of their grid;
- Environmental monitoring: connected devices can collect data related to the quality of air, water, soil, weather and other environmental data. This can help both government agencies to predict natural disasters and better protect wildlife through appropriate policies and companies to be more in control of their carbon footprint and weather conditions that affect their business;
- Smart building and homes: IoT technologies can also be installed both in commercial buildings and in homes. As for the former they help to monitor the state of the infrastructure to ensure efficiency, comfort and safety. Instead, for

[31] IDC, *Worldwide Spending on the Internet of Things Will Slow in 2020 Then Return to Double Digit Growth according to a New IDC Spending Guide*, <https://www.idc.com/getdoc.jsp?containerId=prUS46609320>, 18 Jun 2020

[32] Vailshery L.S., *Forecast end-user spending on IoT solutions worldwide from 2017 to 2025*, on Statista, <https://www.statista.com/statistics/976313/global-iot-market-size/>, 22 Jan 2021

what concerns the latter, it refers to smart technologies such as door locks, appliances, thermostats and smoke detectors;

- Smart cities: in this context IoT technologies are deployed across many facets and help the city management to collect real-time data that provides insights that the city management can use for better decision making and greater efficiency, effectiveness and safety for their communities;
- Supply chain management: informations gathered by connected devices such as sensors and GPS allow companies to manage and control their delivery requirements and shipping times;
- Industrial, commercial and agricultural management: refers to the fact that IoT technologies can be adopted in a very wide range of sectors.[33]

If we focus on IoT business applications we can identify five major ways in which it is transforming companies operational pattern:

- Improved business insights and costumer experience: connected equipment is creating more data streams meaning that companies are now having greater insights into their business operations and costumer habits. This is crucial for companies because being able to fully understands cosumers' needs and expectations allows them to better satisfy them. Doing this they can enhance the chances to ensure costumers' loyalty and therefore improve their performance;
- Cost and downtime reduction: connected devices allow to predict future failures and prevent them avoiding long downtimes that can negatively impact company's perfomance;
- Efficiency and productivity gains: by connecting a company's key processes, entrepreneurs can spot inefficiency and fix them;
- Waste reduction: by using IoT tracking systems it is possible to eliminate waste and inefficiencies in the supply chain. Especially for companies that have a very complex supply chain it is common that certain items, both related to the assembly components and final product, get lost along the process. So being able to track them almost eliminates the risk of wasting them;

[33]Pratt M.K., *Top 8 IoT applications and examples in business*, on IoT Agenda, <https://internetofthingsagenda.techtarget.com/tip/Top-8-IoT-applications-and-examples-in-business>, 6 Apr 2021

- New business models: connected devices allow companies to collect huge amount of data which provide insightful information about costumers' needs and expectations. This helps businesses to find new opportunities for the adoption of new revenue streams and business models which are focused on maximizing costumers' satisfaction.[34]

1.3.3. ADDITIVE MANUFACTURING

Another example of 4.0 technology is Additive Manufacturing, also known as 3D printing.

This term makes reference to the production process carried out following a method, which, starting from a virtual model, puts together different sheets of material by layer. This process is a mix of many techniques, which differ according to the materials and product to be produced.

This kind of technology has been existing for some decade now but it is just on the last few years that the opportunities to use it have expanded thanks to its broader adaptability and capability to print larger objects, such as real industrial product, made of a wide range of materials at a cost which is continously decreasing.[35]

Therefore it is nowadays widely used in many sectors, from the medical to architectural to aerospace to industrial.

Going for this type of production process might not be a successful decision for all companies, it is in fact important to perform a detailed trade-off analysis which weights all pros and cons.

The benefits related to the adoption of 3D production are many:

- Great array of materials can be used which made it possible for this technology to be utilized in many sectors;[36]
- Reduces material waste because only the strictly needed amount of raw material is used;

[34] Hobbs A., *Five ways the Internet of Things is transforming businesses today*, on Internet of Business <https://internetofbusiness.com/5-ways-the-internet-of-things-is-transforming-businesses-today/>, 2018

[35] CENTRO STUDI CONFINDUSTRIA, *La manifattura additiva. Alcune valutazioni economiche con particolare riferimento all'industria italiana*, Scenari industriali, 5, 2, 1- 23, 2014

[36] PETROVIC, V., GONZALEZ, V.H., FERRANDO, O.,GORDILLO, G.D., PUCHADES, R.B. & GRINAN, *Additive layered manufacturing: sectors of industrial application shown through case studies*, International Journal of Production Research, 49, 4, 1061– 1079, 2011

- Production times are very short. This represent an important advantage for companies because they are able to process a higher number of orders a day improving the effectivenness of their internal processes and, at the same time, increase costumer's satisfaction by providing them with a higher quality service;
- 3D printers are reliable and easy to use. This reduces the risk of incurring in failures and errors during the production process so that it will not be necessary to reproduce the product, avoiding further material waste and costs.

Despite the huge set of advantages that this set of techniques guarantees, it has also some disadvanatges, due to which many companies struggle to find their way through it. Some of these cons are, for example:

- High production costs especially related to the equipment needed to support it;
- Limited component in size:. In fact modern 3D printers' ability is limited to moderate sized objects. This prevents companies that produce big items to incorporate it in their production process;
- Limited mechanical properties that impede to mix different materials and components or add them in progress;
- Qualified workers that have specific skills in running this process. Since its adoption in production is relatively recent it is not uncommon to find mature workers who are not updated to the latest innovations. Therefore it will be on the company to finance and support their professional development.[37]

Even if there is still a lot of work to do before it becomes the standard in the industry, especially on a technological point of view, we can say that additive manufacturing represents one of the future trends of manufacturing and it is important for companies to introduce it into their process in an appropriate way so that to enjoy its great set of benefits.

[37] Baldassarre F., Ricciardi F., *The Additive Manufacturing in the Industry 4.0 Era: The case on an Italian FabLab*, Journal of Emerging Trends in Marketing and Management – Vol I, No. 1/2017, 2017

1.3.4. ROBOTICS AND AUTOMATION

During the last decades the market has become more and more competitive forcing companies to always improve their ability to actively and promptly face these challenges.

Automation has represented a strategic answer to the need of taking frequent smart decisions in an evolving economic scenario.

Robotics and industrial automation play a key role in this context and help companies to enhance their productivity and efficiency.

Their range of application is very wide and comprehends various industries, such as:

- Manufacturing: the adoption of automative processes and robots are one of the key features of the modern smart factory;
- Health care: robots are employed in many ways when it comes to health care. For example in the medical sector, such as for surgery, and in the pharmaceutical one in drugs preparation;
- Military and public safety industry: drones are frequently used in battlefield support and to provide real time analysis of of risky situations;
- Retail and supermarkets: many malls, such as Wallmart, are starting to use robots as surrogate in-store shopping assistant and inventory managers that spot when a product is out of stocks and deals with its supply process.

Regardless of its field of application, automation and robotics guarantee important benefits to the sector, which are for example:

- Money and time save: robots can operate 24/7, increasing production and decreasing downtime. Moreover they allow savings in labour costs and price reduction, which can lead to sales enhancement;
- Scalability: they can be easly and rapidly reprogrammed for new tasks;
- Ease of program: they can be easly programmed using simple methods;[38]

Therefore it is nowadays visible in this context the coexistence and collaboration of robots and humans in the same working environment.

[38] *Why Robotic Automation is the Future of Manufacturing?*, <https://www.automate.org/blogs/why-robotic-automation-is-the-future-in-manufacturing>, 25/06/2019

If, on one hand, this may represent a positive aspect because robots can take over some repetitve and mechanic tasks that workers used to perform allowing them to focus on those tasks that require a really require a real person.

Instead, on the other hand, many believe that this trend is gradually destroying many jobs.

Even if there is evidence that this tendancy will creat huge job displacement, especially in office jobs, it is still not clear whether this will be outweight by a correspondent job replacement.

It is, in fact, true that digitech can also have a positive impact on labour market creating new jobs. This perspective can be explained following three main reasoning illustrated by Richard Baldwin in his work "The Globotics Upheaval", which are:

- Online activity is creating a massive explosion of data which are of such a magnitude that is out of worker's control and for this reason need the support from AI. Still, machines will not be able to deal with particularly tricky situations which will require human intervention. And since the work is exploding, the demand for humans employed in these oeprations will increase;
- Many digitech services are free and therefore this encouarges people to intensively use them. The great demand for online and digital related services pushes firms to hire new people to look after robots and do more human-specific tasks such as management, accounting and human resource management;
- New jobs can be created also by reshoring back-office jobs that had been off-shored years ahead, most of which will be replaced by robots but at the same time will require human capabilities and knowledge to be controlled and to handle problems.[39]

In order to have a real feedback and attainable data we need to wait until this process largely takes place.

[39] Baldwin R., *cit*, p.152-163

1.3.5. CLOUD COMPUTING

Cloud computing is the industry 4.0 enabling technolgy that deals with the storage and management of the huge amount of data produced by digital devices.

It is considered the key element to develop an innovative production strategy by leveraging sensors, artificial intelligence and robotics.

In fact it provides companies with the widest range of computing power needed to identify and exploit new business opportunities.

For this reason many companies are nowadays leaning towards new organisational settings, which are based on the idea of collaboration along the whole supply chain in order to increase competitiveness and efficiency.

An example of this which is gaining greater attention is Cloud Manufacturing.

It is a particular business model that enables businesses to virtualise production resources which become consumable via the Internet.

According to this model production and maintanace costs are allocated across the supply chain, allowing all palyers to benefit from the advantages.

These advantages can be particularly relevant for SMEs which can finally have access to a flexible storage and processing capacity without incurring in the cost of establishing an internal data centre.[40]

These benefits can be for example:

- Cost reduction: reduction of costs related to the IT infrastructure and its maintanance;
- Flexibility and scalability: cloud services can be installed and deleted very quickly once a performance limit is spotted;
- Service quality: cloud systems require specialists that constantly update and maintain the infrastructure. This guarantees that the quality of the service is maintained at a very high level;[41]

However the adoption of this technology still finds many industrial operators reluctant to move their data to the cloud; and these doubts are mainly connected to the major cons that it has.

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[40] Red Reply Group, Report on *How to take advantage of cloud computing for industry 4.0 and enterprise 4. 0*

[41] Wogawa A., *Industry 4.0: Pros & Cons of cloud computing in Smart Manufacturing*, <https://www.systema.com/blog/industry-4.0-pros-cons-of-cloud-computing-in-smart-manufacturing>, 16 September 2020

Among the disadvantages we find, above all, concerns about privacy and security issues.

It is, in fact, impossible for users to have full control over their resources and processes which are constantly subjected to the risk of cyberattacks.

Therefore it is important that companies mitigate this risk with the most appropriate plans and strategies.

CHAPTER 2: THE DIGITAL TRANSFORMATION OF THE SUPPLY CHAIN

2.1. THE EVOLUTION OF THE SUPPLY CHAIN

Supply chains have been existing since forever but they have been experiencing an evolution path characterized by an increasing level of complexity, which have reached an unprecedented peak, especially in the last fourty years.

This topic started to be investigated in the 80's and reached its greater popularity the following decade.

In fact, before that, companies tended to focus on traditional logisitc management which primarly used to deal with the optmization of internal flows, avoiding to take into account the influence that the external networks have on firm's performance.

During the last decades many definitions of supply chain have been given; generally we can define it as a system of activities concerning good's creation, starting from raw materials to the final product, including materials supply, production, assembly, storage, inventory and orders management, distribution and delivery to the final client, as well as the management of all the collateral information systems necessary to control all the aformentioned activities.[42]

The supply chain is formed of at least two indipendent entities which cooperate in the products, services, information and money flows management to deliver the final product to the client minimizing inefficiencies and those activities that do not add a proper value to the process.

The ultimate aim of all the members of the chain is to maximize costumer expectations and the value created by it is not equally distributed among the players, rather each company competes to extract the highest portion possible of it.

One of the intrinsic aspects of the supply chain is the concept of integration.

In this context, when we speak about integration, we are referring to the horizontal one, which is related to the quality of collaboration and strategic integration of processes, focusing on how partners cooperate to achieve mutual benefits.[43]

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[42] Quinn F.J. (1997), *What's the buzz?*, Logistics Management, Vol. 36.

[43] O'Learly-Kelly S., Flores B. (2002), *The integration of manufacturing and marketing/sales decisions: impact on organizational performance*, Journal of Operations Management, Vol. 20 No. 3, pp. 221-240

This framework differentiates itself from the more traditional one of vertical integration presented by Porter, which is about the number of activities and transformations carried out internally.

According to Porter's view and as showed by the following figure, broader the internal process, more vertically integrated the company and shorter the supply chain.

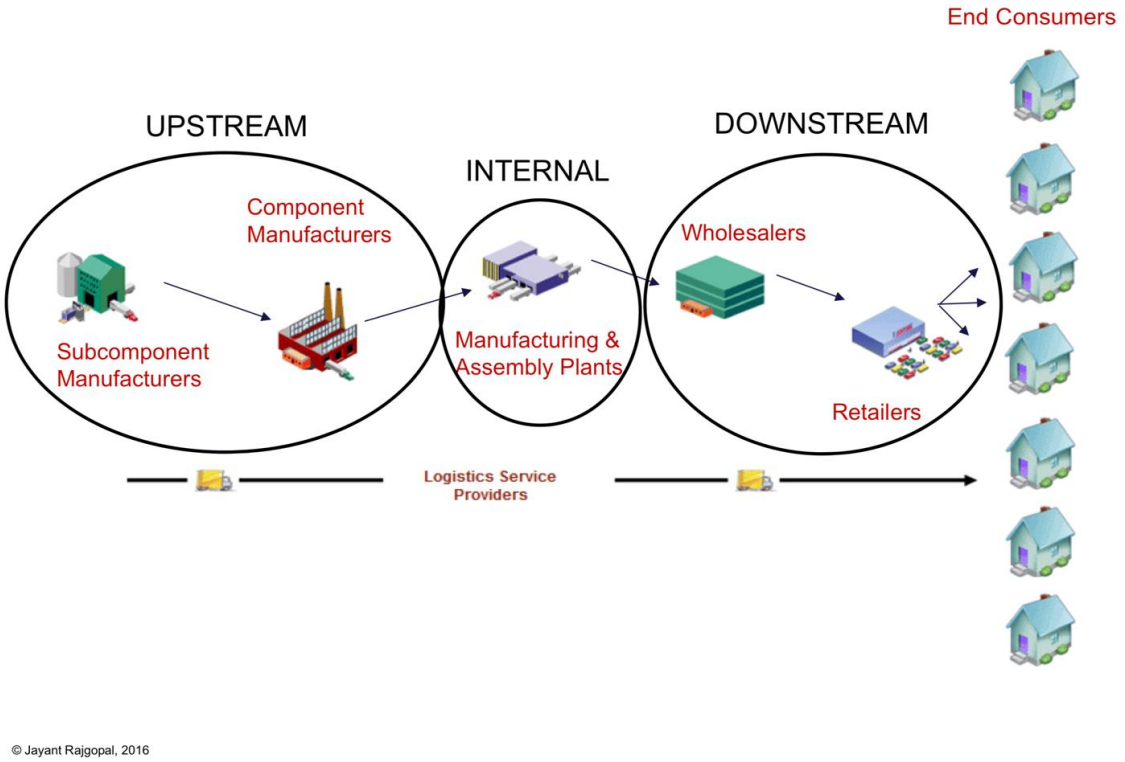

Figure 2: Supply Chain structure (www.pitt.edu)

Nowadays supply chains are experiencing a constant vertical dis-integration since globalization, internet and new technologies have considerably reduced transaction and delocalization problems, increasing the degree of specialization, the control over remote processes and the need to be reactive to the very competitive international and national market scenario.

Therefore the degree of integration and coordination of the supply chain has increased and its management has become a crucial aspect for those company that want to maintain a successful standard of performance.

It is, in fact, important that companies focus only on their core business, meaning only the activities in which it is specialized, so that to be able to guarantee a very high quality of the final product by minimizing costs thanks to economies of scale and specialization.[44]

Over the years supply chains have become more and more structurally complex and crucial for value creation; for this reason in the 90's we have the emergence of the discipline of Supply Chain Management.

We can also identify Supply Chain Management as a management model that integrates all the supply chain's activities into a homogeneus process. It connects all the partners, both internal and external, focusing on exploiting competencies and technologies to increase the company's competitiveness.[45][46]

The change in companies' attitude and the related growing attention for the Supply Chain can be brought back to three main reasons.

The first one is related to the very high degree of competitiveness that characterizes the market and gives to the client great freedom of choice between many options.

For this reason it is important for a company to offer the best service possible in order to convince potential costumer to choose their product and retain existing ones.

The satisfaction of these high standards and the simultaneous minimization of costs can be done only by controlling and coordinating all the areas of the supply chain, to make sure that everything works efficiently.

The second factor refers to the great dependency that exists among the various sectors involved in the supply chain mechanism.

It has become, in fact, evident that decisions taken in one area affect the performance of the whole system, and it is therefore fondamental to always have in mind the complete vision of how the chain works.

The third factor refers to the development of the way in which companies operate.

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[44] Holmstrom J., Partanen J. (2019), *Digital manufacturing-driven transformations of service supply chains for complex products*, Supply Chain Management: An International Journal, Vol. 19 No. 4, pp.421-430

[45] Ellram L., Cooper M.(1993), *Characteristics of supply chain management and the implications for purchasing and logistics strategy*, International Journal of Logistics Management, Vol. 4 No. 2, pp. 1-10

[46]Tan K.C., Kannan V.R., Hand R.B., (1998). *Supply chain management: supplier performance and firm performance.* International Journal of Purchasing and Material Management 34.

The majority of them are, nowadays, organized on the basis of an horizontal integration, meaning that they choose to specialize just on some specific oeprations by outsourcing those activities that are not part of their core.
In this type of organization the coordination and success of all partners along the chain is crucial to guarantee a great performance.
On the basis of these needs companies have started to pay greater attention on the functioning of the whole supply chain, trying to maximize the efficiency of each of its levers in order to increase their competitive advantage.
Moreover Supply Chain Management can be considered itself as an important source of competitive advantage because it differentiates one company from the others and it can represent a booster for the reputation, promoting modernity and efficiency.

2.2. SUPPLY CHAIN 4.0 DEFINITION AND FEATURES

The great changes that have been occuring in the market scenario over the last decades forced companies not only to pay always more attention and effort on supply chain management but also to adapt it to the new market features.

For this reason the Smart Supply Chain or Supply Chain 4.0 has been introduced.

The Supply Chain 4.0 is a new type of supply chain in which Industry 4.0 innovations are applied to jump-start performance and costumer satisfaction.[47]

Industry 4.0 innovations' application to supply chains affects all of its stages changing global production networks.

According to the different stage we take into consideration we can spot many important effects such as:

- Production: machines constantly provide feedback on production capacity and production-shipment status;
- Warehousing: goods are moved to warehouses via driverless trucks and, there, are handled by automated machines;
- Shipping: shipping is based on a predictive model according to which goods are dispatched to stores and online retailers ahead of demand. Moreover costumers can use a mobile app to check the order status;
- Delivery: next generation delivery is based on automated systems like drones, which perform the delivery and pick-up by themselves.

The digitization of the supply chain enables companies to meet the new market challenges without sacrifying quality and costumer satisfaction.

This new kind of supply chain has some major characteristics that distinguish it from the traditional one.

In fact we can describe the new digital one as:

- Faster: advanced forecasting models that use predictive analytics of both internal and external data can provide a more precise forecast of costumer demand, enbling to reduce delivery times;
- More flexible: supply chain 4.0's real-time planning allows companies to respond quickly and flexibly to demand and supply changes, minimizing

[47] Alicke K., Rexhausen D., Seyfert A,, *Supply Chain 4.0 in consumer goods*, on McKinsey Global Institute, <https://www.mckinsey.it/idee/supply-chain-40-in-consumer-goods>, 27 April 2017

planning cycles. With these technologies planning becomes a continous process that reacts dynamically to changing requirements;

- More granular: with market becoming always more costumer-centric, where meeting costumer expectations through micro-segmentation and mass-costumization is fundamental, companies need to manage demand in a more sophisticated way. 4.0's innovations are useful because they allow to combine costumers' costumization needs and very short delivery times;
- More accurate: next generation performance management systems provide a wide range of informations from traditional key indicators such as overall service level, to more granular ones like the exact position of trucks. Data integration coming from all the members of the chain, from suppliers, service providers and others ensure that all the stakeholders decide on the basis of the same data. These data allow the systems to set targets for warehousing, transport and inventory automatically and to adjust them autonomously according to risks and other uprising issues. This ability leads to continous improvements pushing the supply chain to its efficiency frontier;
- More efficient: the automation of both physical and planning tasks boosts the supply chain's efficiency guaranteeing high quality products and services minimizing costs.[48]

Given these objectives and characteristics also the supply chain management needs to adjust to a more smart model which is focused on some specific aspects:

- Information management: given the current demand-driven market, being able to manage informations about the demand can help achieving important results such as reducing lead time, related costs as well as improving the decision-making process;[49]
- IT systems: IT and IoT systems implementation enables an effective management of the information flow along the whole supply chain reducing inefficiencies;

[48]Alicke K., Rexhausen D., Seyfert A., Supply Chain 4.0 in consumer goods, <https://www.mckinsey.it/idee/supply-chain-40-in-consumer-goods>, 27 April 2017

[49] Handfield R., Nichols E. (2002), "*Supply Chain Redesign: Transforming Supply Chains into Integrated Value System*", Financial Times/Prentice Hall, Upper Saddle River, NJ

- Processes' automation: the need of great velocity, reactivity and efficiency required by the market forces companies to automate their processes to save time and resources;[50]
- Advanced Data analytics: data analytics enables companies to enhance their operations' efficiencies on the basis of various insights such as about costumer expectations, production and shipment performance, etc;
- Process integration and innovation: integration and innovation has to be applied to all stages of the supply chain, from procurement to logistic, which combined with coherent information sharing enable to maximize costumer satisfaction, minimize costs and improve the overall performance.[51]

Therefore we can say that Smart Supply Chains offer an unprecedented opportunity to maximize its members surplus.

[50] Savitz E., *The industrial internet: even bigger than big data*, Forbes, October 2013, p.44
[51] Kumar R., Pugazhendhi S. (2012), *Information sharing in supply chains: an overview*, Procedia Engineering, Vol. 38, pp. 2147-2154

2.3. THE IMPLEMENTATION OF INDUSTRY 4.0 INNOVATIONS INTO THE SUPPLY CHAIN LEVERS

As already said before the digitization of the supply chain is a process that includes the application of 4.0 technologies to the activities that are part of it.

This transformation influences each step of the chain, which are: planning, procurement, production, warehousing and logistic.

Throughout this paragraph the implication that digital innovation has on each of them will be investigated.

2.3.1. PLANNING

The first step of a supply chain is planning.

In order to work effectively it is fundamental that everything inside a supply chain is programmed in advance to make sure that the final product is produced and delivered within the predetermined times.

The Supply Chain Planning is, as defined by Gartner «a process, which is part of the Supply Chain Management, of coordinating assets to optimize the delivery of goods, services and information from supplier to costumer, balancing supply and demand». [52]

The SCP in fact covers a very wide range of operations, both internal and external, unifying all members of the chain to make sure that they all operate at the same pace and velocity.

In many cases companies tend to snub this step and focus on production and logistic right from the beginning.

However this tendency can be very dangerous because it exposes them to great uncertainty.

In fact, if a company does not adopt any forecast measure, it is not able to predict, eventually avoid or at least prepare to react to any difficulty that may arise, such as plants and machinery malfunctioning, natural disasters or supply delays.

[52] Gartner Glossary, <https://www.gartner.com/en/information-technology/glossary/scp-supply-chain-planning>

The avoidance of these downfalls can be obtained by focusing on specific elements, such as:

- Data collection: the access to precise and up-to-date data enables the company to improve the efficiency of its decision-making processes, just-in-time production and critical situations management;
- Inventory management: it facilitates the adoption of lean manufacturing techniques as well as a general cost reduction;
- Forecasting: making forecasts about costumers demand can help to improve profitability and margins;
- Collaboration along the supply chain: having an integrated and comprehensive model allows to take truck and define processes and relationships among clients, suppliers and sellers;
- Management of a product's life cycle: having a clear plan of a product's lifecycle favours a smooth transition from product development to distribution;
- Inefficiencies' identification: once a company is able to spot the inefficiencies such as errors, wastes and redundant costs, it can implement measures to fix them. [53]

The great complexities that our world has, especially in this age of digitization, imply that traditional supply chain planning schemes are not enough anymore, rather it is important that it is sufficiently flexible to fit with our changing global scenario.

Traditional processes are not designed to successfully manage the enormous amount of data available on costumer's demand, moreover they still rely heavily on manual analysis, labour-intensive data collection and personal judgement.

However the attempt to fix these problems by introducing specific adjustments led only to even more errors and subconscious bias rather than improving the model.

The answer to these issues can be identified in the digitization of planning processes in order to gain in terms of responsiveness, agility and speed.[54]

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[53] Supply Chain Planning (SCP): cos'è, chi coinvolge e come implementarla, <https://blog.cybertec.it/supply-chain-planning-o-scp>, 11/05/2021

[54] Felix I., Kuntze C., Silva I., Benoliel E., *The route to no-touch planning: Taking the human error out of supply chain planning*, in McKinsey Global Institute, <https://www.mckinsey.com/business-functions/operations/our-insights/the-route-to-no-touch-planning>, 20 August 2018

A contemporary and modern supply chain planning setup is the Supply Chain Planning 4.0.

Supply Chain Planning 4.0 proposes a lean and digitized planning scheme that fosters data-driven decision making.

It is based on an agile organization, characterized by interconnected systems that links all members and components of the chain.

This collaboration is enabled by advanced analytics tools that allow to make more accurate forecasting and effective scenario visualization which to build future plans and more rapid and and informed decision making on.

This new supply chain planning scenario is characterized by some important developments that can be summed up in four main trends:

- Seamless time horizons: traditionally companies used to have different planning schemes for long-term, mid-term and short-term planning. Instead the new trend is based on merging the three time horizons by integrating them into a unified planning solution. This new approach allows to link together long-term strategic planning, mid-term financial planning and short-term operational planning. The main benefits that this brings are related to greate transparency and robusteness;
- Collaborative planning: this trend is based on adopting a collaborative perspective in planning which involves overseeing the interconnected supply chains of both the company itself and its suppliers. This helps to better respond to costumer demands and improve capacity utilization;
- Advanced scenario planning tools: this trend is based on the utilization of advanced tools such as specific algorithms. It processes up-to-date supply chain data and production capacity constraints to develop an optimal scenario which to base future plans on;
- Demand sensing: it is an advanced planning method that uses data analytics by combining historical internal data and external ones to forecast the demand in the near future. It provides better predictions on demand levels, lower operational waste and inventories as well as greater costumer satisfaction and company performance.[55]

[55] Roland Berger, Report on *Supply Chain Planning 4.0 – Supercharge your supply chain planning performance*, February 2018

Supply Chain Planning 4.0 represents the first step toward full autonomous planning.

Autonomous planning refers to a vision in which big data and analytics are used in every step of the supply chain planning process, which will therefore be characterized by always less manual intervention.

Autonomous planning differs from traditional one in several ways:

- Efficiency: traditional planning requires many manual steps and interventions while autonomous one is based on automated inputs for demand and supply planning and streamlined order management;
- Advanced analytics: traditional one is characterized by standard software functionality, which is however largely unrealized while the autonomous one use advanced analytics and machine learning for forecasting and planning optimization;
- Velocity: traditional one has a monthly, weekly and daily cadence while autonomous one guarantees short and cross-functional data relying on real-time informations;
- Integration: traditional one is part of supply chain operations and not integrated into company-wide functions, while autonomous one is fully integrated with all business processes and key performace indicators are coherent across functions;
- Self-transformation: traditional planning provides specific projects fitting a specific situation, while competencies required by the autonomous one bring inside the company expertise and talent that are continually shared.[56]

To fully capture the great potential of autonomous supply chain planning it is important that companies invest in advanced analytics, machine-learning techniques and re-organization initiatives.

Throughout this journey a competent governing infrastructure should appointed to develop the appropriate talent and change management practices.

These centers have various functions such as providing support to cross-functional collaboration and tactical assistence and shaping the overall vision.[57]

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[56] Kuntze C., Lal S., Seibert K., *Launching the journey to autonomous supply chian planning*, in McKinsey Global Institute, <https://www.mckinsey.com/business-functions/operations/our-insights/launching-the-journey-to-autonomous-supply-chain-planning>, 3 June 2020

[57] Felix I., Kuntze I., Silva I., Benoliel E., *The route to no-touch planning: Taking the human error out of supply chain planning*, in McKinsey Global Institute, <https://www.mckinsey.com/business-functions/operations/our-insights/the-route-to-no-touch-planning>, 20 August 2018

The benefits of the adoption of digital technologies in the supply chain planning process have been widely investigated and important results emerged.

According to a survey conducted by Roland Berger across many companies which are mainly operating in the consumer good industry the Supply Chain Planning 4.0 has the strongest impact on increasing leads time, reducing stock-outs and the number of short-term planning changes.

Also other areas of impact have been identified but on the basis of companies' perspective these are less influenced by the digitazion of planning processes; these areas are for example increasing forecasting accuracy, reducing inventory levels and slow-movings.

This analysis has also brought up the fact that most of enterprises already have a certain degree of digitization, but it is mainly concentrated in the traditional production planning area, while the demand and S&OP areas still do not get the deserved degree of care and attention needed.[58]

Therefore it appears clear that the key challenge is not to equid oneself with IT systems for their planning processes per se, but to make sure that the adoption of these advanced technologies is spreaded across all functions that are taken into consideration throughout the planning process.

2.3.2. PROCUREMENT

Procurement is the second stage of the supply chain and one of the key functions in an organization.

Therefore it is important that all the related activities are accurately planned and structured so that the process can proceed smoothly.

As defined by Gartner it is the «corporate function that has governance over purchasing decisions for a company. Activities of the procurement function include strategic vendor evaluation and selection, competitive bidding, contract negotiation and purchasing».[59]

[58] Roland Berger, *Supply Chain Planning 4.0 – Supercharge your supply chain planning performance*, February 2018

[59] Gartner Glossary, <https://www.gartner.com/en/sales/glossary/procurement>

Suppliers have a central role in the functiong of a business because they contribute to maximizing costumer satisfaction by supporting the organization developing products that fit with market requirements through deliverying the appropriate raw materials.

Historically procurement has been characterized by a major problem related to stock management.

Companies in fact have to take actions on two fronts:

- Efficient inventory management to guarantee the necessary amount of stocks to avoid to interrupt the production cycle;
- Just in time strategy with their suppliers that need to be able to deliver goods as soon as they receive the order.

One of the strategies that can be adopted to solve this issue is the digitization of the procurement process.

As an area with many internal and external stakeholders it has great chances to form new value creation ecosystems by linking innovations on the supplier side with costumer needs.

For example higher demand in one region for a type of product can be identified early using demand sensing and analytics and used as a prediction for similar increases in neighboring markets.

This will allow companies to anticipate these trends and increase orders immediately avoiding to run out of stocks.

The digital transformation of procurement will guarantee a competitive advantage through a stronger costumer orientation and ability to rapidly satisfy and adapt to changing costumer requirements.

Outdated enterprises in fact will find it difficult to identify innovative suppliers and integrate them into their value chain.

They will be ultimately forced to rely on traditional suppliers that have not been able to start an innovation process and therefore the gap between the compay and its competitiors will increase always more.[60]

A digital procurement platform can support the overall process of modernization of the whole organization through four main channels:

[60] KPMG International Cooperative, *Digitalization in Procurement: Sustainable added value through digitalization*, 2020

- Automation: robust technology improvements that enable the continous pursuit of process automation;
- Integration: adaptive, simple and intense integration through cloud integration and blockchain;
- Value-added services: managed services and external insights used to help maximize procurement efficiency;
- Artificial Intelligence: AI and machine learning used to automate decisions and their implementation.[61]

One of the main features of the digitalization process that characterizes procurement is the massive usage of data and analytics.

These techniques allow to integrate fragmented data sources to deliver accurate and easily understandable data points.

Adopting a Big Data approach to procurement has a great potential to unlock value for the business.

This happens in four main ways:

- Managed supply risk: big data helps to monitor suppliers and identify warning signs for supply risks. This allows to continously update suppliers' risk profiles and anticipate them with appropriate actions to mitigate them eventually;
- Sourcing cost improvements: big data offers also a great opportunity to find new and more cost efficient sourcing. In fact, by monitoring not only the suppliers per sé but the market as a whole, it takes into account all variables that affect the price of sourcing;
- Organizational efficiency: generally, according to surveys, most of the time in procurement is spent searching for information. Big Data solutions link together all relevant information speeding up the strategic and decisional process;
- Fact-based decision making: Thanks to Big Data procurement managers can ask for data evidence for all major and important decisions.[62]

[61] KPGM International Cooperative, *Future of Procurement*, 2021

[62] Sauter P., *Big Data in Procurement*, in Arthut D Little, < https://www.adlittle.com/sites/default/files/viewpoints/ADL_2014_Big_Data_in_Procurement.pdf >

However the potential of procurement in value creation goes far beyond the adoption of Big Data analytics tactics.

Its impact, in fact, can be traced back to two major areas: identify and create value and prevent value leakage.

These two groups have been further splitted by McKinsey Global Institute into various sub-categories.

For what concerns the first area tools can be divided between those that generate spend visibility and collaborative sourcing.

Spend visibility is much more focused on analyzing spend data to get insights that drive performance improvements, such as great cost savings and efficiency, stronger supplier relationships, greater buying power and strategic sourcing as well as risk exposure identification and management.

Instead collaborative sourcing deals with the adoption of category analytics that has the aim of studying suppliers and their field of operations in order to be able to create and foster strong collaboration pattern with suppliers.

The second area has a more passive attitude, because it does not directly intervene in the value creation process, rather it works to prevent value distruction.

Its main tools are two:

- Procure to pay: these systems enable the linkage between purchasing and financial department. It provides full control over the entire life-cycle of a transaction, providing full insight into cash flow and financial commitments;
- Performance management: this area includes mainly tools such as automated scorecards for supplier's and procurement organization performance management.[63]

At the end of the day however these tools simply deliver their true value to companies, it will be then up to them to invest and build on the right talent to fully exploit their potential

[63] De la Boulaye P., Riedstra P., Spiller P., *Driving superior value through digital procurement*, in McKinsey Global Institute, 13 April 2017, < https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/driving-superior-value-through-digital-procurement>

2.3.3. PRODUCTION

Production refers to the third step of a supply chain, which is called "make" and involves the transformation of raw materials into the final product according to the costumer's preferences.

Therefore it includes various activitites such as assembly, testing and packaging.

This stage of the supply chain is the one in which the higher number of 4.0 enabling technologies are deployed, namely robotics, artificial intelligence, cloud manufacturing and additive manufacturing.

For what concerns robotics industrial robots are considered, according to the International Organization of Standardization as «automatically controlled, reprogrammable multipurpose manipulator programmable in three or more axes».

They can be grouped into three categories according to their structure:

- SCARA: is composed of two arms, one that can be moved on the horizontal plane and one that can rise and fall on the vertical one. They are mainly use for high speed and repeatability;
- Cartesian robot: its arms have three prismatic joints and axes coincide with a cartesian coordinator. They are mainly used for pick-and-place activities, assembly operations and handling machine tools;
- Dual Arm: these kind of robots have two antropomorphic arms eith one elbow each with three joints that allow to position the wrist wherever it is more useful;
- Cobots: this is a new type of robots that are designed to cooperate and physically interact with humans in a shared workplace;
- Articulated robot: it is a robot with at least three rotary joints. [64]

The impact that robotics can have on production can be highly beneficial, especially when we consider quality and accuracy of products.

This aspect can be very important to increase the company's competitiveness because it allows to reduce wastes both of time and materials and to deliver the products with highest value to costumers at the lowest cost.

Instead when we talk about artificial intelligence we refer to the process of leveraging computers and machines to mimic the problem solving and capabilities of human mind.

[64]Martinelli A., Mina A., Moggi M., *The enabling technologies of industry 4.0: examining the seeds of the fourth industrial revolution*, 2019

This term was first coined in 1954 by John McCarthy at the first ever AI conference that took place at Dartmouth College.

It can be divided into two types:

- Weak AI: refers to AI trained to perform specific tasks. It represents the majority of applications we see everyday around us;
- Strong AI: refers to application in which machines have capabilities that are equal to those of the humans, meaning being able to solve problems, learn and plan. Unlike the previous one it is still all at a theoretical level with no practical examples.[65]

It is applicable to various fields and it is therefore dificult to draw precise boundaries.

However its core components can be identified with machine learning, deep learning, natural language processing platforms, predictive application programming interfaces, image and speech recognition.

Investments and deployment of AI in the industrial sector is still at an early stage but it is rapidly evolving especially in the development, validation and deployment of industrial AI algorithms.[66]

Instead cloud manufacturing refers to a specific service-oriented business model based on cloud computing techniques to share manufacturing capabilities and resources on a cloud platform.

This type of model make sure that all companies involved in the production process share their capabilities with potential clients that are visiting the platform.

The adoption of these technologies can bring important benefits to companies, such as:

- Flexibility: the manufacturing of the components of the product chosen by the costumer is assigned to the nearest manufacturer that has the required expertise. This guarantees lower costs and enviromental impact thanks to shorter delivery distances to be covered;
- Shared accouns: all the information needed is accessible on the platform and every part is constantly updated on the state of the project that is being carried out without having to keep in touch with others;

[65] IBM Cloud Educator, *Artificial Intelligence*, in <https://www.ibm.com/cloud/learn/what-is-artificial-intelligence> , 3 June 2020

[66] Martinelli A., Mina A., Moggi M., *The enabling technologies of industry 4.0: examining the seeds of the fourth industrial revolution*, 2019

- Instant quotes: these platform allow companies to receive instant quotations to be used to prepare CAD models and drawings to be sent to the production department. This enhances efficiency and ensures a better allocation of resources, enabling skilled employees to focus on value-adding activities. However some platform still need some more developments especially when regarding the viability of the quotes. It is in fact common that prototypes created by drawing programmes are not manufacturable in real life;
- Volume as leverage: these platform can accumulate large numbers of orders that can make a huge leverage when bargaining lower prices;
- Capabilities and expertise: gathering large numbers of manufacturers and choosing them on the basis on data about performance and limitations ensures that the costumer gets the best service possible.[67]

Several multinationals have started adopting these type of platform since 2000.

Some examples can be Amazon that in 2006 introduced Elastic Compute Cloud, Microsoft released Microsoft Azure in 2014 and Google released Google Compute Engine in 2013.[68]

Nowadays these companies still remain at the top in R&D spending.

Especially Amazon appears to be, according to an analysis made by Nasdaq, the greater R&D spender with $42.74 billion, which is about 11% on their net sales, in 2020 compared to $35.93 in 2019. Most of these expenses seem to be related to the 2244 new patents granted in 2020, most of which in advanced technologies such as AI, cloud computing, machine learning, etc.

The second place of this ranking is occupied by Google, now represented by Alphabet, that in 2020 spent $2757 billion on R&D, which is equivalent to 15% of its revenues. Their expenses have in this field have more than doubled since 2016.

Also Microsoft occupies a good position in this ranking, with a constant 13% of R&D expenditure over revenues, that equals to $1927 billion in 2020. [69]

Lastly we can take into consideration also Additive Manufacturing.

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[67] Velling A., *What is Cloud Manufacturing? And who can benefit from it?*, in <https://fractory.com/cloud-manufacturing/>, 30.10.2019

[68] Martinelli A., Mina A., Moggi M., *The enabling technologies of industry 4.0: examining the seeds of the fourth industrial revolution*, 2019

[69] Bajpai P., *Which companies spend the most in research and development (R&D)?*, in Nasdaq, <https://www.nasdaq.com/articles/which-companies-spend-the-most-in-research-and-development-rd-2021-06-21>, 21 June 2021

It can represent a very beneficial choice for high value and low volume businesses that can make their production process faster and more felixible, with less wastes and reduced assembly time.

Studies and researches show that there is a tendency towards the emergence of distributed local and global supply chains, where manufacturing is done closer to the consumption point, especially in those cases when delivery costs are higher than production costs.

AM fits perfectly in this scenario enabling instant production and reducing inventory and the need for intermediaries at the same time.[70]

AM can give important advantages not only to big established corporations but also to small and medium-sized firms as well as start-ups.

These types of enterprises can get the most out of this technology when they combine it with particular production processes such as bridge manufacturing.

This process uses additive technology to produce low volumes of a product before committing to mass production with traditional methods.

It allows a smooth transition to mass production, giving the company the possibility to test and perfect the prototytpe in advance.

Moreover revenues gained from the pre-sell of the limited amount of product can be used to fund mass production and market validation.

The adoption of AM makes bridge manufacturing faster and cost-efective,and a valid alternative also for SME's and individual innovators that do not have enough funds to support a traditional prototyping and market testing.

Several reports show that the market for AM is rapidly expanding, with forecasts that estimate that its overall economic impact could reach $100 to 250 billion by 2025 if the adoption continues at today's rate.[71]

The adoption of digital technologies in the production process can be very helpful also to mitigate the effects that COVID-19 is being having on manufacturing.

The ways in which it is impacting are multiple: from boosting employee safety to improve asset productivity and product quality.

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[70] Van Barneveld J., Jansson T., *Additive manufacturing: a layered revolution*, European Foundation for the Improvement of Living and Working Conditions, 2017

[71] Bromberger J., Kelly R., *Additive manufacturing: A long-term game changer for manufacturers*, in McKinsey Global Institute <https://www.mckinsey.com/business-functions/operations/our-insights/additive-manufacturing-a-long-term-game-changer-for-manufacturers>, 12 september 2017

2.3.4. WAREHOUSING

Warehousing refers to the function which fits inbetween the make stage and the deliver stage of a supply chain.

Here in fact products that have been carried out during the production process are stored, waiting to be delivered to costumers.

Specifically when we talk about warehouse management we refer to the control and optimization of warehouse operations, from the entry of inventory till its delivery

It is a key function in the overall process of a company's management because it can have huge effects on its performance and profitability.

It is therefore fundamental that the most suitable, according to the type of company, warehouse management system is adopted.

There are two main models:

- Isolated warehousing: this approach considers the warehouse as a standalone entity and the objective is to meet the service requirements at the lowest possible cost;
- Integrated warehousing: according to this view this function is seen as an integral part of its overall value chain and needs to be managed in the context of the whole material and costumer flow.

For a manufacturer who runs complex operation the second choice is for sure the best one because it allows to minimize the total cost of the delivered product, instead of taking care of single operations.

The adoption of integrated warehouse management system is supported by the combination of the new innovations introduced by the digital transformation that is characterizing the business world together with the implementation of a just-in.time model.

Just in Time is a concept developed in Japan in the 70's by Toyota's management that alligns raw material orders from suppliers with production schedules.

This system allows to cut inventory costs and increase efficiency because manufacturers receive materials as they need them for production, avoiding unwanted storage.

This model represents a great opportunity for a company to improve its overall profitability by cutting unnecessary costs, however in order to function properly it is fundamental that the production is steady and suppliers are reliable.

In fact, if a supplier is not able to deliver raw materials in a timely manner this could stall the entire production line.

Same may happen if an unexpected order arrives, postponing all delivery times to end clients.[72]

For these reason another major issue that arises when analyzing JIT is the fact that it needs a very high level of competence both in supply chain management and in the integration of intra- and interorganizational processes.

The digitization of the supply chain can bring important solution to these problems especially through the adoption of cyberphysical systems that are able to self-control.[73]

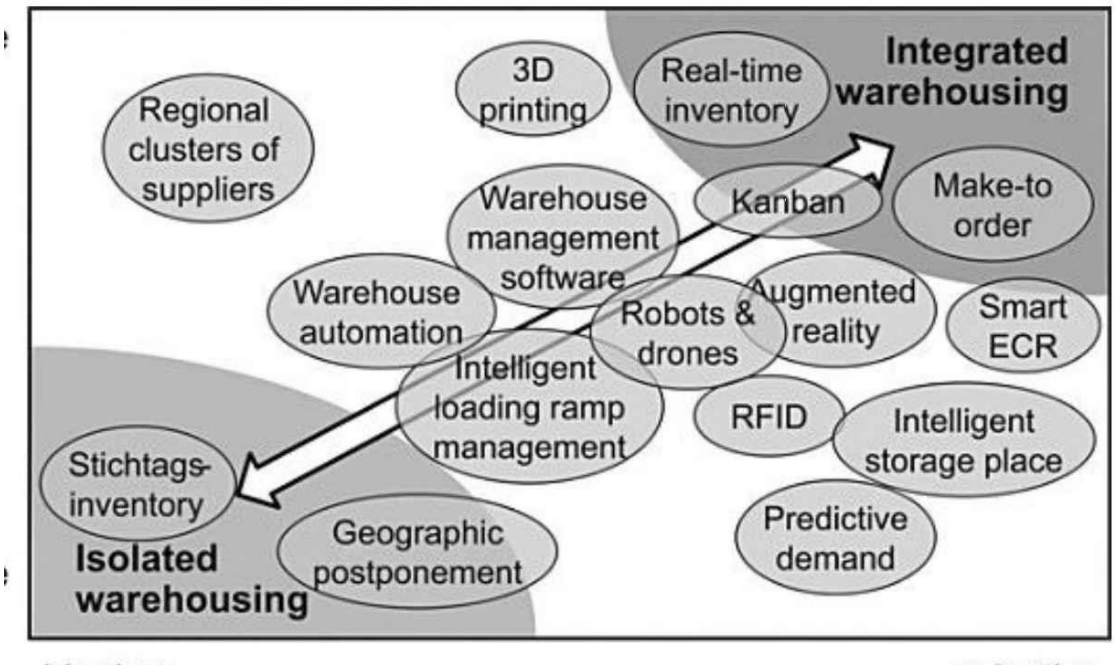

Figure 3: Differentiation of warehousing (G. Wehberg, Digital Supply Chains – *Key Facilitator to Industry 4.0 and New Business Models, Leveraging S/4 HANA and Beyond*, 3rd edition. London. Routledge. 2021

Digital technologies that are adopted in the automation process of a warehouse are multiple:

[72] C. Banton on Investopedia, <https://www.investopedia.com/terms/j/jit.asp>, 28 April 2021

[73]Wehberg G., (2021), *Digital Supply Chains – Key Facilitator to Industry 4.0 and New Business Models, Leveraging S/4 HANA and Beyond*, 3rd edition, London, Routledge

- Shuttle Systems: is an automation solution where a mobile cart “shuttles” items in pallet racking. They are very useful in warehouses characterized by frequent loading and unloading of a large number of pallet;
- Automated Guided Vehicles: these vehicles use sensors and wires to navigate a specific path around the warehouse. AGVs are limited to large and simple locations without much human traffic and space constraints in it;
- Automated Storage and Retrieval System (AS/RS): it refers to a particular fulfilment technology that includes automated systems and equipment to store and retrieve materials or product. This solution is usually adopted in high volume warehouse with space constraints;
- Pick-to-Light and Put-to-Light Systems: they use barcode scanning devices to direct warehouse pickers to where to pick and or place certain items. It grealty reduces error margins and searching time especially in high volume situations;
- Automated Sortation System: these systems allow automated sortation using barcode scanners and sensors. This technique is mostly used in order fulfilment for receiving, picking, packing and shipping.

According to a survey presented by Forbes the adoption of these techniques is going to increase always more over the years.

The research shows that 96% of the respondents expect the warehouse automation value proposition to increase over the next three years, 60% of whom state that it is “very likely” while 19% considered it “likely”.

The interest towards this tendency can be furthermore analyzed by looking at the single technologies, as showed by the following graph.

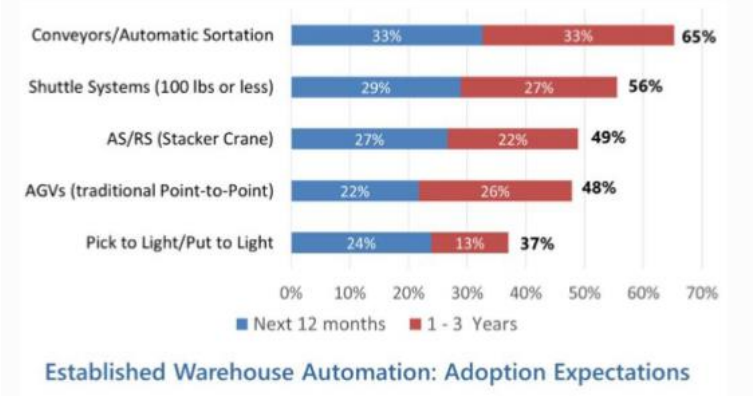

Figure 4: Established Warehouse Automation: Adoption Expectations (Banker S., *Automation is the future of Warehousing*, on Forbes, <https://www.forbes.com/sites/stevebanker/2020/07/31/automation-is-the-future-of-warehousing/?sh=5a77d8ba30f4>, 2020)

Even if this survey has been taken prior to the COVID-19 crisis it appears that companies are still willing to commit themselves to such investment despite the hard times caused by the pandemic because automation, especially autonomous mobile robots, facilitate social distancing and increase employees safety.

This positive forecast may be due to the great advantages that this solution brings to companies' operations and functioning.[74]

The main benefit that derive from the automation of the warehouse are those already mentioned for Just in Time adoption, namely increased efficiency and inventory costs' reduction, together with other sets of advantages that includes for example reduced labour required and the related possibility of human error, better resource utilization, greater inventory control, reduced stockouts events and therefore improved costumer satisfaction.

Warehouse automation will help companies address inefficiency- related issues and are, in fact, one of the most debated topics among managements.

The adoption of such meaures can be quite expensive but failing to plan for these changes can cost more than the expenses associated with the reconfiguration.[75]

2.3.5. TRANSPORT

Transportation plays a connective role among the several steps of a supply chain that lead to the conversion of raw materials into products for the end client.

Since suppliers, manufacturer's plant and costumers are usually scattered geographically and therefore products are rarely produced in the same location in which they are consumed, transportation plays a key role in every supply chain.

In order to be efficient, in fact, any supply chain needs to be linked to the most suitable mode.

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[74] Banker S., *Automation is the future of Warehousing*, on Forbes, <https://www.forbes.com/sites/stevebanker/2020/07/31/automation-is-the-future-of-warehousing/?sh=5a77d8ba30f4>, 2020

[75] Jenkins A., *Warehouse Automation Explained: Types, Benefits & Best Practices*, <https://www.netsuite.com/portal/resource/articles/inventory-management/warehouse-automation.shtml>, 2020

The choice of the best transportation system is industry specific, if not company specific, meaning that it highly depends on the characteristics of each firm.

Every company needs to analyze the most relevant factors that affect this decision, which are:

- Transportation costs: that depend on where all members of the supply chain, meaning manufacturer, suppliers, warehouses, retailers and clients are located;
- The influence that the mode of transport has on the packaging required;
- The influence that the mode of transport will have on inventory requirements. For example if a high speed and high volume transportation is chosen the inventory levels required would be smaller than if a slower and less capable modality is;
- Costumer service goals: the company needs to choose the carrier that ensures quality levels appropriate to those that it plans to ensure to costumers;
- Warehouse equipment: the transportation mode needs to fit with the warehouse material handling equipment to make sure that the loading and unloading procedures are performed smoothly without causing damages to products or undesired delays.

Digital supply chains will highly affect this scenario by mapping appropriate decisions using advanced algorithms.

Decisions will be made autonomously, like products decide on their packaging, the packaging on containers and the latter on the means of transport.

Therefore in the future transport management will be focused both on managing activities and on determining the right algorithms that facilitate this decision making process.

As for warehousing also for this function two different strategies can be identified:

- Isolated transport strategy: it is limited to uni-modal transport with moderate quality. This method uses only one single mode of transport;
- Integrated transport strategy: it applies multi-modal transport chains with high quality levels of intelligence. It represents the best solution to be adopted in combination with a digital supply chain because it is the one most suitable to meet its flexibility requirements on the transport side. Cyberphysical systems, in

fact, enable constant communication with each other allowing the continous share of informations needed to ensure the efficient functioning of the chain.

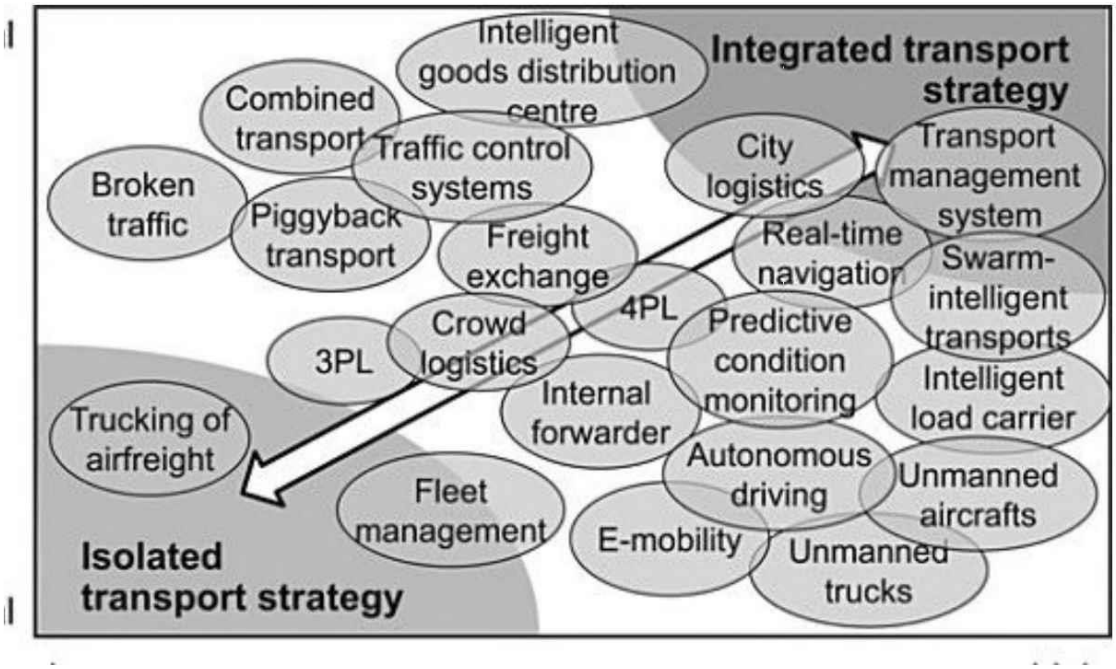

Figure 5: Differentiation of warehousing (Wehberg G., (2021), Digital Supply Chains – *Key Facilitator to Industry 4.0 and New Business Models, Leveraging S/4 HANA and Beyond*, 3rd edition, London, Routledge

The increasingly development of digital technologies has presented another important phenomena, the so called transport avoidance due to de-materialization.

The introduction of new production techniques and ways of working such as Additive Manufacturing and tele-working, allow to offer the same service to clients without having to take care of the material transport.

This offers great potential for minimizing costs and increasing efficiency.[76]

One of the major examples of the digitization of the transport function is the introduction of autonomous trucks.

According to an analysis of the various means of transport utilized in the US for domestic shipping, trucking appears to be the most popular one and to keep expanding in the future.

[76] Wehberg G., (2021), *Digital Supply Chains – Key Facilitator to Industry 4.0 and New Business Models, Leveraging S/4 HANA and Beyond*, 3rd edition, London, Routledge

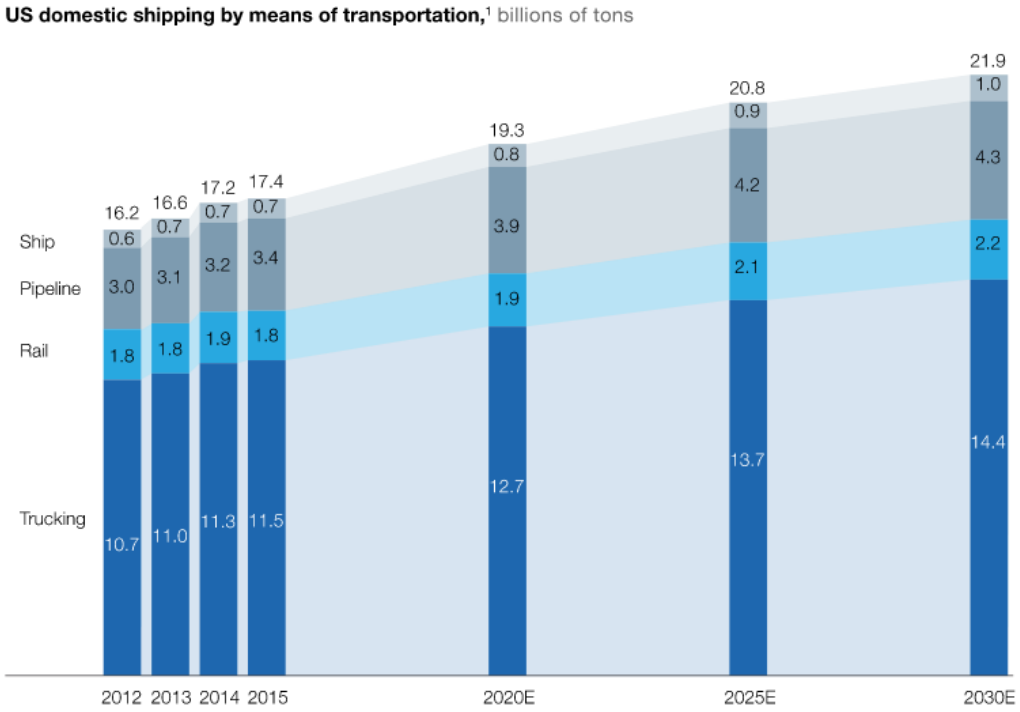

Figure 6: US domestic shipping by means of transportation (Chottani A., Hastings G., Murnane J., Neuhaus F., *Distraction or disruption? Autonomous trucks gain ground in US logistics*, on McKinsey Global Institute, <https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/distraction-or-disruption-autonomous-trucks-gain-ground-in-us-logistics>, 10 december 2018)

By looking at the benefits that automation brings to the trucking industry we can understand the main advantages that the transport function gets from these innovations. Some these can be summarized as:

- Lower operating costs for example related to labour and increase of assets price. Companies in fact will have to face higher capital cost for ATs;
- Increased utilization of latent capacity: ATs are not subject to hours-of-service regulations and therefore trucks can move and work continously and be reduced or increased exclusively on the basis of demand and sales;
- Greater industry concentration: three different types of scale economy will favour big companies instead of small ones. Firstly companies will need a network of infrastructures (garage and maintanance operators) to support autonomous trucks and larger companies are more likely to able to provide it. Secondly autonomous technology uses constant connectivity to receive and

transmit data. And big companies are more equipped to handle this huge amount of data. Lastly only big companies are able to organize big platoons of trucks.[77]

These factors suggest that, as for the other functions, the digitalization of this supply chain's stage can be tricky, beacuse it is not surely a win-win situation.

It is important to analyze the type of industry and company and then verify, by using advanced methods that support the decision making process, that the adoption of such technologies is advantageous, or at least that pros outweights cons.

[77] Chottani A., Hastings G., Murnane J., Neuhaus F., *Distraction or disruption? Autonomous trucks gain ground in US logistics*, on McKinsey Global Institute, <https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/distraction-or-disruption-autonomous-trucks-gain-ground-in-us-logistics>, 10 december 2018

2.4. DRIVERS AND BARRIERS FOR THE ADOPTION OF INDUSTRY 4.0 IN SUPPLY CHAINS

The digital transformation of the supply chain is a long and complex process that needs great effort and resource deployment.

The decision to start this journey of digital transformation can be tricky and quite difficult to make because together with many benefits it also brings some harms.

It is in fact important that the company's management takes into consideration both aspects of the process in order to be ready to adopt the best actions to mitigate their negative influence.

Those aspect that can be considered as barriers to the adoption of 4.0 technologies are various and depend on the industry in which the company operates and how the company itself is structured and manages its processes.

On a more general point of view these barriers can be identified as:

- High investment: the digital transformation can be a capital-intensive process and if the financial resources needed are not take into consideration in advance, the whole process may end up not being efficiently implemented. To mitigate this risk it may be better to introduce it gradually in phases;
- Blurred goals: under this point of view the main problem is that a digital transformation can have multiple objectives. Not being able to clearly state the goals to be achieved creates great confusion and does not allow to mark progresses that have been made;
- Unskilled workforce: people in charge of performing processes are the key to the their success. It is therefore fundamental to assess the differences between existing and required skills in order to be able to plan the right formation to fill them;
- Traditional communication channels: most supply chain teams still rely on traditional communication methods, which are not the best ones to ensure the smooth functioning of a digital supply chain;
- Integration with existing systems: new digital supply chain management software must be able to integrate themselves with existing one and ERPs. The lack of integrability can compromise the entire ecosystem. The main problem

here is that this integration may require huge amount of time and great investments;

- Security concerns: the adoption of such advanced systems increases the risk associated to cyber threats and data thefts. Sometimes such unknown risks and the costs of the systems to be adopted to prevent them can discourage companies to undertake this process;[78]
- Cultural barriers: many studies have in fact showed that people are averse to change, and this attitude extends also to all levels of a business. As a matter of fact research company Gartner identified people and culture as the biggest challenges to digital transformation;
- Lack of support from the government: the infrastructure is fundamental for the digital transformation, but generally governments provide little guidance in supporting its development.[79]

Alongside with these potential obstacles the digital transformation brings also great advantages that can be rapidly summarized as:

- Agility and flexibility: 4.0 technologies enable real time planning and control allowing companies to be flexible in adapting to changing conditions. Moreover it provides insights to improve the capability of predicting future events, such as manufacturing output, costumer behaviour and delivery times;
- Costumization: these technologies allow to perform techniques like micro-segmentation and mass costumization and deliver costumers' order faster than they would expect in oder to exceed their expectations;
- Accuracy: 4.0 technologies provide real-time and accurate data that can be used as the basis for more informed decisions. These data are various, they range from top-level data such aas costumer service to more specific ones such as those related to the tracing of trucks during delivery;
- Efficiency: the automation of physicial tasks, planning, control and information exchange process boost the efficiency of the whole supply chain through more accurate decisions and logistic management.[80]

[78] *9 Barriers that impede digital supply chain transformation*, <https://www.gep.com/blog/technology/9-barriers-that-impede-digital-supply-chain-transformation>, 12 november 2020

[79] Er Kara A., Moradlou M., Goswani H., *The impact of industry 4.0 implementation on supply chains*, Journal of Manufacturing Technology Management, 2020

For an efficient and smooth digital transformation executives need to adjust their attitude toward supply chains by considering not only the good aspectts but also the barriers to industry 4.0 implementation.

[80]Er Kara A., Moradlou M., Goswani H., *The impact of industry 4.0 implementation on supply chains*, Journal of Manufacturing Technology Management, 2020

CHAPTER III: THE IMPACT OF SUPPLY CHAIN 4.0

3.1. THE IMPACT OF SUPPLY CHAIN 4.0 ON FIRMS'S PROFITABILITY AND COMPETITIVE ADVANTAGE

The digital transformation can represent a disruptive phenomenon because it dramatically changes the rule of competition inside an industry and forces companies to adapt their structure and processes in order to avoid being excluded from the market.

Companies that are able to transform technological innovations into competitive opportunities can find new ways to create value and obtain superior performance.

To understand the impact of digitalization on firms competitive advantage and profitability it is important to make a prior analysis of the influence that these innovations have on the structure of the industry in which each company operates.

As outlined in Porter's model, in any industry competition is driven by five competitive forces: the bargaining power of buyers, the bargaining power of suppliers, threat of substitutes, threat of new entrants and the nature and intensity of the rivalry among existing competitors.

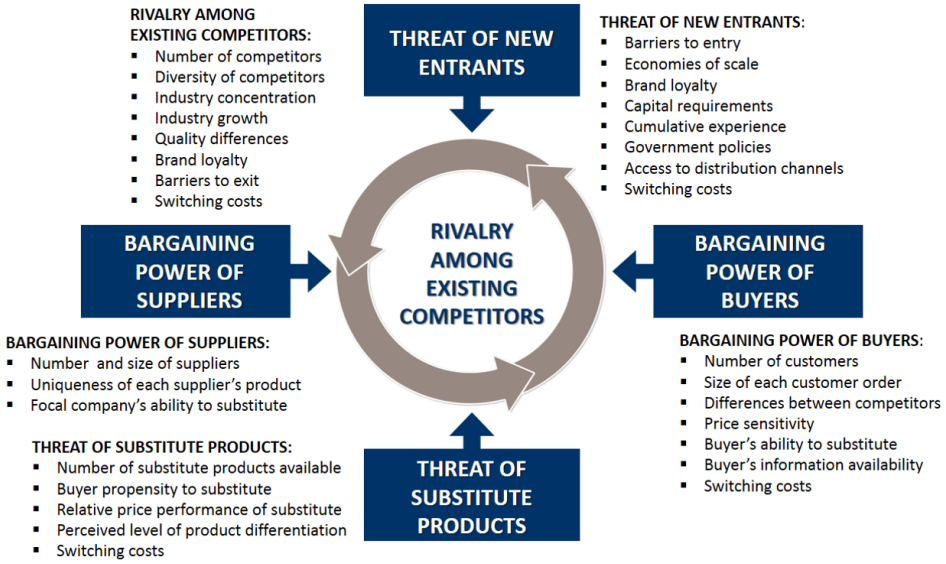

Figure 7: Porter's five forces model

The composition and combination of these forces determine the competition of an industry for incumbents.

Changes in industry structure, that may be due to the introduction of these technological innovations, can shift these five forces and therefore reshape competition.

Analyzing each force we can realize that their reaction to these transformations can be controversial:

- Bargaining power of buyers: in this case the effect can be both positive and negative. Digital technologies allow to collect huge amount of data that can be used to expand opportunities for costumer segmentation and product costumization, strenghtening costumer relationships and increasing switching costs to new suppliers. All these serves to reduce the bargaining power of buyers. However buyer's power may also be increased by sharing with them data that allows them to be more informed about the actual performance of the product and rely always less on the manufacturer for advice and support;
- Bargaining power of suppliers: in this case it is important to distinguish between traditional and new suppliers. Traditional suppliers will see their power decline because the emergence of new software and technologies will commoditize or replace traditional physicial components. While new suppliers, especially those providing software, data storage, analytics, sensors, etc, are gaining always more power, gradually capturing always bigger share of the overall product value and reducing manufacturer's profitability;
- Threat of substitutes: digital products and services offer greater value than traditional ones, reducing the threat of substitution. However the very wide range of capabilities that are created by digital innovations create new types of threats becasue they can be seen as a sort of substitute to conventional product;
- Threats of new entrants: adopting a digital supply chain forces new entrants of an industry to face considerable obstacles of very high fixed costs of complex product design and IT infrastructure management. Moreover incumbents have the advantage that they had the chance to improve buyers' loyalty increasing switching costs. Instead barriers to entry go down when incumbents hesitated to adopt these innovations and therefore new entrants' offers catch them off-guard;

- Rivalry among existing competitors: generally rivalry among existing competitors is decreade byy digital innovations because these technologies enable greater differentiation and costumization and the opportunity to deliver a value proposition that goes beyond the product per se. However rivalry can also increase if new technologies are adopted in the context of a broader system.

Even if changes in these forces will affect competition, the pillars to competitive advantage achievement still remain the same. [81]

The three main strategies are, as explained by Porter in his theory called "Generic Strategies", differentiation, cost leadership or focus and refer to the three possibilities that a company has to pursue competitive advantage.

It can base its strategy on differentiating themselves from other in terms of quality of products and services offered, or it can decide to distinguish itself by minimizing the cost at which the organization delivers products and services, or lastly it can opt for a focus strategy where they would concentrate only on particular niche markets and, after analyzing its structure and costumers, develop only low-cost or specific products.

All these strategies if adopted properly allow to gain superior profitability and growth relative to industry average.

If a company is not constantly updated about new technologies it will fall behind rivals both in terms of cost and quality.

The adoption of these new practices will influence not simply only final products but also other company functions, which are design, marketing, human resources and security.

The design stage is affected especially by those transformation related to the manufacturing process.

These two stages in fact need to be coordinated to make sure that both have the same standards and that what is being designed can then actually be materially realized.

So designers need to take into consideration also the various production phases that the product will go through and integrate all elements that will be necessary to smoothly run the operations.

[81] Porter M.E., Heppelmann J.E., *How Smart Connected Products Are Transforming Competition*, on Harvard Business Review, November 2014

For what concerns marketing the main influence is related to the changes in costumer relationships that 4.0 technologies cause.

As companies store data about costumers' expectations they gain new insights about what creates value for them and this enables better communication of product value enhancing costumers' satisfaction and loyalty.

Furthermore the adoption of digital innovations create new requirements for human resoruces.

The most relevant one is the need to recruit workforce that has specific skill sets in the field of analytics, cloud computing and so on and therefore is able to deal with new processes.

Lastly the huge reliance that companies have on data exposes them to greater risk for the security of data flowing among supply chain members.[82]

Alongside with competition 4.0 technologies can grealty impact also productivity.

These innovations, in fact, help companies to more easily adopt lean manufacturing solutions, which are nowadays considered as the key to growth.[83]

Data analysis and greater integration and information flow between the supply chain members enable to spot essential activities, processes and services and therefore eliminate those that represent a "waste" for the company, meaning those that do not create value for the costumer.

Removing these inefficiencies allow to reduce costs, time, waste and improve products' and services' quality.

[82]Porter M.E., Heppelmann J.E., *How Smart Connected Products Are Transforming Competition*, on Harvard Business Review, November 2014

[83]Bettiol M., Capestro M., Di Maria E., Furlan A., *Impacts of industry 4.0 inevstments on firm performance: evidence from Italy*, on Marco Fanno Working Papers, June 2019

3.2 THE IMPACT OF SUPPLY CHAIN 4.0 ON CONSUMERS

One of the most successful business approaches is nowadays costumer orientation.

This strategy is focused on helping costumer meet their goals and satisfy their needs which are valued more than those of the business.

The tendancy towards the adoption of this line is increasingly developing during the last years and is consistently outweighing the more traditional one of sales-orientation.

The aforementiontioned one is based on delivering the best product or service possible in terms of costs and other business indicator with respect to competitors and industry average.

This approach is generally adopted by those companies that do not have a loyal client base and therefore believe that the best way to drive sales is to offer the best product at the best price.

However even if it does have some advantages, especially in particular and complex industries such as car dealership, the lack of attention and care to costumers prevents companies to have important benefits and gains in term of performance and profitability.

Getting to know costumers and their preferences represent a key source of knowledge for companies because they can use these information to shape their offer by either eliminating or adding products or services that perfectly match costumers' needs.

This can moreover be a winning decision because by being able to fully satisfy costumers' expectations, companies will automatically outperform competitors and convince clients that their offer is the best one available acquiring at the same time their loyalty.

Given this great importance that costumers have on business strategies the decision to enter the journey of digital transformation of the supply chain needs to be carefully pondered also in terms of what will be the effects of this change for clients.

To identify this impact it is useful to analyze the situation using a specific framework: the costumer life cycle.

This approach allows to distinguish the different phases of the process a costumer goes through before, during and after they make the final purchase transaction.

The number and names of these stages is not a closely defined however we can identify three different moments of this journey.

Throughout this analysis the same therminology adopted by the study which this discussion is based on.

Therefore the three stages will be defined as:

- Discover and shop: this phase refers to the moment in which the costumer relationship begins and they become aware of the brand's existence as well as to all those prior research and exploration every potential costumer does before deciding to give their preference to one product instead of another;
- Buy and install: this phase is the one in which costumers make the final decision of buying a certain product at a certain price;
- Use and service: this phase is the real crucial one in this process because is the one where costumers really have the chance to practically use the products they purchased and verify whether what the seller promised is actually true. During this stage the comapny that offered the product has the chance to provide further support to the costumer by offering post-sales services that can greatly improve their perception. Maximizing this moment is fundamental to create an emotional bondage between seller and buyer and to make sure that the costumer jumps back into the lifecycle by purchasing again and ,best of all, by spreading through word of mouth to others their great experience and encouraging them to start the cycle as well.

The adoption of a digital supply chain can have important influence into costumer experience and therefore satisfaction.

This impact can be different according to which stage we consider, starting from the first and down to the third one the effects are various but in a way generally always positive.

The "Discover and shop" stage is focused on looking for information which to base their decisions on.

For years brands have tried to develop costumer experiences through the adoption of digital solutions, however few manufacturers have made significant investments in digital capabilities.

At this phase of the process the main application of technologies would have the aim of leveraging digital platforms to drive costumer value.

Some potentially winning solutions might be the adoption of Artificial Intelligence techniques that help the company to collect data about costumer's preferences and suggest them the best offers according to those standards, as well as the provision of Augmented Reality platforms that enable clients to try out product and quickly narrow down their favourite choices in a realistic experience rather than viewing a set of product in a limited environment.

The benefits of digitazing this phase are:

- Lowering selling costs: AI/AR resources provide lower-cost sales channels for standard offers, and, by reducing the buying cycle, gives greater chances to focus on the development of costumized products;
- Improve costumer retention: the adoption of digital technologies allows to collect data about costumers' beliefs on the offer, both positive and negative, enabling the adoption of actions to fix them eventually;[84]

The second stage is the one in which costumers make their final decision of buying a certain product.

For the company this phase is highly dependent on the relationship that it has with channel partners.

Most manufacturers in fact rely on these figures such as distributors or dealers to identify, develop and deliver their products to end costumers.

The performance of the company is strongly related to those of partners and it is fundamental that their operations are coordinated and integrated enough to ensure that all operations proceed smoothly and not hamper the supply chain performance.

The main benefits of adopting such processes in this phase are:

- Better delivery information to end costumer: generally industrial costumers are frustrated by long lead times and very few insights about the status of their delivery and order. Providing better real-time information about the supply chain is a significant opportunity to improve services offered to costumers and avoid the insurgence of discontent;[85]

[84] Hood J., Brady A., Danahsri R., *Industry 4.0 engages costumers – The digital manufacturing enterprise powers the costumer life cycle*, Deloitte University Press, 2016

[85] Paquin L., *How the cloud powers lean operations for SMB manufacturers*, Manufacturing Business Technology, October 10, 2016, in <https://www.mbtmag.com/article/2016/10/how-cloud-powers-lean-operations-smb-manufacturers>

- Quality and consistency of the channel relationships: companies and partners can leverage digital technologies to improve the consistency and timeliness of the information flow. This can help address inefficiencies in production times, transport and warehousing and to create a valuable costumer experience by improving trust and satisfaction across the value chain;
- Reduce costs: the adoption of integrated platforms that link various partners of the supply chain can help reduce administrative cost for managing the channel. Therefore these resources can be deployed in other strategic activities.[86]

The third phase of the costumer life cycle, called "use and service" is focused on the so called "aftermarket".

This term refers to the full stream of services and interactions that exist between seller and buyer after the purchase transaction.

This phase is for sure the most important and profitable one because it is the one in which costumer loyalty is built.

As already said in the previous chapters, the adoption of 4.0 technologies to digitalize the supply chain greatly improves production and logistic management allowing to deliver the a product that perfectly matches costumer's expectations.

The transformation of this stage can provide great opportunities to capture value, such as:

- Optimize costumer use: companies that, together with the physical product, are able to offer better additional service that can enhance the useability of their product can increase the value of their experience and, moreover, attract also those that are willing to pay an extra amount for an integrated service offering;
- Improve costumer uptime: downtime represents one of the worst enemies of every economic actor, therefore being able to help costumers to increase their uptime provides oppotunities for differentiation;
- Increase post-sales services: one of the main problems for manufacturers is the lack or price of post sales services that they offer. Many costumer in fact opt for low cost and non official providers. The extensive use of integrated platform can

[86] Hood J., Brady A., Danahsri R., *Industry 4.0 engages costumers – The digital manufacturing enterprise powers the costumer life cycle*, Deloitte University Press, 2016

offer those data necessary to identify and respond to those cases by adopting advanced technical support to predict and prevent these behaviours.[87]

All these opportunities offered by digital manufacturing to create value for the costumer are potential sources of differentiation and therefore chances to outperform competitors and build stronger costumer relationships based on loyalty.

[87] Hood J., Brady A., Danahsri R., *Industry 4.0 engages costumers – The digital manufacturing enterprise powers the costumer life cycle*, Deloitte University Press, 2016

3.3. THE IMPACT OF SUPPLY CHAIN 4.0 ON WORKERS

The digital transformation of the supply chain brings important changes and effects not only to firms competitive position and profitability and consumers but also to workers.
Under this point of view the main effects are to be identified on the massive disruption caused by digitalization in the job displacement – job replacement dynamics and on the new particular skill sets required to people in charge of managing supply chain processes.

3.3.1. JOB DISTRUCTION AND JOB CREATION DUE TO AUTOMATION

Transformative technology is a more or less unstoppable process that sooner or later will change our lives for good.
What really matters in this situation is not what will the future look like, because theoretically, the effects of digitalization will change our world for the best, but the real turning point now is to learn how to deal with all the ongoing transformations occuring.
Focusing specifically on the business world, the main problem lies in the speed of these changes and in the ability to adapt to them.
As already explained in Chapter one, one of the field in which the main effects take place is the labour market.
The potential impact of automation on employment varies by occupation and sector, but regardless of the degree at which this influence exists, the main dynamics that has been triggered by this transformation is process is the one related to the relationship between the distruction of certain jobs due to technology and the creation of new ones.
Job displacement refers to the process of distruction that many jobs are going through, where it becomes evident that digitech and globots are able to perform the same tasks of a human worker, but allowing to minimizing the error margin and to reduce costs.
Therefore for some specific jobs, generally those more repetitive and standardized where human creativity and expertise are not fundamental for the final performance, robots will be preferred over humans, who will inevitably find themselves without an occupation anymore.
This tendancy will characterize jobs such as back office processing, paralegal work and accounting.

However the automation of many jobs does not automatically mean that the employment rate in those occupations will fall, rather workers may perform new tasks and be employed in brand new jobs.

On the other hand there are certain occupations that will not be much affected by digitalization, meaning those that involve managing people, require great expertise and human interaction, where machines are not able to offer the same level of performance as humans.

On an empirical basis many studies have analyzed this tendancy.

One run by McKinsey Global Institute showed that 400 to 800 million individuals could be displaced by automation by 2030, according to a scenario of very rapid technological adoption.[88]

Almost the same results emerged from the study performed by the World Economic Forum which states that about 85 million jobs are expected to be distructed by automation by 2025.

This trend will be further emphasized by the fact, nowadays about 30% of all tasks are done by machine, but this share will grow to a 50-50 combination of human and machines in business related activities.[89]

When analyzing this phenomena two main arguments arise: the first one is related to the fact that automation will create better new jobs reducing the need for physical labour and allowing workers to focus only on occupations that enable them to express and nurture their most advanced capabilities.

The other one is realted to the fact people without appropriate skills will find it hard to get another occupation given that most of them require those skills for which they have been displaced in the first place.

For this reason another important trend that is characterizing the present labour market is the switch of many workers, 75 to 375 million according to McKinsey Global Institute, to new occupational categories that require them to learn new skills.

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[88] Manyika J., Lund S., Chui M., Bughin J., Woetzel J., Batra P, Ko R., Sanghvi S., *Jobs lst, jobs gained: What the future of work will mean for jobs, skills and wages*, on McKinsey Global Institute, <https://www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-mean-for-jobs-skills-and-wages>, 28 November 2017

[89] Kelly J., *U.S. Lost Over 60 Million Jobs – Now Robots, Tech and Artificial Intelligence Will Take Millions More*, on Forbes, <https://www.forbes.com/sites/jackkelly/2020/10/27/us-lost-over-60-million-jobs-now-robots-tech-and-artificial-intelligence-will-take-millions-more/?sh=7decb1941a52>, 27 October 2020

This trend is quite homogeneously distributed in all countries, both developed and developing.

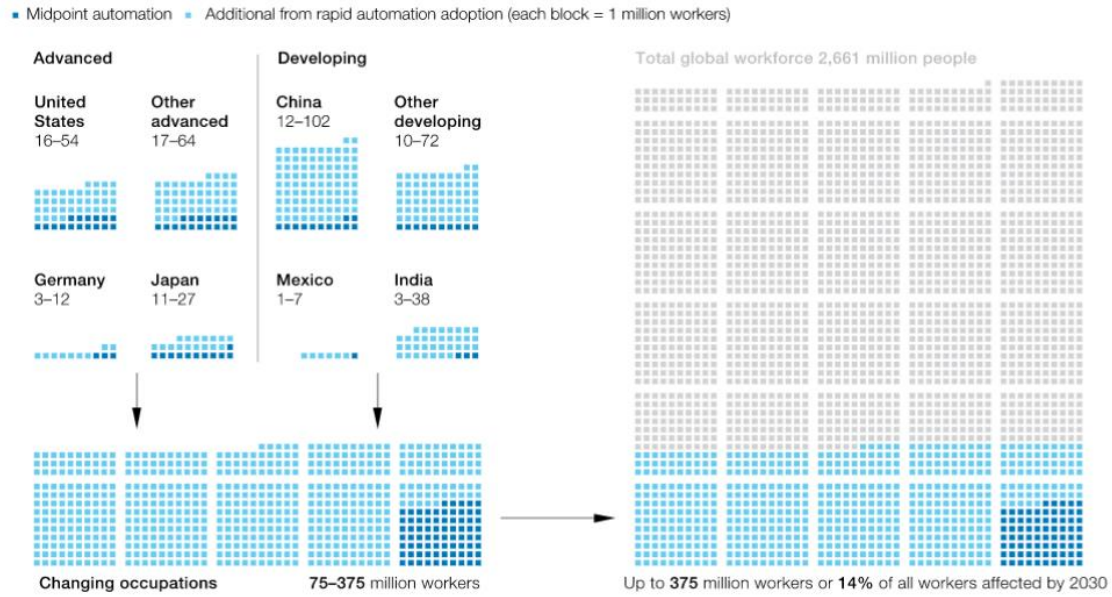

Figure 8: Number of workers needing to move out of current occupational category to go find work, 2016 – 2030 (Manyika J., Lund S., Chui M., Bughin J., Woetzel J., Batra P, Ko R., Sanghvi S., *Jobs lst, jobs gained: What the future of work will mean for jobs, skills and wages*, on McKinsey Global Institute, <https://www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-mean-for-jobs-skills-and-wages>, 28 November 2017

One important aspect of this second trend is the speed at which workers are reemployed. If workers are able to find another job within a short period of time the study shows that full employment is guaranteed in both the short and the long term, wages grow fast and productivity is high.

Otherwise, if workers take time to find another occupation, unemployment increases in the short and medium term.

In the long term the labour market is able to adjust itsel driving the rate down but with slower aggregate wage growth.[90]

[90] Manyika J., Lund S., Chui M., Bughin J., Woetzel J., Batra P, Ko R., Sanghvi S., *Jobs lst, jobs gained: What the future of work will mean for jobs, skills and wages*, on McKinsey Global Institute, <https://www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-mean-for-jobs-skills-and-wages>, 28 November 2017

It then appears clear that the greatly disruptive trait of this phenomenon highlights the importance of an adequate support and protection system.

To make sure that the outcomes of this transformation are not too unfair and violent governments need to help workers adjust to job displacement and foster job replacement through policies or other types of intervention.[91]

Considering this aspect McKinsey Global Insitute has identified some key areas that need to be addressed in order to manage this work transitions.

These areas are:

- Economic growth: monetary and fiscal policies, innovation and investments initiatives that increase aggregate demand support new business and therefore new jobs formation;
- Job retraining and new skills formation: job retraining enables individuals to learn new skills that can be very useful when looking for a new job especially in the midcareer as requirement for a successful career change as years pass;
- Labour market and business dynamism: greater fluidity is needed so that companies can be matched to job seekers easier according to skills offered and skills required;
- Income and transition support: providing support to workers in finding a new employment is essential. Beyond retraining, it can be done by providing special services such as unemployment insurance, pubblic assistence in finding a job and benefits that workers have in between jobs. Other initiatives can directly affect worker's income and have the aim of ensuring societal fairness, such as minimum wage policies, universal basic income and wage gains tied to productivity growth.[92]

Businesses will therefore be on the front lines in these workforce transactions.

This will require them to reprogramm their process and strategies in order to be able to manage the new workforce, considering which individuals are needed, which can be retrained and deployed in other positions or if new talent is required.

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[91]Baldwin R., (2019), *The Globotics Upheaval: Globalization, Robotics and the future of work*, Weidenfeld&Nicolson, London, p.271

[92]Manyika J., Lund S., Chui M., Bughin J., Woetzel J., Batra P, Ko R., Sanghvi S., *Jobs lst, jobs gained: What the future of work will mean for jobs, skills and wages*, on McKinsey Global Institute, <https://www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-mean-for-jobs-skills-and-wages>, 28 November 2017

3.3.2. NEW SKILLS REQUIRED IN SUPPLY CHAIN 4.0 MANAGEMENT

Digitalization is changing jobs as we know them, distructing some and creating others. This shapes labor demand and supply, employment patterns and the demand of skills associated to different jobs, both existing and new.

As jobs change also do the skills required to execute them, which according to the trend of technological advance that is currently characterizing the business environment, tend to be less manual and more higher level and strategic.

This tendency applies to all occupational categories and economic sectors, including supply chain management.

The digital transformation of the supply chain in fact requires huge efforts both in terms of resources, especially financial ones to procure the digital infrastructure necessary for the application of all enabling technologies, and in terms of knowledge requirements.

One of the key elements of this transition is capability building, which has been for years an aspiration for many companies, but rarely executed and poorly connected to business outcomes.

The disruptive feature of digitalization implies that most of the skills needed to efficiently start and manage this process are not in employee's traditional wealth of knowledge, rather they need to be carefully developed and nurtured.

The complexity and the very demanding requirements of this journey are one of the main reasons that prevent companies from meeting their digital aspirations.

To drive digital supply chains, supply chain leaders must combine functional and leadership capabilities with technical skills in the technological field as well as give insights about the ability of these innovations to create real superior value for the bussinesses they are supposed to support.

Given the cross-functional trait of supply chain management it is first of all important that supply chain people are skilled enough both in traditional topics and in digital ones in all relevant domains.

These domains can be summarized as the main functions performed by all members, such as strategy, demand management, forecasting, inventory management, supply and production planning and logistics.

Unfortunately most of supply chain experts, around 60% according to McKinsey Global Institute findings, are specialized in just one area.

The lack of end-to-end experts, who can quite easly master all functions account for only 5% and are usually employed in sub-functions, represents a big obstacle to the implementation of digital solutions.[93]

In fact if the lead of the process is given to executives who may fail to adopt the necessary holistic approach that takes into consideration all variables and functions involved as well as the hypothetical effects that their choices will have on both the company itself and external partners, it may end up just focusing on the area in which he is most expert.

Another major issue regarding supply chain managers is the fact that it is common, due to low organizational capabilities, that top management comes from other functions such as R&D and sales rather than being chosen among those who have a long lasting experience in the field.

The main downside of this is that those leaders might tend to manage the complex supply chain ecosystem as if it was the prior function to which they were assigned, transforming it in a mere planning and execution function.

For what concerns the trend in roles involved, two different pattern can be distinguished, according to the time lapse considered.

In the short term of the transformation new roles for data scientists and analytics will be required.

These new figures will be then trained in supply chain management, in order to be able to link together traditional functions and digital ones.

Instead in the mid- and long term there will not be this mixture of old and new roles, rather capabilities required for each function will be redefined so that each of the people involved will have a full knowledge of both traditional and advanced skills.

Therefore according to each subfunction it is possible to define specific requirements needed:

- Planning: people confident with using complex data sets and algorithms to study and exploit demand and supply patterns;
- Warehousing and transport: cross-functional in house experts in logistics will guide the management of warehouses and transport. Advanced analytical

[93] Alicke K., Dumitrescu E., Leopoldseder M., Sankur A., *Digital Supply Chains: Do you have the skills to run them?*, on McKinsey Global Institute, <https://www.mckinsey.com/business-functions/operations/our-insights/digital-supply-chains-do-you-have-the-skills-to-run-them>, 6 July 2017

capabilities and optimization expertise will help experts to develop tailored solutions for company-specific needs;

- Costumer service: costumer interaction and engagement will be moved to digital channels therefore it is important that people in charge of this area are able to exploit them to establish solid and trustful relationships;
- Strategy: using platforms for data sharing and logistics services will open up new aspirations and ideas, paving the way to new revenue streams eventually.[94]

It becomes evident that a central role is played by talent strategies applied by companies when choosing the members of their supply chain manageemnt teams.

It is important that they clearly state what are the goals they aim to achieve and what are the characteristics useful to reach them.

On the basis of these features the company will be able to choose the most appropriate workers according to their plans for the future.

Given the high degree of complexity attributable to the great level of integration stimulated by digital supply chains, it is not possible to define one single group of traits a person needs to have.

Therefore many consulting firms that support companies in strategy development, included the talent one, have arranged specific frameworks that can be used as a raw model which to base their recruiting operations on.

An example of these methods can be the one proposed by Ernst & Young LLP.

This model presents four personas that possess all the necessary characteristics to ensure an efficient and successful supply chain for the future.

Each persona is not considered as an individual, rather each of the future members of the supply chain staff will need to be a mix of them.

The four personas are:

- Technologist: they will work to design, implement and configure emerging technologies. Moreover they will apply their expertise in the digital area to decide whether the adoption of a new technology is more convenient than carrying out the same tasks relying on humans, and manage the integration of new partners or machines eventually;

[94] Alicke K., Dumitrescu E., Leopoldseder M., Sankur A., *Digital Supply Chains: Do you have the skills to run them?*, on McKinsey Global Institute, <https://www.mckinsey.com/business-functions/operations/our-insights/digital-supply-chains-do-you-have-the-skills-to-run-them>, 6 July 2017

- Orchestrator: the orchestrator has a deep understanding of internal operations and external partners and makes key decisions adopting an holistic point of view of the ecosystem that takes into consideration all pertinent factors;
- Analyst: the analyst uses advanced analytics to model different future scenarios and assess their impact and drive business decisions;
- Innovator: the innovator looks at the big picture to spot opportunities to create new commercial and sales options. They have a deep knowledge and understanding of the costumer and will tend to configure a supply chain unique enough to provide differentiated products to each costumer segment to increase profitability.[95]

Having in mind the structure and functioning of a digital supply chain it appears evident that they would not be able to provide the full set of skills and competencies required.

In fact, given their traits, the innovator will collaborate with the analyst and technologist to model scenarios, and with the orchestrator to implement the required changes according to the scenario previuosly outlined.

This framework is just an example but it clearly shows how important it is for every company to adopt this kind of approaches.

They ensure that whoever is put in charge of managing the supply chain or performs some operations in it, is capable of looking at the problem to be solved under many points of view and therefore making decisions that take into consideration all possible effects that they may have on all functions and members involved in the ecosystem.

[95] Ernst & Young LLP, Report on *Supply Chain: Skills for the Digital Era*, 2019

3.4. THE IMPACT OF SUPPLY CHAIN 4.0 ON GLOBAL VALUE CHIANS

In the last decades various factors related to globalization, such as the decrease of transportation and communication costs, the liberalization of international trade, the reduction of trade barriers and the technological progress allowed companies to re-organize their operations by spreading them accross different countries. [96]

This phenomenon is called Global Value Chains, but can be also explained using other synonyms such as: "disintegration of production, internationalisation of production, outsourcing, offshoring and production relocation" and is considered one of the major feature of globalization.

A Global Value Chain is «a network of interlinked stages of production for the manufacture of goods and services that straddles international borders».[97]

It refers to the entire set of activities that a company performs to bring the final product to life.

It therefore includes all steps that contribute to value creation, starting from design, procurement, production, marketing, distribution and post sales services.

It represents the result of firm's intention to maximize efficiency and profitability by optimizing the location of production processes in order to benefit from other countries' advantages such as workforce, taxes, legislation and lean burocracy.

It is common that, given the interdependence of the two concepts, value chains are confused with supply chains.

They both deal with activities and operations that are necessary to develop the final product but the main difference lies in the lense through which they are analyzed.

Value chain refers to the process through which the company adds value to the final product that is eventually sold to the pubblic.

This concept was pioneered by Porter in his 1985 book *Competitive Advantage: Creating and Sustaining Superior Performance* and is focused on the benefits that, considering the set of activities as potential value drivers, can give to the company's competitive advantage over its competitors.

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[96] Amador J., Cabral S., *Global Value Chains – surveying drivers and measures,* European Central Bank Woring Paper N.1739, 2014

[97] Cheng, K., Rehman, S., Seneviratne, D. & Zhang, S., *Reaping the Benefits from Global Value Chains*, IMF Working Paper, 2015 <https://www.imf.org/en/Publications/WP/Issues/2016/12/31/Reaping-the-Benefits-from-Global-Value-Chains-43311>

Instead the supply chain adopts an operational perspective which is more pragmatic and focused on efficiently fulfilling requests and maxmize costumer satisfaction.
It refers to the whole set of information, material and fund flows between different stages necessary to create and deliver a product to the end costumer.
the main concern according to this perspective is to guarantee operational efficiency, especially by controlling cost of materials and delivery.
A proper supply chain management can bring important advantages to a company because it can improve costumer satisfaction and therefore increase profits.
Despite being two different concepts they still have lots in common, in fact they consider the same set of activites but under a different point of view.
Together with bringing important effects into companies' competitive advantage, profitability, costumer relationships and the labour market, the application of new digital technologies can result in new paradigms of industrial production, with their own labour relations, processes and policy.
The main issue when analyzing the relationship between digitalization and the geographic location of production is to identify to what extent these innovations influence companies' decisions.
The main trend in location of production in today's global value chains is the one of offshoring.
Offshoring refers to the strategy of relocating production plants from costly countries to cheaper ones in order to take advantage from cost differentials and increase profit.
However in recent years this trend seems to be changing, always more companies are, in fact, deciding to reshore their production operations back to their country of origin.
Since it is a quite recent phenomenon and little evidence is shown as for what are real drivers of this decision, it is risky to define it as the main cause of 4.0 technology's application.
It is true that the automation of the supply chain have had some influence in these trends, but it is still unclear whether these effects boost offshoring or reshoring behaviours.
The great pervasiveness of the digital transformation creates a situation in which many variables in supply chain stages need to be taken into consideration.

These variables can be summarized as: the adoption of automated processes and technologies in the production process, logistics and modularization of production.

The general idea that links automation and reshoring is that the adoption of advanced technologies throughout their operations will allow companies to reduce costs and improve efficiency, therefore being able to relocate their plants back in their country of origin since they do not need the advantages guaranteed by developing economies anymore.

However this view does not take into consideration that the digital transformation does not occur only in industrialized countries but also in emerging ones where its diffusion has been the most dynamic one lately.

For example, according to a survey of the International Federation of Robotics, in 2017 China appeared to be the world number one buyer of automation equipment since 2013.

This raises the productivity in traditional offshoring destinations that can benefit from cheaper production costs and advanced plants and hence an increase in competitiveness.

Raising costs in emerging countries may lead to a third trend called nearshoring, which refers to the redirection of investments from a global to a regional level.

The effect of automation in fact hit also low-wage countries located close to high-wage ones, where the combination of productivity gains and geographical proximiy to end users and markets make it an economically viable possibility in certain cases.

The main advantages that this trend provides are mostly related to savings in freight and duties.

This consideration is supported by a research performed by McKinsey Global Institute that shows the savings in shipping times and final prices foer each feasible production location.[98]

[98] Andersson J., Berg A., Hedrich S., Magnus K., *Is Apparel manufacturing coming home?*, on McKinsey Global Institute, <https://www.mckinsey.com/industries/retail/our-insights/is-apparel-manufacturing-coming-home>, 11 October 2018

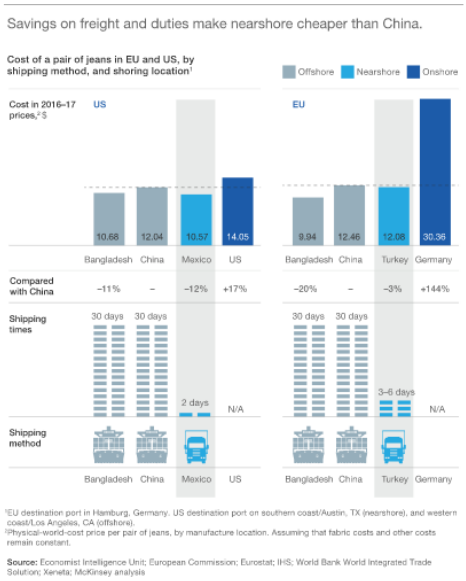

Figure 9: Savings on freight and duties make nearshoring cheaper than China (Andersson J., Berg A., Hedrich S., Magnus K., *Is Apparel manufacturing coming home?*, on McKinsey Global Institute, <https://www.mckinsey.com/industries/retail/our-insights/is-apparel-manufacturing-coming-home>, 11 October 2018)

The second variable refers to the impact that the digitalization of logistics operations, especially those related to transportation, have on the viability of reshoring.

On one hand the emergence of the on-demand economy which is based on the instant satisfaction of costumer requests via the immediate provisioning of goods and services, puts under pressure companies to invest in solutions that allow them to be able to create the product nearby or within target markets to minimize lead time.

This may make reshoring attractive and incentive regional integration of production and markets.

On the other hand the e-commerce/logistics nexus has the opposite effect on this trend.

E-commerce platforms offer a wide range of diversified and costumized products instantly available to costumers as well as the possibility to gather information that can be used to run advanced algorithms that can be useful to detect problems, which ones solved, can improve predictability and efficiency.

Logistics 4.0 technologies enable to bridge great geographical distance while still meeting the fast response requirement.

Lastly the third variable is about the modularization of products.

It refers to a design model that subdivides a system into smaller parts called modules that can be developed, modified and replaced indipendently with other modules.

The creation of modular product allows to fragment the value chain and potentially locate the activities in geographically remote areas.

The combination of modular production and advanced logistics allows to conciliate the exploitation of cost advantages in developing countries and to enable flexible and rapid product adjustments in large target markets, therefore representing a potential driver of reshoring or nearshoring.[99]

It appears clear that the digital transformation that is gradually changing supply chains has great impact on the location of production and Global Value Chains and is influencing companies' decisions on this topic.

It is however not possible to state whether the impact of digitalization causes reshoring or offshoring since all variables previously analyzed all have both elements that support one and also the other trend.

[99]Butollo F., *Digitalization and the geographies of production: towards reshoring or global fragmentation?*, on Sage Journals, <https://journals.sagepub.com/doi/full/10.1177/1024529420918160>, 10 April 2020

CHAPTER IV: SUPPLY CHAIN 4.0 RISKS: THE PROBLEM OF CYBERSECURITY

4.1. DIGITAL TRANSFORMATION AND CYBERSECURITY

The spread of the adoption of digital technologies in business processes ensures great possibility of growth for companies but at the same time it does not come without costs.
The great degree of integration and connection that characterizes supply chain 4.0 exposes companies to the key issue of security and risk assessment.
The huge amount of data and information produced by the advanced technological systems can in fact be very precious for companies, not only the ones that own the machines or platforms that generated them but also to external ones, such as competitors or the organized crime.
Cyberattacks and corporate spies are proliferating nowadays, capitalizing on the disruption generated by the new digital technologies.
As cyber threats mount top management of corporations is trying to identify the sources of their vulnerabilities both internally and by looking at third partners and the supply chains.
Every enterprise's security in fact is dependent on each of its employees, suppliers, resellers, partners and costumers, therefore, given the very wide spectrum of possible influential actors it is important that every company has a global security defense programm.
Each company should define its security strategy according to their structure, partners and operations, however the viability of these depends on the ability to make sure that they address all dimensions of the threat environment, which are:

- Attackers' characteristics and their most common tactics;
- The nature of the enterprise security environment;
- Companies' relationships with costumers and suppliers as well as the nature of the business itself such as market conditions and organizational structure.

These conditions are constantly evolving and therefore should not be taken for granted once identified, rather they must be kept always updated.

Depending on these dimensions each company will develop its own programm that fits with its characteristics, therefore it is not possible to present a unique model that can be applied to every organization.

However when talking about means to reduce the risks of third-parties attacks, McKinsey Global Institute has provided some examples that can represent a useful general guide.

These mechanism are:

- Communication: open communication and transparency between the company itself and third parties reduces the risk of foreign attacks. More concretely some options could be to mandate security training and certificate in third parties' contracts, adopt a risk management framework which, through al algorithm, evaluate suppliers on a relative risk or create incidents guide that partners can use to make sure that they know how to handle certain dangerous situations;
- Legal requirements: another efficient means to reduce the risk for external attacks might be to include in their contracts with partners a clause that impose that third parties meet enterprise security standards and that these standards must be imposed and satisfied also by any subcontractor that could affect company data.[100]

Even if the adoption of a protection mechanism against cyber attacks and threats is vital for companies, their misconception and wrongful development and implementation may represent a barrier to digitization instead of being an enabler.

In fact what emerges from many studies is that existing cybersecurity models are successful in preventing and reducing the risk of cyber breaches but they are in tension with the emerging digital enterprise.[101]

This new model is based on the idea that all partners and members of the supply chain are connected via advanced platforms and cloud solutions, therefore companies heavily rely on these methods, that in order to work properly need to be fully and freely accessible by whoever has an interest in it.

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[100]Issa A. A., Bailey T., Boehm J., Weinstein D., *Enterprise Cybersecurity: Aligning third parties and supply chains*, on McKinsey Global Institute, <https://www.mckinsey.com/business-functions/risk-and-resilience/our-insights/enterprise-cybersecurity-aligning-third-parties-and-supply-chains>, 12 May 2021

[101] Kaplan J., Richter W., Ware D., *Cybersecurity: Linchpin of the digital enterprise*, on McKinsey Global Institute, <https://www.mckinsey.com/business-functions/risk-and-resilience/our-insights/cybersecurity-linchpin-of-the-digital-enterprise>, 19 July 2019

Often, in fact, security teams are misaligned with development and production ones, because they need a very long period of time to perform mandatory controls and sometimes they do not give enough attention and importance on aspects that the latter value the most, such as analytics.

This difficulty of finding a common view can lead to missed business opportunities as new capabilities and items are delayed in reaching the market.

Moreover this tendency can even cause the opposite effect by pushing production teams to adopt certain risky actions that contribute to increasing company's vulnerability.

In order to prevent these downsides cybersecurity teams should focus on three dimensions when developing and performing their functions: use quantitative risk analytics for decision making, incorporate cybersecurity in the business value chain and adopt innovative business platforms.

The first dimension refers to the need for companies to shift their traditional approach to decision making, from a more general qualitative one based on intuition and experience to a quantitative one based on analytics tools.

The increased complexity of data that need to be scrutinized has made the existing approach obsolete, forcing companies to develop tailored risk-management practices for every potential source of danger.

This may include employee and partners segmentation and behavioural analysis to identify possible signs of threats as well as advanced authentication systems to grant access to critical data and systems.

The second dimension deals with the high degree of interconnectivity that every company has with their costumers, suppliers and other partners.

As a result cybersecurity issues influence the whole business value chain and therefore the action that need to be implemented have to included into costumer relationships, supplier interactions and business processes.

Adopting protection systems that are intrinsical to the whole value chain can bring important benefits.

It helps to enhance costumer loyalty, reduce the risk that costumers and suppliers try to circumvent security controls as well as the time needed to perform protection controls.

The last dimension refers to the growing tendency towards the adoption of agile methodologies to replace traditional security systems.

The aim is to create new flexible control tools which are based on cloud services and can be easly included in digital platforms to make them inherently secure.[102]

The development of such security measures is becoming an urgency for companies since the pace at which cyber threats are happening is dramatically increasing and they tend to become always more sophisticated and difficult to spot in advance and prevent.

[102]Kaplan J., Richter W., Ware D., *Cybersecurity: Linchpin of the digital enterprise*, on McKinsey Global Institute, <https://www.mckinsey.com/business-functions/risk-and-resilience/our-insights/cybersecurity-linchpin-of-the-digital-enterprise>, 19 July 2019

4.2. SUPPLY CHAIN ATTACKS

Cyber attacks are a phenomenon that has been spreading a lot during the last decade and which diffusion seems to be proportional to the technological advancement of systems and platforms adopted by companies.

Over the years also the pattern of the commission of the breaches has changed, in fact cyber criminals realized that attacking well protected organizations turns out to be a complex and demanding mission.

For this reason they started to recalibrate their actions by focusing on supply chains, because, since they are made of many smaller indipendent members, they offer a wider range of possible targets.

Moreover, given the great degree of interdependence of the supply chain, a successful attack can also have a broader and disruptive impact because its effects can easily spread also to other members or even organizations that are in a way connected with the original target.

A supply chain attack is a cyberattack that tries to damage a company by exploiting vulnerabilities in its supply chain network.[103]

More specifically it is described by the European Union Agency for Cybersecurity as «a combination of at least two attacks. The first attack is on a supplier that is then used to attack the target to gain access to its assets. The target can be the final customer or another supplier. Therefore, for an attack to be classified as a supply chain one, both the supplier and the customer have to be targets.»[104]

When speaking about supply chain attacks suppliers are considered as the main and most obvious targets, empirical evidence shows a different tendency instead.

Generally in fact suppliers are used only as a mean to get access to costumers' data which are the ones most highly valued.

The great amount of data generated by digital technologies used by costumers represents a big opportunity for companies to get insights to develop new product, services, as well as new advertising and marketing campaigns.

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[103] Frankenfield J., *Supply Chain Attack*, on Investopedia, <https://www.investopedia.com/terms/s/supply-chain-attack.asp>. 11 February 2021

[104] European Union Agency for Cybersecurity, *ENISA Threat Landscape for Supply Chain Attacks*, July 2021

However this massive availability of data also brings important responsabilities regarding their protection.

The huge proliferation of cyber breaches is pushing clients to become more and more wary about whom to share their personal information with and this puts companies under pressure to adopt solid security measures.[105]

Given this general modus operandi we can define a supply chain attack structure as composed of two different moments:

- The attack to the supplier;
- The attack to the orginal target: the costumer.

The supplier is in fact generally considered as a source where to get information and data from, that then are used to break costumer's security systems.

This general framework of attack structure is also adopted by the European Union Agency for Cybersecurity in its report in which it presents the current state of cybersecurity through the analysis of different cyberattacks occured in 2020 and from January to early July 2021.

This analysis shows that out of 24 attacks, 8 were reported in 2020 and 16 in 2021 so far, with empirical evidence based on these data that forecast a trend at the end of 2021 that will be four times the one in 2020.

This research can be useful not only to stress the urgence for companies to adopt protection systems but also because it provides insights about the behaviour of attackers throughout the commitment of the crime.

The European Agency in fact have studied cyberattacks by decomposing them into their building blocks and investigating the main features of the supplier attack and the costumer one, by identifying the major techniques utilized and target chosen.

Even if this list is not completely exhaustive, still it can be considered as a satisfying representation of the most common ways of operating by hackers.

The analysis is splitted in two parts: one regarding attack techniques utilized to compromise the supply chain on both the supplier and the costumer side and one related to the assets targeted by the attack.

For what concerns the supplier side the most used techniques appear to be:

[105]Anant V., Donchak L., Kaplan J., Soller H., *The consumer-data opportunity and the privacy imperative*, on McKinsey Global Instiitue, <https://www.mckinsey.com/business-functions/risk-and-resilience/our-insights/the-consumer-data-opportunity-and-the-privacy-imperative>, 27 April 2020

- Malware infection: malware used to steal credentials from employees ;
- Social engeneering: for example phishing which is a particular type of fraud where the aim is to convince the victim to provide credentials and other personal information;
- Exploitation of software or configuration vulnerability: in these cases attackers take advantage of various problems in configuration or applications structure;
- Physical attack: in this case there is a physical intrusion in the hardware that is modified;
- Counterfeiting: counterfeit hardware is one of the most common supply chain attacks that can cause sever operational and financial problems to the company because it also quite tricky to verify whether a unit is counterfeit or not. Therefore this malfunctioning may last for a long period of time.

These techniques are applied to hit specific targets, which are:

- Software: cloud platforms, web server, applications,etc;
- Code: for example source code;
- Configuration: mainly password and URLs;
- Data: personal data, data from the supplier and costumers, etc.;
- Processes: for example back-ups and updates;
- People: targeted people that have access to sensible infrastructure, data or processes.[106]

As for what concerns costumers there are both some techniques and targets that are in common with supplier attacks such as phishing, malware infection, physical modification, counterfeiting and personal data, software, processes and people respectively.

Together with these one there are also some others which are specifically developed for attacking costumers, especially when it comes to identifying the target asset.

Apart from the already mentioned most traditional targets, many attacks aim to gain access to financial data such as payment data, money transfers and bank account as well as more general data such as documents, emails, video and images feeds.[107]

[106] European Union Agency for Cybersecurity, *ENISA Threat Landscape for Supply Chain Attacks*, July 2021

[107] European Union Agency for Cybersecurity, *ENISA Threat Landscape for Supply Chain Attacks*, July 2021

Even simple and apparently unattractive information in fact can represent a juicy opportunity for hackers to leverage their attacks, therefore no data can be considered safe from cyber threats.

A survey performed by Anchore of over 400 enterprises with at least 1000 employees shows that a significant majority of them, about 64%, have been impacted by supply chain attacks within the last year, 35% of which experienced a significant or moderate one.[108]

Alongside with these information about supply chain attacks diffusion, data about the degree of relevance that cybersecurity has for companies has been elaborated.

What emerges is that generally almost all enterprises realize the importance of securing their supply chain software, even if there is great inhomogeneity in the degree of significance recognized to this issue.

60% of respondents affirm to consider it as a significant or top area topic, 37% simply consider it as an area of interest or is just starting now to pay attention it, while there still is 3% of interviewed that do not consider it at all as a priority theme.[109]

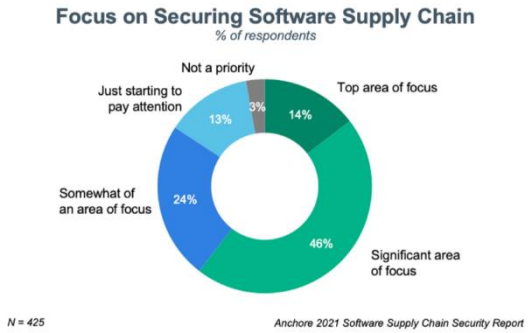

Figure 10: Focus on securing Software Supply Chain (Anchore, Report on Software Supply Chain Security, 2021)

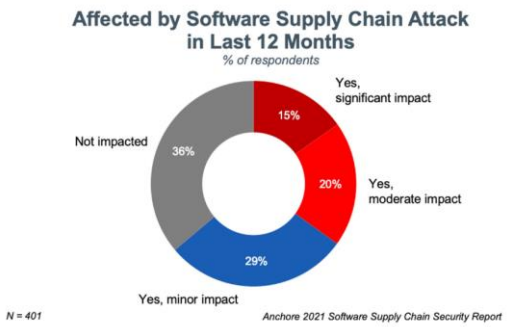

Figure 11: Affected by Software Supply Chain Attacj in the last 12 month (Anchore, Report on Software Supply Chain Security, 2021)

These data represent an empirical evidence of the overall growing attention towards the supply chain security problem, but at the same time it highlights that much still needs to be done by companies to provide themselves with appropriate and advanced security

[108] Anchore, Report on Software Supply Chain Security, 2021
[109] Anchore, Report on Software Supply Chain Security, 2021

systems that are able to protect them from the always more aggressive and potentially destructive cyberattacks.

4.3. THE SMART SUPPLY CHAIN RISK MANAGEMENT

Supply chains are the fulcrum of most businesses todays, which have decided to structure their operations by relying on other organizations to acquire products and services.

Their great complexity is making supply chains always more difficult to manage, control and protect.

Besides being constantly attacked by external events such as natural disasters, geopolitical dynamics or the more recent COVID-19 pandemic, the supply chain is being always more threatened by cyber attacks targeting supplier and costumer networks.

Together these threats increase the relevance of ensuring resilience, business continuity, and recovery planning inside every supply chain.

In fact the intrusion of cyber criminals into organization's network can be very dangerous and cause severe harm to the company's financial and reputational viability, especially for small and medium enterprises which generally are those less prepared to face such challenges.

A study performed by Verizon showed that, if hit by a cyberattack, 60% of small and medium sized businesses are likely to go out of business within six months of the attack.[110]

These numbers emphasize the necessity, especially for those type of companies, to adopt security programms and measures to prevent downfalls.

It is important to underline that small companies may not need the same structure of big ones, therefore these protection systems will need to be developed avoiding the "one size fits all" approach, rather taking into consideration various firm specific features, such as size, organizational structure, industry, and so on.

Therefore it is not possible to describe a specific model that can be considered as the perfect one to guarantee maximum protection, rather some a more conveniente approach would be to identify some basic principles that companies could follow to inspire the design of their security measures.

One major requirement for the creation of an efficient protection system is that critical and key supplier need to be its fulcrum.

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[110] Sridhar K., Ralph D., Copic J., *3 strategies to secure your digital supply chain*, Harvard Business Review, <https://hbr.org/2021/08/3-strategies-to-secure-your-digital-supply-chain>, 9 August 2021

First, it is important to identify those critical suppliers.

In general they are considered to be those that, if hit by a cyber attack would cause a negative business effect.

Many criteria can be adopted to ascertain whether a supplier is a critical one or not, such as: revenue contribution, volume of data they generate, whether it has access to the company's infrastructure or it can become an attack vector allowing threat actors to access the acquirer.

If suppliers are identified and classified, the relative risk can be assessed and they can be prioritized by their criticality.

Alongside the categorization of suppliers in order to manage them according to their priority, another key aspect to develop a solid security programm is to collaborate with suppliers to integrate them in the overall shared ecosystem to ease the management of complex supply chains.[111]

The other big aspect which to focus on security programms development are vulnerabilities, meaning those flaws that weaken company's digital infrastructure and expose it to external attacks.

As for suppliers, also vulnerabilities should be analyzed and classified according to a cost-benefit approach.

In fact not all vulnerabilities are the same, some are very difficult to be triggered and therefore remain unexploited.

A study performed by Fortinet showed how only 6% of vulnerabilities were actually used as a mean for a cyber attack in 10% of the organizations that were part of this survey, while higher probabilities are found only in a smaller fraction of respondents, from 0.1% to 1%.[112]

[111] NIST, *Key Practices in Cyber Supply Chain Risk Management: Observations from Industry*, available on <https://doi.org/10.6028/NIST.IR.8276>, Report n.8276, Febraury 2021

[112] Fortinet, *Global Threat Landscape Report*, February 2021

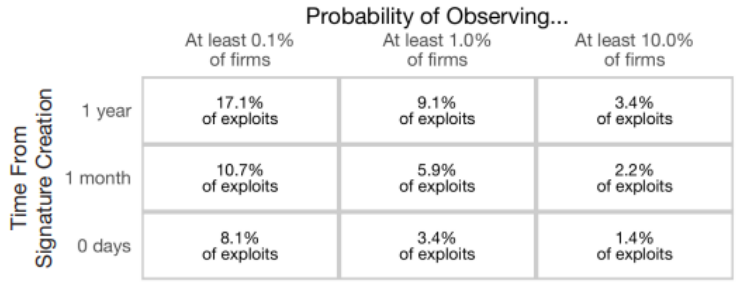

Figure 12: Statistics on the rate and spread of over 1,500 vulnerability exploits in the wild. (Fortinet, *Global Threat Landscape Report*, February 2021)

This scenario shows that, with an efficient analysis, companies can identify those vulnerabilities that are more likely to be exploited and focus on specific measures to fix them, while can wait to treat less urgent ones.

The evaluation of vulnerabilities can be supported also by new and advanced metrics, such as the Exploit Prediction Scoring System, that estimates the probability of a vulnerability on the basis of its characteristics in order to help risk managers to test whether benefits outweigh the costs for remediation.

When talking about simple vulnerabilities, companies should start to rely on automated tools to fix them so that this process does not require an excessive investment of time and resources and can be done easly also by not trained and specialized employees.

On the other hand when it comes to complex vulnerabilities that affect control systems that run factories or energy supply, the major problem is related to the fact that, generally updates and manuevers to be performed to fix them are very demanding and time-consuming.

Usually in fact they can be performed only while these platforms and software are offline, therefore a conflict of interest arises because companies are forced to choose between the availability of these vital services and fixing them.

Since none of the aforementioned possibilities is viable, the best solution would be for software providers to implement hot patching to allow pacthes without having to reboot the software.

If on one hand this solution appears to be quite costly to implement, at the same time it is also one of the best ways to ensure both security and availability.[113]

In general these can be considered as useful guidelines to develop an efficient cybersecurity system, but the development of firm specific ones needs to be supported by experts which have deep knowledge of both security issues and organizational structure and features so that to create the most appropriate and suitable combination of actions and to ensure an extensive support to digital supply chain risk management.

[113] Sridhar K., Ralph D., Copic J., *3 strategies to secure your digital supply chain*, Harvard Business Review, <https://hbr.org/2021/08/3-strategies-to-secure-your-digital-supply-chain>, 9 August 2021

CONCLUSION

Our society is going through a rough patch, characterized by great changes that are shaking up our lives very rapidly.

Under an economic point of view industrial transformations are disrupting processes that completely modify the business scenario and therefore force companies to be prepared to face the irreversible changes that they cause.

The fourth industrial revolution is creating new important opportunities for firms to maximize their performance and efficiency through the adoption of new and advanced technologies, such as analytics, robotics, big data and Internet of Things.

These tools contribute to innovate all business processes, from planning and production, to distribution and post sales services.

The great pervasiveness of these technologies affects not only internal processes like the ones mentioned above, but also the relationships that the company has with external partners such as suppliers, distributors and costumers, meaning the whole supply chain.

This thesis shows how the digitalization of business practices in the planning, procurement, production, warehousing and transport functions is carried out and can bring important benefits to companies.

In fact the adoption of these innovations make each of the aforementioned functions more flexible, agile, efficient and less costly enabling the company to adjust its operations in real time according to changing market conditions and promptly respond to any inconvenience, as well as improving inventory management, reducing waste and lead time.

This characteristics allows to foster business relationships both with suppliers and costumers.

For what concerns the former the innovations lead to greater cooperation and collaboration, enabling both to share information about delivery time and availability of raw materials in order to guarantee just in time production and on time shippment of the final product to the costumer.

Instead the latter benefits from the digitalization process by receiving products and services of higher quality and accuracy, ensuring high levels of satisfaction.

This represents a great opportunity for companies to improve costumer loyalty and retain clients, therefore increasing their market share.

Alongside costumers and suppliers, huge effects are hitting also the labour market which is going through a disruptive process of job distruction and job creation.
The introduction of digital technologies in fact allow many jobs that, till now where performed by human workers, to be automated.
Simultaneously new occupations can be created especially in those functions that require typical human traits such as creativity, empathy and other realtional skills to be combined with digital ones.
The main problem in this dynamic is that it is hard to ensure the perfect matching between the distruction of old jobs and the creation of new ones, without generating unemployment.
Therefore workers, included those employed in supply chain management activities, need to be accurately trained to deal with the characteristics of these new technologies and be able to manage their tricky functioning.
When analyzing such a complex phenomenon it is important not to forget about taking into consideration also the potential disadvantages and obstacles that may arise.
In this case I focused on just one of the many that may affect a company during its process of opening up to the digital transformation, which is cybersecurity.
This issue is becoming extremely relevant as the adoption of innovative technologies speeds up, since most of them rely on shared platforms and data streams, which vulnerabilities can be exploited by cyber criminals to get access to suppliers and costumers informations and software, causing severe harms to companies and threatening their long-term viability.
The undesirable consequences that a cyber attack can cause points out the huge importance of creating a safety net that grants protection and enables the company to preserve its innovative structure.
Things are moving fast and companies need to start the journey of digitalization as soon as possible to avoid being outperformed by competitors.
However it is crucial that they acknowledge the huge risks and efforts that this transition will require, and therefore be prepared to eventually go through a rough and challenging patch before starting to benefit from the numerous advantages that this process can grant.

My guess is that it will all lead to a better economic scenario and environment for companies to work in, but only if they are willing to fully commit to such an unpredictable and risky as well as rewarding path.

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