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GREEN SUPPLY CHAIN MANAGEMENT AND INDUSTRY 4.0: THE IMPACT OF DIGITALIZATION ON SUPPLY CHAIN SUSTAINABILITY PERFORMANCE

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ABSTRACT

The problem of pollution and climate change has become of fundamental importance in recent years. Faced with increasingly extreme climatic phenomena, the economic world is concentrating part of its efforts on the search for new technologies and eco-sustainable processes to be implemented in a greener perspective. Companies, all over the world, have now strengthened their eco-friendly perspective, embedding it into their corporate philosophy and trying to put it in practice throughout the production chain and beyond, in the phases following the consumption of the finished product, with stakeholders increasingly sensitive to these issues. At the same time, we have entered a new era characterized by a digital revolution to which all companies are trying to adapt, in order to strengthen the supply chain of their services both from an economic and an environmental point of view. With this thesis project, I analyzed the impact brought by the birth of industry 4.0 on the implementation of effective GSCM strategies while also considering the challenges and obstacles possibly envisaged in a forward-looking perspective.

I wanted to investigate, through in-depth literature review and from "Smart cities" examples, the influences that a digitized production system can have on GSCM performance (economically and environmentally), considering the spread of the Internet of Things. The aim was to study the effective degree of sustainability guaranteed by the digital economy. Thus, the thesis reviews how digital technology affects the performance of the entire supply chain, trying to understand the phases of the supply chain that are made more efficient, identifying the benefits and the conflicts between digitalization and sustainable commitment.

As a first step, the theme of climate change and environmental pollution was explored, addressing the issues inherent to it (Sustainable Development Goals, Corporate Social Responsibility, etc.). Then, a review of the literature was carried out to better define the concepts of Supply Chain Management, Green Supply Chain Management, and Industry 4.0. The aim was to identify indicators of:

1) environmental performance, selecting those who could most touch the theme of the GSCM.

2) economic performance, understanding the economic areas on which GSCM strategies have the greatest impact.

By studying the concept of Industry 4.0, it was finally possible to note how, among the various existing digital technologies, the IoT was the most impacting on the supply chains of modern companies. Through these variables, a qualitative analysis was carried out on the effects of this technology on the indicators identified. The study showed the beneficial elements in terms of eco-sustainability and economic stability, highlighting, however, the main criticalities.

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CHAPTER 1: INTRODUCTION ON CLIMATE CHANGE AND ENVIRONMENT POLLUTION

1.1 - An overview of climate change impacts and unsustainable practices

In recent years, the debate on climate change has become increasingly heated. Men exert a significant influence on the climate due to the use of fossil fuels, deforestation and intensive livestock farming (*Cause Dei Cambiamenti Climatici*, Commissione europea). The excessive use of fuels and the carrying out of these activities has contributed significantly to increasing the emissions of toxic gases and fueling the so-called greenhouse effect. The gases emitted (among the main ones are CO2, methane, nitrogen oxide and fluorinated gases) generate devastating effects. A worrying data is what concerns, for example, the CO2 present in the air, which in 2020 was registered to be 48% higher than in the pre-industrial era. Climate change is often represented by global warming, which has become worrying especially in the decade 2011-2020, with human-induced warming that seems to have to increase to a level of 0.2° annually (*Cause Dei Cambiamenti Climatici*, Commissione europea).

The consequences can be serious and impact human health, the ecosystem, the behavior of individuals and economic/non-economic organizations.

1.1.2 - Human health

Generally, a human being needs a vaporative cooling which can fail when the outside temperature is excessively high. This can cause a disproportionate overheating generated by a too high body temperature, because the body is unable to rebalance itself. A wet bulb temperature (index which is used for weather forecasts and that indicates the lowest temperature obtained by evaporating water in the air at constant pressure) exceeding 35° can even cause death (Valentová & Bostik, 2021). The heat stress that the body undergoes can lead to hypothermia and other harmful effects, even affecting internal organs such as the brain and heart. But that is not all: due to the overheating of the oceans

and the climate, it is not uncommon for new diseases to come out or the past ones to resurface. One of the most dangerous examples for humans is represented by diseases transmitted by animals to humans, especially those transmitted by mosquitoes. In fact, many types of diseases derive from them, such as malaria, yellow fever and dengue fever, which each year kill hundreds of thousands of people and are the most lethal (*Deadliest Creatures by Human Deaths Annually Worldwide 2018 | Statista*). The most worrying data concerns the fact that these diseases are recorded mainly in areas where floods are frequent or characterized by drought, in which mosquitoes find the right climate to reproduce. In addition, overheating allows the latter to survive longer in civilized areas, becoming a danger even in those zones that were previously considered safe (Valentová & Bostik, 2021).

The heating of water represents also a danger as it generates a habitat suitable for the proliferation of pathogenic bacteria, as for example amoeba Nigeria fowler in freshwater, and the parasite Cryptosporidium in pools (Valentová & Bostik, 2021).

Continuing with the description of what are the possible impacts of climate change on human health and what are the repercussions that it can have on the real life of individuals, it is important to mention the food borne diseases that derive from it. CDC (Centre for Diseases Control and Prevention) estimates 48 million people get sick, 128,000 are hospitalized, and 3,000 die from foodborne diseases each year in the United States (*Estimates of Foodborne Illness in the United States | Estimates of Foodborne Illness | CDC*). But all over the world are detected dead due to the unsafe food causes, for 600 million cases of foodborne diseases and 420.000 deaths (*Estimating the Burden of Foodborne Diseases*). Pathogens campylobacter and salmonella seem to be influenced by climate change. They are two types of diseases for which the number of infected and resulting deaths had dropped considerably thanks to health and hygiene improvements. But this improvement risks being offset in the negative by an increase resulting from global warming (Valentová & Bostik, 2021).

1.1.3 - Ecosystem

Climate change negatively affects the ecosystem. Not only it has negative effects directly on human health, but it also affects ecosystems by breaking the subtle balances that compose them. The action of man over the years has greatly affected this process. Thus, these changes could have consequences on the health of other animal species and the environment itself. Specifically, the terrestrial, marine and fresh water systems are affected (H. Mooney et al., 2009).

According to the Millennium Ecosystem Assessment, the major cause of the alterations arises from the land cover change, mostly due to the conversion to cropland, and to the technological development that allows to increase the production and supply of food and similar products (H. A. Mooney et al., 2005b). The only areas left intact (deserts, boreal forests, and tundra) are those that are not suitable for cultivation and that cannot be exploited for artificial purposes (H. A. Mooney et al., 2005a).

For marine ecosystem, in addition to the melting of the ice, which will cause the submersion of many inhabited coastal areas due to the rising seas, the greatest impact on the ecosystem itself is due to fishing. World fish consumption has reached remarkable numbers (20.5 kilograms per capita per year) (*FAO - News Article: La Gestione Delle Risorse Ittiche Funziona: È Giunto Il Momento Di Applicarla in Modo Più Ampio*, 2020). According to the benchmark analysis of the SOFIA report, around 34.2% of fish stocks are fished at biologically unsustainable levels. However, the marine ecosystem is damaged by a number of other indirect factors such as the pollution of lands, rivers and oceans, habitat loss, invasive species, and nutrient loading (H. A. Mooney et al., 2005b). This is particularly evident for the fresh water ecosystem; it is estimated that 50% of the inland water ecosystem was converted during the 20th century (H. A. Mooney et al., 2005b). These are the determining and best-known factors when it comes to climate change. The latter influences individual human behaviors and consequently also those of organizations, of whatever nature they may be.

1.1.4 – Air pollution and International Agreements

Air pollution is one of the most discussed issues of recent decades, and it is the most impactful regarding climate change and global warming. It is often associated to large cities. In fact, observing the statistics it is possible to notice how the world megacities contribute to polluting the air in a decisive way; the most polluted cities are the eastern ones, in particular the Indian cities (Delhi, Kolkata and Mumbai), the Chinese ones (Tianjin, Beijing and Shanghai) but also those of Pakistan (Lahore) and Bangladesh (Dhaka) (*APAC: Annual Average Air Pollution Level PM2.5 in Megacities 2020 | Statista*). Air pollution is probably the "hottest" topic both from an environmental point of view and from a political one, as the governments of countries all over the world find themselves having to face this problem, which over the years becomes more and more invasive.

Agreements between governments have long been needed to limit greenhouse gas emissions, which in the past have probably not been given the right weight. Until 2016 the only point of reference in this sense was the Kyoto protocol of 1997 (but entered into force in 2005), to which 192 countries of the UNFCCC (United Nations Framework Convention on Climate Change) have joined, including the EU countries (*Negoziati Sul Clima*, Commissione europea). The purpose of the protocol was precisely to reduce the level of Greenhouse Gases (GHGs) released into the air in such a way as not to negatively affect the climate system. To achieve this goal, each country has been called upon to comply with certain guidelines by committing to:

"1) Limit or reduce GHGs emissions 2) Implement policies to reduce emissions so as not to burden third parties in any way, especially developing countries 3) Provide adequate financial resources to allow developing countries to commit themselves to implementing these eco-sustainable policies. Both industrialized and developing countries have been called to cooperate on the development, application and diffusion of climate friendly technologies, to collaborate on the systematic monitoring of climate system; to educate, to train, and to enhance public awareness of climate change; finally, to improve methodologies and data for GHG inventories" (Ki-moon, 2008).

Each part involved in the protocol had an emission target not to be overstepped.

In general, these were the provisions expressed in the Kyoto protocol, which as mentioned, remained the only legally binding instrument useful until 2015, for fighting and limiting the phenomenon of pollution, even though, it only covers 12% of world emissions as many countries have not joined it. Currently, the legal instrument on which more reference is made, is represented by the Paris Agreement, in which all the parties to the UNFCCC took part. The Paris Agreement, signed in 2015 and entered into force in 2016, provides for the commitment of the parties in order to reduce emissions of 55% by 2030 and to limit global warming, trying not to exceed 2 ° C in excess of the pre-industrial era (*Accordo Di Parigi*, Commissione europea). The objective is to remain below the 1.5C ° threshold in order to significantly reduce the impact that overheating has on the environment.

All the considerations regarding the cooperation between countries in this direction, already mentioned in relation to the Kyoto protocol, remain valid in the Paris Agreement. The positions taken by the various countries are comforting in this sense and this is the line that must be maintained to combat everything concerning pollution and climate change.

CHAPTER 2: SUSTAINABILITY AND CORPORATE SOCIAL RESPONSIBILITY (CSR)

2.1 The basis for the transition to a sustainable system

The term “Sustainability” is most often associated with environmentally friendly practices. It means “something that can be maintained over time”.

In Europe the first use of the word dates to 1713, in Germany by the scientist Hans Carl von Carlowitz in his work Sylvicultura Oeconomica. Its spread, however, took place in the late 1980s, when the United Nations' World Commission on Environment and Development defined “Sustainable Development” as one that:

“meets the needs of the present generation without compromising the ability of future generations to meet their own needs”(Heinberg, 2010; Wilkinson et al., 2001).

In addition, Swedish oncologist Dr. Karl-Henrik Robèrt, formulated the so-called *Natural Step*, a scheme composed by four conditions that allows to build a sustainable society. To respect the conditions, the society should not be subject to a constant growing of the elements described below:

1) Concentration of substances extracted from the earth's crust
2) Concentrations of substances produced by society
3) Degradation by physical means
4) People subject to conditions that systematically undermine their capacity to meet their needs

Subsequent intellectual efforts on this issue focused on the search for indicators able to best represent the degree of sustainability of a given system.

The term "ecological footprint" was coined by Canadian ecologists William Rees and Mathis Wackernagel. This meant the level of land and water needed to maintain a certain population ensuring total absorption of waste (Heinberg, 2010).

Through that introduction on the meanings hidden behind the term *Sustainability*, it is possible to assert that a society need to avoid the unconditional use of critical resource to avoid collapse. Furthermore, the increase in population, albeit at a minimal rate, will lead to a gradual increase in the need for resources which could become unsustainable over time. In this regard, the use of renewable resources must be moderate, in the sense that the rate at which they are consumed must be lower than that at which they regenerate. About non-renewable ones, on the other hand, the consumption rate must be decreasing and not exceeding the depletion rate.

The government and corporations have a central role on the sustainability theme. The first, above all, has the task of providing environmental standards to guarantee a fair quality of products and life. Usually, these rules can be detrimental to companies in the short term. In most cases, they are associated with an inevitable increase in production costs and therefore lower profit margins. However, in the long term they could prove to be advantageous: in fact they would lead to the use of more sophisticated and innovative technologies, thus guaranteeing greater productivity, offsetting the previously mentioned costs (Wilkinson et al., 2001).

Innovation is the most important factor in directing the economic system towards greater sustainability, even more so because the demand for eco-sustainable technologies has become a competitive element in international markets.

Nevertheless, to guarantee this transition towards an innovative eco-friendlier production, adequate human resources policies cannot be ignored. In fact, more and more attention is paid to providing the right skills and techniques (the term "knowledge workers" is often used to indicate highly qualified and experienced workers in those innovative and growing business areas), keeping the working environment healthy and always looking at the needs of workers (Wilkinson et al., 2001, Moore and Miller, 1994).

If at first the issue of sustainability was only perceived as an external pressure by governments on companies, now it is clear how governments cannot solve the problem of sustainability alone. A supportive behavior on the part of the economic system and individual organizations is a fundamental element. Sustainability has become an internal and interorganizational issue, both as regards the management of the “new workforce" and the production side.

In *Figure 1*, a model represented the factors of influence for HR sustainability is provided.

Figure 1. Influences and outcomes for HR sustainability

The meaning, developed by Dunphy and Griffiths, is that to generate value and be able to regenerate it in a sustainable way, important investments in human resources are necessary. To achieve results in terms of corporate sustainability, is important to make the methods of managing workers sustainable. Five factors are considered fundamental in this regard:

1) Organizational Change
2) Employee Consultation and Involvement
3) Career development and organizational learning
4) Workplace institutions and systems
5) Work and life balance

These elements together with HR policies and practices need to be integrated in order to reach a high level of employees' satisfaction and at the same time a good degree of profit and productivity (Wilkinson et al., 2001). This concept can be extended to the

attempt of a company to reach eco-sustainable objectives and to obtain good environmental performances. To orient the entire organizational system towards a sustainable approach, it is essential to start by making workplaces sustainable, not only by ensuring the well-being and safety of workers. But also providing them with the skills, the mentality, and the right tools to be able to face such a transition sustained over time, both from an environmental and an economic point of view. It is possible to achieve satisfactory long-term results in this sense only through continuous investments in human knowledge.

2.1.1 Sustainable development goals (SDGs)

In this first phase of the thesis, data and information concerning climate change, pollution and their effects on humans and the ecosystem were analyzed. Some of the main agreements between the various countries to limit their environmental impact have also been introduced. However, what represents the largest global commitment undertaken by the UN and supported by 190 countries has not yet been described: *Sustainable Development Goals*.

The sustainable goals are 17 in total and include 169 targets, each of them representing the priorities in terms of sustainability. Thanks to the targets, it is possible to measure progress and monitor them (Wackernagel et al., 2017). The SDGs, therefore, represent a common program towards a better future, but they require collaboration between the various economic and non-economic agents, with targeted actions according to their context and purpose (Fonseca et al., 2020).

Below (Table 1), it is explained each individual SDG that are based on five areas of interest: People, Planet, Prosperity, Peace, Partnership (Sustainable & Goals, 2019).

Sustainable Development Goals	Description

SDG 01. No poverty	*"End poverty in all its forms, everywhere".* The percentage of people living in condition of extreme poverty is decrease from the 36% in 1990 to 10% in 2015. This decrease occurred mainly thanks to the progress of Eastern Asia, but poverty remains a current problem (suffice it to consider that in sub-Saharan Africa, about one third of workers earns less than $ 1.90 per day), especially in rural areas (79%) and in those where there are political conflicts. By 2030, the goal is a decrease in the number of poor people below 6%.
SDG 02. Zero hunger	*"End hunger, achieve food security and improved nutrition and promote sustainable agriculture"* Unfortunately, world hunger is increasing again, after a gradual decrease from 2005 to 2014. From 2014 to 2017, the number of malnourished people began to rise, reaching 820 million, with prevalence in sub-Saharan Africa (23.2%) and in Central and South Asia, where the percentage of stunted children is the highest.
SDG 03. Good health and well-being	*"Ensure healthy lives and promote well-being for all at all ages"* Much progress has been made in terms of maternal and child mortality, life expectancy and treatment of some infectious diseases. However, further efforts are needed to solve problems such as malaria or tuberculosis, or to decrease the number of people who do not have access to health services (at least half of the world population). Furthermore, too many women still die after childbirth (about 300,000 in 2017) due to poor hygiene and health conditions.

SDG 04. Quality education	*"Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all"* Education is fundamental for economic social progress, which would also make it possible to alleviate the poverty issue. Globally, more than half of children and adolescents do not meet minimum education standards (almost a fifth of the world population), with significant discrepancies between the various regions of the world. Furthermore, 750 million adults (of whom two thirds are women) cannot read and write.
SDG 05. Gender equality	"Achieve gender equality and empower all women and girls" Despite the progress that has been made compared to the past, the condition of women remains complicated. Partner violence, female genital mutilation, child marriages, wages and rights discrepancies, and a lack of representative leadership are just a few examples of how much more needs to be done to ensure social balance in terms of gender equality.
SDG 06. Clean water and sanitation	*"Ensure available and sustainable management of water and sanitation for all"* Fresh water is a fundamental element for human life. With the increase in population, demand has increased significantly and about half of the world's inhabitants suffer from water shortages at least one month a year. The rate of water consumption in the last century has grown by almost double the growth rate of the population. Although 90% of people have water available, water management is needed that allows for

	sustainable availability over time, and above all a reduction in waste.
SDG 07. Affordable and clean energy	*"Ensure access to affordable, reliable, sustainable, and modern energy for all"* From this point of view, considerable progress has been made. The use of clean energy is becoming more widespread and accessible. Above all, electricity is rapidly gaining ground even in the poorest countries, and energy efficiency is increasing. 9 out of 10 people have access to electricity. However, there remains a large gap between the various regions of the globe, especially with rural areas (sub-Saharan Africa), where however there has been progress since 2015. Still 3 billion (about 39% of the world population) of people do not have clean cooking fuels and technologies. Furthermore, the progress made in the electricity sector must be concretely extended to the transport sector.
SDG 08. Decent work and economic growth	*"Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all"* Here too, there have been big improvements, with real GDP increases around the world, with an unemployment rate returning to pre-financial crisis levels. However, the problem of informal employment remains a major challenge to be addressed, as well as the wage discrepancies between men and women. Furthermore, as always, in terms of employment there are large discrepancies between regions. In addition, more than a fifth of young talents remain unexpressed or poorly managed.

SDG 09. Industry, innovation, and infrastructure	*"Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation"* Building a sustainable industry through infrastructures and innovations is a key element for generating employment, and for the diffusion of new technologies, also facilitating international trade. Especially in low-development countries, such infrastructure is needed, and there has been positive feedback in recent years. The manufacturing industry reduced its carbon emissions by 3% from 2010 to 2016, reducing CO2 emissions and increasing GDP. Furthermore, technological advances have led an ever-increasing number of people to own a mobile phone, joining a communication network, with 90% of people having access to at least a 3G network.
SDG 10. Reduced inequalities	*"Reduce inequality within and among countries"* As mentioned also for the other indicators, the existing inequalities between the various states are still very large, and the differences in income still grow in some countries. Great efforts are needed to reduce this gap especially as regards access to the labor market and trade.
SDG 11. Sustainable cities and communities	*"Make cities and human settlements inclusive, safe, resilient and sustainable"* The world is becoming more and more urbanized, and by 2030 city dwellers are expected to make up 60% of the total population. However, this increase in density in cities causes a 70% increase in total carbon emissions and a much

	more intensive use of resources (60%). In addition, many people live in slums, with a growing lack of adequate sanitation, health, and transport infrastructure. In this regard, many nations have made efforts to implement national urbanization plans.
SDG 12. Responsible consumption and production	*"Ensure sustainable consumption and production patterns"* About a third of the food produced for consumption is wasted every year, particularly in the richest and most developed countries. It is therefore necessary to avoid that the need for materials leads to an excessive exploitation of natural resources, leading to the deterioration of the environment. This is achieved through a reduction of our "material footprint", that is the quantity of raw materials extracted to satisfy the demand, which is growing at a higher rate than both the population and the GDP.
SDG 13. Climate action	*"Take urgent action to combat climate change and its impacts"* Global pollution is changing the climate, with serious consequences. Therefore, there is a need for a collective effort by the various countries (through plans to boost their resilience and capacity to adapt to climate change and with disaster risk reduction strategies) to resolve the issue, which leads to changes in society without precedents.
SDG 14. Life below water	*"Conserve and sustainably use the oceans, seas and marine resources for sustainable development"* Marine waters considerably mitigate

	man-made CO2 emissions by absorbing about a quarter of them. However, with the continuous increase in emissions over the years, the oceans are acidifying, changing their chemical composition, causing climate change and environmental disasters, with the melting of the ice that would lead to the submersion of coastal areas. Ocean acidification is not only a problem for ecosystems but also for organisms, harming aquatic animals and sometimes human food.
SDG 15. Life on land	*"Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation, and halt biodiversity loss"* A United Nations report estimated that between 2000 and 2015 about 20% of the earth's land areas were damaged (particularly in Oceania and Central and South Asia). Ecosystems are irreversibly changing, with many species dying out, threatening the level of biodiversity which is decreasing at a rate never seen before. International interventions have been implemented to protect ecosystems, biodiversity, counteracting the deterioration of land areas, forests, mountains, etc.
SDG 16. Peace, justice, and strong institutions	*"Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels"* In 2018, several people afflicted by wars and persecutions was estimated to exceed 70 million, the highest value ever recorded by the

	United Nations High Commissioner for Refugees in the last 70 years. Moreover, little has been done to reduce violence and to ensure human rights (as birth registration) and justice for all. Many people still do not have access to the minimum requirements of justice and attacks on human rights activists and journalists are still very frequent.
SDG 17. Partnerships for the goals	*"Strengthen the means of implementation and revitalize the global partnership for sustainable development"* International cooperation is required to achieve the goals set by the SDGs. The total net value of ODA (the main source of external financing for low-development countries) is declining, particularly due to a reduction in aid to countries hosting refugees. National resources deriving from taxation (which in the top 20 countries reached 23% of GDP in 2017, while 18% for developing countries), must be best managed to achieve the SDGs. Personal remittances have become the major form of financing for developing countries, and trade tensions are increasing, creating problems for producers and consumers. More than half of the world's population is connected and digitized, while the other half is not, and therefore the gap must be bridged.

Table 1. SDGs description, UN-SDGs, 2019

To measure the level of countries' performance on each SDG, an *SDGs index* was developed by researchers supported by two no-profit organizations, the Bertelsmann Stiftung, and the sustainable development solutions network. This is the only tool that

allows to aggregate results.

An index needs two fundamental dimensions, that are *a) how each component is evaluated* and *b) how components are aggregated*.

In this case, no degree of preference or priority has been set for any objective; indicators can be divided into three most important groups:

1) Those that decrease the people's resource dependence (i.e., activities that increase the availability of water or crops). It had a weight on the index equal to 13.6%, considering the results obtained to assess the graph.

2) Those that increase people's resource dependence (i.e., activities that provide benefits but require resources to be implemented like hospitals). The weight on the index results was 67,6%.

3) Those that neither increase or decrease resource dependence (i.e., those activities that change some aspects of society, but they do not concern the consumption or the increase of availability of resources, such as ensuring certain rights for women or workers). The weight resulted to be 18,8%.

(Wackernagel et al., 2017).

Starting from this assumption, a graph of the sustainable ranking of the different countries is provided to compare their performances (Figure 2).

The graph was constructed considering two variables, the development achievements of each country (represented on the horizontal axis through UN's human development index) and their level of use of resources (placed on the vertical axis and indicated by the ecological footprint for person).

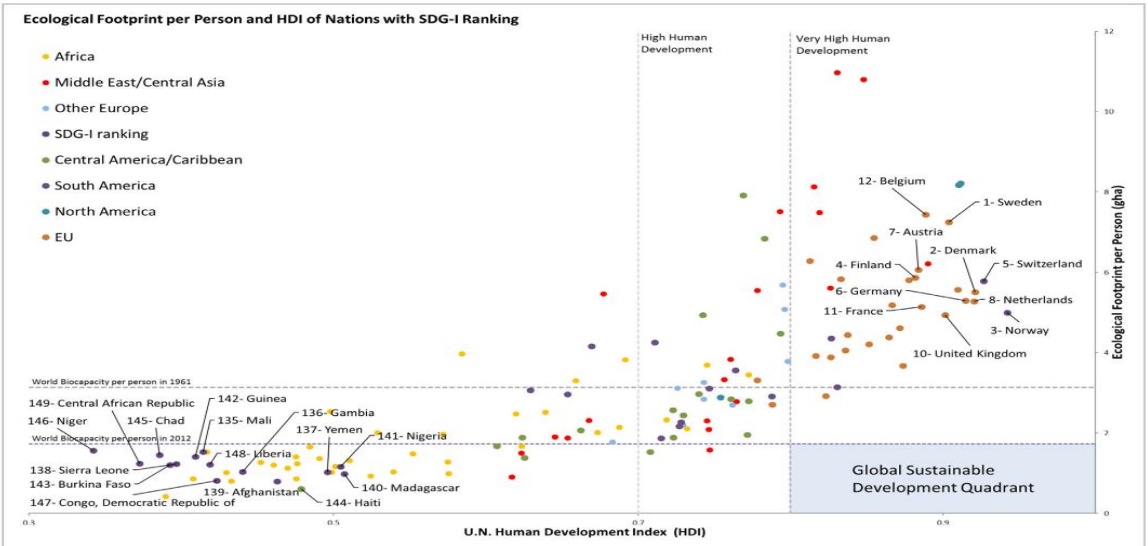


FIGURE 1 | Ecological Footprint per person and HDI by country indicate how close each country is to basic global sustainable development criteria (high human development, within resource requirements that are globally replicable). Each number indicates the country's ranking on the sustainable development goal (SDG) index (only top and bottom 10 are marked here).

Figure 2. Sustainable ranking based on SDGs performance

As shown in the figure, although some European country as Belgium, Sweden and Austria has a High Human Development Index, there are no countries inside the Global Sustainable Development Quadrant. The correlation between a high ecological footprint rate and a high performance of the SDGs index appears to be just a coincidence. As human development increases, so does the ecological footprint, not allowing any country to cover the area of sustainable development, not even the ten with the highest-ranking SDGs.

This is significant of how much work still needs to be done in terms of emissions and pollution. Despite the commitments undertaken by the various countries, to reduce the ecological impact, the results are still not very encouraging. However, the technological processes that are gradually developing, and the innovations of various kinds that are taking place, the situation could change in the not-too-distant future.

2.2 Corporate Social Responsibility (CSR): definition and different approaches

Considering the scenarios just described, even economic organizations have become increasingly sensitive over time and have begun to adopt eco-sustainable strategies in respect of the interests of all stakeholders. Analyzing more in detail, the literature offers us many insights regarding the concept of CSR and how the latter is increasingly consolidating in the mindset and strategy of companies.

Starting from understanding the meaning of the expression "Corporate Social Responsibility", there are several interpretations of the topic: one of the first concrete definitions is provided by Keith Davis (1960) which suggested that,

"CSR includes decisions and actions taken for reasons at least partially beyond the firm's direct economic or technical interest".

together with that of Eells and Walton (1961) which state that:

"*CSR refers to the problems that arise when corporate enterprise casts its shadow on the social scene, and the ethical principles that ought to govern the relationship between the corporation and society"*

The World Business Council for Sustainable Development defined it as:

"The continuing commitment by business to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as of the local community and society at large"

Instead, the European Commission described it as:

"A concept whereby companies decide voluntarily to contribute to a better society and a cleaner environment. A concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis" (Fontaine, 2013; Mahajan, 2015)

To summarize the general meaning incorporated in the definitions cited above, the CSR represents the commitment of the various businesses to meet their economic and financial objectives, in such a way that the processes involved in achieving them follow the ethical, social, and environmental principles required by the various stakeholders. It is an idea that goes beyond the mere corporate research of achieving its profit goals, and which does not represent an obligation, but it is in any case, albeit on a voluntary basis, inherent in the mission of companies as an indispensable social commitment.

In this sense is important to introduce *"The Pyramid of Corporate Social Responsibility"* developed by A. Carroll (1991). It breaks down CSR into four components: economic, legal, ethical, and philanthropic. The first two (Figure 3a), refer to the role of businesses as profit optimizers (Economic component), pursuing economic objectives through and in compliance with legal framework (Legal component).

Economic and Legal Components of Corporate Social Responsibility

Economic Components (Responsibilities)	Legal Components (Responsibilities)
1. It is important to perform in a manner consistent with maximizing earnings per share.	1. It is important to perform in a manner consistent with expectations of government and law.
2. It is important to be committed to being as profitable as possible.	2. It is important to comply with various federal, state, and local regulations.
3. It is important to maintain a strong competitive position.	3. It is important to be a law-abiding corporate citizen.
4. It is important to maintain a high level of operating efficiency.	4 It is important that a successful firm be defined as one that fulfills its legal obligations.
5 It is important that a successful firm be defined as one that is consistently profitable.	5. It is important to provide goods and services that at least meet minimal legal requirements.

Figure 3a. CSR components: economic and legal

Ethical responsibilities (Ethical component), on the other hand, represent a separate block, but, they are extremely linked to the law. In fact, many of the values and standards shared by the company were subsequently transformed into law, thus acting as

a driver of the legal framework, pushing the economic subjects to act according to the regulations and sometimes even requiring ethical performances above those established by the legislator. Finally, the philanthropy (Philanthropic component) represents the propensity of a company to invest through its financial resources for the good of society, so that it achieves the aspect of a good "citizen". It differs from ethical responsibilities in that if a company does not reach the level of contribution expected by the public it will not be labeled as unethical. So, Philanthropy is driven more by the discretion of the companies (Carroll, 1991). These two last components are described below (Figure 3b).

Ethical and Philanthropic Components of Corporate Social Responsibility

Ethical Components (Responsibilities)	Philanthropic Components (Responsibilities)
1. It is important to perform in a manner consistent with expectations of societal mores and ethical norms.	1. It is important to perform in a manner consistent with the philanthropic and charitable expectations of society.
2. It is important to recognize and respect new or evolving ethical/moral norms adopted by society.	2. It is important to assist the fine and performing arts.
3. It is important to prevent ethical norms from being compromised in order to achieve corporate goals.	3. It is important that managers and employees participate in voluntary and charitable activities within their local communities.
4. It is important that good corporate citizenship be defined as doing what is expected morally or ethically.	4. It is important to provide assistance to private and public educational institutions.
5. It is important to recognize that corporate integrity and ethical behavior go beyond mere compliance with laws and regulations.	5. It is important to assist voluntarily those projects that enhance a community's "quality of life."

Figure 3b. CSR components: ethical and philanthropic

These aspects represent four separate blocks that, put together, make-up the "pyramid" of the CSR (Figure 4). The pyramid metaphor serves to indicate that among these four categories, there are certainly some that have greater relevance than other (Carroll, 1991; Sheehy & Farneti, 2021). The economic component is certainly the main one and constitutes the base of the pyramid. Moving on to the legal and ethical

components, we arrive at the top of the structure, that is the least impacting side of the CSR. This theory allows to describe and study individually each part mentioned above, but at the same time provide an explanation of how the concept is composed by every single voice interdependent from the others.

It can be affirmed that the economic component is connected to all the others, to represent the eternal dilemma that sees economic profit opposing social welfare.

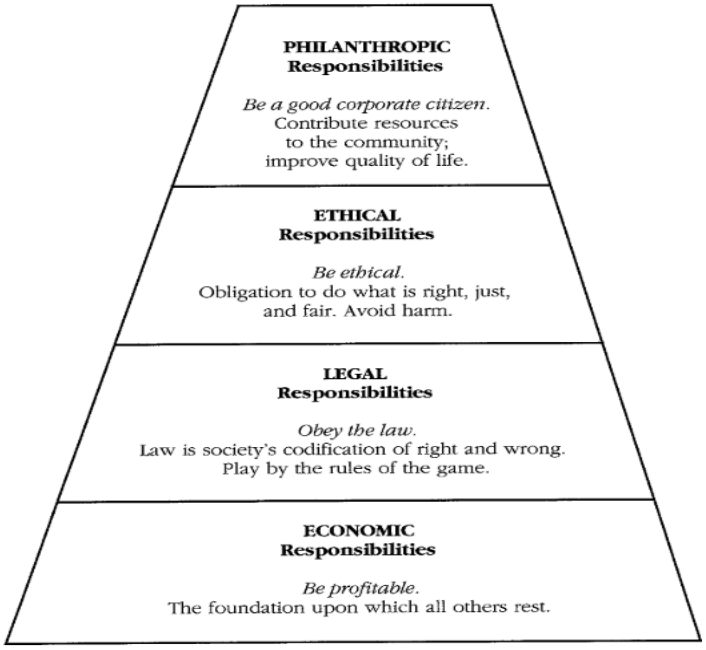


Figure 4. The Pyramid of CSR

In general, CSR commitment is considered as a mix of two different elements: one internal and one another external. The internal component regards skills and education, workplace safety, human and labor rights, working conditions and equal opportunities. The external component instead represents the concern on corporate obligations as a "*citizens*", on the need of their external stakeholders and on the global environment (Dara Singh et al., 2015).

Practically, there are several types of approaches to CSR, as community-based development approach, philanthropy, incorporating the CSR strategy directly into the business strategy of an organization, or garnering increasing corporate responsibility interest (Creating Share Value) and benchmarking. The first one is the so-called community-based development approach in which businesses must work together with

local communities to create benefits for both parties (Mahajan, 2015).

Philanthropy, on the other hand, includes aid in the form of donations to the poorest organizations and communities (so dedicating to these initiatives a part of the earnings) and it is even more often used as a marketing strategy, to enhance brand recognition and customer perceptions, therefore going to meet the economic needs of the business as well as the social and sustainable ones (Fontaine, 2013).

Other two common approaches are: including CSR in the corporate business strategies (such as KPMG, and its Fair coffee and tea procurement) that concerns the so-called CSV (Creating Share Value) and represents the belief that business success and social well-being must be dependent on each other. The latter is based on the idea that to be competitive it is necessary to implement behaviors, internally and externally to the organization, that are sustainable in the various shades of the term.

Some companies use benchmarking to implement their CSR strategy, in order to compete in terms of CSR policy, implementation, and effectiveness, studying the strategies implemented by competitors and the performances deriving from them; this implies a review of the CSR actions adopted by other companies in the sector trying to establish their social and environmental impact (Mahajan, 2015).

CSR can be considered also as a risk management tool: to empower this concepts, shareholders are inclined to consider CSR as an element that has a positive impact on the economic and financial performance of a company and that could be useful to manage financial risk, reputation risk, environment and supply chain risk (Fontaine, 2013).
However, the effects of these actions on company performance are not immediate but they manifest themselves over the long term, generally 3-5 years, and each strategy has different impacts. It is possible to synthesize them by considering the following model provided by M. Fontaine (2013), based on the purpose, impact, and benefits of each CSR approach (in particular for Creating Share Value, Risk Management Tool and Philanthropy).

Starting from CSR as value creation, the purpose of this implementation is to create an innovative and sustainable business model to obtain a fundamental strategic and operational impact; the benefits provided are the shared value between businesses, institutions, and communities; the competitive, innovative, and sustainable business model promoted the fact that business is integrated into the community in a way for which

CSR is incorporated into the Business Strategy. Furthermore, the CSR as a risk management tool has "compliance" as a purpose with a medium/high strategic and operational impact; the benefits ensured are the mitigation of operational impact and operational risks and in addition it supports the external relationships. At the end the CSR as a corporate philanthropy aims to provide funding and skills; it has a little strategic and operational impact. This final approach allows to guarantee corporate sponsorships and short-term benefits; limited funds are available, and the impact is reduced by the limited amount of budget allocated to donations; in brief, it ensures a not so strong use of corporate competencies and assets, the misalignment between social-economic strategy and functions, that result in a low impact of social programs.

2.2.1 Factors influencing CSR

At this point, after having identified the different interpretations regarding CSR, the attention shifts to what are the elements which influence its implementation.

The concept of stakeholder pressure is central to the dissemination and development of CSR, to the point of being defined as a stakeholder-oriented concept (Maon et al., 2009). *Stakeholders*, defined as all subjects that can affect an organization mission, are divided by stakeholder theory into two categories (Maon et al., 2009):

a. *Primary stakeholders*: they are those that have a fundamental importance in the realization of the product and service offered by an organization. Consumers, internal managers and employees, government, suppliers, and investors belong to this group.

b. *Secondary stakeholders*: that are all those, who have a mainly external socio-political influence on the organization. Competitors, media, local community, and governmental / non-governmental organizations (NGOs) are part of it

Among the most influential are government bodies and NGOs, which establish the rules and conducts deemed socially acceptable. Then, in a sort of "influence ranking" there are consumers and investors, increasingly interested in socially ethical and eco-sustainable behavior on the part of the companies they come into contact with (Fontaine, 2013; Mahajan, 2015).

Another important element influencing the development of CSR, is the increase of *globalization*; companies could cross new borders (geographical and technological), growing more and more in size and ambitions. Thanks to this desire to explore and successfully enter foreign markets, multinational enterprises (MNEs) understood the importance of using practices that comply with ethical standards, that allows to promote the contact with local systems and stakeholders (Park et al., 2015). In fact, companies instinctively try to implement actions and initiatives that maximize stakeholder satisfaction and at the same time guarantee profit. Also in this case, as can be seen, the influence of the stakeholders is crucial.

To conclude, the element that most influences the diffusion of the concept of CSR within an organization is *competition*. In fact, companies use this concept in their business in order to survive in the competitive environment (S.A et al., 2013). The paradox lies in having to increase the costs associated with an increase in sustainability to remain competitive, but at the same time having to pursue profit to remain in the market. This is a further confirmation of the contrast between ethics and performance, which will be analyzed in the next chapter with reference to the relationship between Green Supply Chain Management and financial and economic results.

CHAPTER 3: A LITERATURE REVIEW OF SUPPLY CHAIN MANAGEMENT (SCM) DEFINITIONS

The climate conditions and the environmental degradation have shifted the focus on sustainable and eco-friendly economy. The pressure from stakeholders has gradually increased the difficulty in managing supply chain operations in the most environmentally sustainable way possible. At this point of the study, it is provided at first a more in-depth definition of what Supply Chain represents and of the importance of management that allows to optimize the processes. In the same way the Green Supply Chain Management is illustrated, identifying what are the relevant and related indicators and the impact of GSCM practices on performance.

3.1 Supply Chain dynamics

Starting from the definition of the Supply Chain, Green Supply Chain and the relative GSCM will be developed, based on information provided by literature. According to Mentzer et al., 2001, the supply chain is:

"a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a consumer"

Breaking down this definition it is possible to identify three different types of supply chain. As can be seen (Figure 5), it can be direct, extended, or ultimate:

1) The *direct supply chain* involves a supplier that supplies a company and the consumers it satisfies.
2) The *extended supply chain* involves a supplier of the immediate supplier, a company, and customers of immediate customers.

3) The *ultimate supply* chain includes all the companies that interact together starting from the activities and flow of products located at the origin of the supply chain (upstream activities) to those located at the end of it (downstream activities). Thus, financing parts, third party logistics suppliers and market research firms are included.

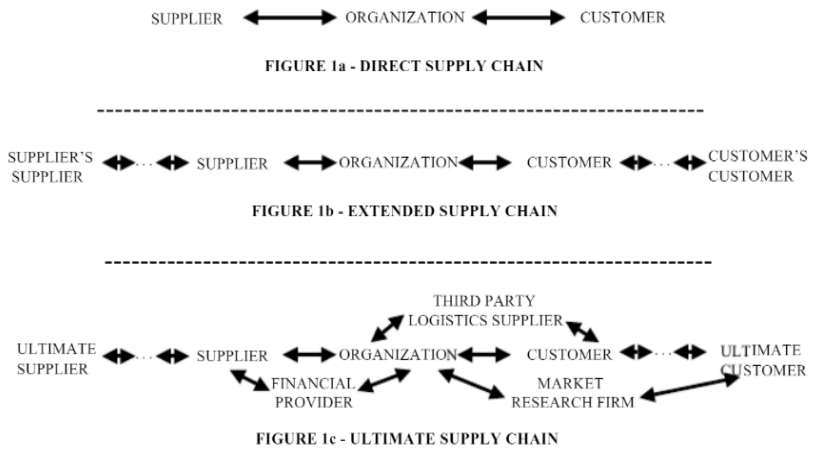


Figure 5. Types of Channel Relationships

So, the supply chain is the set of all the activities that make it possible to make a product available to the final consumer, starting from the raw materials up to the finished product. Among these activities there are marketing, manufacturing, purchasing, logistic processes etc.

If we look at the meaning of supply chain, it is possible to understand how it can exist also without a management able to handle it. It is not purely necessary SCM to allow the existence of a supply chain, as it is made up of inter-organizational relationships that are independent of a specific managerial structure. However, since the supply chain consists of the flow of information and activities from the producer to the consumer, it is necessary for managers to handle these dynamics to integrate the production system through different approaches (strategic, tactical, or operational), coordinating the use of facilities, people, finance and systems, so as to optimize their outputs. Therefore, it is true that a management body is not strictly necessary, but its presence is essential to ensure that all processes are coordinated in the best possible way (Mentzer et al., 2001).

3.2 Supply Chain Management (SCM)

SCM is often associated with logistics for their similarities relating to the flow of materials. To clarify the meaning of this term, it is possible to quote the summary definition provided by Christopher, 2011:

"Logistics is the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organization and its marketing channels in such a way that current and future profitability are maximized through the cost-effective fulfilment of orders"

Logistics is the fundamental scheme, through which it is possible to organize the flows of products and information relating to a particular business. This idea represents the basis for the analysis and definition of SCM. In the table (Table 2) some of the main definitions provided by the literature are shown:

Author	**Interpretation of SCM**
Jones and Riley (1985)	*"Supply chain management deals with the total flow of materials from suppliers through end users..."*
Houlihan (1988)	*"Differences between supply chain management and classical materials and manufacturing control:* *1) The supply chain is viewed as a single process. Responsibility for the various segments in the chain is not fragmented*

	and relegated to functional areas such as manufacturing, purchasing, distribution, and sales. *2) Supply chain management calls for, and in the end depends on, strategic decision making. "Supply" is a shared objective of practically every function in the chain and is of particular strategic significance because of its impact on overall costs and market share.* *3) Supply chain management calls for a different perspective on inventories which are used as a balancing mechanism of last, not first, resort.* *4) A new approach to systems is required—integration rather than interfacing."*
Stevens (1989)	*"The objective of managing the supply chain is to synchronize the requirements of the customer with the flow of materials from suppliers in order to effect a balance between what are often seen as conflicting goals of high customer service, low inventory management, and low unit cost."*
La Londe and Masters (1994)	*Supply chain strategy includes: "... two or more firms in a supply chain entering*

	into a long-term agreement; ... the development of trust and commitment to the relationship; ... the integration of logistics activities involving the sharing of demand and sales data; ... the potential for a shift in the locus of control of the logistics process."
Cooper et al. (1997)	*Supply chain management is "... an integrative philosophy to manage the total flow of a distribution channel from supplier to the ultimate user."*
Monczka, Trent, and Handfield (1998)	*SCM requires traditionally separate materials functions to report to an executive responsible for coordinating the entire materials process, and also requires joint relationships with suppliers across multiple tiers. SCM is a concept, "whose primary objective is to integrate and manage the sourcing, flow, and control of materials using a total systems perspective across multiple functions and multiple tiers of suppliers."*

Table 2. Different interpretations of SCM

Starting from these assumptions, it is possible to state that the logistics concerns processes related to a single organization. Instead, with the integration of the procedures relating to each company, the entire supply chain is obtained, in which processes are

considered and managed as a single entity. Logistics is nothing more than the planning, execution, and control of the products to be delivered to customers, therefore it constitutes an integral part of the supply chain management, which includes a broader meaning.

The previous ones represent only a small sample of the definitions concerning the discipline of SCM. The interpretations are manifold and there is no common line among academics to define the concept uniformly. It is also important to consider that a discrepancy exists between the meaning that the researchers attribute to the role of the SCM and what is instead considered by practitioners (Gibson et al., 2005). According to this last statement, it is the fact that there are several types of interpretations regarding the role of the SCM, that focus on strategy, activities, processes, or a combination of them.

Primary Role of SCM within an Organization	Percent of Responses
A combination of strategy and activity	72.6
A strategy that transcends individual functions	15.6
A corporate function or activity	9.0
Something else	2.7
No response	0.1

Figure 6. Perception of SCM role

Thanks to the quantitative study conducted by Gibson et al. (2005), it can be seen that in the majority of the observations it is believed that the SCM concerns both strategy and activity, with little consideration instead of a focus on each of them as a single component. Confirming what has been said, from the results obtained it is possible to distinguish how practitioners have a greater propensity to consider the SCM as a strategy rather than a merger of strategy and activity. In the specific case the respondents represent all the member of CSCMP (Council of Supply Chain Management Professionals), composed of members of the following sectors: Manufacturer (33,6%), Logistics Service Provider (20,5%), Consultancy (16,7%), Education (10%), Merchandiser (7,9%), Technology (5,2%), Others (6,1%).

Academics, on the other hand, are more likely to think of SCM as a pure strategy, while instead they should analyze it as a mix of strategy and functions like practitioners.

In the next paragraph it will be analyzed specifically how the practitioners define and delimit the scope of action of the SCM.

3.3 SCM boundaries

The CSCMP gives us what is its most recent definition of the SCM boundaries of 2005:

"*Supply Chain Management is an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model. It includes all of the Logistics Management activities noted above, as well as manufacturing operations, and it drives coordination of processes and activities with and across marketing, sales, product design, finance and information technology."*

It was possible to determine general macro-categories that characterize the SCM, based on the topics most covered by this and other definitions existing in literature. Three categories were identified: Activities, Benefits, and Constituents or Components. Belonging to these macro-areas, sub-groups have also been identified that explain their characteristics and main components (Stock & Boyer, 2009).

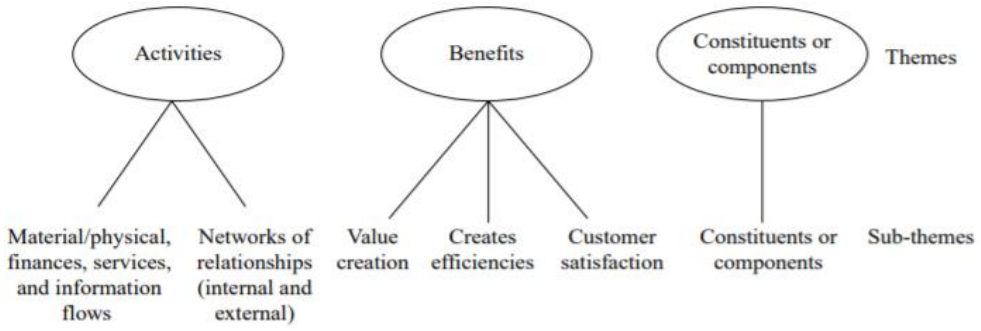


Figure 7. Categories and sub-categories of SCM boundaries

As can be seen, the *activities* inherent to the SCM are very frequently associated with *flows* of materials, finances, services, and information. The transmission of these elements is possible only thanks to the interactions between the various market players, who build *networks of relationships* through which it is possible to realize the transfer of resources. What is interesting to underline is how in most cases these flows are understood

as unidirectional (i.e., flows of materials from supplier to consumer, or vice versa flows of information from consumer to supplier). However, there are authors who have recognized the bidirectional nature of these processes, such as Handfield (1999), but also CSCMP (2005): they explain how the flow is not unidirectional because it would not be possible to explain the flows of materials to upstream caused by reverse logistics as well as downstream information from raw material suppliers to manufacturers and ultimately to retailers (Gibson et al., 2005).

As mentioned above, the supply chain is organized by a specific management, as it must coordinate the activities in a harmoniously way and it is considered an element that adds value to the entire system, providing important *benefits*:

- *Value Creation*. Many authors such as Christopher (1992) recognized SCM as a creator of added value for consumers, that is one another relevant factor that differentiate it from the logistics. The actions that take place along the supply chain contribute a lot to create the value that influences the purchase decision, and therefore each component of the chain brings value (even for example some forms of support, such as 24h technical support). However, implicit in the intentions of the SCM is to increase the value of the final product at a lower rate than the costs related to the management of the production chain.

- *Efficiencies Creation*. It contributes to create efficiency in terms of cost savings and profit (thanks to the networks that allow operating synergy), use of resources (internal and external of the organization), and competitive advantage.

- *Consumer Satisfaction.* Satisfying consumers by offering a product that meets their requirements is the purpose that SCM must set itself. So it has to be customer-oriented, for example managing the inventory along the chain in order to enhance the customer service as suggested by Cooper et al. (1997), and reducing investments without sacrificing the customer satisfaction (Spekman et al., 1998).

CHAPTER 4: GREEN SUPPLY CHAIN MANAGEMENT (GSCM) AND THE IMPACT OF ITS PRACTICES ON ORGANIZATIONAL PERFORMANCES

4.1 Green Supply Chain Management (GSCM): concept definition and green practices

After having developed the general picture of the situation, with a careful analysis of the literature on the issue of CSR and sustainability and deepened the concepts of Supply Chain and Supply Chain Management, it is now possible to enter the merits of what is the central topic of this study. GSCM is defined in the literature in several ways, with an interest that started to growth from late 1990s. It differs from SSCM (Sustainable Supply Chain Management), in that the second represents a broader concept, concerning social, environmental and economic issues, than the first, which instead is more specifically referred to practices that impact on the environment (Ahi, Payman & Searcy, 2013; Sarkis, 2012). Numerous researches and studies have been carried out in recent years regarding the theme of the GSCM and its practices: Green et al. (1996) for example propose an approach that is concerned on the innovation in the supply chain management and industrial purchasing considered in the environmental context.

Also in this case, there is no univocal and agreed definition. This is because the GSCM represents the joint consideration of Corporate Environmental Management and SCM, which represent two areas of research that are still immature (Zhu & Sarkis, 2004). Nevertheless, the definition that is most shared is that provided by Srivastava (2007), who identifies it as*:*

" Integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as the end-of-life management of the product after its useful life "

It can be understood as a proactive environmental management must be applied, not only at the company level, but along the entire supply chain from raw material to finished product. All this, through the use of the so-called Rs (Reduce, Re-use, Rework, Refurbish, Reclaim, Recycle, Remanufacture, Reverse logistics, etc.) (Ebula De Oliveira et al., 2018). Thus, it represents a concept that goes beyond the simple application of ecological practices, but it is a broader concept that concerns the improvement of both environmental and inter-organizational performance of companies (Kafa et al., 2013).

However, according to Zhu & Sarkis (2004) and Zhu et al. (2013) four types of practices relating to GSCM can be identified, that have to be integrative and need cross-functional cooperation:

1) *Internal Environmental Management*, that represents GSCM as an organizational strategy, as for example the commitment of GSCM from senior managers supported by the mid-level management or the environmental compliance and audit programs, the cross-functional cooperation for environmental improvement and total quality environmental management.

2) *External GSCM*, as Green Purchasing and cooperation with suppliers for environmental goals, but also with customer for eco-design, cleaner production, or green packaging.

3) *Investment Recovery*, that involves the sale of excess inventories, scrape or used materials, and excess capital equipment.

4) *Eco-design*, for reduced consumption of energy and materials, but also for reuse, recycle and recovery of the latter.

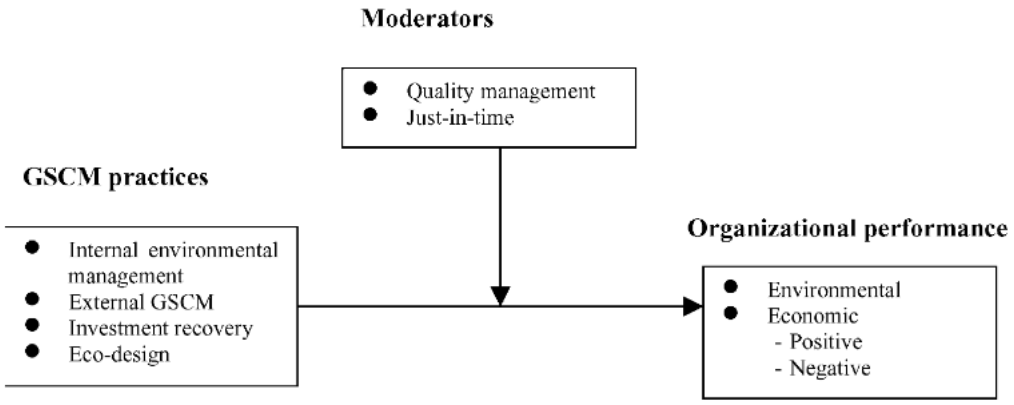


Figure 8. GSCM practices, moderators and performances

These four categories can become two, as eco-design is considered belonging to external practices and inventory recovery is included in internal practices (Saeed et al., 2018; Zhu & Sarkis, 2004).

4.2 Drivers for the implementation of GSCM strategies

Considering the impact that GSCM practices have on environmental and economic performance, it is necessary to understand the reasons for which companies are incentivized to conduct such actions. The theories on which the literature mostly bases its assumptions are *Natural Resource-Based View Theory (NRBV)*, representing an extension of Resource-Based view (RBV) focused on organizational resources and capabilities as the most important vector to obtain a competitive advantage, and *Institutional Theory / Institutional Isomorphism*, that is a constraining process that force an organization to behave like others in the same environment (Saeed et al., 2018).

This theories wants to highlight how every organization operates within a social network, in which its behavior and decisions do not depend solely on dyadic relationships, but on many factors, deriving mainly from internal variables and from the external environment pressures, which influence its path (Lin & Sheu, 2012; Saeed et al., 2018).

In the first place, the GSCM practices implemented by a company depend on the

resources it has available. According to RBV, an organization is a series of specific resources and capabilities. A resource ensures a competitive advantage if it respect the following characteristics: 1) It is valuable, 2) It is not substitutable, 3) It is rare and 4) It is imperfectly replicable. In addition, NRBV consider the natural environment an important source of such resources and capabilities (Schmidt, 2017). Therefore, the implementation of practices aimed at minimizing the impact of the business on the environment depends on the resources and skills that the company has available at a specific time. Organizations that have tools to create value (design, technologies, services, etc.) certainly have a more proactive approach to GSCM with higher performances; for example, a study developed by Klassen and Whybark (1999b) showed how the use of technologies to prevent pollution had led to the acquisition of skills and competences that are difficult to replicate by competitors (Schmidt, 2017). In a constantly evolving and innovative context, it is up to individual companies to adapt in terms of resources, often also replacing traditional resources with more advanced ones that allow them to remain competitive.

Therefore, it is certainly a discourse of internal availability that allows to implement economically advantageous environmental strategies, but there is still a great pressure deriving from the external environment, which influences this availability and the consequent development, implementation, and results of GSCM practices.

The pressures from the environment (Institutional Isomorphism) could be coercive, normative, or mimetic; The more influential is the coercive one, that result from the pressure exerted by the legal and regulatory stakeholders, but also the mimetic, that involves firms' adaptation to environmental uncertainty; in fact, when companies encounter such uncertainty, they are inclined to follow the behavior of other organizations. Therefore, except for the normative pressure (that occurs when organizations in the same environment interact, so reinforcing and spreading norms of behaviors between them), the Institutional Theory seems to be able to adequately represent the reasons why companies decide to undertake eco-friendly practices (Lin & Sheu, 2012) that so derive mostly from environmental regulation and external stakeholders (Chien & Shih, 2007).

4.3 The impact of GSCM practices on Environmental Performance

What is meant by environmental performance and what are its key indicators?

It indicates the impact that an organizations activities have on the natural environment, and it requires a precise evaluation system, the Environmental Performance Evaluation (EPE), that is an internal managerial tool capable of verifying whether the practices implemented to protect the environment are effective in terms of performance and whether these results comply with the criteria set by the management. (Chien & Shih, 2007; Jasch, 2000).

Therefore, EPE is an important tool to define the results of the GSCM practices and it involves a series of indicators useful to determine this latter variable for the present study; but it is useful also for the firms in order to compare its own EP over time or with other companies results, to assess environmental reports, to provide feedbacks for motivation and information of workforce, and to obtain a support for the EU-EMAS regulation and ISO 14.00, so identifying those areas that require more attention from an environmental point of view (Jasch, 2000).

Through the joint analysis of the indicators provided for by *Article 5 of the EMAS Regulation* and those provided by *MSCI ESG KLD STATS: 1991-2014* Data Sets Methodology, it was possible to select those which are the most suitable to be considered in the present research. They are represented and described by the table below.

Indicator	Description
Waste Management	
Pollution prevention	"This indicator measures a firm's method of mitigating non-carbon air emissions, water discharges, and solid waste from its operations. Factors affecting this evaluation include, but are not limited to, initiatives to reduce a firm's non-carbon air emissions from its operations; to reduce the release of raw sewage, industrial chemicals,

	and other regulated substances; to reduce hazardous and non-hazardous waste; and programs to reduce the use of packaging materials, to support recycling; and to recycle old products such as televisions and other consumer electronics."
Recycling	"This indicator is designed to assess how companies manage the risks of losing access to markets or of facing added costs to come into compliance with new regulations related to product packaging content and end-of-life recycling or disposal of packaging materials. Companies that proactively reduce the environmental impact of their packaging, including use of recycled content material and establishment of take-back and recycling programs, score higher."
Natural Resource use	
Water stress	"This indicator is designed to assess how companies manage the risks of water shortages impacting their ability to operate, losing access to markets due to stakeholder opposition over water use, or being subject to higher water costs. Companies that proactively employ water efficient processes, water recycling and alternative water sources score higher."
Biodiversity and Land use	"This indicator is designed to assess how companies manage the risks of losing access to markets, or incurring litigation, liability, or reclamation costs due to operations that damage fragile ecosystems. Companies that have policies and programs designed to protect biodiversity and address community concerns on land use score higher."
Raw material sourcing	"This indicator is designed to assess how companies manage the risks of damaging their

	brand value by sourcing raw materials with high environmental impact. Companies that have policies and procedures to source materials with lower environmental impact and participate in initiatives to reduce environmental impact of raw materials production score higher. Management metrics include policies, initiatives, and targets related to sourcing the following materials of concern: seafood and/or aquaculture, timber and/or paper, palm oil, beef and/or dairy, leather, and cotton."
Environmental opportunities	
Green buildings	"This indicator is designed to evaluate the extent to which companies are taking advantage of opportunities to develop or refurbish buildings with leading environmental design features, including lower embodied energy, recycled materials, lower energy and water use, waste reduction, and healthier and more productive working environments. Companies that proactively develop or refurbish buildings to achieve green building certifications score higher."
Beneficial products and services	"This indicator measures the positive environmental impact of a firm's products and/or services. Factors affecting this evaluation include, but are not limited to, products/services that reduce other firms' and individuals' consumption of energy, production/consumption of hazardous chemicals, and overall patterns of resource consumption."
Renewable energy	"This indicator is designed to evaluate the extent to which companies are taking advantage of opportunities linked to the development of renewable power production. Companies that proactively invest in renewable power generation

	and related services score higher. Key management metrics include, efforts to develop renewable power generation capacity and/or proactively complement the development of renewable power through electrical network expansion, equipment commercialization, and 'green power' offerings to its customers."
Climate change	
Energy efficiency	"This indicator is designed to assess how companies manage the risks of increased or volatile energy costs across their operations. Companies that take proactive steps to manage and improve the energy efficiency of their operations score higher."
Product carbon footprint	"This indicator is designed to assess how companies manage the risks of higher input or production costs for their carbon-intense products due to increased energy costs. Companies that measure and reduce the carbon emissions associated with their products and implement programs with their suppliers to reduce carbon footprint, score higher. Key management metrics include efforts to reduce exposure through measurement and reduction of carbon emissions associated with raw materials production, product manufacturing, distribution, and retail."
Clean tech	"This indicator is designed to assess how companies are taking advantages of opportunities in the market for environmental technologies. Companies that proactively invest in product and services that address issues of resource conservation and climate change score higher. Key management metrics include efforts to take advantage of opportunities through strategic targeting of a market for environmental technology

	or through development of clean tech business segments that are related to company's core business."

Table 3. MSCI - Environmental Strenght Indicator (ESI)

To summarize, these are the indicators that are generally considered when analyzing the impact of certain practices on the environment:

- *Waste Management*, that is, everything concerning the organization of waste along the supply chain, which includes the collection, transport, treatment, and consequent reuse of waste, and involves the level of pollution prevention and recycling.

- *Natural Resource use*, it involves Biodiversity and Land use as well as the Raw material sourcing. It refers to the exploitation of the resources provided by nature, which, if too intense, leads to the deterioration of the environment.

- *Environmental Opportunities*, it refers to the intensity through which certain practices incentivize the exploitation of eco-sustainable opportunities, such as the construction of green buildings, the use of renewable energy and the offer of sustainable products and services.

- *Climate Change*, it is a factor influenced by the level of energy efficiency guaranteed by the green practice, product carbon footprint and using clean tech. Therefore, it derives from all those practices that positively or negatively impact on climate change.

What emerges from past researches is that certainly GSCM initiatives have a positive impact on the environmental performance of companies (Chien & Shih, 2007; K. Green et al., 1996; Saeed et al., 2018; Zailani et al., 2015; Zhu & Sarkis, 2004).

However, there are some activities that have more impact on it than others: for example, external practices like cooperation with customers, eco-design and investment recovery have a positive influence and are more impactful. Instead, some internal practices as Green Purchasing, are not directly associated with a positive performance in this sense (K. W. Green et al., 2012). Clearly, each company is different; the situations in specific cases can be multiple and discordant with each other and some practices are aimed at influencing certain indicators more than others. Generally speaking, it is possible to say that the implementations of eco-friendly operations along the supply chain have a positive impact on the environment and therefore must be encouraged, mitigating the resulting costs.

4.4 The impact of GSCM practices on Economic Performance

Considering the influence that GSCM activities have on economic performance, it must be evaluated that there is a clash between the need to implement increasingly sustainable practices to preserve the environment, and the need of organizations to maximize their profit and economic/financial results.

In general, it will be considered that economic performance represents the capability to reduce costs related to purchasing of materials, consumption of energy, waste minimization, and fines for environmental accidents (Zhu et al, 2008).

According to K. W. Green et al. (2012), such practices related to the elimination of wastes or their minimization, could result in a reduction of costs that lead to competitiveness and a better performance. Klassen and McLaughlin (1996) on the other hand, they found that the public recognition of the victory of prizes, relating to environment protection, leads to an increase in the level of share prices of the winning companies, and an improvement of the firm valuation.

If we analyze the impact of the GSCM practices mentioned in the previous paragraphs, it is possible to state that they have different influences: there are some External GSCM practices as Green Purchasing and Cooperation with customers, that are positively correlated to economic performance. In reverse, Eco-design and Investment Recovery negatively affect it, due to the high cost needed to implement these actions (K.

W. Green et al., 2012).

Through different studies present in literature, it is possible to identify key performance indicators. Five types of measures have been identified, each of them composed internally by various factors (Hervani et al., 2005; Kafa et al., 2013):

1. *Environmental Cost*, that represents the total cost incurred in implementing the processes and actions to become green and sustainable. Represents one of the most important indicators for an effective and efficient implementation of GSCM practices since the investment model of organizations has a great impact on environmental performance. It involves several metrics such as cost associated with environmental compliance, recycling cost, cost associated with the consumption of energy, disposal costs, cost for purchasing environmentally friendly materials.

2. *Traditional Supply Chain Cost*, that includes the total cost of normal operations along the supply chain. So, all those expenses that are useful for getting the product into the hands of the final consumer. It involves delivery costs, inventory costs, information sharing costs and ordering costs.

3. *Quality*, related to the standard features of the product. It includes level of customer complaints, availability of green product warranty, scrap and rework and delivery unreliability.

4. *Flexibility*, namely the adaptability of the supply chain to changes related to its processes. It is measured by the demand flexibility, delivery flexibility, production flexibility.

5. *Responsiveness*, that represents the ways in which the supply chain reacts and responds to various factors, and is calculated based on manufacturing lead time, purchasing lead time, on time delivery, product return lead-time, and total supply chain cycle time.

These are the main factors that companies consider when planning and implementing their GSCM strategies. In fact, they represent those costs and elements that are directly affected by these practices and that allow us to certify whether the sustainable actions implemented are successful also from a purely economic and competitive advantage point of view, not only in terms of eco-sustainability. To reiterate what was said previously, companies undertake green practices certainly for a matter of social responsibility, mainly induced by external factors, but this responsibility goes hand in hand with the almost natural need to pursue a profit.

4.5 Final considerations on GSCM

To conclude, it is possible to make general statements on the steps that have been carried out.

First, it was necessary to understand the reasons why an organization is pushed to implement eco-sustainable practices. The answer was found in the external influences of the organization such as the pressures induced by the various stakeholders, and by those that instead come from within, and to be sought in the possibilities and resources of the companies necessary to implement new green processes. Therefore, the main characteristics relating to the GSCM, and its main practices were analyzed. All these factors have been useful in defining the environmental and economic results of GSCM and in constructing fundamental indicators that make it possible to analyze the impact of digital technology and to generalize the results.

However, it was found that these strategies positively influence both environmental and economic performance, even though the number of studies can sometimes have conflicting results.

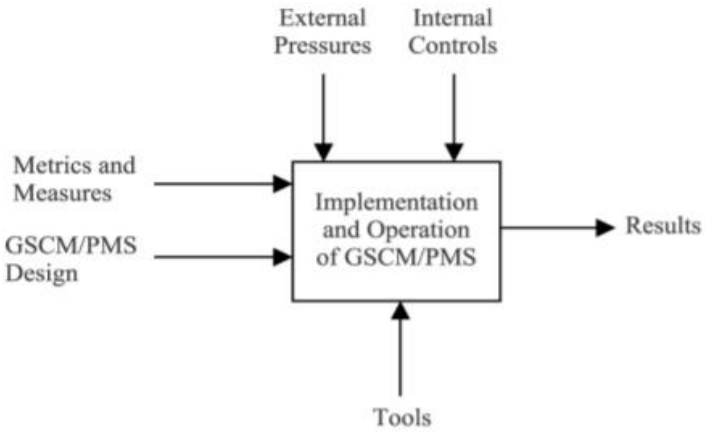


Figure 9. Framework to understand GSCM implementation

However, it is possible to generalize the opinions obtained from the literature, which clearly may vary according to specific cases. In fact, we can state that investments in GSCM represent a win-win strategy, which overall leads to positive business results (Kusi-Sarpong et al., 2019).

CHAPTER 5: DIGITAL INNOVATION: INDUSTRY 4.0 AND ITS IMPACT ON COMPANIES' GREEN PRACTICES

5.1 4th industrial revolution: historical excursus

The term industry 4.0 was used for the first time in Germany during the Hannover Fair/Exhibition, through a proposal for a new approach to German economic policy centered on the use of high-tech and digital tools (Andreja Rojko, 2017; Mosconi, 2015). It is a common perception that the world is going through a phase of profound change both from the academic and research point of view, but above all as regards the industry, as it was conceived up to now. Change, in fact, characterizes what is a phenomenon of clear transition in terms of economic and social structure, due to the development of new technologies, social ideals and world views, which have profoundly and irreversibly changed the way of living.

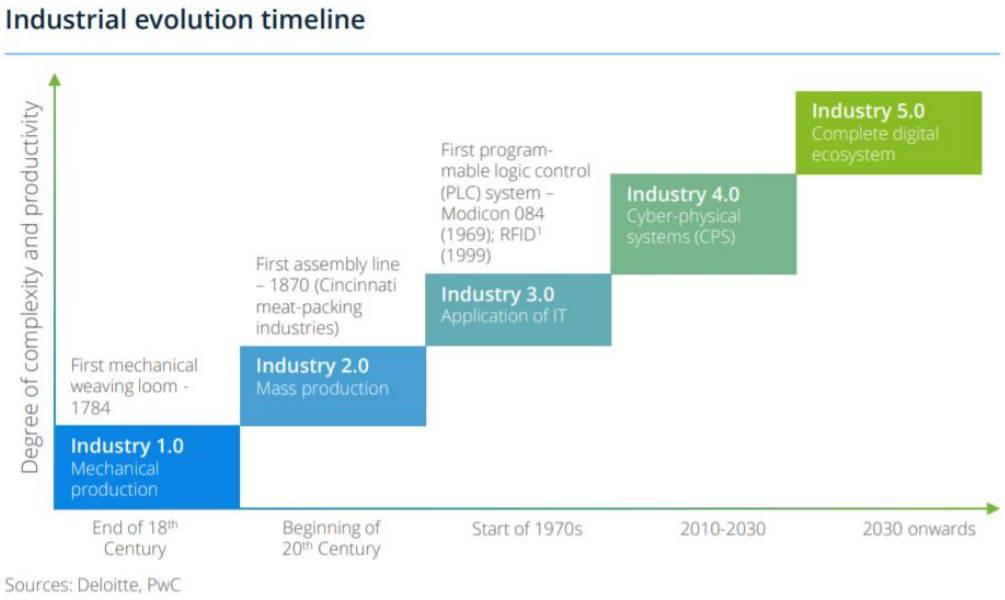


Figure 10. Industrial evolution timeline

After the first agricultural revolution, a series of industrial revolutions followed one another: the first one occurred in the second half of the 18th Century; it concerned the transition from the use of energy closely linked to human labor to mechanical energy, exploited thanks to the discovery of the steam engine of the 17th Century, which needed the turn of the century to be effectively used in the production system. This marked the first major transition from the manufacturing level of the capitalist economy to that characterized by the factories. The second started during the last part of 19th Century and the early part of 20th Century, it was generated by the introduction of electricity and was notable for mass increases in population, prices, GNP, and wages. Electrification has made mass production possible but without the opportunity to create customized products. To represent this historical era, the famous sentence of Henry Ford, on the Ford T-Model car: "You can have any color as long as it is black", to enclose the meaning of what was previously said about the impossibility of creating products "tailored" for the customer (Rojko, 2017).

After the mid-1950s, the third industrial revolution begins, also called the computer revolution or digital revolution, as these last two factors constituted its founding element. Powerful new technologies have been discovered, and not only have they changed the production system, but they have become specific investment and consumer goods and services. Thus, the production lines were more flexible thanks to the automation of the processes, which was not the case regarding the quantity of production. This has laid the foundations for what is now taking the form of a new revolution, mainly in the western part of the globe, starting around 2011 (Klaus Schwab, 2016; Pozdnyakova et al., 2019; Stăncioiu, 2017).

The "New Revolution" therefore seems the most impacting on the system from many points of view. However, it is necessary that it be accompanied by equally influential leadership, which ensures that this transition takes place in line with economic and social needs, and above all, a common line of thought that sheds light on the challenges and opportunities, so that it is guaranteed an effective improvement, avoiding setbacks for individuals and organizations. (Klaus Schwab, 2016). Unlike the others, the 4th revolution is based on the concept of the Internet of Things and seems to be characterized by a much faster diffusion of new technologies (cyber security systems, automatized machine connected to the Internet, nanotechnologies, robototronics etc.) and

the self-organizing cyber physical production system allows high flexibility in production quantity and in mass custom production (Rojko, 2017). To this end, it is also important to look at the differences between these and other industrial revolutions according to Popkova et al. (2019):

1) *The elimination of humans from the production system*, since through artificial intelligence it is possible to completely avoid the margin of error that a man could commit.

2) *The revolutionary change concerns all business processes of an industrial organization*, that is, this process of modernization and improvement of production systems concerns all phases of the production chain (logistics, management, marketing, etc.).

3) *The possibility of simultaneous usage of globalization and of minimizing the negative social impact*, thanks to AI, which, for example, allows information to be exchanged in real time, and allows an order to be transformed into production. The social impact is limited, as man is isolated from the productive system, being able to control it remotely.

4) *Change of the essence of the industrial patents,* which previously served to hide new technologies from rivals so that they did not know how to produce them. Now, they have the sole purpose of protecting the technology of the owners from competitors, not being able to hide the details for the manufacture of it.

5) *Possibility of quick change of specialization of industrial production*, guaranteed by the possibility of 4.0 companies to be able to produce equipment and industrial products. That allows a quick re-orientation of production.

Basically, it is necessary to reiterate how the advent of digital represents a real revolution, which affects all social and economic categories. Human work, seen until recently as a physical effort or in any case intended as manual labor, is rapidly fading,

leaving room for the predominance of the so-called "knowledge economy". The latter is the concept of an economic system increasingly characterized by an intellectual specialization of workers who are required to have technical skills and a very broad cognitive background. Focusing on the economy, it too has been, or will soon be, invested in all its parts, along the entire supply chain. If exploited and organized in an adequate way also thanks to globalization and the ease of exchanging information from one part of the world to another, the New Revolution can represent a positive turning point in many respects.

5.2 Innovative Technologies 4.0

The main technologies that make up this type of reality can be described through several types of innovations (Hopkins, 2021; Stăncioiu, 2017) :

- *3D Printing:* also called 'Additive Manufacturing', it represents a replace of the traditional manufacturing process. This technology makes it possible to transform simple digital data into physical 3D objects. It is very useful where large quantities of production are not required and there is a large demand for customized products, which cannot be created through traditional manufacturing criteria. There is therefore a dematerialization of objects, which allows consumers to purchase digital data and independently produce the purchased product. This allows savings in terms of transportation and storage costs, product development cycles, an outsourcing of manufacturing costs to the end consumer, lower energy usage and a reduction CO2 emission.

- *Artificial Intelligence (AI)*: it allows to store perceptions from the external environment and arrange them in sequence, in order to carry out specific actions, reproducing human intelligence in an artificial way. It is useful for real-time fraud and risk management, for improving inventory placement and removing many human tasks.

- *Autonomous vehicles:* They are vehicles capable of autonomously detecting information from the external environment, and which do not require anyone to drive. They are very important to create a digitalized supply chain, and allow to lower overall shipping costs, reduce accidents, eliminate driver wages, reduce liability, reduce fuel costs, and reduce GHGs.

- *Cloud Systems:* is a technology that allows the shared use, via internet connection, of data and information, upon request by a computer or other devices. It allows for example to provide a service on request, through the internet, from the supplier to the end customer.

- *Big Data analytics (BDA):* Big Data are now considered a fundamental element for supply chain management; in fact, an enormous amount of data is generated along the supply chains, which are produced by the interorganizational relationships necessary to bring the product from the manufacturing company to the final consumer. This collected data is incredibly useful for developing new opportunities and supply chain strategies. BDA enables better targeted marketing, predictive analytics, improved agility, clearer business insights, client-based segmentation, and improved recognition of sales and marketing opportunities.

- *Blockchain:* It is a peer-to-peer network of information technology that keeps records of digital asset transactions using distributed ledgers that are free from control by intermediaries such as banks and governments. Thus,

it can mitigate risks associated with intermediaries' interventions, including hacking, compromised privacy, vulnerability to political turmoil, costly compliance with government rules and regulation, instability of financial institutions, and contractual disputes. Due to its digital nature, it is a sustainable technology as the transactions do not include cash exchanges. They also have a positive impact on the supply chain in terms of collaboration, accuracy, transparency, and security.

- *Drones:* Are unmanned aerial vehicles and micro-aircraft, initially used for military purposes in World War II, now useful in many supply chain operations such as parcel delivery, stock taking, surveillance, the inspection of vehicles and infrastructure (roads, bridges, tunnels, oil rigs etc.), traffic congestion and CO2 reduction.

- *Internet of Things (IoS):* These means that devices, machines, processes and people along the supply chain are digitally interconnected through an internet connection. The IoT seems to have a strong impact on supply chains, as for example through sensors placed on vehicles, containers, or products it is possible to control and evaluate more accurately information related to processes along the entire production chain. Among the main benefits there is an advantage in the identification of counterfeit products, real-time tracking, biometric payments, greater sustainability etc.

- *Robotics:* Are electro-mechanical machines which are mainly used in manufacturing or warehouse companies as a support tool for human activity, carrying out their task (material handling, picking, intensive and repetitive labor, welding, and inspection), independently or through a series of commands, efficiently from the point of view of the quantities produced, costs saved, and sustainability.

- *Virtual Reality (VR) / Augmented Reality (AR):* VR is a realistic three-dimensional simulation generated through head-mounted supports or

immersive helmets. It is a technology that allows you to make decisions by understanding situations better. AR combines the simulation of 3D objects into a real environment and in real time. These technologies provide benefits in training/education, product visualization, improved picking / inventory management, and can create virtual work environments that enables better communication between employees, partners, customers etc.

These are the main technologies that have been introduced and have actually or potentially impacted the industrial model. However, there are some technologies that are more impactful than other for economics and strategically reasons. They are the so-called Big Four and are those that have the most significant influence on businesses and on which the most reference is made when talking about Industry 4.0. The graph below represents a study conducted by Deloitte through a survey proposed to 2.029 business leaders in technology. It reveals that 72% of respondents believe that *IoT* is at the top of the list, believing that it is the most impactful industry 4.0 technology within their organizations. Then follows *AI* with 68%, *Cloud Computing* with 62%, and *Big Data Analytics* with 54%.

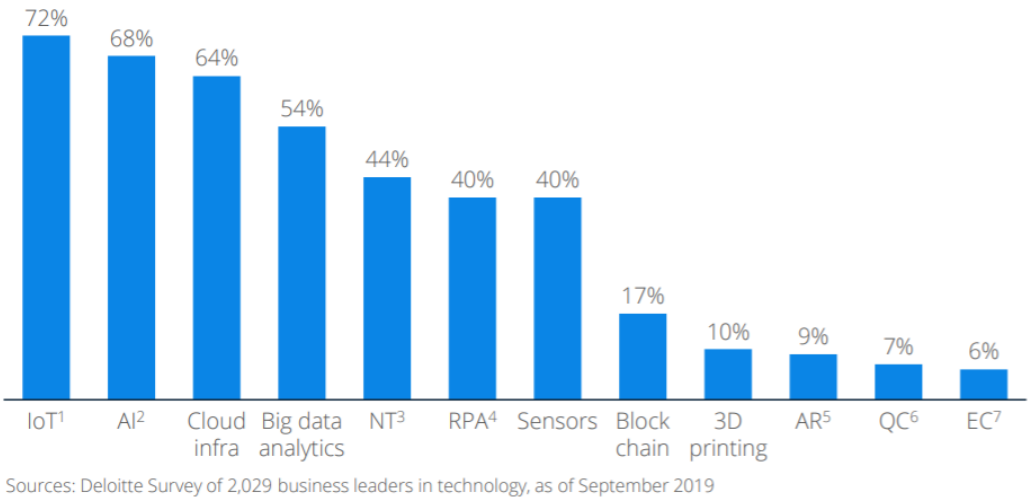


Figure 11. Potential impact of digital technologies on organizations

5.3 Features and components of the “New Revolution”

This immense transformation is now spreading, and many companies are trying to adapt to change by investing in digital and innovative technologies. By now, 32% of logistics companies and start-ups in the world make a high use of digital technologies to strengthen the sustainability of their businesses. It is expected that the next-gen supply chain market, which refers precisely to the above, could go from this starting 32% up to 75% by 2030.

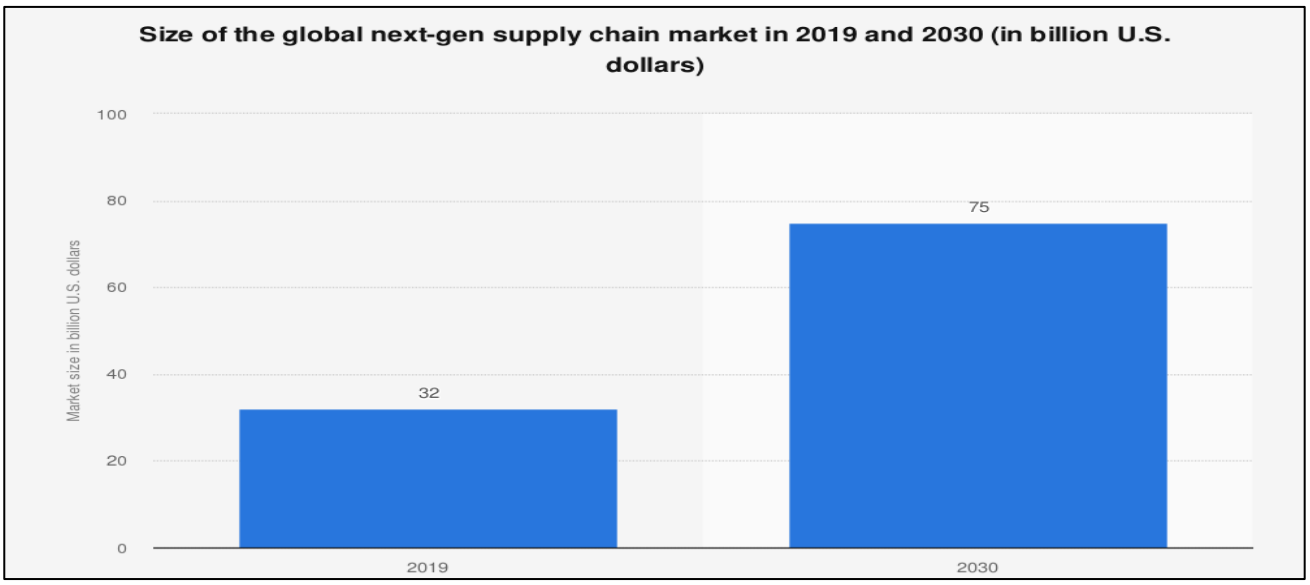


Figure 12. Global Next-Gen Supply Chain Market Size 2019-2030

Other studies instead reveal that among the various innovative factors that can have an impact on the supply chain, the one with the greatest impact could be the digitization of the supply chain together with the use of blockchain technology (• *Disruptive Technologies for Supply Chain by 2023 | Statista*, 2021).

Industry 4.0 is often associated with the term "smart factory", an indicator of the use of digital technologies to coordinate and optimize the processes of the production system, providing advantages in terms of costs. The revolution of the digitalization bases

its development on some fundamental principles of implementation, that according to Mohamed (2018) and Hermann et al. (2015) are:

A) *Interoperability*, which indicates the connection between companies, humans, and the Cyber-Physical System (CPS), through the Internet of Things and the Internet of Services. In Smart Factories, interoperability means that all CPS that are present in the factory (i.e., workpiece carriers and products) can communicate with each other, through open nets and semantic description.

B) *Virtualization*, the CPS, and the digital twins (a digital representation of a real-world entity or system) can produce a virtual copy of the real world, and so are able to monitor the physical processes. It is very useful for Smart Factories; for example, when a failure in a process occurs a human can be immediately alerted.

C) *Real Time Capability*, data is collected in real time during the production process, and constant and accurate data analysis of the environment is necessary to respond adequately to external changes.

D) *Decentralization*, many decisions occur without human interaction and only in case of errors they are delegated to the highest levels of the corporate hierarchy. In Smart Factories, RFID tags gives the input to the machines on the steps to be carried out for production, and therefore the latter perform them autonomously.

E) *Service Orientation*, it is possible to combine functionalities, encapsulating them into a web service, and making them easier to use. This through a Service-orientated architecture (SOA), incorporated in computers' software design.

F) *Security and Privacy* of information must be carefully considered in data exchange through Information and Communication technologies.

5.4 Benefits and Challenges to face in the transition towards a 'New Era'

The implementation of digital technologies in the production system can lead to benefits to the businesses in terms of:

1) **Time**, saved by workers thanks to the greater efficiency of the processes

2) **Costs**, saved by the greater accuracy of the information and data collected, which minimize the margin of error (often a source of high costs)

3) **Flexibility**, guaranteed by the new production systems that are easily adaptable to changes

4) **Integration**, as the digital manufacturing involves the joint development of the product and the production process and allows in this way to save time deriving from traditional production interruptions.

(Stăncioiu, 2017)

Moreover, such digital tools provide benefits to the supply chain processes related to: the creation of the information technology networks through several smart indicators (smart operations, smart logistics, smart warehousing, smart data) that allows to create smart products, increasing the satisfaction of consumers; an higher effectiveness and competitiveness; an increase in production level and quality of final products; less risk related to work accident and waste reduction.

In brief they can lead to a decrease in *production costs, logistic costs, and quality*

management costs. (Rojko, 2017)

Despite being advantageous from many points of view the integration of Industry 4.0 is commonly seen as a long and tortuous process that would take at least a decade to complete (Mohamed, 2018). Although studies are still immature in this field, some authors have identified the main aspects in terms of challenges. As a first consideration, Dennis Kü sters et al. (2017) state that there is not yet enough evidence to confirm the positive financial impact for organizations. Then, many small and medium-sized enterprises are reluctant to this transition as they do not have the organizational skills to coordinate the various internal units, or they don't have the capacity of manufacturing industries to progress technologically. According to Nyberg & Nilsen (2016), the main challenge to be faced to allow a good transformation lies in finding a balance and a coincidence between four fundamental factors that intersected can represent industry 4.0, namely:

- *Horizontal integration* for a manufacturing company is important, as well as understanding where it is located within the value chain and how closer cooperation with their partners can affect their value chain. Thanks to sophisticated technologies that allow to monitor product data immediately, there's the opportunity for R&D departments, purchasing, production and sales to integrate and exchange data in real-time.

- *Vertical integration* within a factory, for example between the advanced machine and the related devices, that is very dependent on tools for information sharing. Data management is becoming a fundamental competence for firms to gain competitive advantage.

- *Life cycle management and end-to-end engineering:* it is now possible to obtain information during the entire life cycle of the product (outside the company boundaries), useful for improving the product by making it more innovative. To allow this, an effective communication apparatus between all members of the value chain is necessary.

- *The human being as a conductor for added value* represents the last element. As said human beings are faced a change in their importance and presence within the production process. Machines can conduct many operations without human intervention and at the same time help people in their monitoring and control tasks.

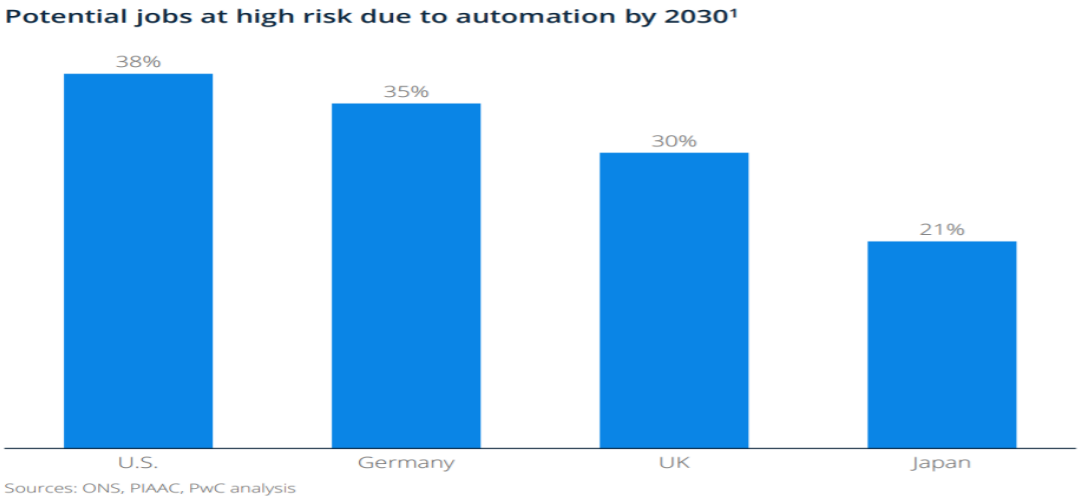


Figure 13. Potential job at high risk due to automation by 2030

This study provided by PwC illustrates that in the USA, the level of job having a high risk of automation is around 38%. In Germany this value is 35%, 30% in UK and 21% in Japan. Again, the automation doesn't mean a loss of job, but a shift in the human roles.

Other problems can be found in the need to create an efficient Cyber Security system. Ensuring quality and integrity of the data collected by the manufacturing system is becoming increasingly important with the growing connectivity and all the threats that it could generate.

It is important to add that dealing with these changes requires huge investments, at company and industrial level, which now not everyone can support (Vaidya et al., 2018). It must also be considered that the entry into the production system of these technologies requires a greater consumption of energy and materials. It is a very significant paradox, as certainly there are many benefits in terms of efficiency.

However, this efficiency is able to reduce unit costs and therefore increase

production and the consequent more intensive use of machinery and processes. So, there could be negative effects in terms of energy usage, resources depletion, hazardous material, solid waste and plastics waste, that need to be managed (Sarkis et al., 2021).

CHAPTER 6: INTERNET OF THINGS "CONNECTED" TO THE GSCM

6.1 Industry 4.0, GSCM, and Innovation

The emergence of Industry 4.0 and its related technologies are changing the way organizations do business and deal with problems (especially short-term ones). Supply chain 4.0 is rapidly taking hold thanks to the increasingly implementation of disruptive technologies, which is driving companies out of their comfort zone. It is a factor that increases the competitiveness between the various market agents, but which at the same time represents a continuous incentive for innovation and also encourages the development of small and medium-sized enterprises, which do not want to be cut off from the market because they are not adequately technologized (Sutawijaya & Nawangsari, 2020).

Process innovations is a mediating factor in the application of GSCM practices and the level of their performance (Shafique et al., 2017; Silva et al., 2019). In fact, very often, some eco-sustainable initiatives require a certain level of process and product innovation to be implemented: for example, the attempt to reuse used paper, by recycling it, requires innovation from the point of view of the product itself (design and use), but also technological innovations that make it reusable (Silva et al., 2019). In this way, the application of these practices becomes accessible, and the environmental performances improve accordingly. So the concept of sustainable innovation (interpreted as a new process, technique, system or product that is useful to reduce the harmful impact on the environment) is a key element of the GSCM (Kusi-Sarpong et al., 2019). It is so possible to build a dynamic capability and the resource-based perspective to identify the most

important drivers of sustainable innovation.

The economic component and financial availability remain essential for an innovative transition, and in this case for the shifting towards a "New Digital Era". To use innovative and sustainable tools it is therefore necessary to have the foundations at a financial level, for this reason an organizational stability in this sense must be ensured. Although a positive correlation has generally been identified in the literature between the introduction of digital and corporate performance, many small and medium-sized enterprises may not have the opportunity to face the initial investments required for the application of new tools, risking having to withdraw from the market. Therefore, targeted actions by organizations are necessary to stimulate this process, forming business networks that allow to build a competitive advantage, R&D organizational support, cost savings, subsidies, and tax cuts, also putting pressure on government bodies. (Kusi-Sarpong et al., 2019)

6.2 Internet of Things (IoT) as the basis for a digitized world: its applications and components

THING		+	IT (Hardware / Software)	=	Thing-based function (Physical / Local)	+	IT-based service (Digital / Global)
	Bulb		IoT stack	→	Light		Security
	Bin		IoT stack	→	Storage capacity		Automatic replenishment
	Tractor		IoT stack	→	Towing vehicle		Predictive maintenance, optimization

Figure 14. Examples of IoT applications

IoT represents the most important technology characterizing Industry 4.0, that has been more implemented at industrial and companies' level, but also in our lives. It describes the network of physical "things" that are connected all together through an internet connection, using sensors, software etc. The purpose of IoT is basically to connect, collect information and exchange it on the internet through different devices. In this way the

main function of the physical object can be strengthened and improved through additional digital functions, making various technologies applicable in different contexts.

An example of this can be the bins, of which the primary function is to guarantee storage capacity. Through the IoT, they can also calculate and control their own weight, then identify if there is a low level of low stock, and consequently fill up themselves. Another example is the light bulb, which is meant to illuminate. The IoT makes it possible to detect human intrusion into a home, activating the lights and sending warning signals to the owner (Wortmann & Flüchter, 2015).

Basically, IoT can be consider as composed by four fundamental layers: the perception layer, the transmission layer, the computation layer and the application layer (Mostafa et al., 2019).

a) *Perception layer*, also called sensor layer, it has the function of identifying, tracking and collecting data from objects, through various technological devices (sensors).

b) *Transmission layer,* that as the function to link the object and the cloud through a network (wireless network technologies) or other tools as RFID tags.

c) *Computation layer,* is the provider of efficient and secure services to the transmission and perception layer. Has the function to receive, process and delivers data to the application layer through an interface technology.

d) *Application layer,* that ensures tracking, monitoring and data management.

In a hyper-connected world, thanks to digital, it is possible to record, monitor and modify the interactions that result between connected objects. In practice, the real world and the digital one cooperate to increase the benefits for both (*What Is the Internet of Things (IoT)?*). However, the existence of the IoT was possible thanks to the implementation of other innovative technologies such as low-cost and low-power sensor technology, connectivity, Cloud Computing Platforms, Machine learning and analytics

and Conversational AI.

The market in this area is growing considerably. As can be seen from the graph (Figure 14), annual global spending on IoT has almost doubled from 2018 to 2023, from $646 billion to $1,100 billion, with unit costs gradually decreasing of almost one third with respect to 2004.

According to a study conducted by the European Commission in 2018 and 2019, the upfront costs are the most important obstacle to the implementation and progress of IoT in Europe. Nevertheless, another study of the Bank of America shows as from 2004 to 2020 the average cost of a sensor is decreased from 1.3 to 0.38 dollars. By 2030, forecasts confirm an increasing trend, assuming a number of connected devices of approximately 25.44 billion.

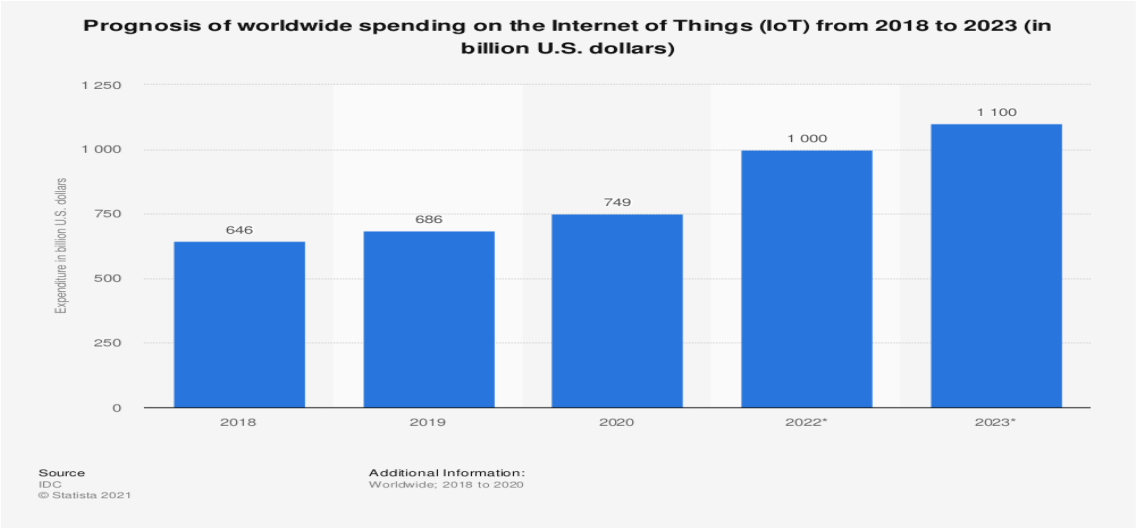


Figure 15. Prognosis of worldwide spending on the IoT from 2018-2023

This is because not only the IoT is mainly applied in Industry 4.0, but it has a multiplicity of other application possibilities in many fields: Smart home, Smart energy and Smart transport are just some examples of its versatility. More specifically, it is possible to divide the fields of applications into three categories (BEREK, 2019):

1) *Industrial*: it refers to Industry 4.0 and includes Smart manufacturing, connected

assets and preventive and predictive maintenance, Smart power grids, Smart cities, connected logistics, Smart digital supply chains.

2) *Automotive*: it involves Car2Car, autonomous vehicles, urban / civic applications.

3) *Consumer*: it includes Smart home, facility automation, entertainment electronics, voice recognition systems (Alexa, Siri etc.).

The first category (IIoT) is clearly the one that most affects the supply chains of companies, as well as being the one that has the greatest impact on pollution, because it is useful for modifying production systems towards greater environmental sustainability. A study conducted by Cisco, predicted that the IIoT will generate 1.9 trillion from the supply chain (Naveen, 2019).

6.3 Indicators to define the influence of the Industrial IoT (IIoT) on GSCM results

A digitized supply chain, as seen in the previous chapter, certainly has a positive impact on the performance of a GSCM. The same assumption can be extended for what concerns the IoT. Through a study carried out on 109 participants belonging to Chinese industrial companies, it was found that 85% of respondents are convinced that the use of digital technologies and the IoT can positively influence GSCM strategies (Beier et al., 2017).

To try to better understand the areas of the GSCM on which this positive effect of the IoT can occur, I tried after a thorough analysis of the literature, to build a sort of framework through which it is possible to interpret the impact of the IoT on the main environmental and economic performance indicators referred to GSCM strategies.

As regards the environmental performance indicators, reference is made to: Waste Management, Natural Resource Use, Environmental Opportunities, Climate Change.

Those relating to the economic performance deriving from sustainable strategies for the supply chain are: Environmental Cost, Traditional Supply Chain Cost, Quality, Flexibility, Responsiveness.

6.3.1 IoT impact on Environmental GSCM performance

IoT and Waste Management (pollution prevention and recycling)

Analyzing the influence on Waste Management, it results advantageous from many points of view: at first, it is important to consider that the use of transportation fuels represents one of the major causes of GHG emissions (13.2%). Through the IoT it is possible to plan land and sea transport, minimizing unnecessary ones and the consequent consumption of fuels that derive from it. It is possible to monitor the status of the products inside the containers, being able to recognize in real time what are damaged, are about to break or expire, and replace them in advance, thus avoiding all the problems deriving from reverse logistics and the resulting pollution. The IoT represents an innovative solution to waste management problems, using Wi-Fi, 3G and 4G networks. For example, weight sensors can be installed on cans, and monitor their capacity level. In this way, especially in large organizations, it is avoided that the bins are still collected semi-empty or harvested too little or too often, ensuring a good quality recycling (Zanella et al., 2014). So, the level of garbage collected is maximized every time. Moreover, through IoT sensors it is possible to monitor waste temperature and fire detection, bin vibration occurrence and bin tilt, presence of waste operators, waste humidity, bin GPS location, etc.

IoT and Natural Resource Use (water stress and raw material sourcing)

Regarding the impact that the IoT can have on the performance in terms of Natural Resource Use, it is possible to state that the effects on this indicator cannot fail to be positive. Through greater control and monitoring of each step of the production and manufacturing system, it is possible to maximize the use of resources, both natural and

non-natural, minimizing waste and reducing the need of raw materials involved in production to a minimum. The real-time monitoring guaranteed by IoT devices, allows to limit the consumption of resources. In particular for limiting water consumption, through Wireless sensors and a smart water management system it is possible to control and manage the level of water consumed per minute in large buildings, also predicting when there may be problems of excessive use of water (Naveen, 2019). This is a concept that many companies (as Costco and Sensoterra) are applying in their business, to monitor water and natural resources use.

IoT and Environmental Opportunities (green buildings and renewable energy)

What has been said for the previous two indicators can also be extended regarding environmental opportunities. The possibility of implementing smart systems inside buildings and constructions, which allow to monitor consumption and waste, and to optimize the use of resources, contributes to increase the number of green buildings**.** This is because the minimization of the use of water and energy, the focus on waste management and recycling, allows to structure buildings that are as green as possible (Tushar et al., 2018).

It is also important to underline that through the IoT, it is not possible to produce renewable energy, but it can certainly be an extremely useful tool to encourage its use. Many studies confirm that a production system not based on fossil energy system is not possible without an efficient management of energy or a reduction of energy demand, that IoT could ensure (Motlagh et al., 2020).

IoT and Climate Change (energy efficiency, product carbon footprint, clean tech):

For this indicator there is little to add. Everything that has been said above can be extended here as well. Thanks to the IoT. Energy efficiency is guaranteed, and thus it is possible to reduce the carbon footprint related to the final products. The IoT itself, as confirmed by many studies, is considered a sustainable and clean technology which, considering the positive impact it can have on pollution, climate change and resource exploitation, respects the components of the "Climate Change" indicator.

6.3.2 IoT impact on Economic GSCM performance

IoT and Environmental Cost

As learned from some market studies carried out regarding the IoT sector, one of the major obstacles to its implementation is precisely the investment costs that must be incurred. It is true that the unit costs of some devices, such as sensors, are decreasing over time, but the overall implementation costs are still too high. The investment risk is also very high, as the technological advancement of these innovations is difficult to predict, creating technical uncertainty, and it could also require additional expenses for upgrading existing technologies (Lee & Lee, 2015). Furthermore, an interconnected production system based on the IoT requires a high consumption of energy, which inevitably pushes costs upwards (Mostafa et al., 2019).

IoT and Traditional Supply Chain Cost

The cost savings along the entire supply chain traditional operations could be very high**.** Thanks to real-time visibility, some of the problems related to costs to be incurred can be mitigated. Examples are, in terms of consolidation and trade financing, that with IoT a prioritization of urgent shipments is allowed which is not possible with traditional processes. During the transportation, possible damages to the product could be monitored, and shipping to the warehouse, fraud and product pilferage could be reduced. Another great advantage, in terms of traditional supply chain costs, is an efficient routing based

on real-time data in the distribution phase (Yusuf et al., 2018). So, real-time traceability provided by IoT allows to *lower the transportation costs* deriving from the inefficiencies existing in traditional systems, enhancing the collaboration between carriers, shippers, and customers, providing users with real-time information, reducing damages, hazards, and incidents, and finally making the whole process more agile.

In addiction it ensures *inventory management advantages,* monitoring in real-time information on the inventory and preventing stock out and inventory shrinkage, with an increase in the visibility of the demand.

It could also provide an advantage in terms of *reduction of ingredients waste* during the manufacturing process due to the monitoring of each step of the production process that can be an important economic saving as well as have advantages in environmental terms.

Finally, it allows an *efficient storage and distribution of products* due to the easier location of goods in warehouses that reduces delivery costs, enabled also by a more efficient communication from shelves and products. (Mohamed, 2018)

IoT and Quality

The fact that the manufacturing process is strictly controlled and managed, but also the real-time visibility of machines, components and status, improve the quality of a product, also from an environmental point of view, as the authenticity of a green raw material or product can be better monitored (Manavalan & Jayakrishna, 2019; Mostafa et al., 2019).

Among the values that make up the indicator of the quality of a product there is also the relationship with the consumer, as well as his perception. Customer complaints and the relationship established with them are all elements that tend to establish the quality of a product. The introduction of the IoT can partly impact on this variable, thanks to real-time communication and information, both as regards the transport and delivery phase, but also for any type of problem relating to the purchase and their administration (Mostafa et al., 2019).

IoT and Responsiveness

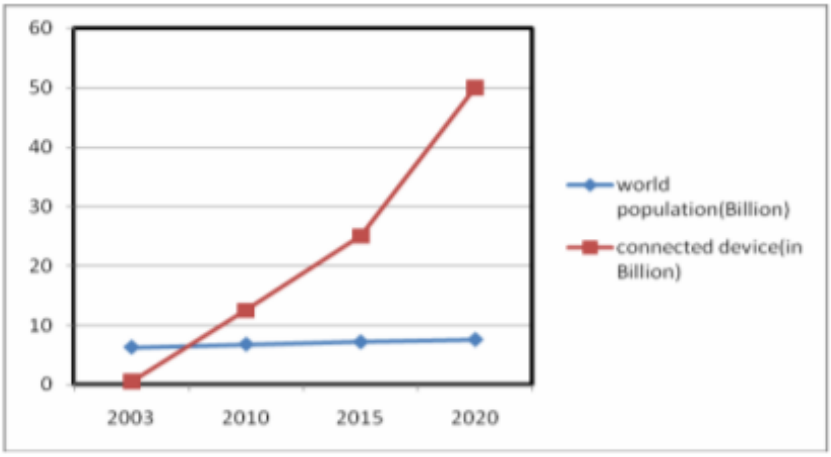
Once it is established that the introduction of IoT technologies brings benefits in terms of transport, delivery times, inventory monitoring, the agility of the entire supply chain is strengthened. In any case, having a large amount of data and information available can sometimes have undesirable effects and can cause evaluation errors that can undermine the responsiveness of the supply chain.

IoT and Flexibility

With an enhanced connectivity the flexibility of a supply chain is improved, thanks to the collection and exchange of information between partners, in a way that they can easily react to unexpected events. Therefore the IoT has direct effects on flexibility, such as smart contracts that allow programmable transactions as well as machine-to-machine communication in the Internet of Things (Cirp et al., 2020). In terms of demand planning, it ensures a certain elasticity, as not only is it possible to predict demand in advance, building accurate predictions thanks to the data collection allowed by IoT devices, but through these tools it is also possible to monitor it, resulting in a production flexibility (Mostafa et al., 2019). However, in an entirely digital and connected supply chain, even a small error or technical problem with different technologies can risk compromising their effectiveness, creating problems for the entire production chain.

Conclusions: a balanced change

Humanity is grappling with an epochal challenge, difficult to face. Pollution and climate change are now a topic of discussion in all countries of the world, and directly affect citizens, authorities, and organizations of all kinds. Everyone is putting their strength into action to solve a complicated situation, trying to find possible solutions. Especially in this pandemic period it has become evident how digital technologies are now becoming part of the lives of each of us, making us aware of the problems but, above all, the possibilities that a system based on such structures can guarantee, also from an environmental point of view. We found ourselves in a totally connected world, through a process that began a decade ago, and today we can count about 50 billion connected devices around the world.



Many companies are evaluating the digitization of their processes, as their impact on the economy and on the sustainability of the company is potentially very positive. Nevertheless, there are some critical issues to be addressed. As has been observed in the present study, a transition to a 4.0 production must be supported by many factors. A very strong management system is needed that can direct this change. First, it is necessary to "re-educate" the workforce, providing them with the skills suitable to perform tasks different from the traditional ones, and which require a high degree of competences.

Specific to the Internet of Things, the positive influence it can have on the GSCM performance variables has occurred in many areas. The function of this technology is mainly based on the amount of data that can potentially be obtained during all the steps of the production process, leading to greater control over it, and to a more efficient

management of processes. However, the amount of data to be handle leads to some critical issues, which require strong skills in data management and solid Cyber Security System, to ensure data correct use, integrity, and quality, leading to a satisfactory result from all points of view. Furthermore, the costs to be incurred are still too high to be accessible to all. The costs for implementation, and for re-setting the entire organization towards such a change, require even a few years to be addressed by the entire economic system, and the role of institutions in this regard is very important.

To have large-scale effects that can effectively change the trends relating to pollution and climate change, the transition must be complete and involve the entire economic world. Otherwise, these technologies cannot have a decisive impact in this global challenge, but would remain only an element, accessible to a few, important for gaining a competitive advantage in the relevant markets.

From a purely environmental point of view, the IoT has enormous potential. Unfortunately, the other side of the coin is the possibility that, due to the facilities and benefits to which its implementation brings, it is used in an unregulated way in terms of production, which would lead on the contrary to an intensive exploitation of resources and to an even more evident environmental pollution, increasing the energy consumption too. IoT is an excellent tool towards an eco-sustainable world, but by itself it does not represent the solution to the problem. It must be integrated with a whole series of other technologies (some of which are described in this study) complementary to the IoT, which help to fill some gaps (for example the use of the blockchain for data security).

To conclude, the digitization of production processes can lead to substantial benefits, for which a balance must be found between the various factors and criticalities.

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SUMMARY

During the recent pandemic, the issue of digitization has become an area that has affected the lives of all of us, influencing them on a daily basis. For some time, it has been debated whether these changes in our lives have brought or can bring added value, or whether they are deleterious, and it is better not to consider them in a possible evolutionary process. On the other hand, perhaps the "hottest" issue of recent years is that of global warming. Hence my interest in the subject of this thesis, i.e., from wanting to tackle the most important topics of our time, in an innovative key, which sees them as extremely correlated themes, and not as different and separate entities. My desire to investigate how it can be useful, not only from a purely entertainment point of view, or as a communication tool, started from digitization that is now more than widespread. Furthermore, many companies are implementing different technologies to obtain an advantage from the point of view of economic efficiency. Therefore, I wanted to deepen the topic, trying to understand what the most widespread uses of digital tools within companies and their production chains are, and above all how these implementations can contribute to making businesses sustainable, in such a way as to match the economic development and the environmental well-being. Time is running out, and the stability of global ecosystems is in extreme danger. It is essential to find a solution quickly, which could be under our eyes, even in our homes.

CHAPTER 1

Before entering on what is the main theme of the study, I wanted to retrace the most evident problems relating to climate change. Those that may be the most devastating effects on human health and ecosystems have emerged. Excessive external heat can cause severe damage to the body, leading to hypothermia and other types of discomfort to internal organs such as the heart and brain. Furthermore, global warming would lead to the re-emergence of various diseases or the advent of new ones. Malaria is one of them, and it is also the deadliest in the world. Global warming is leading to making many areas of the globe arid, where mosquitoes find their ideal habitat, putting human life at risk as a vector of many diseases, even in a period of the year when in

the past they were scarce present. The risk of contracting food-borne illnesses was briefly addressed, which is greatly increasing due to rising temperatures. Therefore, an overview was proposed on the effects that climatic changes have on ecosystems, also highlighting those factors that can accelerate their deterioration, such as fishing, pollution of the seas, and the intensive exploitation of arable land. At the end of the first introductory chapter, a brief excursus was carried out on the main international agreements about air pollution and GHG emissions. For this purpose, a description was made of the main points of the Kyoto protocol and the still current Paris Agreement.

CHAPTER 2

In the second chapter I started to tackle the issue of sustainability, first analyzing its meaning, determining how it does not represent anything other than *"something that can be maintained over time"*, and that sustainable development is *"meets the needs of the present generation without compromising the ability of future generations to meet their own needs "* as defined by United Nations' World Commission on Environment and Development. Swedish oncologist Dr. Karl-Henrik Robèrt, formulated the idea that to build a sustainable society it is necessary to excessively extract substances from the earth's crust, avoid concentrating substances produced by society and degradation by physical means. Furthermore, in such a society people should not be prevented from trying to satisfy their own interests. After this excursus on the meaning of the term, the focus moves on to what represents the basis for a transition to a sustainable business, namely *investment in human resources* (it is the basis of any type of transition). To make a business eco-friendly it is in fact necessary to start by making the HR management approach sustainable, in order not only to create an internal culture in line with the objectives, but also to provide employees with the right tools to deal with change.

Then, I wanted to highlight those that represent the major commitments made in the international field, identifiable in the *17 SDGs*, described individually within the text and based on four fundamental categories: People, Planet, Prosperity, Peace, Partnership. However, with the help of a graph illustrating the ranking for the SDGs of the various countries, it appears that human development and carbon footprint are now

directly proportional, and further efforts are needed in this regard.

The last part of this chapter is dedicated to Corporate Social Responsibility, and to the social and environmental commitment undertaken by companies, using definitions from the literature and from the business world. In addition to the various definitions, use was made of the *"Pyramid of Corporate Social Responsibility"* developed by A. Carrol (1991) to describe the concept. It identifies four fundamental categories that make up the idea of CSR: By degree of importance, at the base of the pyramid there is the economic component (considered the most important), followed by the legal one. Higher up we find the ethical component, and at the top the philanthropic one. So, the different practical applications of the concept were explained, with reference to CSR as a creator of shared value, risk management tool and philanthropy.

Finally, the variables that influence the CSR were studied: the drivers were found to be *stakeholders* (primary and secondary), *globalization* and *competition*.

CHAPTER 3

With chapter three the research officially starts with an introduction on the Supply Chain and its management that leads to the dynamics of GSCM. The SC is *"a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and / or information from a source to a consumer"* as defined by Mentzer et al. (2001). From this definition three types of supply chains have been identified and described (direct, extended, and ultimate) according to the number of participants in the production chain. Subsequently, I carried out an analysis of the definitions of SCM present in the literature, trying to extract their meaning from each, to find common points and create a uniform description. Furthermore, the difference with logistics, which is an integral part of the SCM, and the contrasts of interpretation between academics and practitioners were highlighted.

Therefore, the boundaries of the SCM have been described, illustrating three different components:

- *activities*, represented by the set of material and financial transactions, or transactions relating to services and information flows. The network of relationships has also been

associated with this category.

- *the benefits*, in terms of value creation, efficiencies generated and end customer satisfaction

- *constituents and components*

This part was necessary to better deal with the main characteristics of the Supply Chain and related management, to better consider that of the GSCM, and the areas of the SC on which it has the greatest impact.

CHAPTER 4

The GSCM, intended by Srivastava (2007) as *"Integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as the end-of-life management of the product after its useful life "*, is divided into several fundamental activities; in particular, two types can be considered:

- *external activities*, which concern green operations conducted outside the internal borders of the company, such as Green Purchasing and cooperation with suppliers for environmental goals.

- *internal activities*, which incorporate GSCM activities as an internal strategy to the agenda, such as cross-functional cooperation for environmental improvement and total quality environmental management.

Here too, as for the CSR, the main drivers for the application of GSCM practices have been identified. Reference was made to two fundamental theories present in the literature: the *Resource-Based View Theory (RBV)* and *Institutional Theory / Institutional Isomorphism*. These theories have been considered jointly to explain the reasons for implementing GSCM, as it strictly depends both on internal resources (*valuable, non-replaceable, rare, and imperfectly replicable*), and on external pressures that can be:

-*coercive*, exercised by the legal and regulatory stakeholders.

-*regulatory*, caused by the interaction between organizations of the same environment that lead to the spread of behavioral norms among them.

-*mimetic*, which occurs when a company operates in an uncertain environment and must necessarily adapt to the behavior of other organizations.

When it comes to GSCM, there are two types of performance that must be considered. The first concerns the results obtained in terms of environmental impact, the second, on the other hand, concerns the performance from an economic point of view that green actions and practices generate. Regarding environmental performance, four types of key indicators have been selected:

- *Waste Management*, that is, everything concerning the organization of waste along the supply chain.

-*Natural Resource use*, that refers to the exploitation of the resources provided by nature, which, if too intense, leads to the deterioration of the environment.

- *Environmental Opportunities*, refers to the intensity through which certain practices incentivize the exploitation of eco-sustainable opportunities.

- *Climate Change*, it derives from all those practices that positively or negatively impact on climate change.

On the other hand, as regards the economic performance of the GSCM, with reference to the areas of the supply chain on which the latter impact the most, the following indicators were selected:

- *Environmental Cost*, that represents the total cost incurred in implementing the processes and actions to become green and sustainable.

- *Traditional Supply Chain Cost*, that includes the total cost of normal operations along the supply chain.

- *Quality*, related to the standard features of the product.

- *Flexibility*, namely the adaptability of the supply chain to changes related to its processes.

-*Responsiveness*, that represents the ways in which the supply chain reacts and responds to various factors.

In conclusion of this chapter, considerations based on literature were done in order to establish if such GSCM practices have a positive impact on these two kinds of performances. In general, it turned out that some of these initiatives are very effective

from an environmental point of view, and from an economic perspective too (even if there are important costs to bear). Clearly, in practice there may be discordant results from this last statement, depending on the specific cases.

CHAPTER 5

Chapter 5 finally makes room for the introduction of Industry 4.0. With this term we refer to that industrial system based on the use of high-tech and digital tools. It is understood as a new Industrial Revolution, and it is labeled as the one that is impacting mostly on society. In fact, compared to the others (whose main characteristics have been described in the text) it has some fundamental differences:

- *The elimination of humans from the production system*.
- *The revolutionary change concerns all business processes of an industrial organization*.
- *The possibility of simultaneous usage of globalization and of minimizing the negative social impact.*
- *Change of the essence of the industrial patents*.

Then, the main technologies that characterize this era were introduced, such as 3D Printing, Autonomous vehicles, Cloud systems, Big Data Analytics, Blockchain, Drones, Internet of Things, Robotics, Virtual Reality/Augmented Reality.
Instead, the main features of New Revolution were described in detail, and they were grouped into 6 categories*: Interoperability, Virtualization, Real-Time Capability, Decentralization, Service Orientation, Security and Privacy*. All these characteristics were analyzed in detail.
Finally, benefits and challenges of the introduction of Industry 4.0 in the production system were identified. The main advantages were found for that concerns the *production costs*, *logistics costs* and *quality management costs*.
But some challenges exist: at first the difficulty lies in finding a balance between four fundamental characteristics, which are horizontal integration, vertical integration within a factory, Life cycle management and end-to-end engineering, and the human being as a conductor for added value. Other challenges lie in the implementation costs, in the

enormous amount of data to be managed, and in the risk of using these tools excessively, nullifying the environmental benefit that they can potentially guarantee.

CHAPTER 6

From the analyzes carried out by some companies, such as BCG and Deloitte, it appears that the technology that can most impact on companies and their supply chains is the Internet of Things. For this reason, an introductory speech was also made for this innovation, trying to deepen its concepts and utilities. After the analysis concerning the world of IoT, a study was finally carried out on the impact that this technology has on the indicators previously selected to represent economic and environmental performance, trying to understand through a qualitative analysis if there was a positive impact. The results were mainly positive with some critical issues to be considered and which are described in detail in the text.

This synthesis is intended to briefly represent the study that has been carried out. However, for a complete understanding of the research it is necessary to rely on the text, which contains within it the analysis of the topics described here in summary, but in depth, and with some topics not covered here.