POLITECNICO DI TORINO

**Corso di Laurea Magistrale in**

**Ingegneria della Produzione Industriale e dell'Innovazione Tecnologica**

Tesi di Laurea Magistrale

# Fashion Industry: is a Sustainable Future possible? A deep analysis of the Fashion Industry Supply Chain


**Relatore**

Prof. Massimo Rossetto

**Candidato**

Diego Frigerio


**Dicembre 2020**

# Index

# Abstract

The purpose of the thesis is to offer a view of the Fashion Industry and its economic, environmental, and social impact. In particular, its Supply Chain will be investigated. The Fashion Industry went through a profound transformation that started at the end of the 20$^{th}$ century and changed the pace of what had once been one of the pillars of the sector: the fixed calendar of fashion shows has been ousted by a growing number of collections, characterized by cheap and low-quality clothes. One of the main factors that fuelled this huge change has been globalization, that led to the relocation of a big share of the Fashion Industry outside Europe, mainly to Asian countries, favoured by less stringent Labour and Environmental Laws. Customers are more and more considered "consumers", and the pace at which the industry has been producing and products being incinerated or landfilled is no longer viable. The consequences may even worsen due to an ever-increasing population. Although the beginning of a changing trend has been observed, it is far from being sufficient to transform the Fashion Industry and make it sustainable, achieving an absolute decoupling, breaking the dependence between economic growth and environmental degradation.

Supported by recent studies and business cases, the thesis aims to propose different alternatives that can be applied all along the Supply Chain, to reduce the environmental impact of the Industry and make it sustainable, especially through the application of many solutions that have their roots in the Circular Economy. Specifically, the key role of Supply Chain Management in this switch from a linear to circular flow is outlined. In the first part of the thesis, a general view of the Fashion Industry, along with the context and the megatrend in which companies operate, are described. Moreover, the key aspects that are leading the Industry not to mitigate its impacts are discussed. Secondly, three main themes that play an important role for the understanding of the thesis and will be crucial for the future of the Fashion Industry are presented. Lastly, the technological enablers of the transformation proposed in this thesis are described, and a wider view of the key changes that will take place and may lead to a Circular Supply Chain are given.

# Introduction

## Background

*"Fashion is, indeed, a unique phenomenon. It consistently transforms and fluctuates, reflecting the mood of society. The degree of metamorphosis, however, is within a nominal but a discernable extent in the mind of the consumer"*

(Fernie and Sparks, 2004)[1]

The Fashion Industry has by nature the propension to be an unsustainable business. Making and selling clothes are the key activities of the Industry, and the faster they are carried out, the better. In particular, the last three decades have seen the scenario characterized by low predictability, high impulse purchase, shorter life cycle, and high volatility of market demand. And if the Fashion Industry reflects the society in which we live, and especially its customers, this can be an explanation of why it is one of the industries that is mostly under attack for its impact on the environment and on society. The Fashion Industry also has a big impact on the economy, with its turnover accounting for $2.5 trillion globally[2], employing directly 75 million people throughout its value chain. It is the world's third-largest manufacturing sector after the automobile and technology industries.[3] Despite its huge economic importance, the production of our garments has a crucial impact on overall air pollution, water consumption, water pollution, chemical usage and land exploitation, which are being progressively criticized. Fashion environmental impact is hard to measure, due to its frequently outsourced remote production sites, fragmented supply chains and lack of standards and regulations, along with the multitude of uses that textiles can have, not only in the Fashion sector, but also in other sectors. Even if it is hard to convert the harm done by the Industry to a monetary value, companies like Kering are trying to do so: with the Economic Profit & Loss report, the famous Luxury Group can give an estimate value in economic terms of its environmental impact, that last year (2019) amounted for €524 milion.[4] If we compare Kering's 2019 turnover, €15.88 billion[5], with the total value of the industry globally (€2.13 trillion) as cited before, it can be stated the environmental impact of the industry stands above €70 billion (Assuming all other companies involved in the Industry operate as sustainably as Kering. Kering's market share in the Fashion Industry accounts for only 0.75%). The evolution of the market, along with its globalization, have given rise to an unbalanced distribution of the repercussions the fashion system has on the environment.[6] The majority of retailers, in order to maximise their profits, outsource their production processes to countries that not only offer lower labour costs[7], but also do not require strict rules regarding the environment and workers' condition[8]. One of the recent events that shocked the world, The Rana Plaza accident that occurred on 24th of April 2013, killing 1,132 people and injuring more than 2,500[9], is a clear

demonstration that the Clothing Industry still has a lot to improve on before becoming sustainable. This modus operandi is further stimulated by overconsumption. A report by the global management consulting firm McKinsey states that global clothing production doubled between 2000-2014 and is expected to rise an additional 63% by 2030[10]. One of the reasons for this can be the rise of Fast Fashion, a model that has emerged in the last 20 years, based on producing a product at the lowest cost and cheapest quality. The industry's objective is to encourage customers to visit stores frequently, introducing smaller collections, at an increasing pace and with lower prices [11]. This feeds the need of instant gratification that is motivating consumers to prefer retailers such as Zara and H&M[12], which offer between 12-24 clothing collections per year, compared to 2-4 seasons offered by traditional retailers[13]. Consumers are then induced into a behaviour that makes them keep each item for half the time than in 2000[13], and the impacts these trends are having on the environment, and will continue to have unless a radical change takes place, are significant (See Figure 1).


*Figure 1 – Projected Global Fashion Consumption[14]*

At the same time, the number of times an item is worn has decreased in the last 15 years (Figure 2). A report by McKinsey claims that more than half of fast fashion produced is disposed of in under a year[10], and this is a trend that is mostly visible in developed countries: for example in the US, clothes are worn approximately a quarter of the global average[15]. But if countries like China, India, Indonesia and Brazil, which are the most populous developing countries[16], are destined to ameliorate their living conditions, consumption of fashion products in these countries is going to rise. The impact, especially in China and India, which jointly represent 36.2% of the population, could undermine the Paris Agreement goal to combat climate change and, in particular, to maintain the rise of the global temperature well below 2 degrees Celsius above pre-industrial levels. Already in "The State of Fashion 2019" Report by BoF and McKinsey, Indian ascent was seen as one of the focal points in the Global Economy, also due to the fact that the middle-class consumer base was growing, forecasting

the value of India's apparel market at $59.3 billion in 2022, which would make it the sixth-largest market in the world. On the other hand, China has increased its share in the luxury market by 70% since 2012[2].

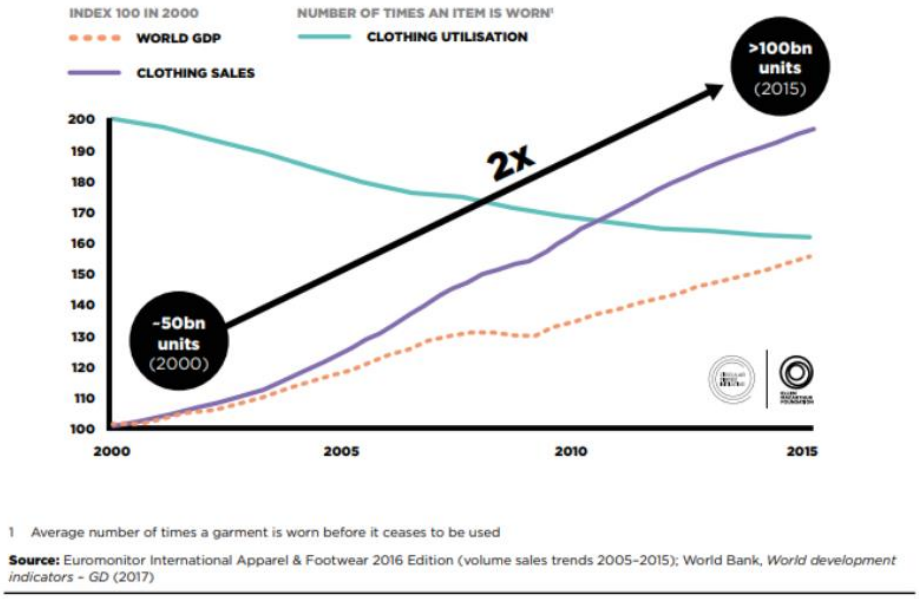



*Figure 2 – Growth of Clothing Sales and Decline in Clothing Utilisation since 2000*

Overconsumption and overproduction are interconnected and play a big role in the intensification of the production of clothes. Moreover, the population is expected to continue to grow: even if the annual world population growth rate is decreasing (from 2.2% 50 years ago to 1.05% today), in the next 20 years the absolute increase of the population is expected to be between 60 to 80 million people per year[17]. This raises questions as to what extent our globe is going to support our production system. Specifically, the production of clothing requires huge amounts of water and energy, emitting large quantities of $CO_2$. As we can see from Figure 3, cotton, which is the most used natural fibre, requires roughly 1,600 litres of water per kg of fibre produced. Generally speaking, even if natural fibres require less energy consumption, natural fibres need enormous quantity of water, and this is happening while freshwater resources are depleting and becoming a limited resource. In addition, cotton production is often outsourced to developing countries, that have to deal with the cotton-related water footprint: a study by Chapagain et Al (2005)[18] found that 84% of the water footprint due to cotton consumption in the European Union lies outside the territory of the member states, which are particularly dependant on water resources in Asia. Yet, in developing countries, which include the majority of Asia, 90% of the untreated wastewater is discharged into rivers and lakes.[19] In addition, the United Nations World Water Assessment Programme (WWAP) estimates that by 2030, in a business as usual scenario, the global water demand will exceed supply by 40%.[20] Lastly,

notwithstanding cotton may not consume as much energy as other fibres, nonetheless cotton cultivations are renowned for being chemical intense.

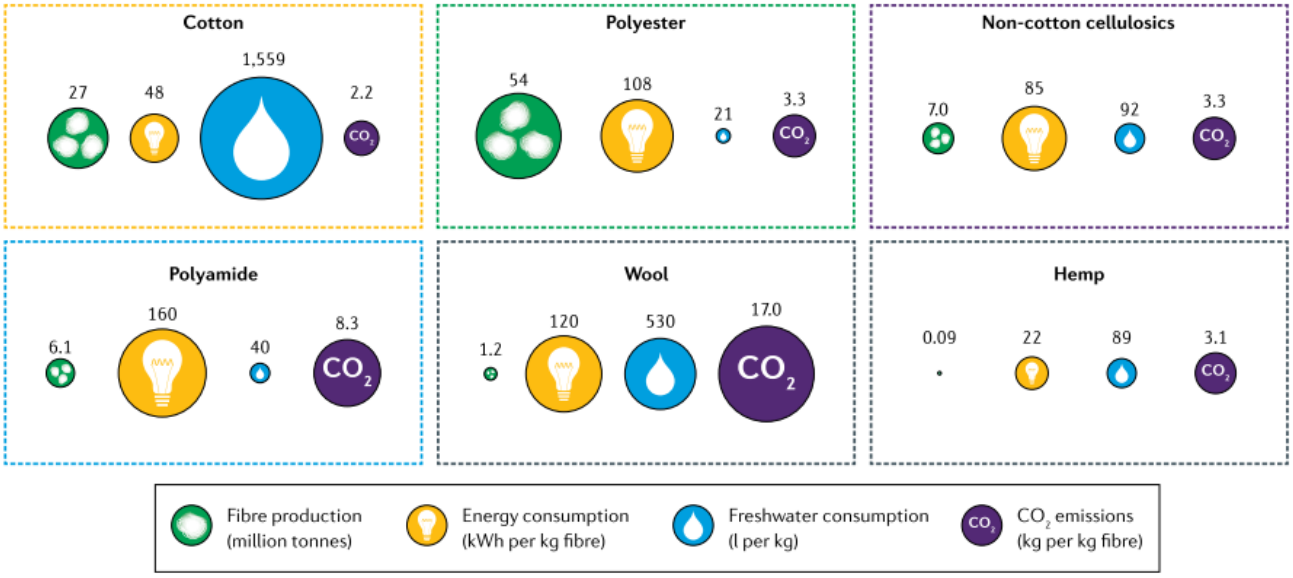



*Figure 3 – Environmental Impact of six types of fibres*[21]

## Fast Fashion

*"Fashion is the imitation of a given example and satisfies the demand for social adaptation…The more an article becomes subject to rapid changes of fashion, the greater the demand for cheap products of its kind."*

(Georg Simmel, 1904)[22]

Many of the changes that have been occurring in the last 30 years in the business, concerning the entire Supply Chain, and the intensification of both production as well as retailing, are being attributed to Fast Fashion. With the rise of Fast Fashion, all the components that formed the long-established stable structure of the traditional fashion industry have been fragmented. The fixed calendar of seasons that dictated the pace of the market has changed completely: now the retailers' objective is quantity, pushing customers to become "consumers", based on the fact that the faster they get rid of their old clothes (and by old we mean 1 year-old clothes) the better. This is achieved by increasing the number of seasons and collections, supported by low-price strategies, which foment the "throwaway mindset" of the customer, causing an increase in landfilled textile waste: for example, the USA have seen an increase in dumped textiles of 40% between 1999 and 2009 and the average lifespan of three types of clothing (T-shirts, knit collared shirts and woven pants) in six countries (China, Germany, Italy, Japan, the UK and the USA) has been calculated to range 3.1 and 3.5 years

on average [23]. Fast Fashion brands are renowned for redesigning luxury clothes, copied from the last catwalk of the season, and bring them from the shows of the most famous luxury brands to their own stores within two weeks. For this reason, Cimatti et Al. (2017)[24] define Fast Fashion as a fast-response system that encourages disposability, as a means through which customers try to differentiate themselves from others, satisfying their desire for Luxury Fashion at affordable prices and trying to achieve personal affirmation. But their shopping habits are further stimulated by mass media, making customers think they always need more and more clothes, given also to the fact that their clothes are not made to last: both perceived obsolescence, which makes customer feel their garments old after only one year, and poor quality products, due to too low prices, make Fast Fashion companies sure their customers will go back to their stores to buy again.[25] Speed requirements and the distance-from-market constraint also implies the displacement of products contribute to the problem of carbon emissions, especially due to increasing preference of deliveries by air due to time pressure[26].

In order to obtain low prices, companies look for places where labour cost is favourable, and this is always found in developing countries: 68% of clothing imported to Europe in 2012 was supplied by only three countries: China (43%), Bangladesh (13%) and Turkey (13%). Even companies that used to source to local manufacturers, began to look for new suppliers in countries like China, Bangladesh, India, Turkey and Morocco.[27] This is not only due to the fact that these manufacturers can comply with new flexibility and design requirements, as the article from which the previous information comes from, but also because labour costs are much lower. However, even China is becoming less reliant on the apparel industry, shifting their interest to other manufacturing sectors that require the development of higher skills: the percentage of garment exports as a fraction of total merchandise exports decreased in 20 years (from 1995 to 2014) by around 15%, accounting now for 15.3% of the total[28]. The reasons for this shift can be many, but the main driver can be identified in the decision of China's authorities to focus on capital- and technology-intensive industries. Therefore, the labour-intensive clothing sector has begun to lose its power in China, since the country's efforts, after the entry to the global market due to the acceptance of China into the WTO, moved to value-added activities and branding cultivation, rather than to assembling and manufacturing.[29] The increasing use of machinery in production improved the industrial output, increasing its efficiency, and in some activities replaced manual work, resulting in a decline of the demand of cheap labour. If we look at the average monthly wages in garment, textile and footwear sectors reported by the International Labour Organization (Figure 4), China, compared to the other Asia-Pacific economies, has the highest average monthly earnings, and the second most expensive workers, those in Thailand, are 43% cheaper.

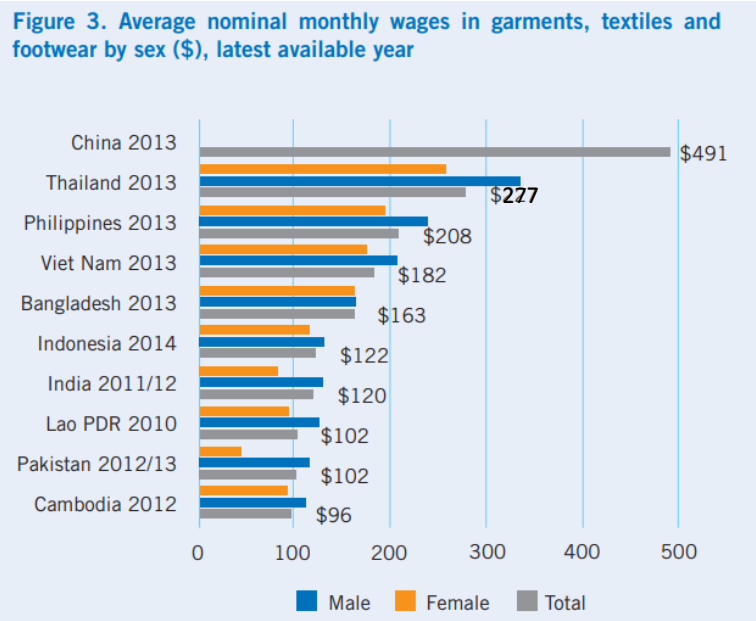



*Figure 4 - Average nominal monthly wages*[28]

Therefore, it is evident why, the production of low cost garments is increasingly moving from China to other countries, such as Bangladesh, where the cost of a worker is approximately a third of the same worker in China, and Cambodia, where in 2012 the average cost of labour was less than a quarter compared to China. This does not only mean that China is becoming an industrially mature country, having gone through the industrialization process and by investing in new technologies, but it is the demonstration of the cheap-labour-cost rush the Fashion Industry is experiencing, from which China has somehow declared its independence by distancing itself. It is clear the Industry still relies on labour-intensive jobs, moving from one country to another, in search for the economy that will offer the lowest cost on manufacturing, despite the huge investments being made in R&D.

If we break down the retail price of a T-shirt (Figure 5), we note that labour cost only accounts for a small percentage of the final price: 0.2 CHF of the 29 CHF, less than 0.7%. Even a minimum reduction in transportation cost, a reengineering of administrative procedures to rend them more efficient or a 2% reduction of profit at the retail level would justify a twofold increase in the workers' salary.

Figure 12: Breakdown of the Price of a T-Shirt

| | CHF | % Price |
|---|---|---|
| **T-Shirt Retail Price** | **29.0** | |
| - Cost of Goods Sold | 12.0 | |
| - Selling, General & Administration Costs | 10.0 | |
| = Profit | 7.0 | 24% |
| **T-Shirt Intermediary Price** | **12.0** | |
| - Transportation Costs | 2.2 | |
| - Selling, General & Administration Costs | 1.2 | |
| - Cost of Goods Sold | 5.0 | |
| = Profit | 3.6 | 30% |
| **T-Shirt Production Price** | **5.0** | |
| - Cost of Material | 3.4 | |
| - Labor Costs | 0.2 | |
| - Selling, General & Administration Costs | 0.3 | |
| = Profit | 1.1 | 22% |

Source: Clean Clothes Campaign (2014), J. Safra Sarasin Assumptions

*Figure 5 - T-shirt price breakdown*[30]

The cheap-labour-cost rush is linked to another rush, the price-rush, that got people used to "buy more and spend less"[31]. To maintain, or even decrease, the price of clothes, fashion companies put huge pressure on suppliers in developing countries. Besides lower prices, companies increasingly require the production of smaller batches and the reduction of leading times[11]. Moreover, subcontractors act in a playground where firms have low switching costs, which almost oblige them to accept the contract, regardless of the real cost they are going to face during the manufacturing process, reducing their profit margins. The lack of control over suppliers that are in charge of the manufacturing process situated thousands of miles away from the headquarter of the contracting firm, along with the strong pressure on cost, often result in toxic pollution and unethical working practices, since their profits do not enable to assure fair labour conditions and the respect of the environment. However, it is no coincidence: as Turker et al. analysis of corporate reports outlines, and as stated by H&M's report, "garment production is often located where human rights are at risk and environmental awareness is less developed''[27]. Seen that the requirements in order to work for the clothing manufacturing process are not many, factories tend to hire without looking at particular skills, ability or motivation. This is why, along with the high offer of labour and the fact that most of the workforce is composed of young and poorly educated people27, sweatshops offer socially unacceptable working conditions[32]. The results of this industry trend can be seen in the same report of the International Labour Organization cited before: even if minimum wage levels in developing countries are low, especially in the Asia-Pacific region, non-compliance with regulations is dangerously high (Figure 6). In particular, data collected about India and the Philippines show that more than one out of two workers are not guaranteed the minimum wage.

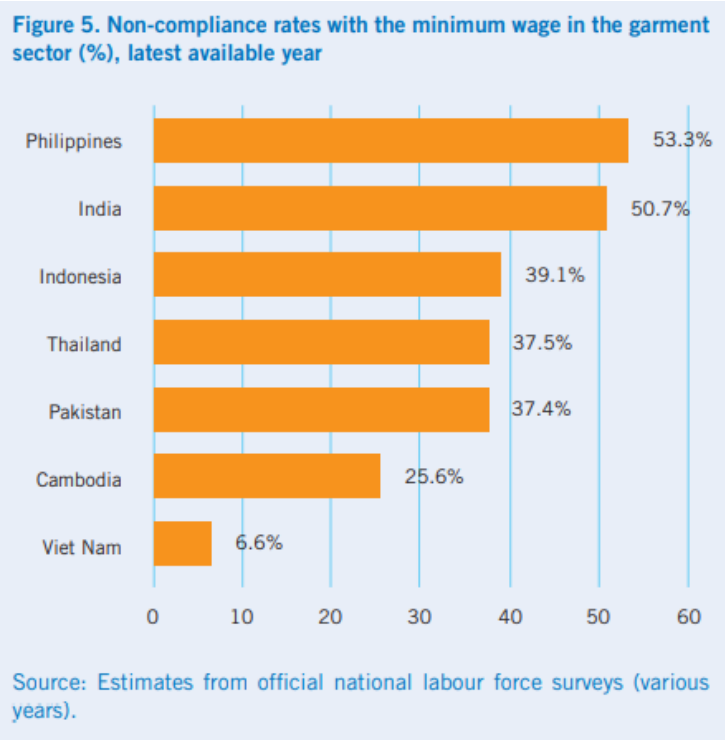



*Figure 6 – Non-compliance rates with the minimum wage in the garment sector*[28]

Another data that shows the lack of respect for workers is the one that represents the long hours workers are subject to: In Cambodia, more than half of the workers work more than 48 hours per week (Figure 7). Additionally, governments apparently have no advantage in implementing, or improving already existing, Labour and Environmental Laws, since these would lead to a rise in costs and result in companies finding new countries to outsource their production in[30].

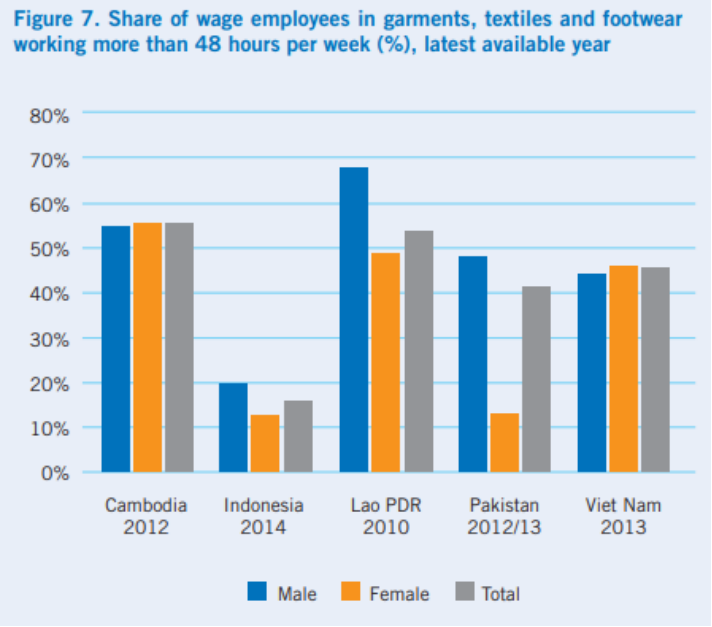



*Figure 7 - Share of employees working more than 48 hours/week*[28]

The whole mechanism described above is illustrated in Figure 8. As it can be seen, the system operates in a dangerous cyclic way, at the risk of collapsing the entire structure due to the rush for the lowest price. All these changes gave rise to a generation of spoiled clients that got used to buying a new garment almost every month[33]. The wide availability of economic and low-quality clothing fuel overconsumption and premature disposal of fashion products[34], and generated a throwaway commodity in which clothes are worn an average of 7 times before the consumer gets rid of them. According to "The Ellen MacArthur Foundation" report, one garbage truck of textiles is landfilled or incinerated every second.[35] Many questions arise from this analysis, especially whether this system is built to last. The next chapter will elucidate the structure of the Supply Chain in the Fashion Industry.


*Figure 8 - Fast Fashion Cycle*

## The Fashion Industry Supply Chain

*"A supply chain is a network of partners who collectively convert a basic commodity (upstream) into a finished product (downstream) that is valued by end-customers, and who manage returns at each stage."*

(Harrison and Van Hoek, 2008)[36]

In the Fashion Industry, focal firms do not deal directly with all the operations. As we have seen in the previous chapter, manufacturing is usually outsourced to countries with lower production costs.

However, manufacturing is not the only activity that fashion companies like Zara do not handle: if we look at Figure 9, it can be stated that actually many levels compose the value chain of a textile industry. In the illustration, the example of Puma, a company producing sports goods, is reported. The same scheme can be used to represent other giants of the industry, with some changes in the various activities performed by the different tiers of suppliers. However, what is most important about this illustration is the distance that tends to be between the focal firm and the different suppliers. In general, the different levels of suppliers that can be identified in the Fashion Industry are 4:

- 4th Tier: Producers of raw materials. Raw materials include:
    - synthetic fibres, like polyester which accounts for 51% of the global textile production[21], along with other materials like polyamide and elastane.
    - bio-based fibres, especially cotton. With its 25% of global fibre production, it is the most used natural fibre. Unlike synthetic fibres, cotton is found by nature in the shape of fibres when harvested, and it goes through a process that separates the fibrous part from the seed.
- 3rd Tier: Yarn Manufacturers and Dyeing. While synthetic fibres are normally given their fibre shape extruding them through a nozzle, that can give them different thicknesses, bio-based fibres, except silk, are harvested ready to go through the spinning process. The spinning process can be made from a mix of fibres or from a single one. In order to make yarns more resistant to following treatments, spinning is followed by twisting. Dyehouses are in charge of the wet treatment of fabrics, that include pre-treatment, dyeing and finishing, and sometimes also printing. However, the whole process or part of it is postponed to later stages of the supply chain, for example right before the creation of the fabric, or immediately after. Other common processes that usually take place at this stage are sizing (addition of chemicals in order to lubricate the yarn before it is waved, in order to reduce the wear), desizing (the removal of sizing agents) and bleaching (chemicals are used in order to remove unwanted colour from the fibres, treating them with chemicals)[37]. These processes are all incorporated under the category of Wet Treatment: it is important to know that they all have a strong environmental impact, due to their large usage of energy, water and chemicals. According to a study by Olsson et al. (2009), between 1.5 and 6.9 kg of chemicals are needed in Wet Treatment processes to produce 1 kg of garment[38]. Further details about treatments and processes are not required for the analysis and understanding of the thesis.
- 2nd Tier: Textile Manufacturers. At this stage, yarn is waved or knitted, or nonwovens fabrics are produced from staple fibres or filaments.

- 1st Tier: Garment Manufacturers. Sewing factories are the direct suppliers to fashion companies. They are in charge of cutting, sewing, ironing packaging and sometimes also garment finishing (washing, bleaching, printing, …).[39] They can be seen as the assembly part of the supply chain, where fibres meet other materials, such as buttons or zips. At this stage of production is where most of workers' rights are violated. It is the most labour-intensive activity of the entire supply chain.

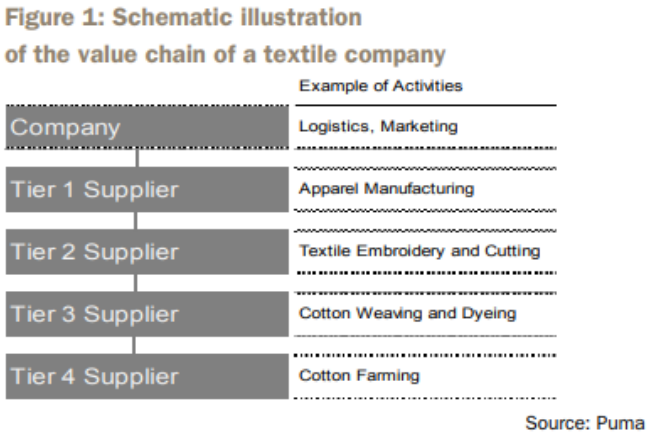



*Figure 9 - The Value Chain of a Textile Company*[30]

When garments are finished, they are shipped to Distribution Centres that eventually send smaller batches to stores. The most important stages of the Industry are summarized in Figure 10. The picture also shows at which stage of the supply chain the most common environmental impacts of the industry, energy consumption, chemical use, water use and waste production, take place and where each step of garment production is sourced. Figure 11 gives a more detailed view of the Fast Fashion Supply Chain.

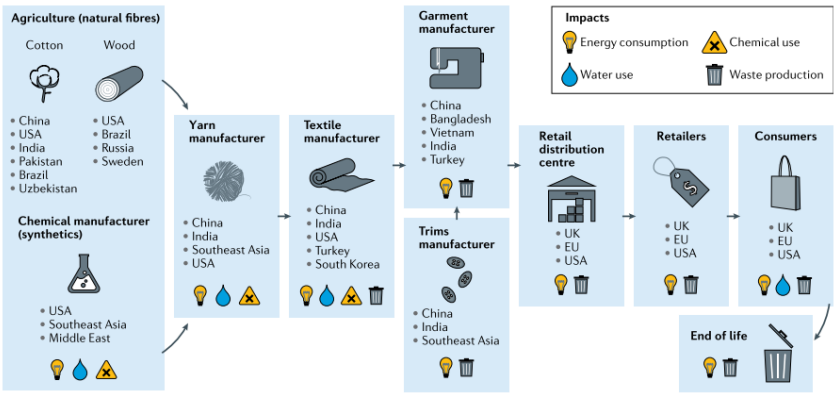



*Figure 10 - Fashion Industry Supply Chain Key Stages*[21]

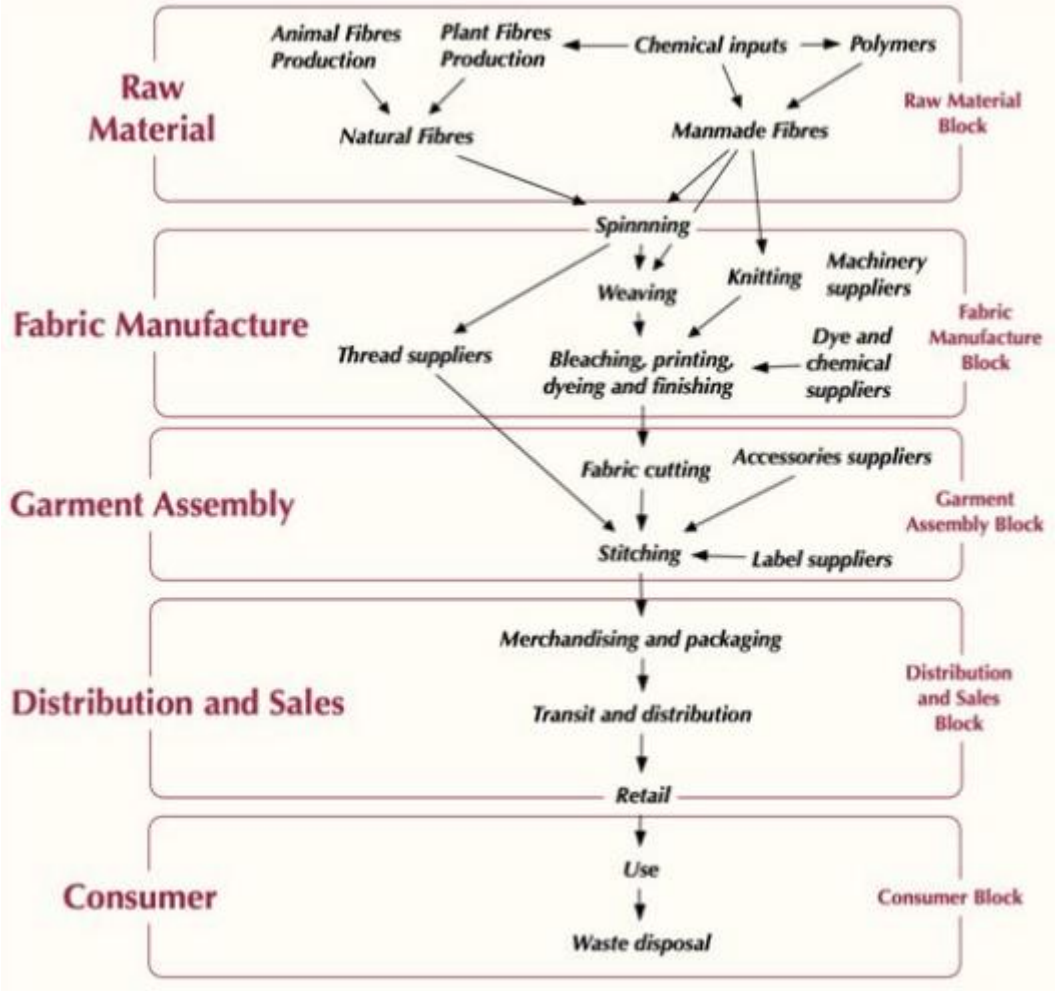


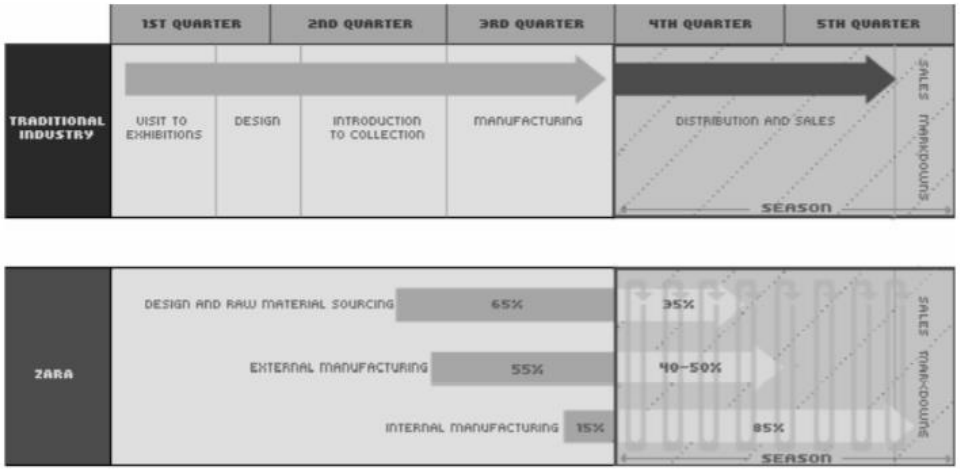

*Figure 11 - Fast-Fashion Supply Chain (detailed)*[40]

## Design at Zara

In order to better understand how fashion brands work, it is essential to explain how one of the most important Fast Fashion retailers, Zara, sees Design, one of the characterizing activities of the industry, in a completely different way. The information is from "Ghemawat, P., & Nueno J.L. (2006). ZARA : Fast Fashion. Harvard Business School"[41] and Inditex's website[42]:

Product Development at Zara starts with designers attending fashion shows in cities like Paris, Milan, London and New-York, where they can find the most probable upcoming trends. Right after, close collaboration between designers and store managers begins, in order to find out what is selling and what is not. The close relationship with customers is key to designers of Fast Fashion brands: collections and trends last even less, thus it is crucial to predict what customers are going to buy during the few weeks of a specific collection lifetime. However, even if designers start working on future collections up to nine months before their arrival in the stores, continuous modifications and adaptations to market requirements can be made after the season has started, since the majority of

manufacturing takes place after the season begins (Figure 12): in particular, 40 to 50% of external manufacturing and 85% of internal manufacturing take place after the beginning of the season and Zara is able to bring a new item from the drawing board to stores in just 3 weeks[43]. Additionally, designers' decisions, including the determination of the correct moment to introduce new items, are increasingly based on the analysis of real-time data obtained from social media (like Instagram) and Zara's online platform. Therewith, when a new collection is going to be launched and if lead-times make it possible, a limited volume of new products is unveiled in selected stores and mass production only begins if customers respond unquestionably positive to new releases.




Source: Inditex.

*Figure 12 - Zara vs. Traditional Industry* ***Errore. Il segnalibro non è definito.***

Designers job at Zara transcends the definition of designer. The designer follows the development of the product, as described above, being also involved in the choice of materials, but designers' scope goes well beyond their specialisation: designers become real-time data collectors, in an industry that has pushed shop windows to change every two weeks and therefore information, and trends, change constantly, and their information comes from a variety of sources, like social media, sales and customer feedback (collected thanks to their close relationship with local sales managers), catalogues of luxury brands, film content, but also through experiences such as runway shows, discotheques events or every episode where trend spotters can track Zara's potential customers' fashion behaviours. Designers, along with other companies' departments, are supported in their decisions by an information system that enables a detailed analysis of product lifecycles, in order to know when to interrupt or increase the production of specific products.

This whole product development process at Zara, which involves both quantitative and qualitative data, is intended to reduce failure rates as much as possible. The result is a 1% failure rate in the launch of new products, compared to an average of 10% for Zara's competitors. However, collections

are refreshed twice a week in all Inditex's stores and specific orders can be delivered in 48 hours or less. This is enabled by the flat structure which permits designers to have important information and cardinal people at their reach, especially from other company's divisions. Designers become a bridge between merchandising and production, but above all, being closer to customers allows them to take important and real-time decisions. This is also made possible by flexible and responsive logistics centres along with local production (or at least close to Spain, where all Distribution Centres are located) for strategic products. In fact, Zara, in contrast with other companies operating in the same sector, owns the manufacturing plants, which are mostly utilized for the most fashionable items, since their demand tends to be the most difficult to forecast. Another solution for the production of these products can be outsourcing to suppliers located in Spain, or nearby countries like Portugal, Turkey or Morocco, that ensure flexibility and efficiency.

## Problem Discussion

Despite the growing share of fashion industry related exportations in many developing countries (as we have seen in the previous chapter), the beginning of a counter trend can be seen: in order to respond quicker to the increasingly frequency at which trends change and customers get rid of their new garments, companies are moving their production sites closer to their final markets[30]. Production costs increase significantly, but companies reduce costs related to transportation, especially since smaller batches deliveries has increased the number of freight movements[44], and have an enormous gain in demand responsiveness, since lead times are reduced from up to 3 months for Asian suppliers, to two or three weeks for goods made in southern Europe[11]. But even shortening lead times, implementing a Just-In-Time manufacturing like Zara or Uniqlo[45], overstock will always be produced, due to the varying demands by consumers and the vast offer of clothes, that make customer's behaviour difficult to predict. A study by Ellen MacArthur Foundation found out that 3% of the global production of clothes is retailers' overstock which ends up being landfilled or incinerated (in Figure 13 it is included in the 12% loss in production, since it does not reach the "use phase"). H&M was reported to have $4.3 billion worth of accumulated inventory in 2018, an impressive number that is the living proof of how many brands are struggling with overproduction.[4647] The same study states that 73% of the 53 million tonnes of fibre production for clothing end up either landfilled or incinerated, and less than 1% of the total production is used to produce clothes of the same or similar quality.

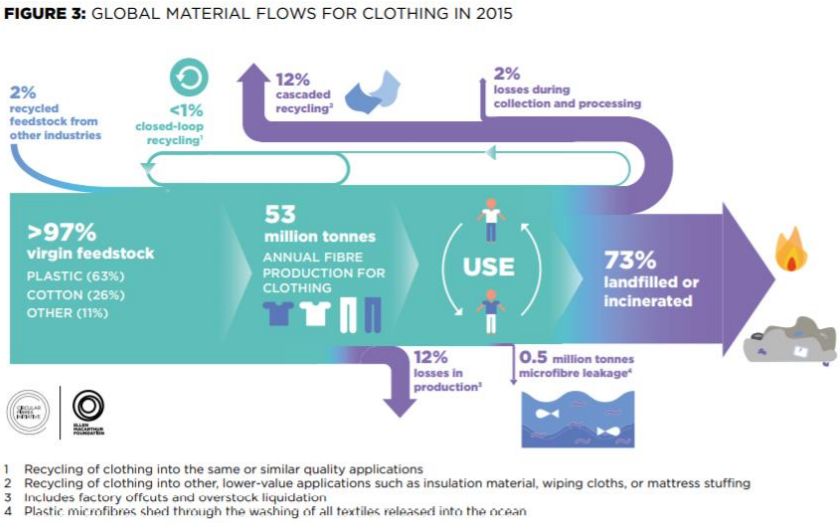



*Figure 13 - Clothing Flow*[35]

The increasing attention on social and environmental topics among a growing share of customers has put pressure on fashion companies, in particular on those operating in the fast fashion industry, which have started to direct their efforts to the implementation of Sustainable Supply Chain Management (SSCM) practices[27]. De Brito et al. identify three main drivers that encourage corporations to get involved in sustainability: first of all, companies are forced by legislation, that rules to their activities in order to make them less polluting; on the other hand, firms engage in sustainable programs in order to gain a competitive advantage above other competitors, not only reaching a new customer base, but also by making their processes more efficient; thirdly, organizations have a ever-greater accountability, which converges in the Corporate Responsibility (CR) theory, towards all those directly or indirectly involved in their activities, and not only towards their shareholders. At the same time, the same article (De Brito et al.)[44], as well as Turker et al.[27], claim the lack of a sector-wide criteria that would help all companies involved in the fashion industry align to common standards, make their performances objectively measurable and propose solutions for improvement. The absence of shared indicators and standards is further fuelled by the multiplication of independent agencies, all with a variety of criteria adopted to classify fashion companies based on their implementation of sustainable practices.

Two other factors that emphasise the need for a radical change in the industry are overconsumption and population growth. However, between these two factors, the one that seems mostly affecting the fashion industry seems to be the first one. From Figure 14, it can be seen that even if from 1970 to 2000 textile production was growing, it was following the population growth trend. But starting from the first years of the new millennia, the world has seen an acceleration in the amount of fibres produced, which is strongly visible from the change in the slope of the line representing the total

textile production, significantly influenced by an unprecedent growth in the utilisation of Polyester, a PET-made material that has become the most used fibre in the fashion industry[21]. The change in consumers' trends, mainly driven by the expanding middle class, seems to be affecting global fibre production more than population growth.

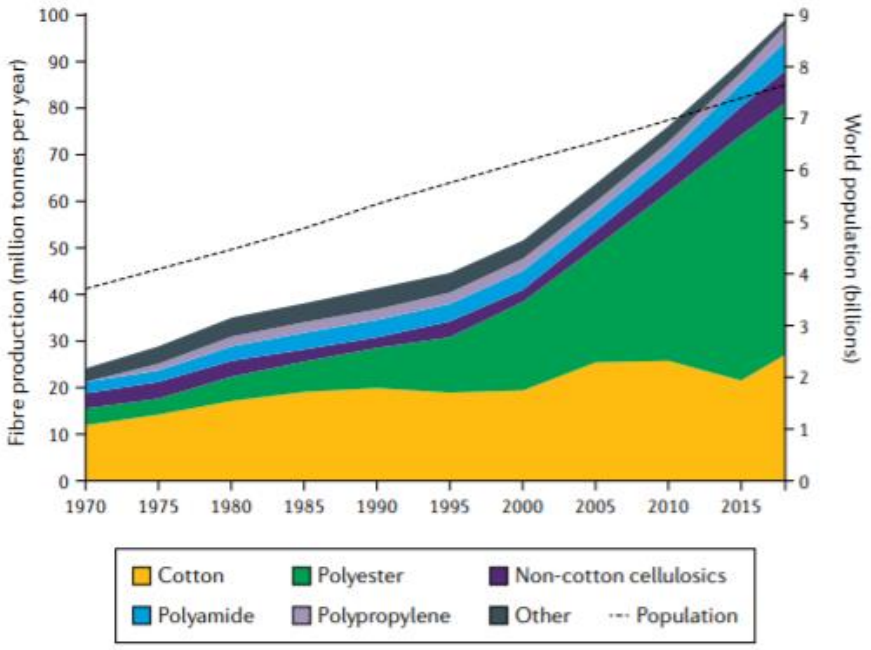



Fig. 1 | **Growth in global population and textile production by fibre type.** Fibre types include cotton, polyester, non-cotton cellulosics, polyamide and polypropylene, with silk and wool represented together as 'other'. Growth in world population is also depicted. By the 2010s, textile-production growth overtook world-population growth, largely driven by the rise of cheap manufacturing and fast fashion.

*Figure 14 - Population and Textile Production Growth[21]*

The unsustainability of the current linear model, based on the "take-make-waste" flow of materials, is further motivated by the price increase that has been seen between 2000 and 2013, where each 1% growth in GDP was followed by an average increase in prices of 1.9% (Lacy & Rutqvist, 2015). Companies are consuming increasingly faster non-renewable resources, putting in serious danger the future availability of these materials for upcoming generations, along with renewables that have been increasingly stressed, causing environmental problems. Rising demand, in addition to the diminishing reserve of limited resources, is what is causing volatility in commodities' prices. Cotton prices has seen an increase of almost 90% between 2000 and 2011, forcing customers to raise their prices by up to 30% and make retailers face the decision of whether increase final products price or reduce their margins, like H&M decided to do paying with a 30% drop in first-quarter net profits in order to defend the company's "cheap chic" identity [4849]. Cotton price, like other renewable resources, is sensible not only to its availability, but also to nutrients, like nitrogen and phosphorous, and other products prices,

like fertilizers, that have seen also a 110% increase from 2000 to 2014 (Lacy & Rutqvist, 2015). Lastly, the crossing of the planetary boundaries defined by Rockström et al., could mean irreversible environmental changes, and the world has already crossed three out of nine: extinction rate, atmospheric carbon dioxide concentration and atmospheric nitrogen fixation[50].

A survey by McKinsey shows that respondents see Sustainability both as the biggest challenge, and the biggest opportunity for the Fashion Industry in 2020, and the Covid-19 pandemic could accelerate the transition to greener practices[51]. Many brands are starting to take action and change their operations into more sustainable ones: Zara has announced the intention to use 100% sustainable fabrics by 2025, LVMH declared, among others commitments, to increase the percentage of leather sourced in the certified tanneries of the Leather Working Group (LWG) with a target of at least 70% supplied by this controlled group (the actual share of leather supplied by LWG is 48%)[52]. But will the pace at which the company is changing be enough in order to reinvert the environmental impact trend of the Fashion Industry? Questions arise from the analysis of the current business model that fashion industry shares with other sectors: since technology has not been able to follow the growth both in world population and consumption, could a different model, specifically a circular one, be the solution, and change the industry into a sustainable one? What are the main changes it will provoke in firms' operational and strategic plans? What are the technologies that will foster and support the new business model and will help managers to make the whole supply chain run effectively and efficiently?

These questions will be answered in the following chapters, after a short introduction to Supply Chain Management, Sustainability, and Circular Economy.

# Theoretical Framework

## Supply Chain Management

When the term Supply Chain Management was coined in 1982 by Keith Oliver in an interview for the Financial Times, companies where facing a significant change in the business environment with the introduction of personal computers, that led to an improvement in scheduling efficiency, while also facilitating the exchange and sharing of information, making them faster and easier. Computers allowed to support companies in the increasingly complicated world with shorter product lifecycles and greater product variety. The term Supply Chain Management finally refers to a broader vision of business management, where companies are no longer autonomous entities, but they compete in an environment where competitive advantage can only be achieved being a competitive value-creating Supply Chain. The growing fragmentation of supply chains and the larger distances that separate the different steps of supply chains, fostered by globalization and the outsourcing-trend, did not only give birth to the WTO at the end of the twentieth century (1995), but where the consequence of a deep change in firms' attitude towards suppliers[53]. We recall the definition of Supply Chain already given in the Introduction chapter, when talking about The Fashion Industry Supply Chain:

*"A supply chain is a network of partners who collectively convert a basic commodity (upstream) into a finished product (downstream) that is valued by end-customers, and who manage returns at each stage."*

(Harrison & Van Hoek – 2008)[36]

In fact, instead of a Supply Chain we should be talking about it as a Supply Network, since the own suppliers of a firm will be leading with other players that will provide them with materials and/or services in order to accomplish their customer's order. Therefore, we can introduce the simplest, yet clearest definition of Supply Chain Management:

*Since a supply chain is a network of companies, then the management of that network is supply chain management.*

(Lambert & Cooper, 2001)[54]

This transforms the adversarial relationship companies used to have with the upstream and downstream organizations they worked with to a cooperative one: switching to a new competition environment, from company against company to supply chain against supply chain, requires a total-cost and goal approach, focusing on the activities that generates the value the customer is expecting and creating a responsive system in order to deal with the fast-changing markets[55]. The management

of the supply chain is therefore fundamental in the development of a competitive advantage. Another definition for Supply Chain Management is:

*"Planning and controlling all of the business processes – from end-customer to raw material suppliers – that link together partners in a supply chain in order to serve the needs of the end-customer."*

(Harrison & Van Hoek – 2008)[36]

The focus is always the final customer, whose needs give rise to a series of processes in order to meet them, which add value to the raw materials or services used in order to satisfy the customer. To plan and control all processes involved in the value creation activities is Supply Chain Managers' job. Planning, as all the other processes that concern the supply chain, is based on the customer needs, this means that the focal point is again its demand: based on customer demand, which is forecasted based on multiple factors (such as demand history, if available, or market trends), the Supply Chain Manager defines a plan that sets out what should be bought, made, distributed and sold in the next days, weeks, months or even years[36]. Controlling refers to the continuous activity of checking if the network is sticking to plans, and act consequently. Key Performance Indicators (KPI) can be very helpful to monitor the performance of the whole supply chain. One of the most used metrics by Supply Chain Managers are the following ones:

- *Out-of-stock:* it refers to the firm's ability to meet customer demand. For some businesses, it can be hard to accurately calculate it: for example, grocery stores may not be able to detect if a customer did not find the product he was looking for, because whether he did not reported it to any sale assistant or he found a similar product that could substitute the one he was intentioned to buy. Companies that do not meet customer needs may incur in lost sales, reduced customer loyalty and missed opportunities. Out-of-stock KPI, by line items, is calculated as:

$$OOS\ \% = \frac{\#\ of\ order\ lines\ not\ met\ because\ of\ OOS}{total\ \#\ of\ order\ lines} \times 100$$

- *Forecast accuracy:* being involved in the calculation of safety stock, forecast accuracy has an impact on how much firms have to invest in inventory, those reducing their profitability when forecast accuracy is low. Even if 100% forecast accuracy seems impossible, its improvement will also improve overall planning. Forecast Accuracy KPI is calculated as

$$FA\ \% = \left|\frac{R_t - F_t}{R_t}\right| \times 100$$

Where:

$R_t$ is the actual observed value of demand for the reference period $t$

$F_t$ is the forecasted value of demand for the reference period $t$

$t$ is the reference period

- *Fill Rate:* since customer needs are always the main focus of the supply chain management, an indication for a perfect order is needed. An order is considered perfectly fulfilled when it is shipped on time, complete, with no damage and with the correct documentation. Therefore Fill Rate KPI is calculated as:

$$FR\ \% = \frac{\#\ of\ perfect\ orders}{total\ \#\ of\ orders} \times 100$$

Hence, Supply Chain Managers' job can be represented by the never-ending PDCA Cycle, where:

- **Plan** refers to the planning process, therefore it includes what should be bought, produced distributed and sold based on the demand (Demand Planning). Here is where targets (KPIs and their expected values) are set
- **Do** concerns the execution of what has been planned in the previous phase, and the recording of performances
- **Check** has to do with the evaluation of the performances (KPIs)
- **Act** refers to the corrective actions managers implement in order to correct the situation and prevent further errors.

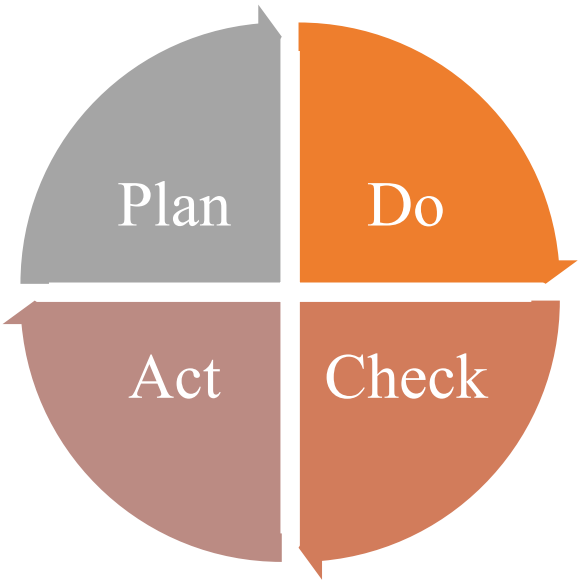



*Figure 15 - PDCA Cycle*

It is essential to always keep in mind customer needs as the focal point of the supply chain. Therefore, the focal firm must make sure that all the organizations that make up its network understand and take into account final customer's needs in their processes, as well as firm's competitive priority. Cousins (2005)[56] affirms that when all the members of a given network are aligned with a shared priority, the whole supply chain will perform better in the competitive marketplace. It is focal firm's Supply Chain Managers responsibility to coordinate the network of organizations and make sure they are all aligned to the same competitive strategy. Supply chain managers are like the director of an orchestra, or like Pirlo for the Italia's National Football Team: they coordinate and dictate the different instruments (or players) that compose the orchestra (or team); Supply Chain Managers' role is also to integrate supply chain partners' processes: it is not a vertical integration, where firms are supposed to own or control their upstream or downstream partners, integration looks much more like an improvement in coordination and relationships between the focal firm and its network. While the focal firm focus on its own core business, outsourcing everything else, complexity of the supply chain increases, therefore it is important not to lose control over it, and reduce lead times between every connecting point of the network and become demand-driven. However, in order to make relationships work, it is fundamental to switch from a linear and functional view to a process approach, where all the different organizations that take part to the supply network are involved in a variety of processes. Kopczak and Johnson (2003) offer a broader view (Figure 16) of the new supply chain approach, that is no more a sequential handoff of materials, information or finances from player to player, but it implies a general involvement of all the participants.

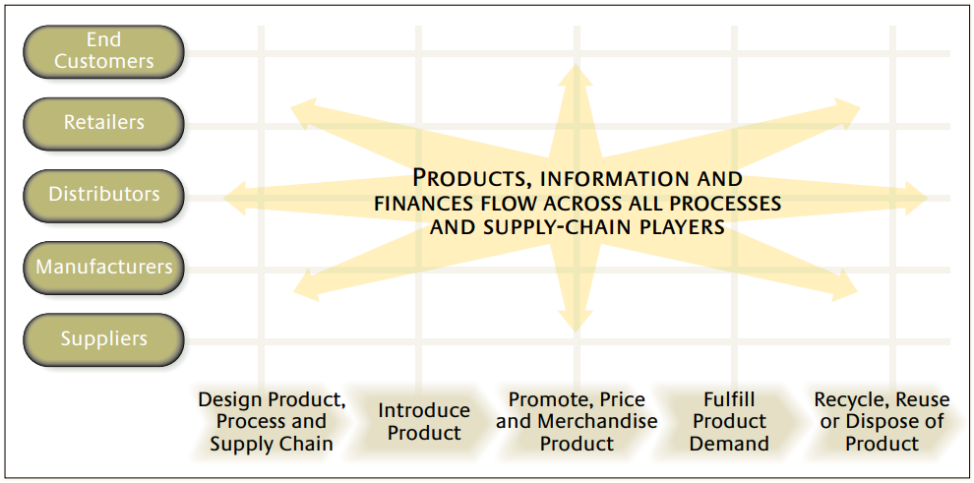



*Figure 16 - Process/Supply Chain Players Matrix*[53]

In order to do so, the first step is the intra-company integration. The Global Supply Chain Forum (GSCF) identified 8 cross-functional processes around which teams inside a company should be organized that are in broad terms described below. What can be seen from Figure 17 is that Supply Chain Management Processes include all the cross-functional processes:[57] [54]

- **Customer relationship management:** it refers to the identification of key customers or customer groups. The decision is not always based on the economic value of customers, since a critical customer can be one that the company considers as an investment, due to its growing potential or because of a particular innovation it is pursuing. The main goal is to increase key-customer loyalty by offering tailored products and/or services. Product and Service Agreements (PSAs) are developed in this process: they are negotiated with key-customers and distributed without negotiation to the other customers.
- **Supplier relationship management:** it can be seen as the upstream reflection of the Customer relationship management process. Partnerships are developed with a reduced number of suppliers through the negotiation of PSAs. For other suppliers, a standard format of PSA is defined and provided.
- **Customer service management:** it is the process that monitors if customer needs are satisfied and intervenes if a problem occurs.
- **Demand management:** Demand management is the supply chain management process that makes sure customer demand can be met by the supply chain capability. Data, especially from points-of-sale, is a key tool for this process and coordination is a fundamental aspect in order to reduce variability between the different activities and increase flexibility among the different actors.

- **Order fulfilment:** it refers to all the activities that need to be implemented in order to coordinate a network that will be able to deliver the quality and quantity asked by the customer, while maximising firm's profitability.
- **Manufacturing flow management:** Manufacturing flow management process is the set of actions required to obtain, implement and manage manufacturing flexibility in the supply chain and to move products into, through and out of the plants.
- **Product development and commercialization:** the team of this process is in charge of the participation of both suppliers and customers in the product development. Hence, the team must coordinate with customer relationship management team to identify customer needs, with supplier relationship management team to identify suppliers capacity and with the manufacturing flow management team to develop the adequate production technologies needed to achieve the manufacturing flexibility that meets the requirements of both customer and suppliers.
- **Returns Management:** besides the environmental issues related with reverse logistics, it also refers with the identification of opportunities in order to avoid unwanted returns.

However, to efficiently operate a supply chain, it is not enough to align the different functions of a company to a shared set of processes, it is necessary to agree with the firms involved in the upstream and downstream network, especially with the key customers and suppliers. But a problem that is very often faced by firms is the lack of inter-consistency between firms' processes: each firm has its own processes, that differ in number and names, even if they are similar, or have the same or similar names even if they are completely different. While functional divisions are generally understood, processes that should be implemented in every company, without any distinction of the sector it is operating in, are not usually shared. Hence, having a standardized set of business processes, like the ones proposed by the GSCF, makes inter-company integration more efficient and effective. Accordingly, the 8 Supply Chain Management Processes described above do not only act as intra-company integrators between functional silos, but they also work as inter-company integrators. This is the reason why they are represented in Figure 17 crossing all the supply chain. However the number of business process that have to be integrated and managed between companies varies depending on the situation, and it is executives' job to decide which are the processes that is convenient to integrate and which are the key upstream and downstream partners to integrate with.

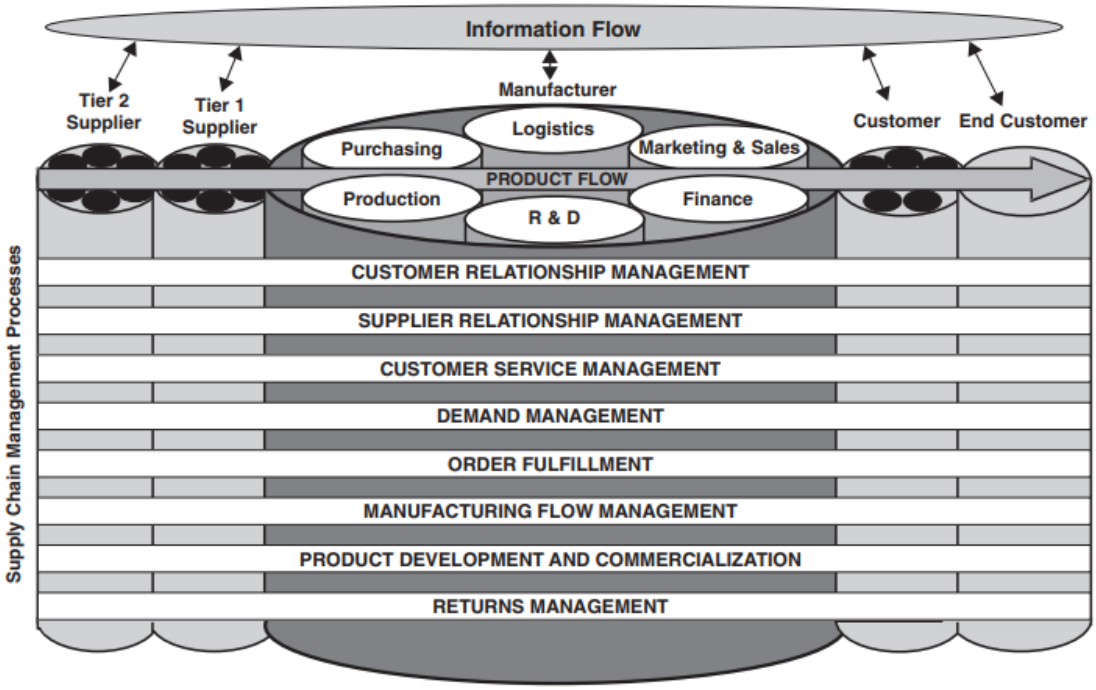



*Figure 17 - Business Processes Across The Supply Chain*[54]

Achieving strategic partnerships with suppliers and/or customers is of paramount importance, but the level of integration should vary depending on the potential partner's process criticality with respect to the customer requirements. Moreover, focal companies can closely manage and integrate relationships between two or more players of the network. A research by Lambert & Cooper (2000) identifies four different types of business process links between members of a supply chain, which are divided as follows. An example is further illustrated in Figure 18:

- **Managed process links:** these are the most important link for the focal company. Consequently, the focal company will closely coordinate and integrate the members of the network that have a critical impact on its value creation. Normally, first tier customers and suppliers relationships are managed process links.
- **Monitored process links:** despite not being as important as the previous described relationship, monitored process links still play an important role in focal firm's competitiveness, thus it has to monitor the relationship between the two players of the supply chain. Monitors or audits can be used.
- **Not-managed process links:** these are links that the company does not consider as critical, so it leaves the members to manage their relationship as they please.
- **Non-member process links:** they refer to links between members of the focal firm's supply chain and non-members of their supply chain.

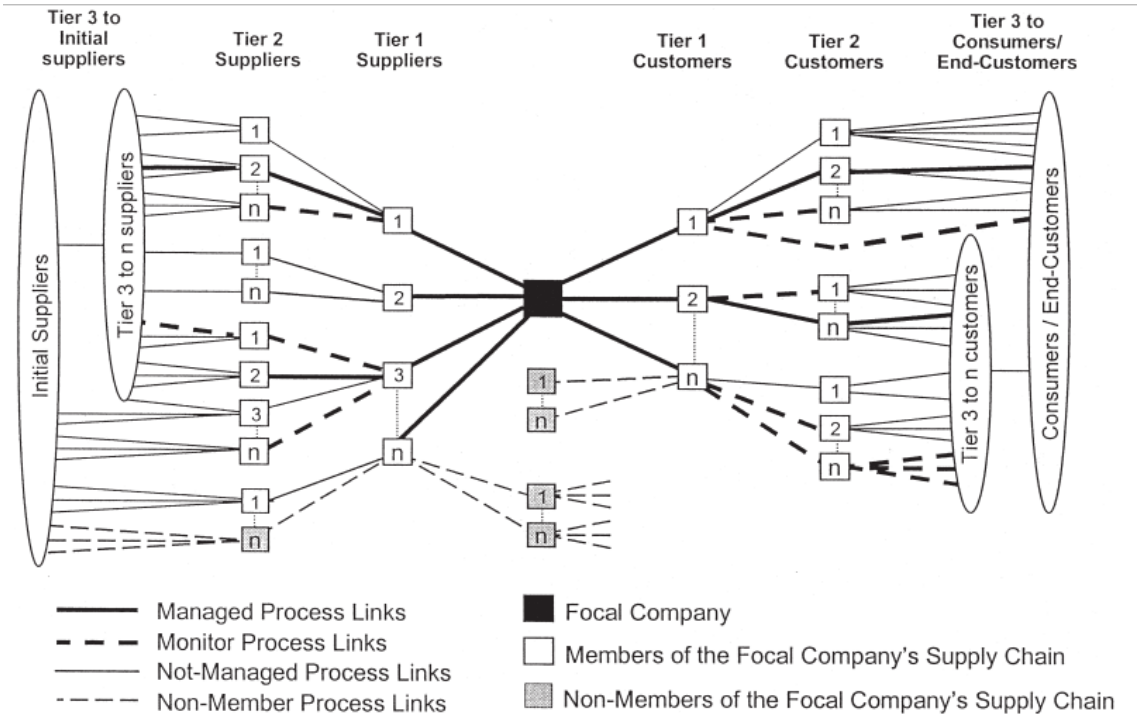



*Figure 18 - Types of Intercompany Business Process Links*[58]

Based on a publication of Michael Hammer (1990)[59], the functional silos are part of a set of old rules over which work design is based, but the focus of organizations has switched from cost, growth and control to quality, innovation and service. Business processes and structures are "outmoded and obsolete", since they are based on a division of work that has its roots back in the Industrial Revolution, when work was organized in simple and short tasks, separated between them, that only led to an increased difficulty of coordination , traceability and waiting times between tasks, and the implementation of functional departments did not solve the problems. Therefore, the solution proposed by Hammer is a radical redesign of business processes, and one of the fundamental aspects is the cross-functional perspective that processes need to have in order to achieve "dramatic improvements in their performance". In Figure 19, we see examples of how managers belonging to the most common business divisions contribute to the supply chain management processes and need to cooperate with other divisions to manage the different processes. It is essential to promote process sponsorship and ownership, in order to accomplish the supply chain vision and get rid of the functional division mentality[54]. Moreover, as shown in the illustration, involvement of both customers and suppliers is also needed in order to achieve the best results.

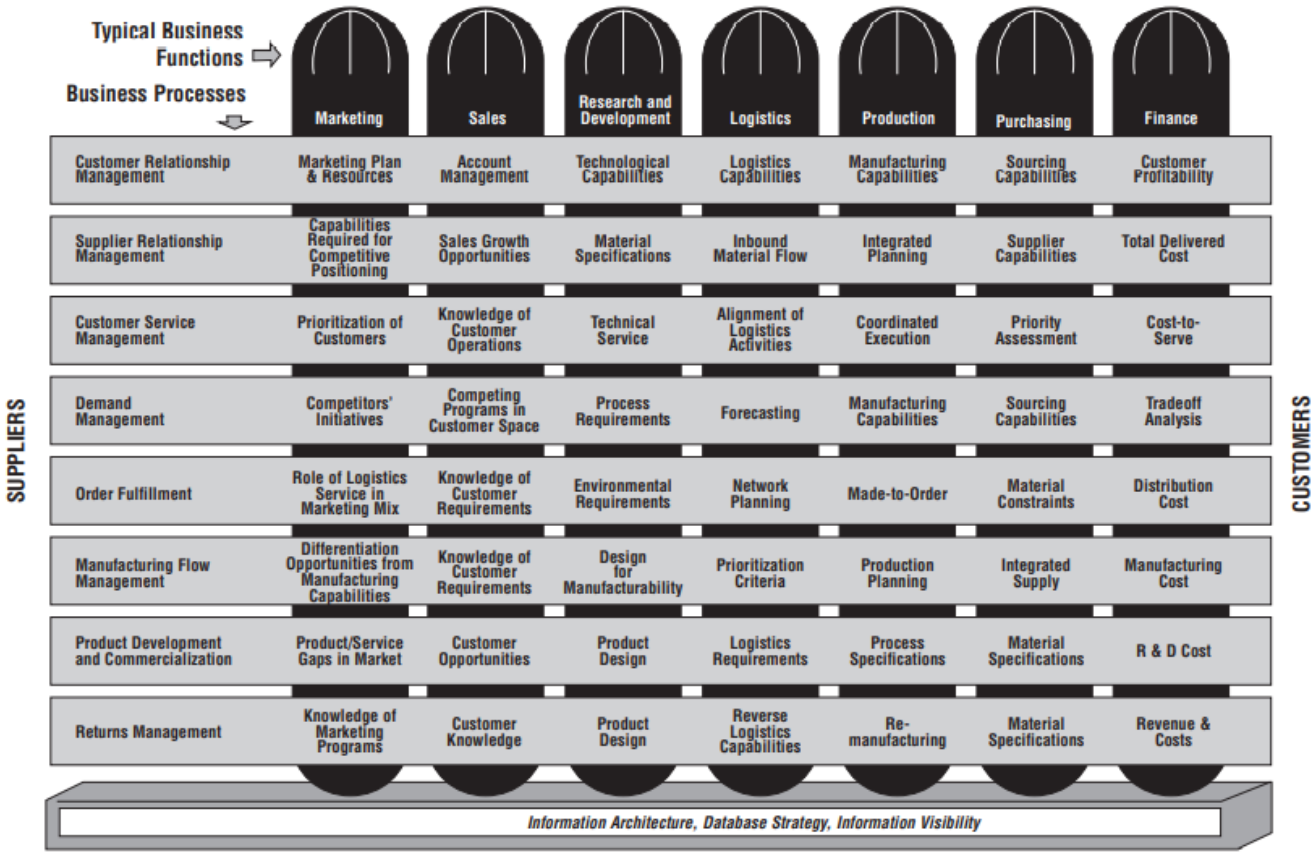



*Figure 19 - Functional Involvement in the Supply Chain Management Processes*[60]

After having analysed Supply Chain Management, it can be stated that Supply Chain Management can not be secluded in a single functional division, neither in a single process. Supply Chain Management involves three key aspects:

- the identification of all the members of the network, especially the critical ones;
- the selection of the critical processes that need to be integrated with the key members of the supply chain;
- the decision on the level of integration for each link of the network.

The management of these three key aspects is what makes up SCM. Therefore, Supply Chain Management, especially today, can be defined as the Relationship Management.

*"SCM deals with total business process excellence and represents a new way of managing the business and relationships with other members of the supply chain"*

(Lambert & Cooper, 2001)[54]

## Sustainability

The rise of awareness about social and environmental problems due, inter alia, to the growing population, climate change and scandals related to workers' conditions, have brought attention to Sustainability issues among the public opinion. It is important to report one of the most cited definitions of Sustainable Development, coined by the World Commission of Environment and Development (WCED) in 1987:

*"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."*

(WCED, 1987)[61]

At the time the WCED expressed its definition of Sustainable Development, the economic performance was the only measure of Sustainability in a business environment. Nowadays, Sustainability is often referred to only environmental improvements. The 'Our Common Future' report, from where the previous citation has been extracted, underlines the importance of a holistic perspective, where three key dimensions, economic prosperity, environmental quality and social equity, must coexist and be equally considered by companies when operating, no matter where. These three key areas have been further evidenced by Elkington (1997), who coined the term "Three Bottom Line", which refers to People (Society), Planet (Environment), and Profit (Economy), strengthening the need of a multidimensional approach to Sustainability[62]. In September 2015, the Heads of State and Government and High Representatives, meeting at the United Nations Headquarters in New York, set out the 2030 Agenda, where they identified 17 Sustainable Development Goals (SDGs) and 169 targets that will be implemented by 2030.

*"We are setting out together on the path towards sustainable development, devoting ourselves collectively to the pursuit of global development and of "win-win" cooperation which can bring huge gains to all countries and all parts of the world."*

(UN, 2015)[63]

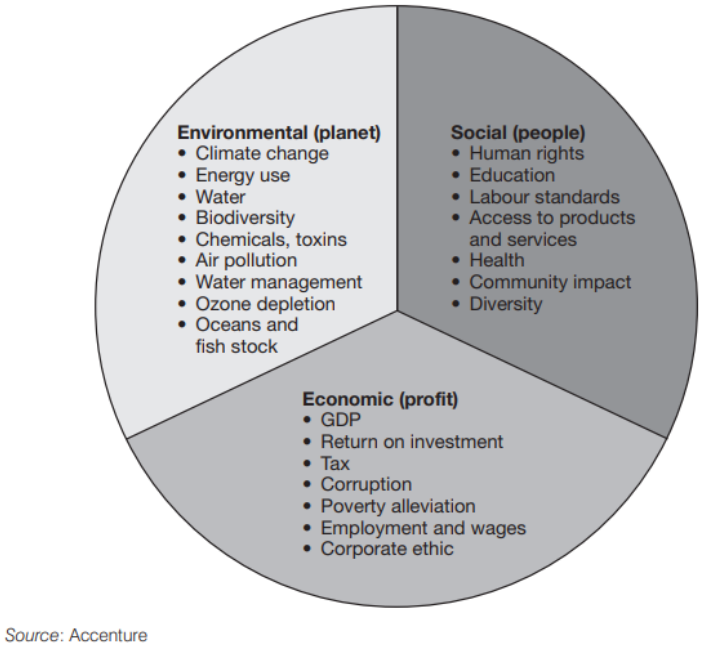



*Figure 20 - The Triple Bottom Line: Planet, People, Profit*[55]

Again, the three dimensions - economic, social and environmental – are part of the Program. In addition, the United Nations (UN) complemented the 3Ps (People, Planet, Profit) with two new critical dimensions: Peace and Partnership. Therefore, the pursuit of a Sustainable Development includes much more than being profitable or protecting the planet from degradation, as the 17 SDGs demonstrate. It is of fundamental importance to take into account different levels of national development and capacities, realizing the interdependence not just of the different objectives, but also the interdependence between different countries. In order to avoid ecological or other crisis, it is important to guarantee the basic needs even to people living in developing countries, and to eliminate the negative impacts that some countries have on the possibility of development of other countries: the 'Our Common Future' report drew attention to the priority that has to be given to the developing countries' growth, since "poverty reduces people's capacity to use resources in a sustainable manner" and least developed countries are the places where "the links between economic growth, the alleviation of poverty, and environmental conditions operate most directly[61]."


*Figure 21 - Sustainable Development Goals*[64]

Due to the growing interest towards the environment, the impact of company's operations is increasingly taken into account: "organizations are constantly under pressure to develop environmentally responsible and friendly operations" (Lin and Ho, 2008)[65]. A study by Sarkis & Lai (2007) observed that Green procurement in developing nations such as China has become a key approach for enterprises seeking to become environmentally sustainable and increase performance in instances where there is increased competition[66]. However, according to Makmor and Saad (2017), some companies, especially SME, are under the assumption that adopting green logistics will increase their operational costs, without considering the benefit that can be gained from its implementation. In the same article by Makmor and Saad (2017), it is said that by practicing green logistics, firms can distinguish themselves from competitors, target new groups of customers and open up the opportunity to tap into new markets[67]. As up-to-date studies demonstrate, with the increasing application of green supply chain solutions, an increase in performance is expected (Chrisostom and Monari, 2018)[68]. A study by Oclu & Erdal (2016), gives a detailed list of costs that are reduced when green options are applied and improve the financial performance: the cost of raw materials, energy consumption costs, waste treatment costs, waste disposal costs and penalty costs[69]. Seeing that Green Logistics is connected with producing and distributing goods in a sustainable way, taking into account environmental and social factors (Sbihi and Eglese, 2010), even the improvement during the design phase can be an addressable stage in order to reduce the environmental impact of products, by using lightweight. materials, improving fuel efficiency, inventing new energy sources (Chrisostom and Monari, 2018)[70] [68].

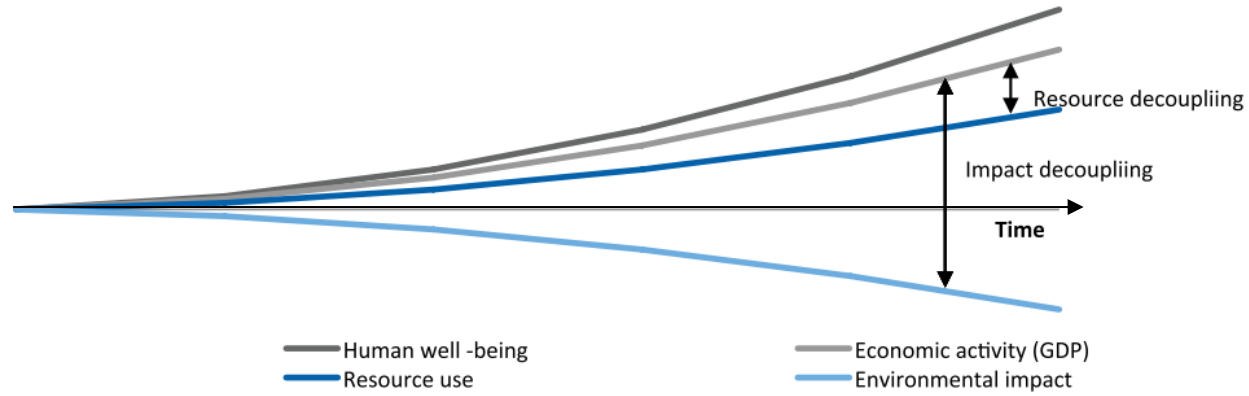
As businesses get more and more involved in Sustainability issues, Supply Chain Managers must adapt to new requirements: the job of a Supply Chain Manager must now include ecological and social aspects, as well as the economic one, since companies, especially focal firms, are considered accountable not only for what happens inside their organization, but customers are increasingly aware of what happens before and after the company has completed its tasks: beverage companies are blamed for selling products in plastic bottles[71]; fashion retailers are attacked for the lack of decent labour conditions at their suppliers' sites[72]. This is why, in recent years, Sustainable Supply Chain Management (SSCM) has earned fame among academic researchers. SSCM is defined as "a firm's plans and activities that integrate environmental and social issues into supply chain management in order to improve the company's environmental and social performance and that of its suppliers and customers without compromising its economic performance[73]". Hence, just like for countries that must support developing countries and establish partnerships between them in order to handle economic, social and environmental problems, companies cannot face Sustainability only looking within their own walls. It is fundamental to include customers and suppliers in the development of sustainable initiatives. As well as for nations, social responsibility aspects should be approached considering their potential interrelation, and not as standalone problems[74]. Moreover, apart from contemplating the whole Supply Chain, the entire lifecycle of a product or service must be taken into account in order to consider their total impact [73].

## Circular Economy

*"A number of trends are coming together: the rapid growth of people on the planet and, with it, a need for more energy and more efficient food production. History will judge us not just by what we produce but also by what we preserve. It is time to rethink tomorrow."*

(Steen Riisgaard, 2012)[48]

Circular Economy (CE) concept has gained fame in the last years due to the non-stop global resource use that is making people question if the linear model most businesses are based on can be sustainable. The facts show that a 342% world population growth from 1900 to 2014 (from 1.65 billion to 7.3 billion) has been followed by an increase of 1026% in global resource usage[75] [76] [77]. Circular Economy aim is to break the dependence between economic (and population) growth and environmental degradation. This process is called "decoupling", and it can be divided in resource decoupling, when referring to resources extracted, and impact decoupling, when referring to the negative environmental impacts[48].




Source: UNEP, 2011

*Figure 22 - Decoupling GDP growth from Environmental Impact*[48]

Decoupling can also be divided in other two types: relative and absolute. The first one is about "doing more with less", therefore it can be measured by the efficiency of a process: if a company becomes able to produce the same product with less resource inputs, it has achieved a more efficient production process. And since resources also represent a cost for organizations, the reduction in resource use can be translated in economic savings and could also represent a potential profit[78]. Instead, absolute decoupling happens when global resource use declines, no matter the growth of the economic output (i.e. GDP or Turnover): if a company achieves a turnover growth compared to the previous year, while reducing the absolute resource use, and/or its environmental impact, it has achieved an absolute decoupling[79].

$$if: T_i > T_{i-1} \cap \frac{T_i}{T_{i-1}} > \frac{U_i}{U_{i-1}} \rightarrow relative\ decoupling$$

$$if: \forall\, T_i > T_{i-1};\ U_{i-1} - U_i > 0 \rightarrow absolute\ decoupling$$

Where:

$i$ represents a period (for example, a year)

$T_i$ stands for Turnover of a certain period $i$

$U_i$ stands for resource use or negative environmental impact of a certain period $i$

It is important to notice that absolute decoupling includes relative decoupling. Moreover, absolute decoupling is only achieved when the rate of relative decoupling is greater than the combination of the rate of increase in population and the rate of increase in income[78]:

$$-\frac{dU}{dt} > \frac{dP}{dt} + \frac{dI}{dt}$$

Where:

$t$ represents time

$P$ refers to Population

$I$ refers to Income

$U$ stands for resource use or negative environmental impact

Therefore, it is clear that the most important between the two types of decoupling is the absolute decoupling, since it is the only one that guarantees an overall decline in resource extraction and an actual improvement for the environment. In Figure 20, for example, a relative resource decoupling is represented, but only for the environmental impact an absolute decoupling is achieved.

However, despite the huge improvements in technology, an absolute decoupling has not been achieved. In Figure 21, a relative decoupling is depicted, since the world GDP has grown faster than the consumption of the resources illustrated. Similar, or even worse scenarios, can be observed in graphs representing other used resources. But since a real progress can only be achieved through an absolute decoupling, no actual improvement has been achieved. As long as an increase in sales brings along with it an increase in waste, pollution and inequality, an augmented turnover will never mean an improvement.

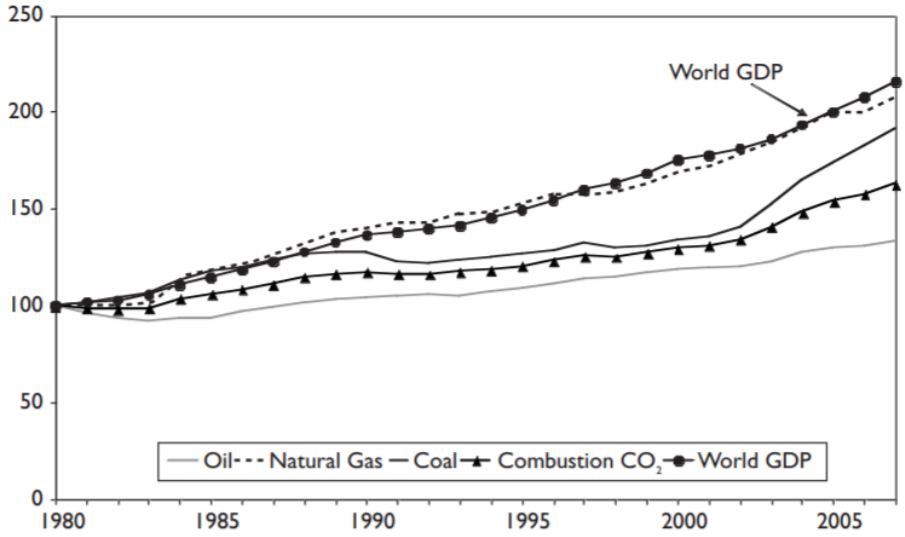



*Figure 23 - Trends in fossil fuel consumption and related CO2: 1980–2007*[78]

The circular economy tries to achieve an absolute decoupling from increasingly constrained energy and material resources through the implementation of actions that aim at increasing the efficiency of resource use, minimizing their extraction, relying on the 3R principles: Reduce, Reuse and Recycle[80].

- **Reduce:** It refers to the minimization of the extraction of new resources, as well as the reduction or elimination of waste from the production and usage phases. The reduction principle can be achieved through the implementation of new eco-efficient production processes and a change in consumption behaviours.

- **Reuse:** The European Union defines the Reuse Principle as "any operation by which products or components that are not waste are used again for the same purpose for which they were conceived"[81]. Since reusing a product normally requires less resources rather than the ones needed in order to producing a new one from virgin materials, it is a behavioural pattern that would lead to a significant reduction of the environmental impact that a product entails along its life-cycle[82].

- **Recycle:** It refers to "any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations"[81]. Despite being the activity that is most frequently used when defining CE, many authors agree in considering recycling as the least sustainable solution compared to the other principles (Reduce and Reuse): "most recycling is actually downcycling, it reduces the quality of a material over

time", until a point where further recycling becomes environmentally or economically to significant[83] [84] [85].

Since waste is a key aspect of the Circular Economy, it is important here to cite the different interpretations of waste given by Lacy & Rutqvist (2015) in their book "Waste to Wealth" where "waste" is divided in 4 distinct forms:

- **Wasted resources:** they refer to those materials that once they are used, they are gone forever.

- **Wasted lifecycles:** products that are built to last a short period of time or consumers get rid of them even if they could still be used by other people.

- **Wasted capabilities:** products that are unoccupied by their owner but could be used by others.

- **Wasted embedded values:** the value that is embedded in a product because of processes it has gone through that required materials, components, and energy. Those elements (materials, components and energy) are not recovered from disposed products but rather they end up building waste in landfills or being incinerated[77].

However, the observation of successful cases of CE adoption demonstrate that in order for the transition from a linear to a circular economy to be effective, all actors of the system must be involved and build closer relationships between them: companies, consumers, and institutions. There is a significant shift from the linear model to the circular model which includes the need for a shift from an adversary relationship between the different actors to a more collaborative and healthier one. Companies are required to implement more resource-efficient processes and design products and processes in order to make the return process easier and economically viable, but consumers' behaviour play a key role in strengthening the closed loop and reducing their consumption, as well institutions can change the legislative framework in order to facilitate the adoption of more effective circular patterns[86] [87]. Even if a unique definition of Circular Economy does not exist, in this text the definition adopted for CE comes from a study of Kirchherr et al. (2017), whom after an analysis of 114 definitions came out with their own:

*"A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and*

*beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations."*

(Kirchherr et al., 2017)[83]

Circular Economy is a $4.5 trillion opportunity that requires a "radical rethink of the relationship between markets, customers and natural resources" which implies a redesign of the Supply Chain [77].

# A New Supply Chain

## Technological Enablers

Michael Hammer & James Champy, in their book "Reengineering the corporation: A manifesto for business revolution"[88], define Reengineering as "the fundamental rethinking and radical redesign of business processes to bring about dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed". A Reengineering is what is needed to change the Fashion Industry Supply Chain. Even if new technologies will not solve it all, since people and processes are still the most important elements that make up an organization, technologies can still support this big change, not as a tool to automate, but as an innovative way to do new things[36]. Organizations must reimagine their business considering the new opportunities innovations offer. The following subchapters illustrate the main innovations that will facilitate a new, circular, supply chain for the Fashion Industry, disrupting what has been done until now.

### RFID

RFID stands for "radio-frequency identification", and it is a diffused wireless technology that allows the transmission of data between a reader and a tag using radio waves to transmit information from RFID tags to an RFID reader[89]. Hence, "any RFID system is composed of three main elements: the tag that embeds specific information of the item on which it is attached, the reader that empowers the tag and reads the information stored within it and a data base that processes the information and performs the global RFID application"[90]. As opposed to barcodes, RFID tags do not need to be in a certain position in order to be detected and scanned, moreover, RFID technology enables scanning a large quantity of tags at the same time and the tags' memory can be accessed and written.

Even if Fashion Industry is slower than other industries in implementing new technologies, RFID is already in use in some of the biggest groups of the sector: Inditex uses RFID in order to individually track every garment sold by Zara and have total control over them all along the supply chain. At store level, RFID enables store staff to know exactly the position of the products, to know which product to reorder, make inventory tracking easier, improve sales' data-collecting and theft mitigation[91]. Salvatore Ferragamo and Moncler are using the same technology in order to tackle the counterfeiting phenomenon[92]. The apparel industry uses the three types of RFID tags existing, depending on the specific usage: passive, semi-passive and active tags. The first ones are activated by the reader and do not have battery, they draw power from the reader; the semi-passive do have a battery that is activated by the RFID scanners; the active tags are powered by a battery and are normally used when there is the need to track the location of the object. The read distance is another key element that

distinguish the three types of tags: while passive tags can be detected from 6 meters, active ones are read even from more than 30 meters[89].

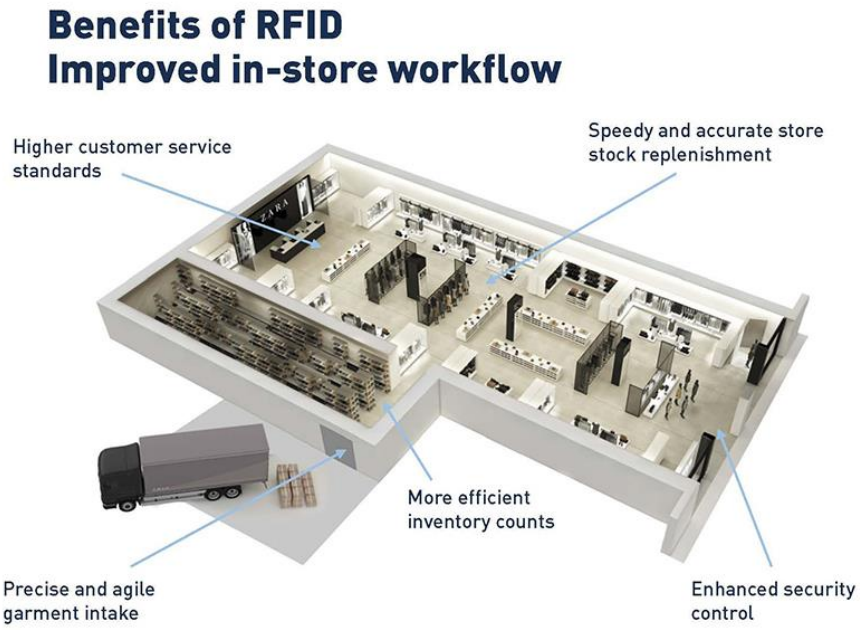



*Figure 24 - RFID Benefits at Store Level (Zara example)[91]*

### Blockchain

Blockchain derives its name from its structure, being a chain of blocks in a distributed ledger. Each block represents a set of transaction that has been validated by the network. Each block points to a previous block, since each block is composed by its own "hash" and the previous block's hash, and thus creates "a link in a chain of such relations"[93]. A block is only added to the chain if the participants to the blockchain (called "nodes", all the computers where the blockchain is registered) authenticate the transaction. If the transaction is validated, a new block is added to the chain.

The explanation above is a general and a simplified explanation of a much more complex process. There are some key aspects that must be clearly explained in order to fully understand the most important innovations that Blockchain brings along with it and the differences that there can be between different types of Blockchains:

- **Block:** A block in the Blockchain represents a set of transactions. Each block of the chain is unique, and it is defined by many aspects, such as the Block number and the Timestamp (time at which the block has been validated). Moreover, each block is also identified by the previous block's hash, the block's transactions details, the nonce and the hash of the block ("hash address"), that is produced applying the hashing function applied to the previous three

values[40]. Every Blockchain has its own pace of Block's verification. For Bitcoin, it is 10 minutes. So every 10 minutes a block is added to the chain in the case of Bitcoin.

- **Network Nodes:** The Nodes represent the machines/computers (namely, the users) that are part of the Network. Every Node normally has a registered and always actualized copy of the Blockchain, that is to say the list of all the transactions that happen across the Network and compose the Blockchain. In general, the more the agents involved in the Network, the more backups are made, enhancing the reliability of the system.

- **Miners:** Network's participants that, in a Proof-of-Work Consensus Algorithm, are dedicated to the confirmation of the transactions. Anyone can become a miner.

- **Validators:** A subset of the Network Nodes that are dedicated to the validation of the transactions in a Proof-of-Stake Consensus Algorithm. They are the "virtual notaries" of the Blockchain.

**Hash:** Hash is a certain type of cryptography[94]. A hash is a function that converts an input (it could be letters and/or numbers) into a variable of a fixed length. The fact that the encrypted output is of a fixed lengths makes the system more secure since the length of the input will be unknown. Hash functions are non-reversable, so it is not possible to re-obtain the input message once it has been hashed, unless random-guesses are executed. Moreover, Hash functions are deterministic, the hash of a particular input will always be the same. For example, when we have a die, instead of having the result showed with a number, we have its hashed value:


*Figure 25 - Die Face in SHA-256*

In order to know what is the number corresponding to the output showed, we have to guess hashing the values that correspond to the numbers usually showed in a die (in this case, we consider a die of 6 faces), hence:

| INPUT | OUTPUT (hash) |
|---|---|
| 1 | 6b86b273ff34fce19d6b804eff5a3f5747 ada4eaa22f1d49c01e52ddb7875b4b |
| 2 | d4735e3a265e16eee03f59718b9b5d030 19c07d8b6c51f90da3a666eec13ab35 |
| 3 | 4e07408562bedb8b60ce05c1decfe3ad1 6b72230967de01f640b7e4729b49fce |
| 4 | 4b227777d4dd1fc61c6f884f48641d02b 4d121d3fd328cb08b5531fcacdabf8a |
| **5** | **ef2d127de37b942baad06145e54b0c61 9a1f22327b2ebbcfbec78f5564afe39d** |
| 6 | e7f6c011776e8db7cd330b54174fd76f7 d0216b612387a5ffcfb81e6f0919683 |

*Table 1 - SHA-256 Hashed Values for a Die*

It can be stated that the number showed by the die is 5, and it was found just trying to guess from a limited set of numbers (6), comparing their hashed value with the one given by the die. Here we have an example of Hash, using the algorithm SHA-256, the one used in Bitcoin:

| INPUT | OUTPUT (hash) |
|---|---|
| I want to send 1000€ to Diego | 95a0173f4af76bbe77849d0a3ec106f7246ac45dc 308ff97c6029fb01f100f7d |
| I want to send 1000€ to diego | 03a15a84f1189849fd7088a74f28a68c0c3c117d4 4caad59f4b6a593c73c019f |
| Hi | 8f434346648f6b96df89dda901c5176b10a6d839 61dd3c1ac88b59b2dc327aa4 |

*Table 2 - SHA-256 Examples*

Table 2 shows how a small change in a phrase, even just changing the letter “D” from a uppercase to a lowercase, completely changes the output. This is functional to the Blockchain since a tiny change in the content of a block (from an attacker, for example) can be

immediately noted, especially since every block is connected to previous blocks through the previous block's hash and the ledger is distributed to all the network, and therefore the change would not be referenced by another block, which means it would not be accepted by the rest of the network and a fork would be created. In Blockchain, the longest chain is the one that leads, so in order to get its chain validated by the network, the attacker should grow the chain faster than the rest of the network, which is likely unfeasible[94].

- **Public Key and Private Key:** Each user has their own private key, that remains personal (like the pin of a credit card), and a public key, that derives from the private one. The public key is then further encrypted (using SHA-256), and the address that is obtained is the one used by others to send their money/assets.

- **Ledger:** Once the block is added, the ledger, replicated for all the members of the network, is simultaneously updated[95].

- **Cryptography:** Cryptography is mathematical and computer science algorithms used to mask messages. It is used in bitcoin addresses, hash functions, and the blockchain.

- **Consensus Mechanism:** A Consensus Mechanism is a way to validate the safety of the transaction without the need of a central authority. The Consensus is governed by algorithms that check if the transaction responds to specific criteria, but algorithms also play an important role avoiding the information to be hacked. Different algorithms can be used, depending on the type of Blockchain (public, private, …). The following ones are the most used:

    - **Proof of Work:** It is the consensus algorithm used in many Blockchains, for example in Bitcoin. Miners in a Network will compete against each other in solving complex computational puzzles: normally, they have to guess a pseudo-random number, called "nonce" (the solution of a specific block, or "blockhash"), which when combined with the data in the block, and passed through the Hash function, must match given conditions. When the miners think they have found the solution, they can share it with the other nodes of the network, which will verify and eventually confirm the validity of the outcome. Since the verification of the validity of the solution is easy, every node can do it, hence guaranteeing the transparency of the Blockchain, but the solution of the algorithm is expensive in terms of time and/or computing power. This is why the

first miner who finds the "nonce" is awarded with a certain amount of cryptocurrencies. PoW aim is to make miners compete with each other, thus avoiding the risk of monopolization, awarding the miner that comes up with the correct solution faster than all the others. A monopoly would make the Blockchain controlled by a single node, threatening one of the key aspects of Blockchain, which is decentralization.

- **Proof of Stake:** Here Miners are better called Validators. The node that will validate the next block is selected randomly, but probabilities are weighted based on the share of money the different nodes have in the Network and based on the time they have been present in the Network. This Consensus Algorithm is much more energy efficient compared to PoW, but it is mostly used in Private Blockchains, where nodes know each other and can trust a faster solution[96] [97].

- **Blockchain Types**

  The most common Blockchain types are Public and Private, but hybrid solutions can be found (called Consortium):

  - **Public:** Anyone can join and participate in the Blockchain, and the blockchain is truly decentralized, since no particular node controls the whole network, and the data is public.

  - **Private:** These blockchains usually put restrictions both to the participants that can join the Network, as well as their role[40].

- **Smart contract:** Smart Contracts are software programs where the participants set different business rules. When those agreed conditions are met, the contracts are executed automatically, and a set of transactions take place. Smart Contracts play an important role in Enterprises' Blockchain. A supplier and a client can agree on some specific conditions, for example: "when order #345 arrives at the store, pay the supplier 1000€". The conditions actually translates into a software program (i.e. coded conditions). When the client approves the delivery, or more generally that the conditions are met, it triggers the execution of the software code. Since the Smart Contract is shared between all the nodes of the Network, when the majority of the validators (i.e. nodes) agrees on the result given by the execution of the

software code (if the consensus mechanism follows the majority protocol) the output that the majority comes up to is what gets written in the Blockchain and becomes immutable. Smart Contracts can be implemented and executed with the integration of IoT (Internet of Things), connecting objects to the Internet, which send signals and trigger the execution of the Smart Contracts, reducing the intervention of humans which could lead to errors and increased lead times[98].

- **3 key characteristics:**

    - **Decentralization:** differently to most of the solutions the world used to rely on, Blockchain is a decentralized system, where the information is not stored by one single entity (for example a bank, Google, …), but by all the nodes (actually the "Full Nodes"), that can interact without intermediary.
    - **Transparency:** Users in the Blockchain are represented by hash strings (for example, f536fb10ec50ead5cb957530f32cc06a9e2d517b9a31bfe45a3c8e3117c8012c), but all the transactions of every entity are traceable.

    - **Immutability:** In the previous points, it has been explained how unlikely it is that someone changes the data of one or more blocks, without the Network noticing it.

In summary, the fundamental steps for a transaction to be completed are described below and illustrated in Figure 24:

1. **Transaction Request:** Two parties want to exchange data (money, contracts, or any other asset). The transaction is broadcasted to the network.

2. **Queuing:** Depending on the type of Network, the transaction could be stored in a queue, waiting to be validated along with other transactions.

3. **Validation:** Depending on the Consensus Algorithm, the Miners/Validators verify the safety of the transactions included in the block, solving complex mathematical problems.

4. **Network Verification:** When the solution to the mathematical problem is found (the "nonce" in the case of PoW), it is shared with the network, that can easily verify the validity of the solution through the hash function applied to the data of the block, and confirm the validation.

5. **Award:** When a block is validated, the miner (or group of miners) that solved the complex mathematical problem are rewarded.

6. **Block added to the chain:** Once validated, the block is permanently added to the chain and is now an immutable set of transactions.

7. **Transaction Execution:** The transaction, included in the block, is completed.


*Figure 26 - Key Steps for a Transaction to be completed in the Blockchain*

The first application of Blockchain technology was seen with Bitcoin in 2008, a cryptocurrency that did not need a central authority for its emission and therefore decentralized its control. Bitcoin's creator (or creators), identified with the pseudonym of Satoshi Nakamoto, defines the Bitcoin system as "a purely peer-to-peer version of digital currency that allows online payments to be made directly from one user to another without having to go through a financial institution[99]."

But Bitcoin is only one of the many applications Blockchain can have in our world. Many companies have already used the Blockchain technology in order to improve their Supply Chain transparency and traceability: for example, Walmart first implemented Blockchain in order to trace pork in its China stores and mangos sold in the US. Before the introduction of the new blockchain-based food traceability system, the time it took Walmart to check the provenance of the mangoes was 7 days. Walmart can now trace their provenance in 2.2 seconds. In the next chapter, the potentialities of Blockchain in the Fashion Industry Supply Chain will be shown[100].

### 3D Printing

3D Printing is one of the most revolutionizing Manufacturing Technologies of the 21st century: even if it has been invented in 1983 by Charles Hull, it has seen a "democratization" only in the last two decades. Firstly intended to produce prototypes, it has now advanced into more accurate products, with higher quality[101]. The process of 3D Printing can be resumed as follows:

1. First, the product must be designed through a software (for example, AutoCAD)

2. Once a three-dimensional CAD model is available, it is sliced into extremely thin two-dimensional layers. This step is necessary since 3D printers print objects layer-by-layer. The slicing process is done by a specific software
3. The file is then converted from.STL into G-Code and downloaded into an SD-Card that is inserted into the 3D Printer
4. The filament to use is selected and installed into the printhead
5. The machine can now produce the object by building each layer on top of the previous one
6. The finished product can now be taken out
7. Post processing may be necessary in order to refine the final object.

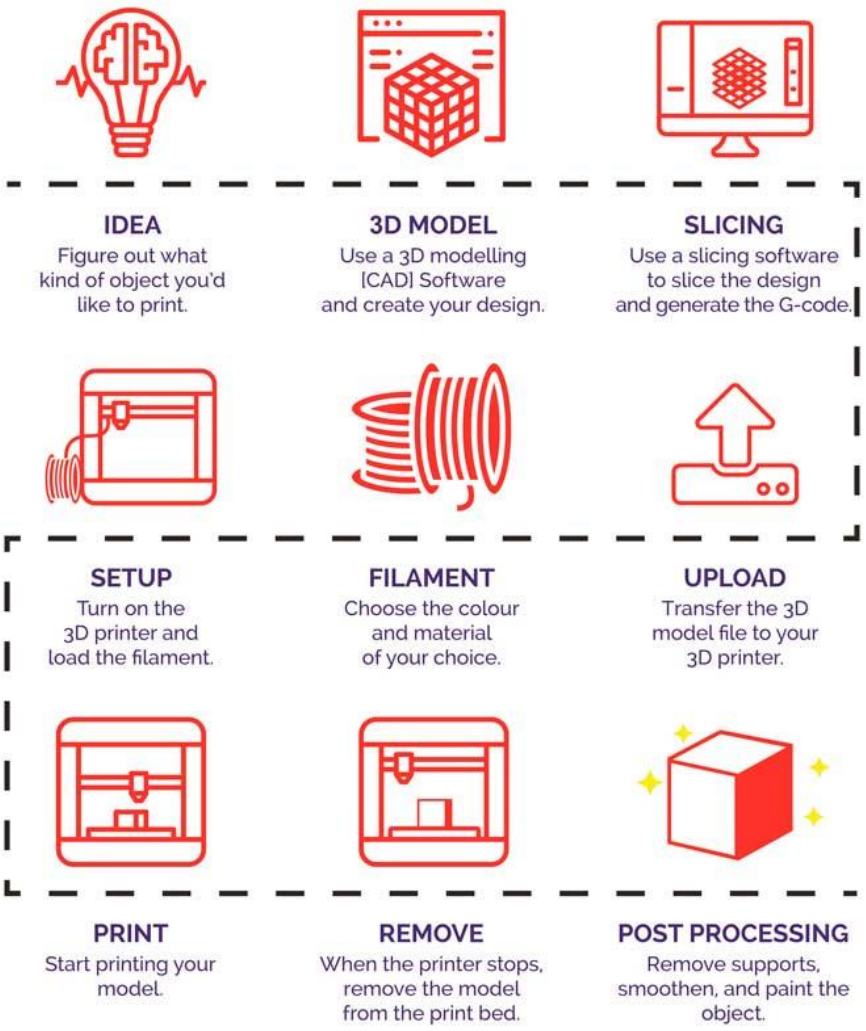



*Figure 27 - 3D Printing Process*[102]

One of the key differentiators between 3D Printing and Computerized Numerical Control is that 3D Printing is a Manufacturing Technique called Additive Manufacturing, where material is "added", while in CNC Manufacturing material is subtracted from a rough object.

3D Printing offers a series of advantages compared to other types of manufacturing processes (CNC, Molding, Casting, …)[55]:

- Local-for-local manufacturing can be achieved more cost-effectively, hence reducing the environmental impact related to transport
- Higher level of personalization and flexibility available at lower costs
- Material and energy use can be minimized and postponed until customers express their needs
- No need of finished-goods inventory

Since 3D printing significantly reduces the number of process steps necessary to produce garments and the amount of waste material, it can be one of the solutions on order to reduce Fashion Industry's environmental impact, but also to reduce cost, "using only 3D printing machinery rather than having a multitude of machines"[103]. However, 3D Printing Sustainability also depends on the materials used: PLA (Polylactic Acid) could be a practical substitute of other common petroleum-based filaments, since it is a renewable material that derives from corn and sugarcane. Moreover, 3D Printing waste must be reused as a resource in order to produce new filaments, otherwise the plastic waste from 3D Printing may not reduce the already existing problem[104].

3D Printing in Fashion Industry has been mostly applied to accessories and shoes, rather than garments, due to the limited range of materials that can comply to the needs of customers in terms of comfortability. A study by Lussenburg et al. (2014) found out that in order to offer a suitable garment, a part from considering functional and environmental properties, it is important to take into account experiential characteristics, such as garment's flexibility, warmth retention and absorption, softness and elasticity[105]. Nike, for example, has developed the "First Performance 3D Printed Textile Upper" with the Nike Flyprint. It is a performance shoe manufactured using Solid Deposition Modeling where a Thermoplastic polyurethane (TPU) filament is melted and laid down in layers[106]. However, every filament has its reason to exist, since their distribution derives from the translation of the data captured on how the athlete runs, through a computational design software[107]. The optimization of every thread reduces material utilization by even 80%[77]. 3D Printing can jointly work with Bodyscan, which can be used to eliminate prototyping, and increase personalization, since customer's exact measures are used to design the final product[103]. The Bodyscan technology is fuelled by online shopping, that looks at Bodyscan as a possible solution to the high return rates[108]. Adidas, in December 2016, opened a pop-up store in Berlin called "*Knit for you*" that lasted 4 months, where customers who wanted to buy a sweater could choose interactively from a set of patterns their preferred one and then they could select a standard size or measure their body through a laser body scanner used by a staff member. Once the design and size are selected, the production of the sweater was performed in-site by an

industrial knitting machine, finished by hand and washed and dried in the store. The whole process took 4 hours and the sweater was sold at 200€[109] [110].

### Innovative Textiles

In order to reduce the environmental footprint of Fashion Industry, it is fundamental to change the type of textiles used in the sector. The Industry is deeply dependant on non-renewable resources that have a big responsibility on Fashion Industry's environmental footprint, especially because man-made fibres like nylon and polyester are derived from oil, which means making virgin nylon or polyester translates into fossil fuel extraction, and fertilisers and chemicals are strongly used in different phases of production (growth of cotton, wet treatments, finishing, …)[111]. Apart from using eco-friendly dyes, a switch to more sustainable textiles is vital for the environment. Cotton, despite being renewable, is cultivated in a very unsustainable manner: cotton requires approximately 10,000 litres of water per kg of cotton and the cultivation is often located in water-scarce areas (Kooistra et al., 2006)[112]. In addition, due to the lack of modern technologies in cotton-grower's countries, water usage is not even calculated and this does not allow to correctly measure the ecological impact of cotton growing[113]. Moreover, cotton farming includes the use of synthetic chemicals such as pesticides and fertilizers. As a response to polluting practices, some companies have taken initiatives to improve the situation, and encouraged the adoption of organic cotton as a substitute to traditional Cotton. The main difference is the way organic cotton is grown, which "preserves the soil fertility, protects the biodiversity, and does not affect both human health and the environment"[114]. In order to be declared organic, cotton must respect national standards of both countries where it is grown, as well as the importer country. Chemicals are avoided, as well as pesticides or synthetic fertilizers, reducing the negative impact on the environment and on nearby communities[115]. Tencel™ is another widely used sustainable fibre: produced by Lenzing Group, it originates from wood (eucalyptus for Tencel™ Lyocell and beech wood for Tencel™ Modal), a renewable raw material that is sustainably sourced by group's suppliers that must comply with a "Global Supplier Code of Conduct" put in place by the Group and are annually assessed by EcoVadis, a recognized platform for Platform for assessing Corporate Social Responsibility and sustainable procurement[116] [117]. Tencel™ fibres are also certified as compostable and biodegradable, closing the loop of the Supply Chain. The particular environmentally responsible production process for Lyocell fibre includes the following steps:

1. Shredded wood is wetted to obtain the pulp
2. The pulp is mixed with a non-toxic solvent (organic solvent called N-methylmorpholine-N-oxide) and then heated to remove water and dissolve it
3. The honey-like viscous mass is extruded through fine nozzles

4. Fibres are cut, washed, and dried

In the production of Tencel™ Lyocell, the process water is recycled, and the solvent is recovered, purified and reused at a recovery rate of more than 99%[118].

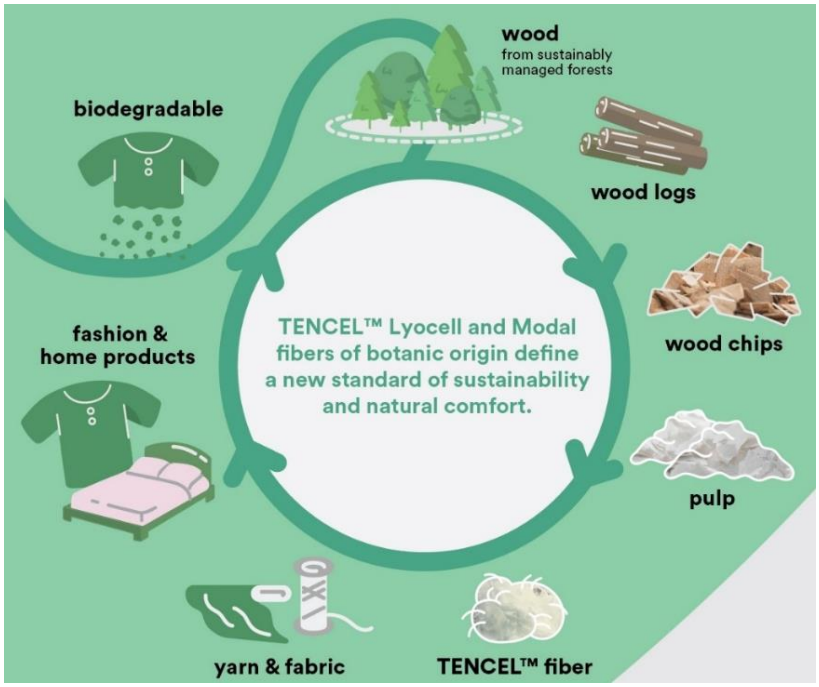



*Figure 28 - Tencel™ Lyocell and Modal Fibres Lifecycle[118]*

Viscose and Modal fibres production are slightly more water (Lyocell consumes only about one third of the process water needed in the viscose and Modal technology) and chemicals intensive (the solvent used for these fibres is not organic) compared to Lyocell fibre. Nevertheless, despite the release of chemicals as gases in the process, mainly carbon disulfide ($CS_2$) and hydrogen sulfide ($H_2S$) , the closed loop production allows not to release these gases into the environment, but to recover, convert and return them to the beginning of the production process to be used as raw materials.

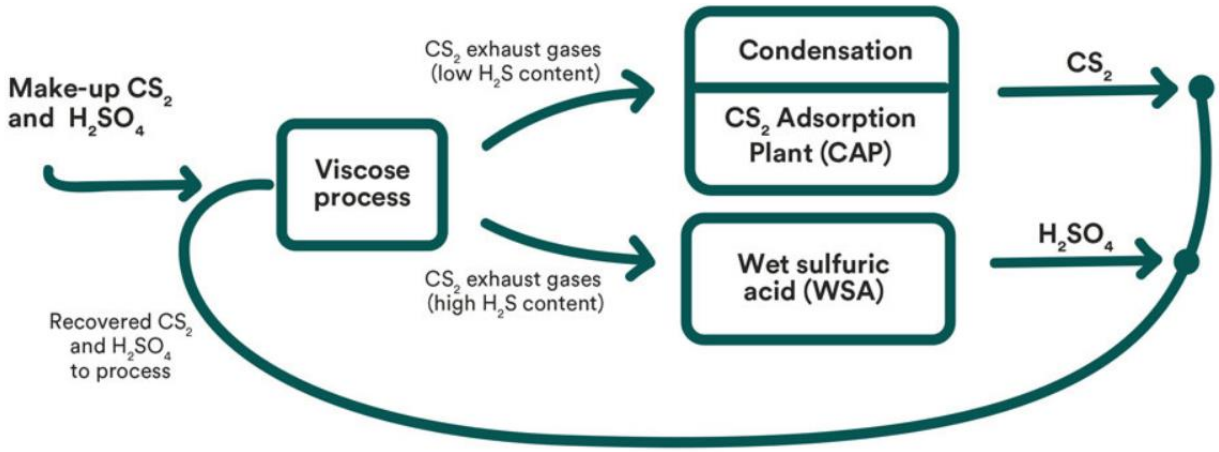



*Figure 29 - Tencel™ Closed Loop Chemicals Recovery*[119]

To further strengthen their commitment to Circular Supply Chains, Lenzing Group has developed REFIBRA™, a technology that enables to add to wood pulp, up to one-third of shredded waste material generated by the production of cotton garments (pre-consumer waste), and recently, it has been made possible to aggregate post-consumer cotton textile waste to the pulp to be processed[120].

Organic cotton and Tencel™ are not the only solutions available. Many innovative end eco-friendly solutions have entered the market in the last years, for example: Piñatex®, a fibre that is produced through leftover leaves from pineapple trees, or CRAiLAR, a flax fibre that only needs 17 litres of water to produce 1 kg of material, with a saving of 99% compared with cotton[121] [122]. Furthermore, Innovative Textiles does not only mean new: "the reinvention of ancient fibres is one of the most promising innovations", according to BoF's report, and people like Lidewij (Li) Edelkoort are already experimenting in this direction[52]. However, it is not enough to produce raw materials in a sustainable way: it is fundamental to address sustainability to the entire supply chain, especially in Fashion Industry, where many other processes that occur after the growth of natural fibres are chemical intensive and the risk is to reduce environmental footprint only of a small fraction compared to what could be achieved with a holistic approach. Thus, organic labels should extend their focus to processes too, in order to certify the whole supply chain has an organic perspective and increase transparency for customers[123]. The next chapter takes into account this consideration and tries to propose solutions that have an impact at different levels of Fashion Industry's Supply Chain.

## Changes in the new circular model

*"Despite years of process breakthroughs and elegant technology solutions, an agile, adaptive supply chain remains an elusive goal. Maybe it's the people who are getting in the way ... Supply chains it seems are really about talent, not technology, especially as the marketplace grows ever more complex."*

(Beth et al., 2003)[124]

It could seem incoherent to declare at this point of the thesis, after an entire chapter dedicated to Technology, that Supply Chains are not really about Technology, what really adds value to Supply chains are talented people. However, even if Technology plays a fundamental role, the informatization, or technological change of the Supply Chain, does not guarantee a redesign and therefore an improvement. First of all, all the players of the Supply Chain must be educated to deal with new advancements, and secondly, increasing technology does not always mean more efficient processes. The real power of Technology does not rely on its ability to perform old processes better, its real value is based on the fact that it enables new ways of thinking about old processes and creating new ways of doing business, breaking long established rules[88]. The following sub-chapters will therefore describe these new ways of doing business in the case where the Fashion Industry aims to become circular and thus implement a Circular Supply Chain. Companies have now the choice to start implementing circular economy initiatives in order to have an advantage over competitors, breaking up their dependence on volatile commodity prices and on the extraction of raw materials.

### Re-Design

Seen the importance of Design in the Fashion Industry, it is fundamental to address circularity from the conception of a product. Nowadays, products are designed to satisfy the impulsive customers' behaviour, and to last only a few wears. Circular Economy requires the design of products for plural functional use, thus an evergreen style. In addition, there is the need of a careful selection of sustainable and long-lasting materials (such as organic cotton instead of synthetic fibres), the use of natural substances instead of chemical ones. While considering, starting from the development phase, the possible recycling and repairing processes that the product could go through[24 125 126]. Non-toxic materials must substitute toxic resources, in order to guarantee a fully sustainable (and circular) supply chain. Apart from these considerations, other factors such as transportation, packaging and manufacturing must be taken into account, thus requiring collaboration throughout the Supply Chain and training for designers in order to make them able to have a transversal vision of operations. In fact, the Design stage is a key part of product development, where even more than 80% of the environmental impact the product will have during its lifecycle is determined[127]. Moreover, "design

phase, although contributing on average only 5% of the total product cost, is responsible for about 75% of the overall manufacturing cost, for about 70% of its life cycle cost and for over 80% of its qualitative characteristics" (Franceschini, 2001)[128]. The Design process that takes into consideration the sustainability of the product is being developed is called Eco-design. Eco-Design includes, for example, Design For Disassembling (DFD), a design strategy whose aim is to conceive a product in such a way that it is cheaper, easier, and faster to assemble but also to disassemble for maintenance, replacement of parts, recycling and use of components in new products. Eventually, clothes can also be designed to be compostable, being buried in the ground at the end of their lifecycle[129].

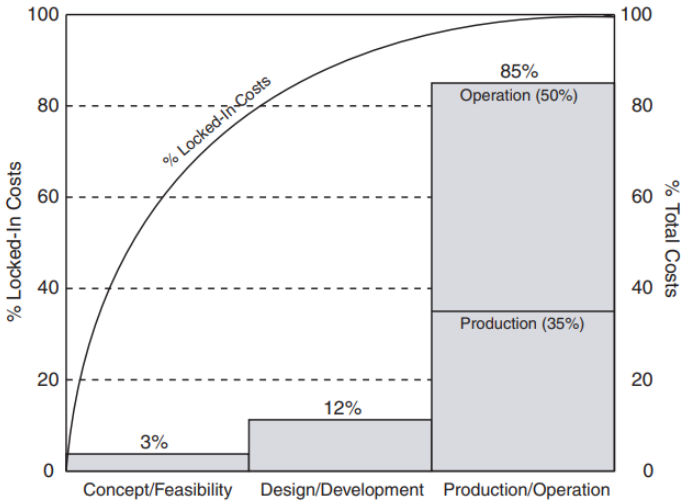



*Figure 30 - Pareto Analysis: Invested Money Depending on Product Advancement*[130]

Environmentally friendly choices are gaining fame, both across companies and consumers. However, one of the most disruptive ideas that will help transform the Design process is that "User-Centred Innovation is not sustainable"[131]. According to Professor Roberto Verganti, sustainability is not at the base of our behavioural patterns, which, on the contrary, has led us to an unsustainable world. So as to introduce, and then make customers adopt, sustainable products, "forward-looking executives, designers and, of course, policy makers" are needed, and then, "within the framework of a vision-centred process", user perception can be analysed and contribute to incrementally improve products that will be "meaningful for people, good for the environment, and profitable for businesses". Circular Economy is about doing what companies did not do before, hence a radical innovation, or a set of radical innovations, are needed in order to bring the Industry to a completely different frame from the one it has been in for decades. Human-Centred Design can lead to incremental improvement, but what enables a radical change is technology or meaning change, that breaks with the past and leads to new practices[132]. According to Dahlin and Behrens, an innovation brings a radical change if:

1. It is dissimilar from prior inventions

2. It is dissimilar from current inventions[133]

The success of the idea is determined by the maturity of the market, hence the right idea at the wrong time will fail. Moreover, as Norman and Verganti underline, most radical innovations are not usually immediately accepted. This is why Human-Centred Design can only occur once the radical innovation comes out on the market, and will be used to make the new product acceptable to the consumers, and make it more performant, cheaper and user-friendly. 3D printing, applied to textiles, could be considered as a Technology Epiphany, since it will bring "a radical change in meaning, enabled by the emergence of new technologies or the use of existing technologies in totally new contexts", like its application to the Fashion Industry. The radical change in meaning will be the change from clothes being seen as an expression of one's taste, to being seen as the expression of one's ideas. In short, in the case of 3D printing: the statement of a sustainable and innovative way of being dressed. The technological change occurs from the application of a technology firstly conceived for other sectors, to the Fashion Industry. The introduction of 3D Printing as a new way of producing (or ameliorating) clothes, implies the rise of new skills needed in order to be a Designer.

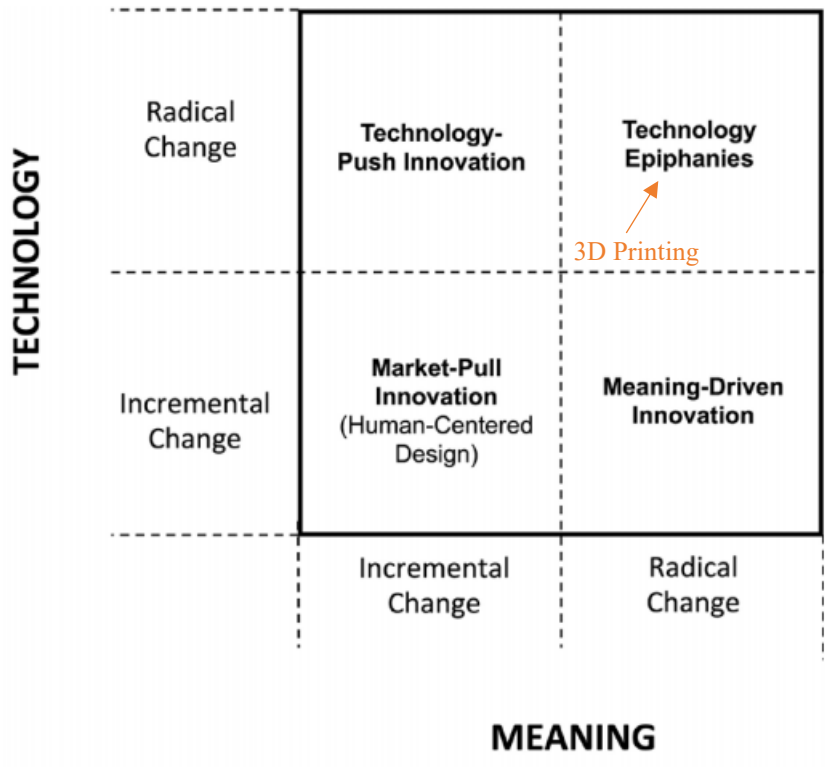



*Figure 31 - 3D Printing and Its Impact on Fashion Industry's Innovation*[132]

The Re-Design of the product extends the Re-Design process to the whole Supply Chain: in order to change the way of doing business, Supply Chains, which are the framework of a business, must take a complete different shape. Design also has an impact on Supply Chain Management, since it can make Supply Chains more complex. The source of complexity can be various, Christopher (2011)

proposes different ways product design decision can affect Supply Chain complexity, which can be resumed in:

- Manufacturing Complexity: flexibility and responsiveness can be threatened by decisions made at the drawing board, as well as increased complexity can be added, by complicating the Bill of Materials, which usually means more components and therefore more suppliers.
- Increased Lead Times: certain components can only be found offshore, undermining supply chain reliability due to lack of control over suppliers and increasing lead times.
- Endangered Customer Experience: the complexity of a product can reduce the possibility of customization, as well as making after sale support more difficult[55].

However, Christopher proposes a strategic process to control supply chain complexity, focusing on the most valuable activities, through the Pareto Analysis:

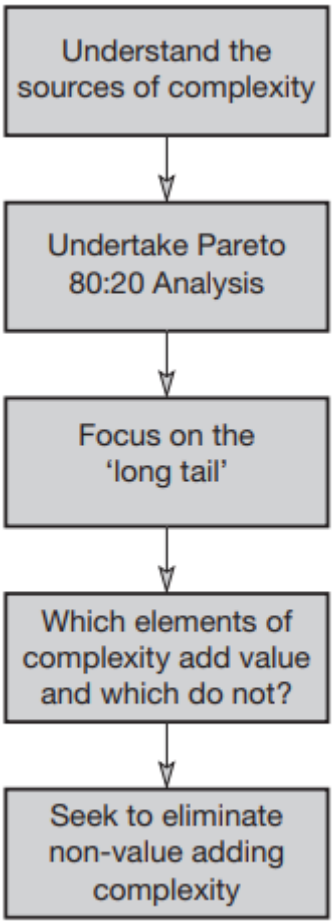



*Figure 32 - Complexity Management*[55]

### Worker Transformation

As we have seen in the example of designers' jobs at Zara, and in the previous chapter, the growing need for designers to be able to have a wider view of the product, considering all its lifecycle: taking into account different steps, such as transportation, packaging and manufacturing. These aspects emphasize the fact that designers, as well as other function-based workers, will transcend their role and will be trained to take decisions that go beyond their traditional reach. The development of these capabilities will be assisted by technology: even if the future of the majority of the industries is moving towards digitalization, people will still be at the centre of companies. This is "because they provide the degree of flexibility and decision-making capabilities required to deal with demanding customers"[134]. The Manufacturing phase of the Fashion Industry is still labour-intensive, and mostly relies on old-style production methods, but the appearance of new technologies, such as sonic welding, automated knitting or ink-jet printing on textiles, will revolutionize production[44]. If these will be the premises, better-skilled workers are needed: companies will have to educate them to interact with information technology, in order to take faster and correct decisions with the aid of IT; from plant-floor workers, to shop sellers, from designers, to Supply Chain Managers, will be considered as capital to invest in. In particular, employees who are closer to customers, such as plant-floor workers or store vendors, will have to be included in decision-making processes and be more involved in product improvements, since they well know customer's needs and can lead to incremental ameliorations. Real-time information, gathered through factory automation and sales data, will be essential to monitor every step of the Supply Chain. Workers' education must also include sustainable-oriented business practices. IT and education are key elements for the creation of multidisciplinary teams that will be able to take decisions that will lead to lower Total Costs and will take into consideration the entire product lifecycle, from an economic, social and environmental perspective, both at the development stage, as in operational activities. At the same time, integration with customers and suppliers will enhance the ability to respond unforeseen changes at higher speed and encourage recycle practices through reverse logistics.

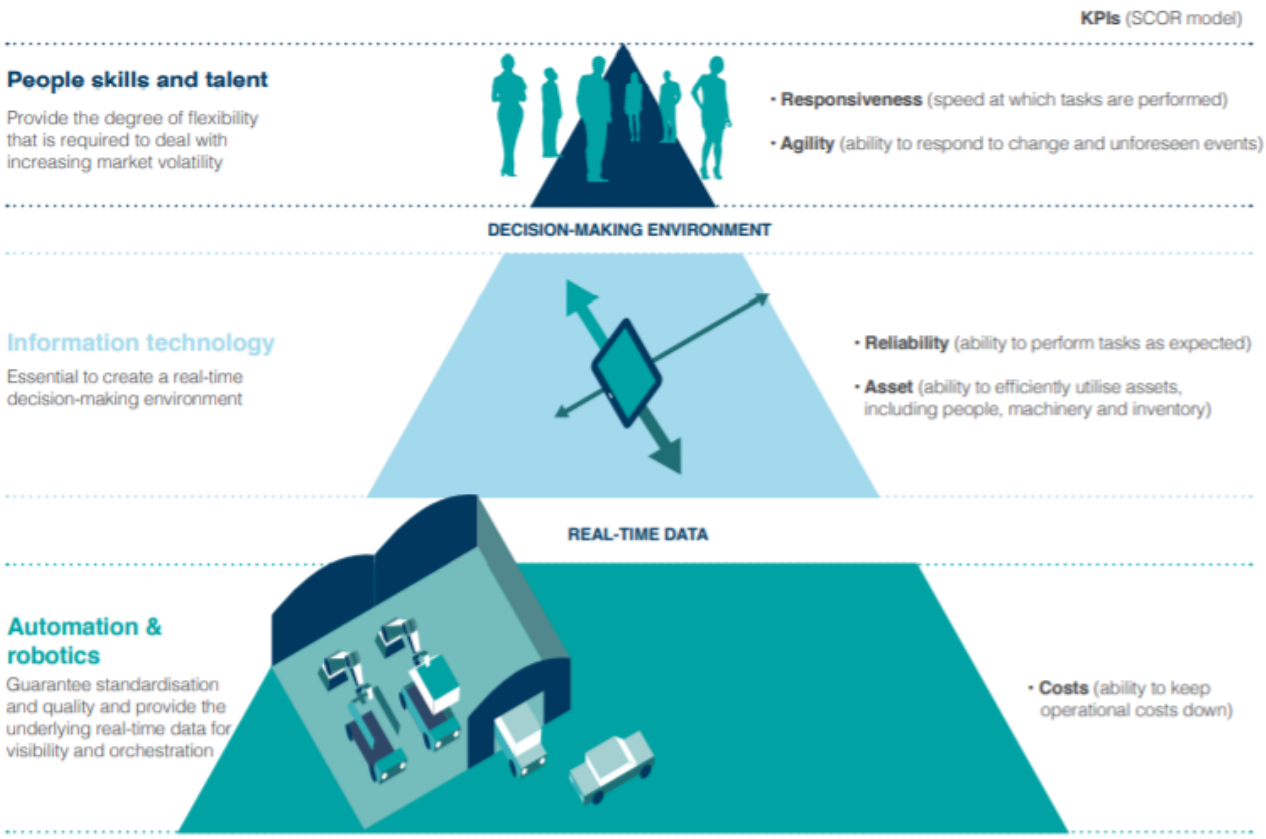



*Figure 33 - The Three Layers of the Digital Factory, according to Manenti (2014)*[134]

All the improvements described above suggest the paramount importance of education provided to human capital. The challenge is how to establish education programmes that have the ability to provide companies with "T-shaped" employees, especially managers, which have a general understanding of all the key business functions of the company, and also an in-depth knowledge of their specific unit[55]. However, to enable this switch in organizations, a change in their structure is required, from a functional structure to a market oriented one, therefore from a vertical structure to a horizontal one, organizing based on the outputs, not on the inputs. It is important to make a difference between training and education: while in vertical structures training was the preferred method to teach employees "how" to do their job, in horizontal structures education is the preferred method, since workers are not taught "what" to do, or "how" to do it, with strict rules, in contrast they are taught "why" they do things, to make them able to take decisions in the most diverse situations. People do not climb the corporate ladder, they enlarge their knowledge of the process, in order to make them able to cover a greater part of business processes. Therefore, managers are not auditors, they become facilitators and workers' educators. Figure 34 and 35 represent the traditional model and the new organizational model.

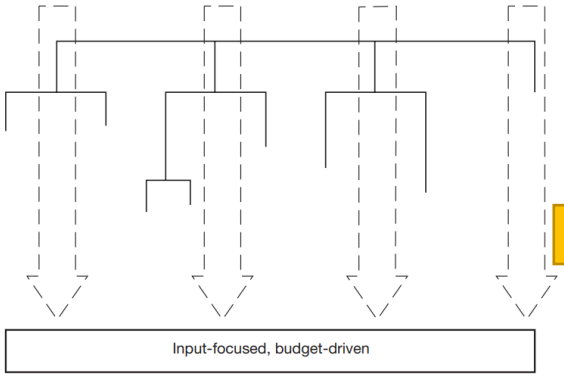



*Figure 34 - Traditional, Functional Organisation*[55]

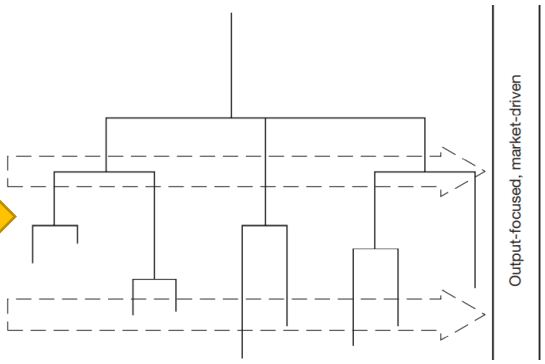



*Figure 35 - Market Oriented Organisation*[55]

Many studies have shown the impact of education, even in the Fast Fashion Industry: education fuels productivity, improving it by increasing efficiency, not work intensity, one of the main problems of the industry, especially at manufacturing level and in developing countries[28]. Education boosts the likelihood that workers are retained, and those workers will be ever more skilled and will benefit from better working conditions, studies show[135] [136] [137] [138]. Europe, through educational programs, could specialize in luxury and premium products, leaving less expensive products to be produced in countries where labour cost is lower. While Asian countries could educate their employees with the aim of aggregating other services to their offer, such as research and product design, in order to increase their competitiveness, since labour cost is destined to increase, and even the economic sustainability of the fast-fashion business may be at stake. Moreover, developing countries could implement bonuses linked with productivity, in order to raise wages and productivity at the same time, while keeping overall price levels attractive[32].

### Transparency and Traceability

Transparency and Traceability are two key features of Supply Chains, especially if the aim is to become sustainable, and more specifically, circular. One of the most used technologies in the Fashion Industry that benefits both Traceability and Transparency is RFID. RFID can be considered a mature technology due to its diffused usage in the Industry. Transparency creates accountability, and in a sector like the one studied by this thesis, where environmental scandals and human rights violation are frequent, it can have a big impact on business practices. Traceability reduces different kinds of waste: overstock, excessive movement or transportation, waiting times, overproduction, overprocessing and defects (the 7 forms of waste of Lean Management). The reduction of these wastes may lead to significant environmental savings. Zara uses RFID in its stores, in order to track clothes all along its distribution process. Garments are tagged at manufacturing, allowing Zara to track products at different levels (as shown in Figure 36), reducing human labour due to the automation of the control and sorting phases.

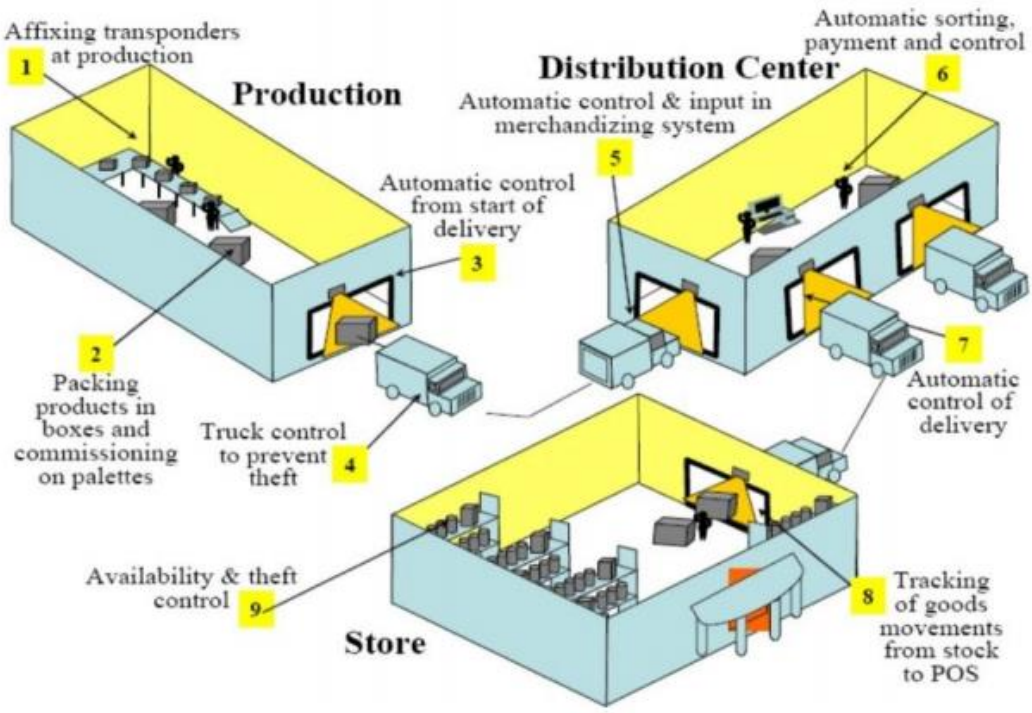



*Figure 36 - RFID in the Supply Chain*[139]

Hence, products are tracked during their journey from manufacturing to stores, and at store level they are constantly monitored through stores' Wi-Fi. The main reason RFID is used at Zara is inventory accuracy: at every moment, Zara's employees, and generally speaking Zara's Enterprise Resource Planning, know if customer request can be satisfied, and if the product is not available in-store, they can immediately track a product's availability in other stores or at previous levels of the supply chain. Apart from increasing sales and reducing Out-of-Stocks, RFID raises inventory accuracy, reducing the Safety Stock needed since the variability of information is reduced through precise inventory monitoring. By reducing Safety Stock, overstock at the end of the season is also reduced. This means fewer products going to landfills or being incinerated, which not only reduces one of the most diffused problems in the Fashion Industry, but it also means reduced Greenhouse Gases Emission from the reduced production and transportation of unnecessary products[140]. Studies show stock reduction for Fashion Industry players, after RFID introduction, ranges between 2 and 13%, while stock availability increased by 90%[89].


*Figure 37 - RFID at Zara: Flowchart*[141]

RFID can also be useful at production level: a denim manufacturer reduced product loss by 50% through the implementation of RFID along the production lines, therefore reducing the amount of pre-consumer waste that could be landfilled or incinerated[89]. In fact, the technology can be used, for example, to avoid different size or different style patterns being mixed together or to transmit real time data related to production (like work progress, efficiency of the assembly lines, productivity of each sewing machine) or rapidly track the responsibility of a defect[142].

The most used type of RFID in the Fashion Industry is passive tags since they are cheaper and do not need a battery. However, active RFID are also able to store data sent by the transceiver, thus information about the product (for example, the process in fibre production, yarn manufacturing, chemical processing, labour and in general data concerning the sustainability of the product) could be uploaded to the RFID while the different products travel through the SC. In the store, the RFID tag, when scanned by the end user, can transmit transparent information about the product, enabling them to make sustainability-oriented choices[89]. The same system can also help companies of the Textile Industry to monitor their suppliers, gaining total visibility of their supply chains, even in real-time, thanks to the sharing of real data information through RFID. If all the information is transferred to a blockchain system, transparency and immutability of the information are guaranteed. A private and open blockchain could be the best solution for fashion companies in this case: the different nodes of the network, which correspond with the actors involved in the entire supply chain, broadcast the information (or transaction) to the network, and based on the Consensus Mechanism implemented in the specific blockchain, the various nodes are allowed to verify the blocks which are then added to the blockchain. Those blocks, which will contain the information related to the different steps, will

be recorded in a ledger, which is distributed to all the agents of the SC. The Blockchain translates the Clothing Supply Chain into a series of blocks represented in Figure 38, where a non-exhaustive example of the information to be recorded and transcribed into the blockchain is given. Other entities can be involved in the network, such as freight operators, importers, or other suppliers (label suppliers, chemical suppliers, …). Blockchain can make Supply Chain auditing easier and faster, reducing the need to directly monitor suppliers. Information on how to return, recycle, or reuse the product can be also shared with the customer, before and after the sale, through RFID or QR codes installed in the product. Blockchain finds one of its main strengths in the absence of intermediaries, which could mean that the different certifications which are now diffused in the Industry may become obsolete with this new mechanism, since the technology guarantees the reliability of the information stored in the blocks.

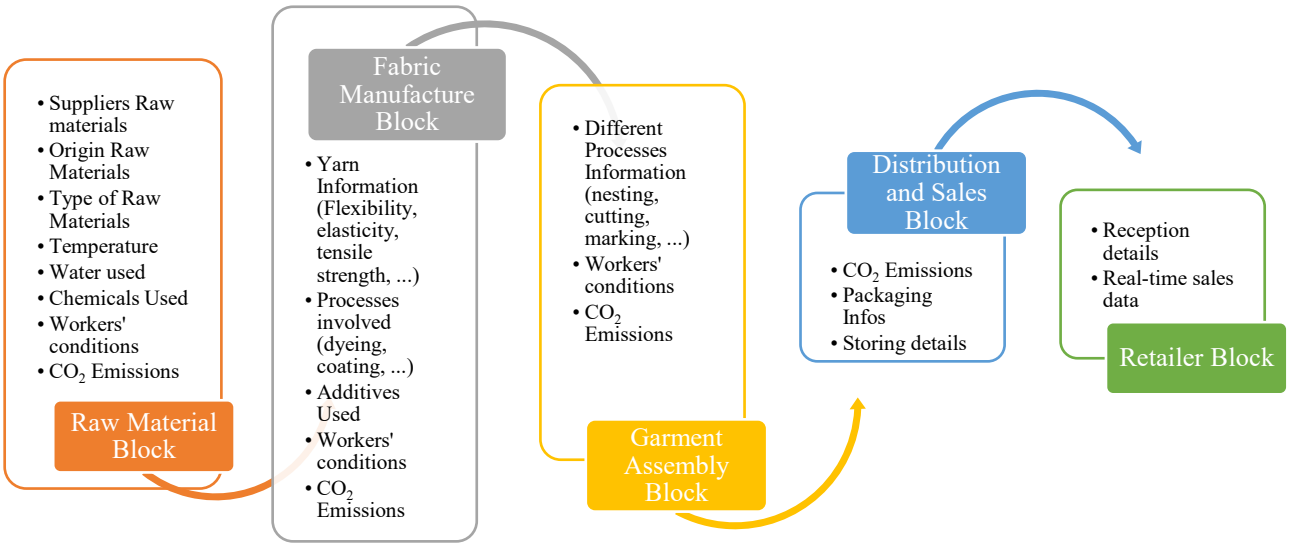



*Figure 38 - Fashion Industry Blockchain Representation*

In this way, the information of a given product, tracked by its ID, is stored in the blockchain and is fully traceable during the enitre lifecycle of the product. The algorithm to search for the information of a specific product is described by Bullón Pérez et Al. (2020) and is represented in Figure 39:

**Algorithm 1:** How to trace a garment

INPUT: GarmentID;
OUTPUT: Garment detailed information;
**for** *each* $i-th$ *block in the blockchain* **do**
  **if** *GarmentID* $\subset$ $i-th$ *block* **then**
    Retrieve block number;
    Retrieve block header;
    Hash from $i-$th block $\leftarrow$ Hash from $(i-1)-$th block $||$ Header block;
    Retrieve information from the block transaction;
  **else**
    Hash from $i-$th block $\leftarrow$ Hash from $(i-1)-$th block $||$ Header block;
  **end**
**end**

*Figure 39 - Algorithm to Trace a Garment in a Blockchain System*[143]

The same model, relying on blockchain technology, can be used to track economic transactions through different agents. The implementation of Smart Contracts can be useful in this case, with the help of RFID: automatic payments are sent to the suppliers once orders are received, whose reception, correct quantities and timely delivery can be verified through the scan of RFID. Therefore, RFID combined with blockchain, can further reduce the intentional manhandled information, and increase the trust among the participants in the network.

### Local Sourcing

A Sustainable and Circular Supply Chain usually fosters local sourcing. In previous chapters, the unsustainability of the price-rush companies are pursuing has been described, due to its impact on developing countries' environment, economy, and society. Furthermore, developing countries are destined to increase labour cost, and there will come a time when companies' outsourcing will not be economically sustainable, since transportation costs along with a series of factors such as reduction in supply chain responsiveness, distance from customers, cultural differences between company and production site. Moreover, the cost of controlling a site located far from the headquarters will not justify the difference in labour costs. Companies are already realizing that customers need personalized in-store experiences and tailored offers, "with stores that reflect the local community and focus on service and experience"[52]. The Covid-19 Pandemic made companies realize that long SCs increase their complexity and the ability to track and trace materials. Local sourcing has re-gained hype since it gives more visibility on products and assets, while supporting local economies and favouring local initiatives which contribute to the social component. Last but not least, it also reduces lead-times as well as $CO_2$ emissions[144]. Complexity also means uncertainty, and in an Industry like Fashion where the demand is very variable and not easily predictable, it could be lifesaving to implement solutions that help to deal with the poor ability to correctly forecast demand. Local or regional production usually increases responsiveness, reduces lead times, and reduces the

dependence on forecasting in favour of a more demand and event driven supply chain, adopting a quick response strategy[115]. Local sourcing, due to its closeness to demand, helps to reduce overproduction and, partially as a consequence, carbon emissions. Reducing overproduction, companies will have, on the other hand, increased margins, since products sold at lower prices than their original ones would significantly decrease. In addition, the reduction of $CO_2$ emissions can be favoured through Eco-Design, which, apart from seeking the production through easily recyclable materials, also encourages the use of local materials, hence reducing even more transportation. Local production can be further boosted with 3D Printing, due to reduce transportation costs, as well as faster and cheaper design and product development. Finally, 3D Printing can be implemented at in-store level, further shortening the distance from the production site to the end-user.

Local sourcing could also mean that local production sites may be in charge of various parts of the whole process, functioning as Distribution Centres, but at the same time as a production site. They could even include recycling facilities or serve as Showcases, where both clients and potential (final) customers can visit the plant and see and check the whole production process, making sure their future supplier or current supplier is respecting the terms of the contract. If the cost of the infrastructure is too high, parts of the site (for example, the recycling facility) can be subcontracted to or shared between one or several companies, making the plant a collaborative plant, not only because of the agglomeration of separated parts of the SC in the same place, but also because of the cooperation between different companies, that play as partners in certain steps of the production process. This cuts distances between suppliers and clients, enabling a better control of the whole SC, bringing a reduction in the Total Cost for all the companies involved in the Shared Plant and improving the efficiency in fulfilling customer needs. The Shared Plant can also result in an Industrial Hub, where companies, research centres, universities and local institutions cooperate to become more efficient and consequently more sustainable, continuously investigating in the search for new production technologies and processes which can bring substantial improvements and achieve the independence from virgin or non-renewable materials. This kind of Industrial Districts translate in a multifaced environment, where workers need transversal skills in order to be able to cooperate with different actors and in different steps of the SC. Italy could be a perfect place where the implementation of this solution may lead (and in some case, is already leading) to gains in productivity, due to its distinctive industrial network, characterized by small and medium enterprises, which are often horizontally and vertically integrated between them. More specifically, for the Fashion Industry, industrial districts are particularly present in regions like Tuscany, Lombardy and Marche. However, the same model can be applied to different countries, especially where a certain specialization in Fashion can be

found. Being closer to demand means being able to shorten lead times and to fulfil customer needs faster and more effectively, while also efficiently responding to products customization's demands[134].

Local sourcing could be favoured by the deployment of a well-designed carbon footprint taxation scheme by governing body. A study by Choi (2013) found out that when a carbon footprint tax is not implemented, a local manufacturer would be selected if the cost difference is not high and/or if the gain in forecast accuracy is significant (for the calculation of the conditions that favour the selection of a local supplier, see Source[145]). On the other hand, "In the presence of the carbon footprint tax, the fashion retailer will easily be enticed to employ the local manufacturer as the sole sourcing mode because the respective analytical conditions can easily be satisfied"[145]. A Carbon Tax has already been proposed by the International Monetary Fund (IMF), which states that through a 75$/ton $CO_2$ emitted in the air applicable to G20 Countries, emission would be cut by 35%. If implemented at a global level, by 2100 GHG emissions would be cut by 33%, while $CO_2$ emissions by 38% (both values are compared to a Business as Usual Scenario. Calculations are made through the utilization of the En-ROADS Climate Solutions Simulator developed by Climate Interactive, Ventana Systems, Todd Fincannon, UML Climate Change Initiative, and MIT Sloan. The link to the scenary that pictures the situation escribe above is: https://en-roads.climateinteractive.org/scenario.html?p39=75&v=2.7.29).

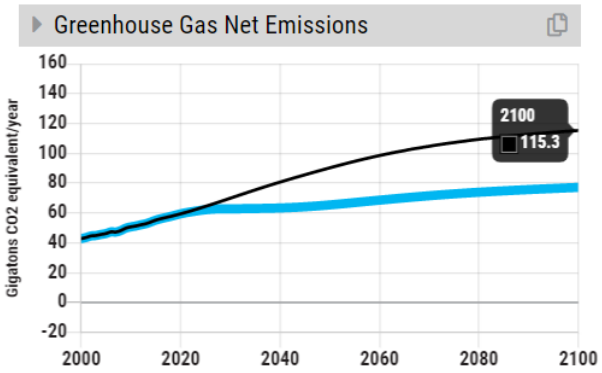



*Figure 40 - GHG Emissions Business as Usual Scenario by 2100*

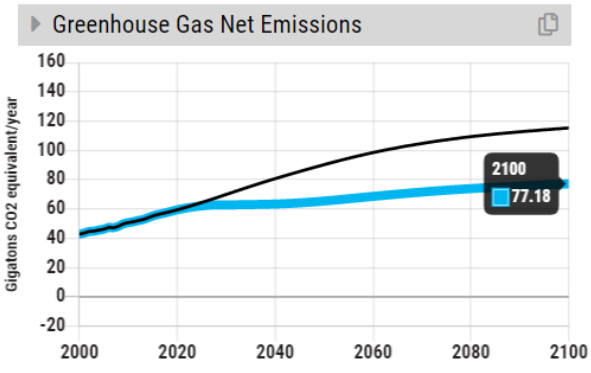



*Figure 41 - GHG Emissions with 75$/ton CO2 Carbon Tax*

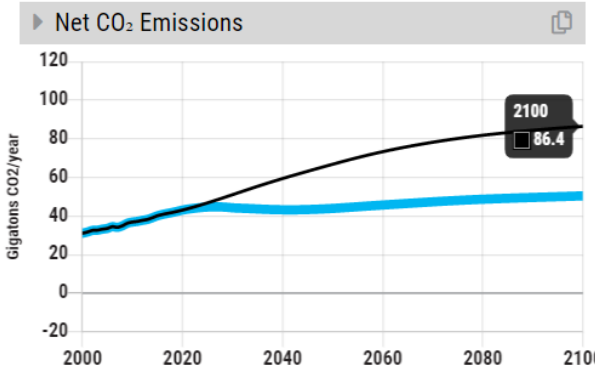



*Figure 42 - CO2 Emissions Business as Usual Scenario by 2100*

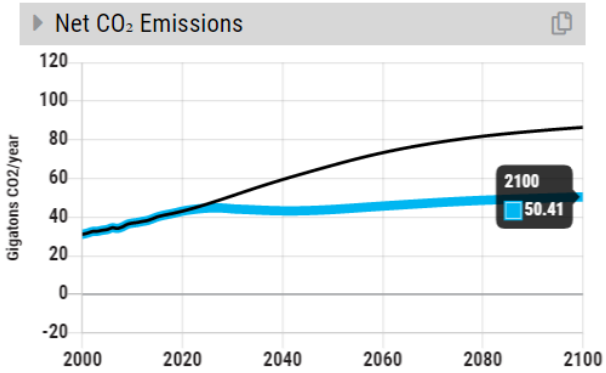



*Figure 43 - CO2 Emissions with 75$/ton CO2 Carbon Tax by 2100*

### Customer Collaboration

Customer collaboration is fundamental if a company wants to achieve circularity in its Supply Chain. Circular economies are based on the return of products in order for companies to reuse or recycle them, and this role is often assigned to customers. But the lack of consumer interest and awareness implies low engagements when circular business models are implemented[146]. Cooperation with customers can be a driver for building closed-loop Supply Chains, but it requires a change in the approach to Customer Relationship Management: in this new business model, customers are required to act as suppliers, by providing products firms can re-enter in the production process, avoiding them to be incinerated or landfilled[147]. The new responsibility assigned to customers require, aside from a lifecycle approach (already described for the Design phase), a close relationship with them, in order to involve them in the value creation process of Returns Management and understand, influence and satisfy their purchase, consumption and disposal needs[146]. Customers must therefore be accompanied along the whole process, from the moment they enter the shop and make a purchase, until the moment they decide to get rid of their product. Information on how to reuse or recycle what they buy is key, and it has to be replicated along customer's journey: from informational banners at the point of sales, to suggestions given by store assistants, from periodic emails that remind customers of different ways to return its products into the loop, to information embedded in the clothes through RFID or QR codes. In fact, RFID labels can embody useful information to reduce clothing wear, such as washing and drying instructions, along with information on recycling methods and associations or collecting points to which clothes can be donated and guarantee a correct recycling[89]. The value of the product being purchased should always be remembered by an intensive marketing campaign, that could also rely on modern tools like social media, which have a strong impact on new generations, which tend to be the ones with higher interest in sustainable garments and could even enable one-to-one communication[148].


*Figure 44 - Importance Given to Sustainability by Consumers[149]*

Increased returns rates are achieved through multi-channel solutions to collect clothes: apart from in-store product take-back systems, partnerships with other brands and expert garment collectors, as well as local charities, matched with an explicit declaration of the aim of the project firms are carrying out, are determinant to ensure customer involvement in the new practice[146]. As proposed by Saicheua et al. (2012), micromarketing strategies jointly carried out by companies in the Fashion Industry could change consumer preferences and grow the demand related to sustainable products, hence promoting a change to sustainable practices across the sector26[26]. Collaboration between departments, especially Sales, Marketing, Production and Logistics, is essential to jointly work towards an integration of Customers in firms' Supply Chains. Educated customers are much more likely to return their products and this would also enhance client loyalty, due to the frequent contacts between firms and customers through several tools, which would make them return to store for different reasons, and maintain a solid relationship with the brand. Technologies such as 3D Printing, Bodyscan and Made-to-Order solutions can further strengthen the brand-customer link, thanks to personalized solutions that enable the inclusion of the client in the production phase. Interactive websites could even make customers able to select the supplier from where they want their materials or manufacturing to be sourced from, taking responsibilities that were usually assigned to Supply Chain Managers. This requires education, but it could increase the awareness and interest in the Fashion Industry and its environmental, social, and economic impacts. In conclusion, in circular supply chains, customers add to their traditional role the roles of sellers, partners and suppliers.

### Inter-company Collaboration

As previously described in the Theoretical Framework Chapter, Collaboration across the entire SC is fundamental, and its importance is increasingly growing due to its benefits, especially when referring to responsiveness to changes in the demand. Its importance is further underlined by the integration of "Partnership" in one of the SDGs, as well as being part of the 5 essential elements to guarantee the implementation of the Agenda 2030. Sustainability, and especially circularity, can only be achieved through Inter-company Collaboration. This is a completely new way of seeing business: fast, uncontrolled and sometimes unjustified growth is replaced by slow, sustainable, and careful investment and in order to make it work, not only investors must share the missions and the vision of the company, but all the organizations involved in the network must share the values of the business, as well as their employees, making the selection of every supplier and every employee a fundamental choice for the whole Supply Chain. Culture must be shared across companies, and upwards and downwards partners must be integrated so that the sustainable approaches is adopted equally. What could increase the adoption of sustainable practices is the adoption of a sector-wide system, where strategies and code of conducts are defined, thus creating a shared perspective and overcome

problems arising due to the variety of compliance systems present today[27]. Hence, Collaboration among companies in the Fashion Industry, especially between those firms that have a big share in the sector, is fundamental, and must be facilitated by Public Institutions. But the integration of other companies and smaller suppliers and customers is as important as the collaboration between big firms: due to the high volatility of demand which characterizes the Fashion Industry Supply Chain, shared information across all supply chain partners is key, as well as close collaboration between them, and the organization around common processes, with the aim of reducing the total environmental and social impact of the network[150] [73]. The first solutions that are implemented in successful collaborations are:

- The share of customer forecasting to suppliers
- The share of customer orders to suppliers, which can include them into their planning systems
- The cooperation with suppliers and customers in the product and packaging design and development

These first-step solutions can bring visible improvements such as improved customer satisfaction thanks to the reduction of Out-of-Stocks and enhanced forecast accuracy, while reducing overproduction and waste and shrinking lead times. However, the level of collaboration can rise depending on the level of engagement that partners want to have, especially towards Sustainability. For companies to achieve a Sustainable Development, A network-based SC orientation and a proactive approach are needed to allow companies achieve outstanding results in economical, environmental, and social goals[151]. Processes and products may need to change to achieve it, and thus collaborative, long-term, close relationships are vital, and these have to be mutually beneficial for supply chain partners.

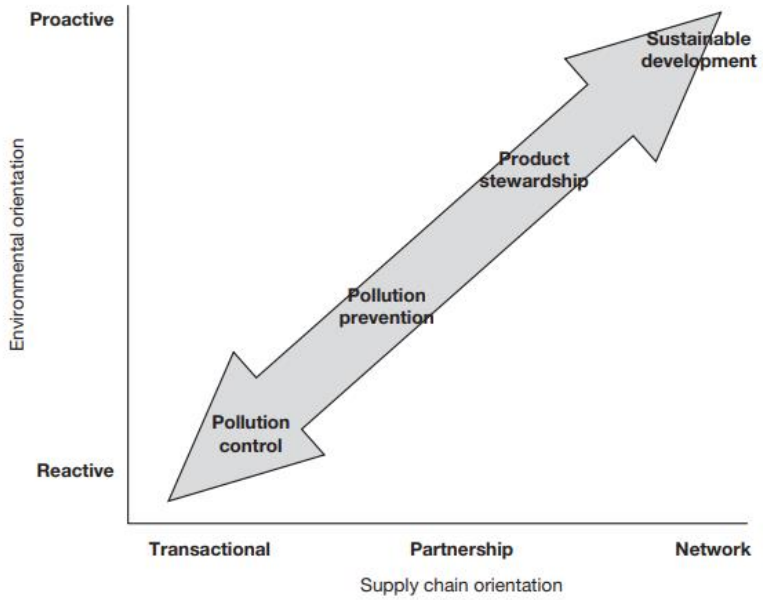



*Figure 45 - SC and Environmental Orientation to Achieve Sustainable Development*[151]

Circular Models require the highest level of collaboration among companies: apart from initiatives such as HR practices implemented to align network's commitment, or supply chain audits to ensure dangerous materials are not used and workers are paid a fair salary, which are typical of firms seeking sustainable development, circularity may imply the disappearance of companies' borders. A real-world example is the typically Italian phenomenon of Industrial Symbiosis, which is described as the engagement of "traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water and by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity"[152]. Industrial Symbiosis have already made circular practices more easily achievable, due to two main characteristics:

- Networking Nature: The Networking Nature enables close cooperation and increases Network's total resources capacity (especially financial resources)
- Geographical Proximity: Proximity favours eco-innovations, due to "knowledge spillover and learn-by-interacting", especially if companies interacting are jointly involved in a sustainability-focused environment[153] [154].

"Macrolotto 1", which is part of Prato's textile industrial cluster, engaged in voluntary and continuative environmental improvement programmes which led to:

- The implementation of a centralised water recycling plant, shared between 700 small and micro companies, to significantly reduce water usage and its pollution, two major issues in

the industry[155]. The water management system purifies wastewater from industries and citizens of Prato and the treated water is then used within the district.

- The building of a 20 hectares photovoltaic system which reduced the cost of energy for "Macrolotto 1" by more than €4.5 millions per year and the $CO_2$ emissions by 16,000 tonnes.
- The offer of services and facilities to the employees, like inter-company kindergarten, Centralised laundry, pharmacy, post and grocery services, with, inter alia, the aim of reducing environmental impact caused by traffic[156].

The "Macrolotto 1" case is an example of how Industrial symbiosis can build synergies between firms, creating projects that would have not been achievable if carried out individually. Moreover, it is important to underline the importance of Public Institutions and other agents in the pursuit of circular solutions. In fact, new laws implementation led to €300,000 saved by the whole Industrial cluster due to different taxation schemes for water polluters, and a local bank was involved in the construction of the photovoltaic system[157]. Hence, collaboration may not limit to suppliers or customers that firms always had. Circular economy may be a new business model to many companies, and it is more than likely that new frontiers will open, together with new business opportunities. For example, the Fashion Industry may find partners in the Agricultural or Food Industry: Piñatex, which is "an innovative natural textile made from waste pineapple leaf fibre", creating additional income for farming communities thanks to what is now considered a by-product; or Orange Fiber, which transforms the citrus industry waste into a valuable resource for the fashion industry[158] [159].

Trust and personal knowledge enable the implementation of Blockchain solutions (already described in the Chapter "Transparency and Traceability"), especially in industrial districts like the one in Prato, or the Marche shoe district[36]. The transparency achievable with this solution may lead to the establishment of long-term objectives. A longstanding vision, coupled with the intention of switching to a circular model, may rebalance the relationship between the focal firm and its partners, especially its suppliers, which usually are oppressed due to their reduced bargaining power. But in a Circular Fashion Industry, suppliers may become key elements of the supply chain and improve their margins, ameliorate workers' conditions and salary, reduce their environmental impact due to the implementation of new and greener practices, and achieve competitive advantage over their rivals[147]. Blockchain may be used to make Life Cycle Assessments (LCA) of a product (or service) in order to calculate its environmental footprint and prioritize interventions where significant improvements can be achieved. Blockchain-based LCA analysis enables the consideration of all the inputs of the complex product supply chains, and the calculation of the amount of materials regenerated or restored[160] [161]. Again, Blockchain, with the aid of smart technologies (IoT, big data analytics, …),

guarantees the authenticity of data, a key element to ensure the accuracy and reliability of the entire system. LCA may lead to better decision making at many levels, improving the capability to improve supply chain's performance.

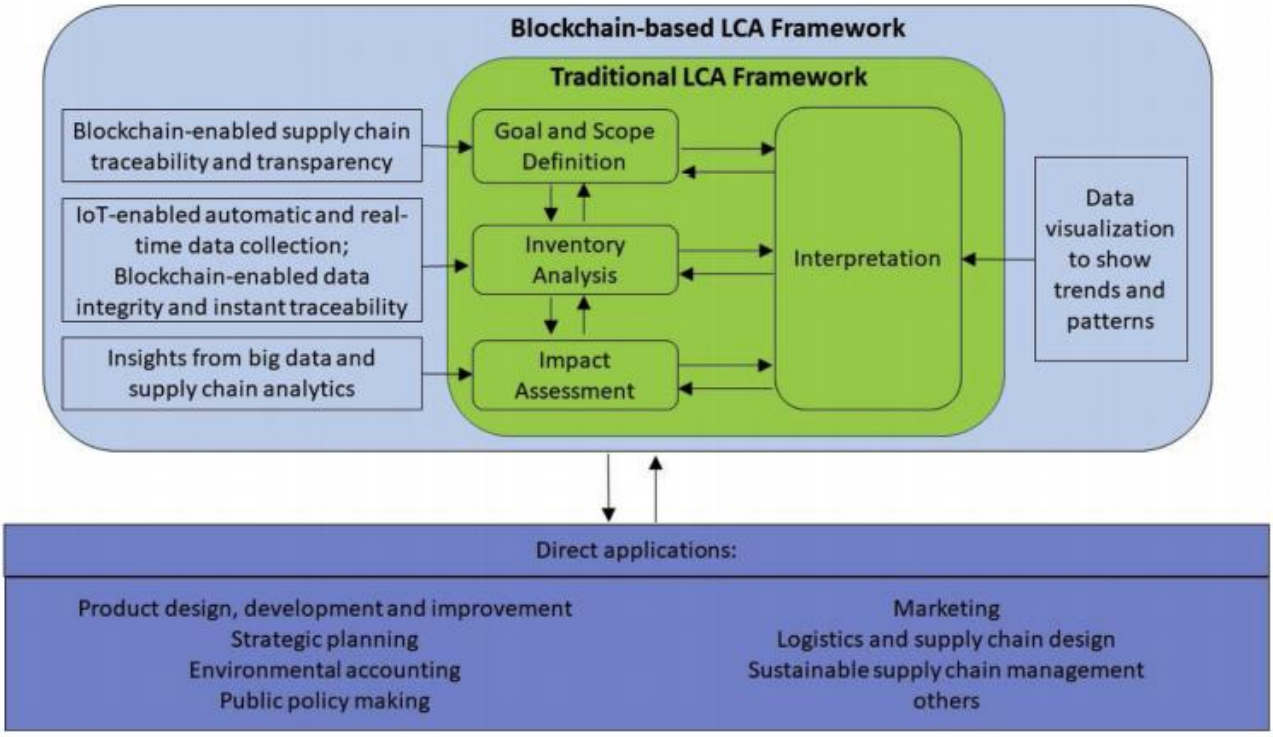



*Figure 46 - Blockchain-Based LCA Framework*[162]

## Reverse Logistics

Logistics is fundamental for supply chain that want to become circular and Reverse Logistics deserves particular attention, since it is the activity that, if well implemented, avoids products to end up landfilled or incinerated and stay in the loop. In the case of clothes, the main critical aspects in the implementation of Reverse Logistics are customer education, employees lack of education, and the scarce presence of an appropriate infrastructure. The influence that companies can have on customers has been explained in the chapter "Customer Collaboration", while employees' education has been discussed in the chapter "Worker Transformation". Here, the infrastructure to be built to facilitate Reverse Logistics will be described.

Clothes can avoid being landfilled or incinerated in different ways in a circular business model:

- They can be shared among different users, with or without the need of an intermediate, to maintain or prolong products' value
- They can be resold or rented, usually through a service provider, to reuse what still has useful life left

- They can be remanufactured or refurbished, in order to take advantage of a product that has already been produced, and requires much less energy, and materials, than a completely new product (remanufacture = disassemble and rebuild; refurbish = repair)
- They can be recycled, exploiting materials that have already been introduced in the loop, without the need of substituting those materials with others that are new, or adding new materials to the supply chain.

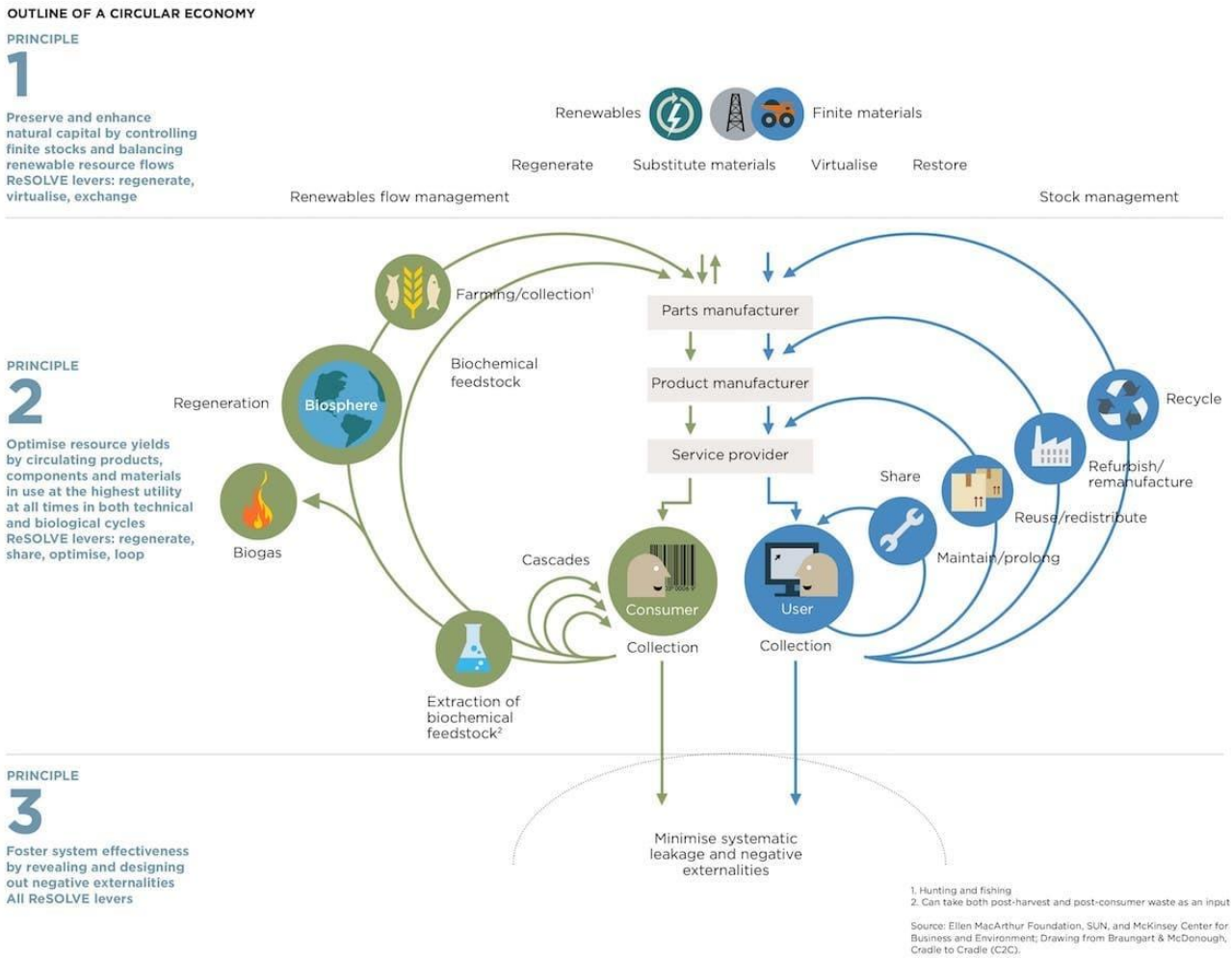



*Figure 47 - The Circular Economy System Diagram*[163]

In order to make every of these 4 different options possible, collaboration among the different players of the industry is key. Large companies, as well as SMEs, must build strategic partnerships to maintain clothes value in the supply chain. For example, collaborations with innovative start-ups like Ambercycle may become a way to efficiently develop new solutions. Ambercycle is a disruptive start-up in the plastic sector that engineered microbes that are able to degrade PET (the most used plastic in the world) and polyester from old textiles (polyester are the most used fibres in the world) into its

chemical constituents[52]. This could solve two problems at the same time: avoiding plastic being dispersed into the environment or being incinerated, and avoiding non-renewable materials from being used, since the new secondary raw material will be all the plastic and synthetic textiles already in the loop. Other collaborations should look at experts in textile waste stream management, like I:CO. I:CO is a company that offers a systematization of access to materials on an industry-wide basis, enabling economies of scale to be achieved, justifying the investment in recycling logistics and infrastructures. I:CO forms partnerships with different retailers, installing in-store collection bins. Consumers exchange their used clothes or shoes with a reward that can be used in the retailer's store. Collected garments are sold to I:CO an then collected and transported to the nearest I:CO's partner sorting and recycling facility. Sorting is carried out by hand, according to the international waste hierarchy where reuse comes before recycling. Clothes that are selected as "reusable" are sold in the second-hand market, while the rest of the products remain in the closed loop, thanks to recycling technologies available through collaborations with other entities. The recycled fibres are spun into yarns and sold to I:CO's partners. If products are not suitable for recycling, they are directed to uses for other industries (for example for the production of insulated materials in the automotive and construction sector).

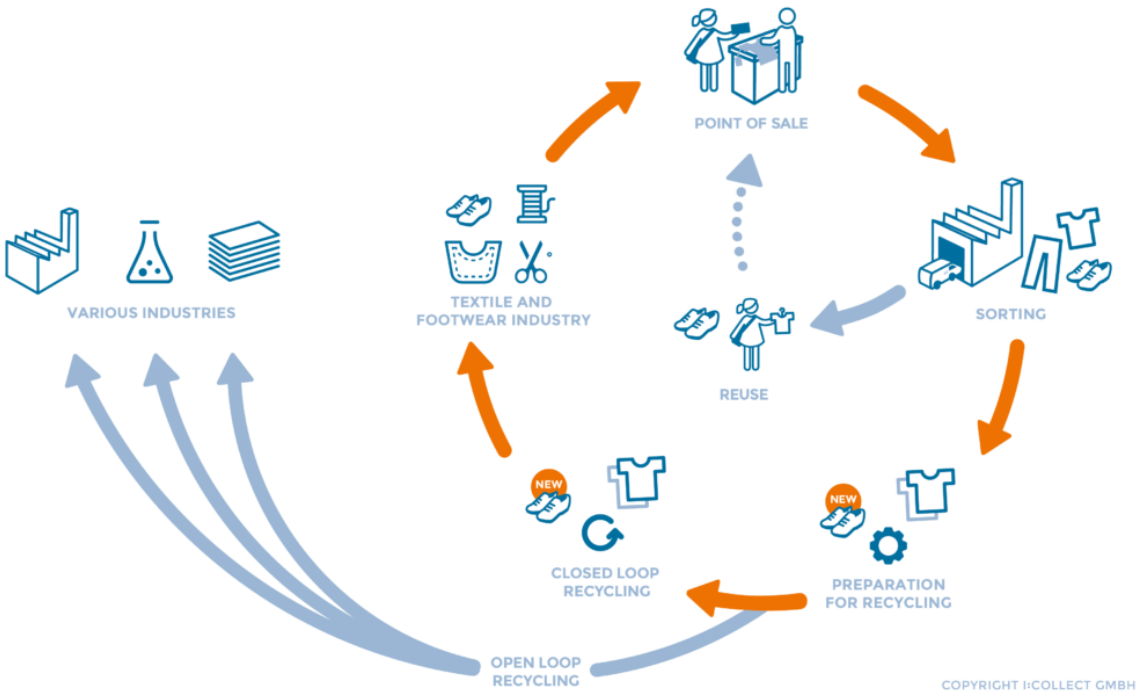



*Figure 48 - I:CO's Supply Chain*[164]

It is evident that Reverse Logistics involves exchanges that go beyond organizational boundaries, hence requiring the building of collaboration, and a strong network of diverse players from different sectors[165].

RFID technology can be also useful in the Reverse Logistics, and its implementation can address two aspects:

- **Recycle:** RFIDs can bring with them information about garments, like the composition and the different processes it went through during its lifecycle. Knowing these information, the identification of easily-recyclable products is made more efficient and effective at the sorting facility. Once the product has been collected, RFIDs enable the almost completely automated process of sorting, leaving to the workers the only job to determine the quality of the product (since technologies for the recognition of the level of wear are still not highly developed and are still too expensive). The products can therefore be divided firstly depending on their quality (data that is rapidly submitted by operators through a smartphone or a similar device) in order to divide products that can be sold in the second-hand market from those that are going to be recycled; then the products that are going to be recycled go through another inspection, that will divide them based on their composition. The information related to their materials is received from the scan of RFIDs. The products are transported on smart conveyor rollers that are able to move products based on the information received by sensors. Once clothes end up in their respective category, the information is uploaded into company's ERP, and then shared through cloud or Blockchain technology. Companies that use recycled materials as raw materials can now see in real time where and what materials are available, as well as who is keeping those materials, and hence make a request to buy depending on their needs. This system would facilitate the match between offer and demand of recycled products, through a real-time share of information that favours both. It would also reduce operating costs, increase the amount of used textiles recycled, enable consumers to know where their products end up. Recycling, compared to the production from virgin materials, may reduce chemical use by 88%, save 99% of water and reduce energy consumption by up to 53%[89].
- **Repair:** Warranty-covered products can be tagged with RFIDs, thus helping customers to know if their products can still be repaid for free. This could increase the number of customers that take advantage of the repair service, reducing the amount of products discarded.

Recycling facilities should not be the first option to opt for when deciding to which step of the supply chain products should be returned to, especially if the product can still be used at its current state. Recycling is in fact the last option among the 3 Rs proposed by the Circular Economy model. Even repairing and upcycling services usually lead to more significant energy and resource savings.

The following chapter will focus on a different business model that requires different customer behavioural patterns which may further reduce the impact of clothes by reducing products bought and use them as long as they have useful lifetime left: Product as a Service.

## Product as a Service

New business models are emerging in the Fashion Industry in response to unsustainable practices. This is also due to the fact that it is not easy to work with used clothes at various stages of wear, especially in lack of automation systems like the one described in the previous chapter, and sometimes recycling, upcycling or repairing are not possible. Companies that think in terms of "job to be done" instead of "product to offer" completely changes the way to approach customers, which are increasingly looking for buying a desired function rather than a specific product. Here is where companies that offer Products as a Service (PaaS) are capitalizing these opportunities in new business strategies. Differently to Sharing Platforms, where the ownership of the product belongs to users, in PaaS models companies usually are the ones that retain ownership of products and offer them to a multitude of users. In order to make it possible, the product must be designed in a way that enables multiple uses (built to last), and also facilitates maintenance, remanufacturing and recycling. It is a disruptive change compared to the Fast Fashion model, where products are designed to last a limited number of wears. Customer benefit from this new business model since products' performance costs significantly less compared to buying a new product, and people who like being trendy can update their style at a lower cost. However, products used in this business model are usually designed to be "evergreen" products, in order to make the revenue stream last longer. Companies gain more control over products, which are returned by users after use, and inspected to check if repair or maintenance are needed, and then put back in service. Once products reached the end of their lifetime, they can be sent to recycling facilities and be used to make new fibres. This model makes users' and service-providers' needs meet: they are both looking for long-lasting, high-quality products, which guarantee long-term profitability to providers, also due to increased customer engagement, while assuring cost reduction to customers. The frequent provider-customer interactions that the PaaS model implies, may lead to the generation of additional revenues through add-on sales and services and the development of better products through customer's feedbacks.

In the Fashion Industry, an example of PaaS model is clothing libraries, where, paying a monthly membership, users are allowed to use a limited number of clothes for a limited time span. Clothing libraries augment the productive life of garments, reducing the production of additional clothes and the environmental impact related to their production and disposal[166]. However, the savings from an

environmental point of view are dependant on the means of transport used to move goods from the clothing library to users and backwards, which risk offsetting the gains of clothing libraries implementation. This is why it is important the provider takes charge of logistics, through green logistics, or promotes non-polluting pick-ups (by walk or bike). A study carried out by Zamani et Al. (2017) demonstrated that, with regard to $CO_2$ Emissions related to each singular use of a T-shirt, a clothing library where certain conditions are met (Scenario 6 in Figure 49: service life extended by a factor of 4, user moves by foot or bike, the setup is an online store with a pick-up point for deliverables) guarantees a cut by 68% (compared to a traditional scenario: Baseline in Figure 49). Similar results are achieved if the products involved are a pair of jeans or a dress.

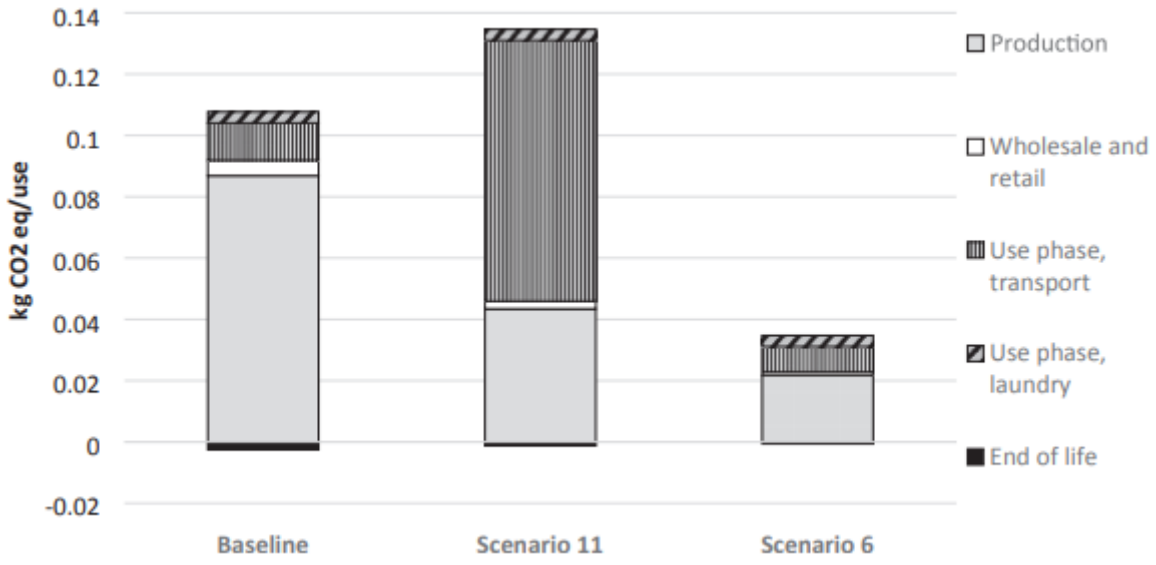



*Figure 49 - Global Warming Potential of Different Scenarios*[166]

Besides, clothing libraries may reduce their impact on the environment by installing microfiber filters to washing machines in order to prevent synthetic fibres to pollute while being washed. Clothing libraries may also be a place where overstock can flow instead of being landfilled or incinerated.

Thanks to 3D printing, we could experience the appearance of a phenomenon that is already in use for other products: 3D Hubs. Customers may be able to login into the company's website, buy a file that represent a garment, order the printing of that garment and pick it up at the store or receive it directly at home. Otherwise, creators may be able to print their clothes in 3D hubs, or customers may buy garment-files online and print them in 3D Hubs as well or directly at their home if they are 3D printer owners. All these solutions would eliminate overproduction, since products are only produced when ordered, and may reduce GHG emissions related to transportation, as well as energy and resources consumption related to production. Recycling facilities may introduce technologies that

enable the cost-effective recycling of products produced by 3D Printers in order to avoid those products to end in landfills or incinerators.

# Conclusion

This thesis wants to open new opportunities and bring a new vision for an Industry that is frequently attacked for its unsustainable practices. Many solutions have been presented, but obviously they are not exhaustive and new technologies are continuously emerging, as well as innovative applications for existing ones. Form Figure 49 of the previous chapter, it can be depicted that the phase with the biggest impact on the environment is production, hence it should also be the one to be redesigned first. Kering Economic Profit & Loss (EP&L) analysis confirms that production is where most of the polluting activities take place, and more specifically, Raw Material Production is the SC phase with the biggest impact.

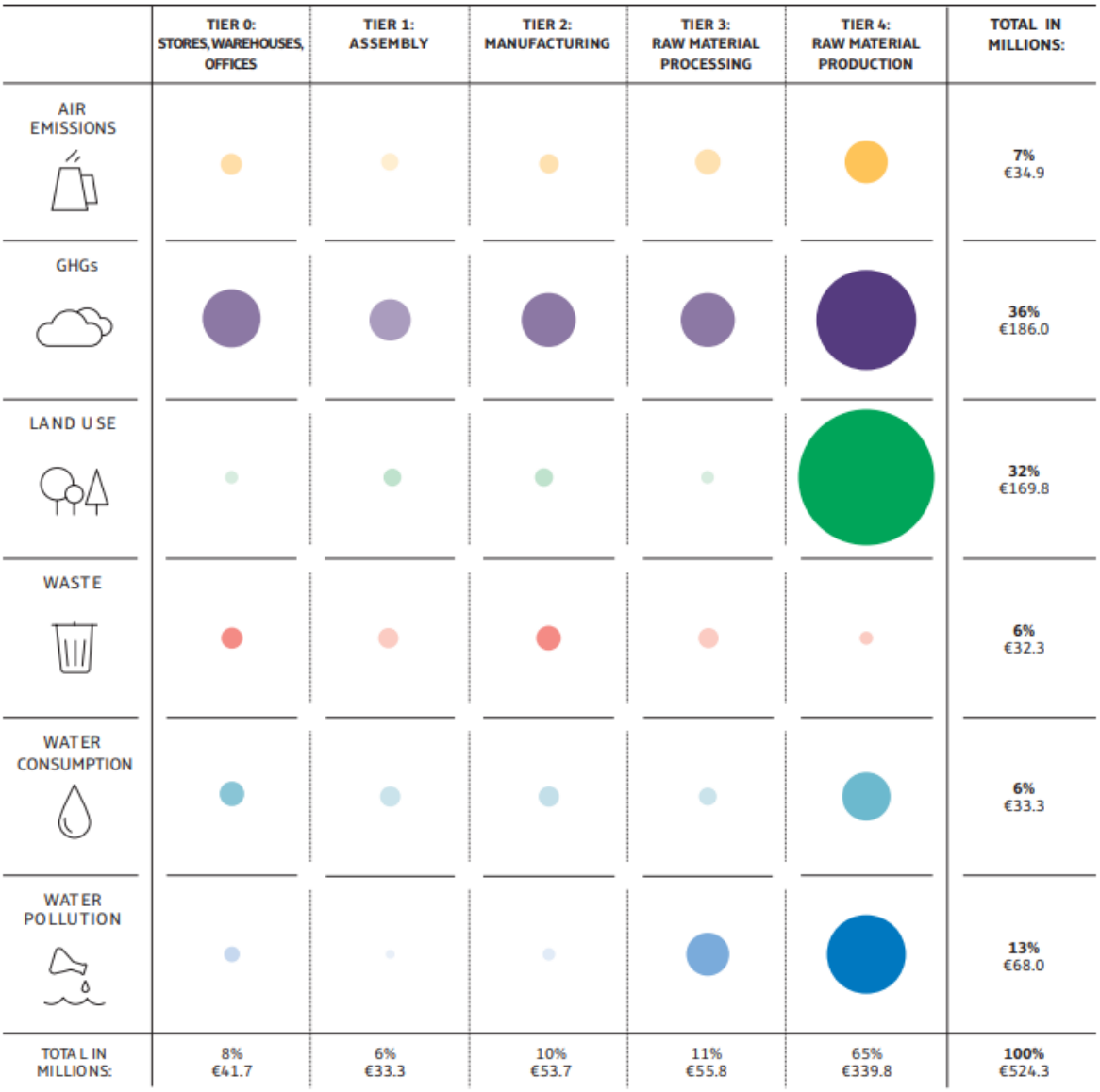



*Figure 50 - Kering Group EP&L Group Results 2019*[4]

Even if Kering belongs to the Luxury sector, similar results can be observed for other companies of the Fashion Industry[167] [168]. This evidences the need to deeply investigate eco-friendly materials, and the importance of design, which has an influence on materials' and suppliers' selection, to guarantee products' lifecycle impact is monitored and reduced. Materials like Tencel, which shows significant lower impacts on the environment compared to cotton and polyester, should be preferred[169]. But there should be a continuous investment in R&D for innovative and sustainable materials. Recycled fibres guarantee a reduction on the environmental footprint, especially if the corresponding virgin materials has a substantial repercussion on nature. Stella McCartney was able to phase out high-impact virgin cashmere with recycled one, reducing the proportion of impact associated with it from 28% in 2014 to 5% in 2017. So, focusing on the most damaging materials first, can lead to outstanding ameliorations, which is difficult to achieve when addressing company's effort to lower impact products or activities.

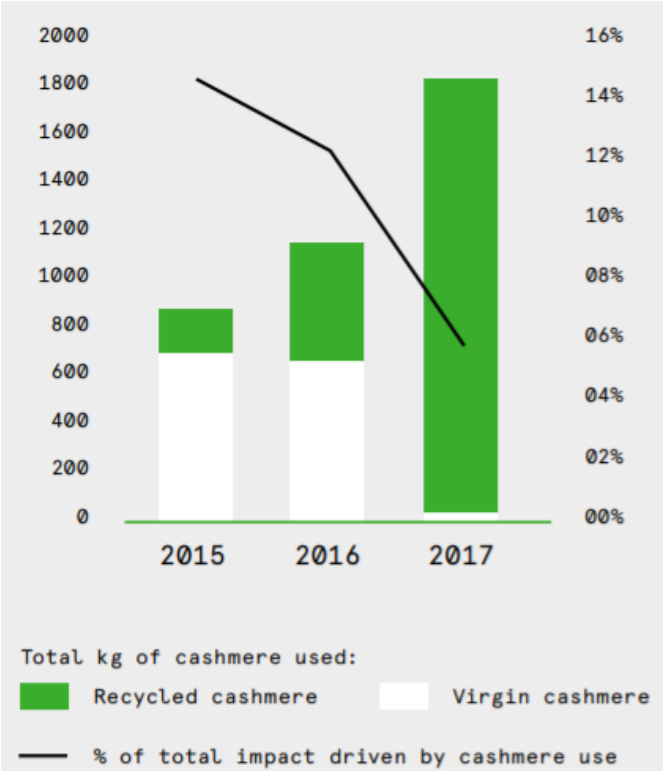



*Figure 51 - Stella McCartney Improvements: Kg of Cashmere Used vs. % of Total Impact Driven by Cashmere (2015 - 2017)[168]*

Innovative ways of producing clothes can also be applied: it has been seen that 3D Printing can bring substantial changes and improvements to the Fashion Industry. The production phase is also where human rights are most frequently violated, hence additionally justifying the attention Supply Chain Managers must devote to it. Moreover, renewable energy and natural resources should be preferred to further reduce the impact of the whole SC.

However, what must be clear at this point of the thesis, is that no silver bullet can be identified to solve the deep-rooted unsustainability of the Industry. All the opportunities proposed throughout the thesis are not independent, instead, they are deeply interconnected and can provide synergies if applied simultaneously. For example, Transparency and Traceability may help monitoring, measuring and controlling, but improvement measures must be implemented if labours conditions wants to be saved, or water pollution wants to be avoided, perhaps by changing production processes or raw materials. Transparency also means not only companies know what is happening throughout their SCs, but customers become more aware of the impact their clothes have on the environment, on society, and on economy. Transparency may eventually push customers to collaborate with companies, governments, and NGOs to build a fairer, cleaner, and safer fashion industry. At the same time, it may also help reduce clothing consumption, which should be the preferred behavioural pattern, since it is the one that leads to the biggest reduction on resource consumption. In fact, future studies should further investigate how to induce customers to adopt more sustainable behavioural patterns and to be more conscious on what lies behind a product, namely garments, in addition to foster clothes-sharing between users. In fact, the reuse of 1 ton of garments requires 2.6%, if made of cotton, and 1.8%, if made of polyester, of the energy used to manufacture them from virgin materials.

The importance of coordination between all the actors has been deeply analysed, and this empowers Supply Chain Managers who will be the creators of a productive network, being responsible for the sustainability of the partnerships, which will be the building blocks of a new Supply Chain. In fact, besides the different changes that can occur at an operational level, there is a fundamental need to embed sustainability in the relationships that build the Network. At the same time, Supply Chain Managers must also make sure that the vision and goals of the SC matches the internal objectives, in order to grow the potential gains. They are also responsible for the smooth unfolding of operations, and must act when there is a misalignment between targets and current measured KPI. These kind of interventions are usually reduced when both vertical and horizontal integration are achieved. Technologies like Blockchain and RFID make the monitoring of the whole SC more efficient and effective, but the building of cross-functional teams, not only inside the company but also outside its walls, may be a key aspect to obtain better results, since it enables the creation of a collaborative environment where the performances of individuals, processes, and organizations are enhanced. In addition, Supply Chain Managers must be able not only to deal with suppliers, but also to interface customers and their needs: this new capability will lead to improvements that lay beyond the relation with customers, since end-users requirements influence the whole SC. Interpersonal skills will be fundamental to deal with customers, as well as with cross-functional teams. Building connections inside and outside their own company, Supply Chain Managers will be able to take into account the

total costs and impacts of operations, helping them to make better decisions which aim at benefitting the whole SC's shareholder and stakeholders, and not only the focal company or singular functional divisions. In the end, People will still be at the centre of SC.

What needs to be investigated in future studies is the role of governments and policymakers in the switch from a linear to a circular economy. As stated multiple times throughout the thesis, collaboration is key for the effective implementation of a completely new business model, and institutions can not be exempt from cooperating. First of all, governments should act as facilitators of the transition to a circular model: linear models should be disadvantaged, for example, by changing taxation schemes. Circular economy strongly relies on talents, but higher taxes to be paid on employees compared to virgin resources favours the linear economy. Moreover, the "polluters pay principle" may be implemented: instead of paying to be certified as Fair Trade, or to be acknowledge as a sustainable business, companies which are not aligned with sustainable principles should pay a fine. This would decrease the attractiveness of garments produced unsustainably, favouring circular companies. In addition, other solutions, like carbon tax, have been explored, which may favour local sourcing and geographical specialization, leading to circular industrial hubs. Institutions not only have an important role in taxes-related issues, as it has been described in the "Macrolotto 1" example, but they are also key players in supporting the development of highly skilled workers and the creation of synergies between companies and other agents (like universities or banks). Institutions should also cooperate at an international level to favour a standardization of circular practices and avoid companies to move where linear economies are still favoured. In addition, a product passport should be implemented to promote the recycling and reuse of products: RFID is one of the technologies that has been investigated in this thesis which could be used with this aim, but other enablers may be found. While the private sector must decide which information to be included and must establish standards, governments may support the adoption of product passport through incentives and rules, and lead to an industry-wide and international adoption. Sector-specific measurement methodologies may additionally foster its adoption. Many have already been developed, but actors should agree on a single set of methods and be shared it among all the actors involved in the SC. In fact, the responsibility of the change to a circular model should be shared among customers, suppliers, focal firms, and institutions, since everyone is accountable for the unsustainability of the Industry.

Circular Supply Chains are made of many changes, all of which are important and dependant on each other, this means that there is the need to act in multiple areas at the same time. Sustainability, and in particular Circularity in the Fashion Industry not only are possible, but they also are economically, socially and environmentally favourable. The unsustainability of the Fashion Industry may lead to a

point of no-return, not only for the sector, but for the whole planet. The time to change is now, and circular solutions are already available and operating. New ones are coming, and working on their development and implementation will be a continuous challenge, but it will also lead to an enormous benefit for all the stakeholders.

# Figures Index

# References


[1] Fernie, J., Sparks L., Logistics and Retail Management: Insights Into Current Practice and Trends from Leading Experts (2004)

[2] BOF, McKinsey & Company, "The State of Fashion 2019" (November 29, 2018)

[3] https://www.worldbank.org/en/news/feature/2019/09/23/costo-moda-medio-ambiente

[4] Kering Group (2020), ENVIRONMENTAL PROFIT & LOSS (EP&L) 2019 Group Results

[5] https://www.kering.com/it/finance/about-kering/

[6] The Carbon Trust. International carbon flows. Clothing. CTC793. Trust https://prod-drupal-files. storage.googleapis.com/documents/resource/public/ International%20Carbon%20Flows%20-%20 Clothing%20-%20REPORT.pdf (2011).

[7] https://www.wbur.org/hereandnow/2019/12/03/fast-fashion-devastates-environment

[8] Déri, E., Challenges of Environmental and Social Responsibility in the Fashion Industry (2013)

[9] http://www.oit.org/global/topics/geip/WCMS_614394/lang--en/index.htm

[10] McKinsey & Company, Style that's sustainable: A new fast fashion formula (*2016), https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/style-thats-sustainable-a-new-fast-fashion-formula*

[11] Bhardwaj, V., & Fairhurst, A. (2014). Fast fashion : Response to changes in the fashion industry, (February 2010). *https://doi.org/10.1080/09593960903498300*

[12] National Post. 2009. Fast fashion. http://trendwatching.com/about/inmedia/articles/2009_ fast_fashion.html

[13] Remy, Speelman, and Swartz, "Style that's sustainable: A new fast-fashion formula

[14] https://digital.hbs.edu/platform-rctom/submission/reforming-retail-reformations-fashion-forward-approach-to-sustainability/

[15] Circular Fibres Initiative analysis based on Euromonitor International Apparel & Footwear 2016 Edition (volume sales trends 2005–2015). All numbers include all uses until the garment is discarded, including reuse after collection and resale.

[16] https://ourworldindata.org/world-population-growth

[17] https://ourworldindata.org/grapher/absolute-increase-global-population

[18] Chapagain, A., Hoekstra, A., & Savenije, H. H. G. (2005). The Water Footprint of Cotton Consumption The water footprint of, (May 2014).

[19] Mead, B. and Cataldi, C. (2013) Fast Facts: Water and Chemical Management, Textile Exchange (2013) Available online at:http://info.textileexchange.org/Portals/135316/docs/2013.27.03-Webinar-FastFacts.pdf (accessed 05 May 2013).

[20] United Nations World Water Assessment Programme, The United Nations World Water Development Report 2015: Water for a Sustainable World, WWAP, Paris, UNESCO, 2015.

[21] Perry, P. (2020). The environmental price of fast fashion, (August). https://doi.org/10.1038/s43017-020-0039-9

[22] Georg Simmel , "Fashion", *International Quarterly*, 10, n. 1, October 1904, pp. 130-155; "Fashion", *American Journal of Sociology*, n. 62, 1957 [*Philosophie der Mode*, Pan-Verlag, Berlin 1905]. Quotations from this text are taken from the October 1904 translation, and labeled as *F*.

[23] Office of Solid Waste, United States Environmental Protection Agency. Municipal solid waste in the United States: Facts and figures (EPS, 2010)

[24] Cimatti, B., Campana, G., & Carluccio, L. (2017). Eco Design and Sustainable Manufacturing in Fashion : a Case Study in the Luxury Personal Accessories Industry. *Procedia Manufacturing*, *8*(October 2016), 393–400. https://doi.org/10.1016/j.promfg.2017.02.050

[25] Reena, S.P.; Aswathi, M.A.; Anand, S.R.M.; (2020). Planned Fashion Obsolescence In The Light Of Supply Chain Uncertainty, Academy of Strategic Management Journal , *Volume 19, Issue 1, 2020.*

[26] Saicheua, V., Knox, A. & Cooper, T. (2012). Sustainability in clothing supply chain – implications for marketing. In proceedings of the 37th macromarketing conference (pp. 284–307) 13–16 June, Freie Universitat, Berlin

[27] Turker, D., & Altuntas, C. (2014). Sustainable supply chain management in the fast fashion industry : An analysis of corporate reports. *European Management Journal*, *32*(5), 837–849. https://doi.org/10.1016/j.emj.2014.02.001

[28] International Labour Organization. (2016). Wages and productivity in the garment sector in Asia and the Pacific and the Arab States, 5(5), 1–8.

[29] Zhang, M., Kong, X. X., & Ramu, S. C. (2015). The Transformation of the Clothing Industry in China.

[30] J. Safra Sarasin Sustainable Investment Research. (2014). Supply Chains in the Clothing Industry – A House of Cards ?!

[31] Pookulangara, S., & Shephard, A. (2013). Slow fashion movement: Understanding consumer perceptions—An exploratory study. *Journal of Retailing and Consumer Services*, *20*(2), 200–206. https://doi.org/10.1016/j.jretconser.2012.12.002

[32] Hearle, C. (2016). Skills , Employment and Productivity in the Garments and Construction Sectors in Bangladesh and elsewhere, (October).

[33] https://www.wsj.com/articles/the-high-price-of-fast-fashion-11567096637

[34] Niinimäki, K. (2011). From disposable to sustainable: the complex interplay between design and consumption of textiles & clothing. Helsinki: Aalto university publishing.

[35] Ellen MacArthur Foundation, A new textiles economy: Redesigning fashion's future, (2017, http://www.ellenmacarthurfoundation.org/publications).

[36] Harrison, A., & Hoek, R. Van. (2008). *Logistics Management and Strategy*. Competing through the supply chain. 3rd edition

[37] Saini, R. D. (2018). Synthetic Textile Dyes: Constitution, Dying process and Environmental Impacts

[38] Olsson, E., Posner, S., Roos, S., Wilson, K., 2009. Kartläggning av kemikalieanvändning i kläder. Mölndal, Sweden.

[39] Roos, S. (2016). Advancing life cycle assessment of textile products to include textile chemicals

[40] José, J., Pérez, B., & Martín, Á. (2020). Traceability of Ready-to-Wear Clothing through Blockchain Technology, 1–21. https://doi.org/10.3390/su12187491

[41] Ghemawat, P., & Nueno J.L. (2006). ZARA : Fast Fashion. Harvard Business School

[42] https://www.inditex.com/

[43] https://www.inditex.com/how-we-do-business/our-model/design

[44] De Brito, M. P., Carbone, V., & Meunier, C. (2008). Towards a sustainable fashion retail supply chain in Europe : Organisation and performance, *114*, 534–553. https://doi.org/10.1016/j.ijpe.2007.06.012

[45] https://fashioninsiders.co/toolkit/business-basics/just-in-time-manufacturing/

[46] https://www.fastcompany.com/90311509/we-have-to-fix-fashion-if-we-want-to-survive-the-next-century

[47] https://www.nytimes.com/2018/03/27/business/hm-clothes-stock-sales.html

[48] World Economic Forum and Accenture (2012). More with Less : Scaling Sustainable Consumption and Resource Efficiency, (January). http://w2l.dk/file/401301/wef-more-with-less.pdf

[49] https://www.ft.com/content/95c54d66-5b68-11e0-b965-00144feab49a

[50] Rockström, J., W. Steffen, K. Noone, Å. Persson, F. S. Chapin, III, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. Foley. 2009. Planetary boundaries:exploring the safe operating space for humanity. *Ecology and Society* 14(2): 32. [online] URL: http://www.ecologyandsociety.org/vol14/iss2/art32/

[51] BOF, Mckinsey & Company (2020). The State of Fashion 2020 Coronavirus Update.

[52] BOF, McKinsey & Company, The State of Fashion 2020

[53] Kopczak, L. R., & Johnson, M. E. (2003). The Supply-Chain management Effect, 44(3). MITSloan Management Review

[54] Douglas M. Lambert, Martha C. Cooper and Janus D. Pagh, "Supply Chain Management: Implementation Issues and Research Opportunities," The International Journal of Logistics Management, Vol. 9, No. 2 (1998), pp. 1-19

[55] Christopher, Martin. Logistics and supply chain management : creating value-adding networks / Martin Christopher. -- 4th ed.

[56] Cousins, P. D. (2005). The alignment of appropriate firm and supply strategies for competitive advantage. *International Journal of Operations & production management*.

[57] Cooper, Martha C., Douglas M. Lambert and Janus D. Pagh, "Supply Chain Management: More than a New Name for Logistics," The International Journal of Logistics Management, Vol. 8, No. 1 (1997), pp. 1-14;

[58] Lambert, D. M., Cooper, M. C., and Pagh, J. D.: Supply Chain Manage- ment: Implementation Issues and Research Opportunities. The Interna- tional Journal of Logistics Management 9(2), 1–19 (1998)

[59] Hammer, M. (1990). Reengineering Work: Don't Automate, Obliterate. Harvard Business Review.

[60] Adapted from: Keely L. Croxton, Sebastian J. García-Dastugue and Douglas M. Lambert, "The Supply Chain Management Processes," The International Journal of Logistics Management, Vol. 12, No. 2 (2001), p.31.

[61] WCED (World Commission on Environment and Development). Our common future. Oxford: Oxford University Press; 1987.

[62] Elkington, J., cannibals with Forks: The Triple bottom line for 21st century business, Capstone Publishing, oxford, 1997.

[63] United Nations (2015). Transforming Our World: The 2030 Agenda For Sustainable Development A/Res/70/1. sustainabledevelopment.un.org

[64] https://www.un.org/sustainabledevelopment/news/communications-material/

[65] Lin, C. Y., & Ho, Y. H. (2008). An empirical study on logistics service providers' intention to adopt green innovations. Journal of Technology Management and Innovation, 3(1), 17–26.

[66] Zhu, Q., & Sarkis, J. (2007). Green supply chain management: pressures, practices and performance within the Chinese automobile industry. Journal of Cleaner Production, 15(2), 1041-1052

[67] Makmor, M. F. M., & Saad, M. (2017). Leadership and Management Commitment towards Logistics Performance Improvement in Malaysia with the Adoption of Green Logistics as the Moderating Variable. International Journal of Academic Research in Business and Social Sciences, 7(11), 751–764.

[68] Chrisostom, A. O., & Monari, F. (2018). Influence Green Logistics Management on Performance of registered Automotive Firms in Kenya. International Journal of Academic Research in business and Social Sciences, 8(4), 351–365.

[69] Oclu, B., Erdal, M. (2016). The Relationship Between Green Supply Chain Management And The Relationship Between Green Supply Chain Management And Firm Performance : A Study, (December 2016).

[70] Sbihi, A., Eglese, R. W.. Combinatorial optimization and Green Logistics. Annals of Operations Research, Springer Verlag, 2010, 175 (1), pp.159-175.

[71] https://www.mirror.co.uk/news/world-news/companies-being-blamed-most-plastic-13395103

[72] https://www.businesstimes.com.sg/consumer/fashion-brands-accused-of-exploiting-workers-at-risk-of-layoffs

[73] Terrany, N., & Tarigh, H. D. (2020). A survey on Sustainable Supply Chain Management, (September 2020).

[74] Gimenez, C., Sierra, V., & Rodon, J. (2012). Sustainable operations : Their impact on the triple bottom line. *Intern. Journal of Production Economics*, *140*(1), 149–159. https://doi.org/10.1016/j.ijpe.2012.01.035

[75] https://themasites.pbl.nl/tridion/en/themasites/hyde/basicdrivingfactors/population/index-2.html

[76] https://esa.un.org/unpd/wpp/Download/Standard/Population/

[77] Lacy, P., & Rutqvist, J. (2015). Waste to Wealth: The Circular Economy Advantage. In P. Lacy, & J. Rutqvist, Waste to Wealth: The Circular Economy Advantage (p. 6). Palgrave MacMillan.

[78] Jackson, T. 2009. Prosperity without growth: Economics for a finite planet, edited by Earthscan. London: Earthscan

[79] Kjaer, L. L., & Pigosso, D. C. A. (2018). Product / Service-Systems for a Circular Economy The Route to Decoupling Economic Growth from Resource Consumption ?, *23*(1). https://doi.org/10.1111/jiec.12747

[80] Ghisellini, P., Cialani, C., & Ulgiati, S. (2015). A review on circular economy : the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2015.09.007

[81] EU, 2008. Official Journal of EU, L 312, 19.11.2008. Directive 2008/98/EC of the European Parliament and of the Council of 19 november 2008 on waste and repealing certain directives. Available: http://eur-lex.europa.eu/LexUriServ/ LexUriServ.do?uri¼OJ:L:2008:312:0003:0030:en:PDF.

[82] Castellani, V., Sala, S., Mirabella, N., 2015. Beyond the throwaway society: a life cycle-based assessment of the environmental benefit of reuse. Integr. Environ. Assess. Manag. 11 (3), 373e382.

[83] Kirchherr, J., Reike, D., & Hekkert, M. (2017). Resources , Conservation & Recycling Conceptualizing the circular economy : An analysis of 114 definitions, 127(April), 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

[84] Braungart, M., McDonough, W., 2002. Cradle to Cradle: Remaking the Way We Make Things. North Point Press, New York, United States.

[85] Andersen, M.S., 2007. An introductory note on the environmental economics of the circular economy. Sustain. Sci. 2, 133e140.

[86] Van Berkel, R., Fujita, T., Hashimoto, S., Geng, Y., 2009b. Industrial and urban symbiosis in Japan: analysis of the Eco-Town program 1997e2006. J. Environ. Manag. 90, 1544e1556.

[87] Wrinkler, H., 2011. Closed-loop production systems e a sustainable supply chain approach. CIRP J. Manuf. Sci. Technol. 4, 243e246.

[88] Hammer, M., & Champy, J. (1993). Reengineering the corporation: A manifesto for business revolution. New York, NY: HarperBusiness.

[89] Denuwara, N., & Maijala, J. (2019). Sustainability Benefits of RFID Technology in the Apparel Industry, 1–14.

[90] Duroc, Y., & Tedjini, S. (2018). Comptes Rendus Physique RFID : A key technology for Humanity. *Comptes Rendus Physique*, *19*(1–2), 64–71. https://doi.org/10.1016/j.crhy.2018.01.003

[91] https://www.inditex.com/en/article?articleId=150174&&title=Inditex+deploys+RFID+technology+in+its+stores

[92]https://www.launchmetrics.com/it/risorse/blog/la-tecnologia-rfid-5-modi-in-cui-i-brand-della-moda-la-stanno-utilizzando

[93] Hastig, G.M.; Sodhi, M.S. Blockchain for supply chain traceability: Business requirements and critical success factors. Prod. Oper. Manag. 2020, 29, 935–954.

[94] Kalis, R., & Belloum, A. (n.d.). Validating data integrity with blockchain, (August 2018).

[95] https://hbr.org/2017/01/the-truth-about-blockchain

[96] I. Bashir, Mastering Blockchain: Deeper insights into decentralization, cryptography, Bitcoin, and popular Blockchain frameworks, Packt, ISBN 978-1787125445, 2017.

[97] T. Laurence, Blockchain for Dummies, John Wiley & Sons, May 2017, ISBN 978-1119365594.

[98] Fu, B., & Shu, Z. (2018). Blockchain Enhanced Emission Trading Framework in Fashion Apparel Manufacturing Industry, 1–19. https://doi.org/10.3390/su10041105

[99] S. Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System," 2008.

[100] https://www.hyperledger.org/learn/publications/walmart-case-study

[101] Khajavi, S. H., Partanen, J., & Holmstro, J. (2014). Additive manufacturing in the spare parts supply chain, *65*, Computers in Industry 50–63. https://doi.org/10.1016/j.compind.2013.07.008

[102] https://thestempedia.com/tutorials/getting-started-with-3d-printing/#Process

[103] Pasricha, A., & Greeninger, R. (2018). Exploration of 3D printing to create zero - waste sustainable fashion notions and jewelry. Fashion and Textiles. https://doi.org/10.1186/s40691-018-0152-2

[104] Kim, H. (2018). Market Analysis and the Future of Sustainable Design Using 3D Printing Technology, 23–35.

[105] Lussenburg, K., Velden, N. M. Van Der, Doubrovski, Z., & Karana, E. (2014). Designing with 3D Printed Textiles A case study of Material Driven Design, (October).

[106] https://news.nike.com/news/nike-flyprint-3d-printed-textile

[107] https://manufactur3dmag.com/how-nike-is-leveraging-3d-printing-in-the-footwear-industry/

[108]https://www.lead-innovation.com/english-blog/3d-printing-in-the-textile-industry#:~:text=The%203D%20simulation%20makes%20the,much%20faster%20to%20new%20trends.

[109] https://www.businessoffashion.com/articles/news-analysis/adidas-trials-customer-personalisation-in-bid-to-tackle-fast-fashion

[110] https://www.knittingindustry.com/adidas-explores-localised-production-with-knit-for-you-popup-store/

[111] https://www.patagonia.com/stories/letter-from-tuscany-where-we-get-our-used-wool/story-73510.html

[112] Kooistra, K.J., Pyburn, R., Termorshuizen, A.J., 2006. The sustainability of cotton - Consequences for man and environment. Wageningen, The Netherlands.

[113] Oral, E. (2019). Sustainability Challenges of Fast Fashion: Environmental and Social Impacts of Cotton Growing and the Ready-Made Garment Industry in Turkey, *34*(3). https://doi.org/10.20473/ydk.v34i3.14937

[114] Angelova, R. A. (2019). Organic Cotton : Technological and Environmental Aspects (March 2019).

[115] Shen, B. (2014). Fashion Supply Chain: Lessons from H&M, 6236–6249. https://doi.org/10.3390/su6096236

[116] https://www.tencel.com/sustainability

[117] https://ecovadis.com/it/

[118] https://www.tencel.com/fiber-story

[119] https://www.lenzing.com/sustainability/production/resources/chemicals

[120] https://www.lenzing.com/sustainability/production/technologies

[121] https://www.ananas-anam.com/

[122] https://web.archive.org/web/20130824034632/http://www.crailar.com/revolution

[123] Rieple, A., & Singh, R. (2010). A value chain analysis of the organic cotton industry : The case of UK retailers and Indian suppliers. *Ecological Economics*, *69*(11), 2292–2302. https://doi.org/10.1016/j.ecolecon.2010.06.025

[124] Beth S, Burt DN, Copacino W, Gopal C, Lee HL, Lynch RP, Morris S. Kirby, J. Supply chain challenges. building relationships. Harv Bus Rev. 2003 Jul;81(7):64-73, 117. PMID: 12858712.

[125] Circular Economy Action Plan, For a cleaner and more competitive Europe. EU, 2020

[126] Pal, R., Shen, B., Sandberg, E. (2019). Circular fashion supply chain management: exploring impediments and prescribing future research agenda. Journal of Fashion Marketing and Management Vol. 23 No. 3, 2019 pp. 298-307 © Emerald Publishing Limited 1361-2026 DOI 10.1108/JFMM-07-2019-166

[127]European Commission (2014) Ecodesign your future: How Ecodesign can help the environment by making products smarter. Available at: https://op.europa.eu/en/publication-detail/-/publication/4d42d597-4f92-4498-8e1d-857cc157e6db#

[128] Franceschini, F. (2001) Advanced quality function deployment. St. Lucie Press

[129] https://www.patagonia.com/stories/from-shirt-to-dirt-thoughts-on-the-patagonia-design-philosophy/story-33153.html

[130] https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5a4fed46f&appId=PPGMS

[131] Roberto Verganti, "User-Centered Innovation Is Not Sustainable," Harvard Business Review Blogs, https://hbr.org/2010/03/user-centered-innovation-is-no (accessed November 18, 2020)

[132] Norman, D. A., & Verganti, R. (2014). Incremental and Radical Innovation : Design Research vs . Technology and Meaning Change, 30(1). https://doi.org/10.1162/DESI

[133] Kristina B. Dahlin and Dean M. Behrens, "When Is an Invention Really Radical? Defining and Measuring Technological Radicalness," Research Policy 34 (2005): 717–37.

[134] Manenti, P., The Future of Manufacturing, SCM World, October 2014

[135] ILO (2016a) Progress and Potential: How Better Work is improving garment workers' lives and boosting factory competitiveness, International Labour Organization

[136] Adhvaryu, A., Kala, N. and Nyshadham, A. (2016) The Skills to Pay the Bills: Returns to On-the-job Soft Skills Training, Centre for Economic Policy Research

[137] KfW DEG (2016) Bridging the skills gaps in Bangladesh: JMS Holdings Ltd.—A Bangladeshi garment manufacturer boosts its productivity through workforce development, KfW DEG

[138] Nanda, P., Mishra, A., Walia, S., Sharma, S., Weiss, E. and Abrahamson, J. (2013) Advancing Women, Changing Lives: An Evaluation of Gap Inc.'s P.A.C.E. Programme, International Centre for Research on Women

[139] Meyerson, J. (2007). RFID in Supply Chain: A Guide to Selection and Implementation, Taylor & Francis Group, New York.

[140] Shiau Wei Chan, Tasmin, R., A. H. Nor Aziati, Raja Zuraidah Rasi, Fadillah Binti Ismail, Li Ping Yaw (2017) Factors Influencing the Effectiveness of Inventory Management in Manufacturing SMEs. IOP Conf. Ser.: Mater. Sci. Eng. 226 012024

[141] https://mis320final.home.blog/2019/03/14/mis-320-final-project/

[142] Nayak, R. Radio Frequency Identification (RFID) Technology and Application in Fashion and Textile Supply Chain; CRC Press: Boca Raton, FL, USA, 2019.

[143] Bullòn Perez, J. J., Queiruga-Dios, A., Martìnez, V.G., Rey del, A. M. (2020). Traceability of Ready-to-Wear Clothing through Blockchain Technology, 1–21. https://doi.org/10.3390/su12187491

[144] Podcast: Exploring Supply Chain Reselience in Navigating COVID an Beyond & the Wicked Debate of Sustainability Versus Circular Economy w/ James George of the Ellen MacArthur Foundation (26 July 2020), Supply Chain Revolution. 16 min

[145] Choi, T. (2013). Local sourcing and fashion quick response system : The impacts of carbon footprint tax q. Transportation Research Part E, 55, 43–54. https://doi.org/10.1016/j.tre.2013.03.006

[146] Hvass, K. K., Rahbek, E., & Pedersen, G. (2019). Toward circular economy of fashion. Experiences from a brand's product take-back initiative, *23*(3), 345–365. https://doi.org/10.1108/JFMM-04-2018-0059

[147] Jia, F., Yin, S., Chen, L., & Chen, X. (2020). The circular economy in the textile and apparel industry : A systematic literature review. *Journal of Cleaner Production*, *259*, 120728. https://doi.org/10.1016/j.jclepro.2020.120728

[148] McKinsey New Age of the Consumer US Survey - 2019

[149] https://www.cgsinc.com/sites/default/files/media/resources/pdf/CGS_2019_Retail_Sustainability_infographic.pdf

[150] Kabukcu, E. (2017). RFID adoption for agility in the fashion business. Journal of Management, Marketing and Logistics (JMML), V.4, Iss.3, p.209-216. http://doi.org/10.17261/Pressacademia.2017.482

[151] New, S., and R. Westbrook (2004) Understanding Supply Chains: Concepts, Critiques and Future (Oxford, UK: Oxford University Press)

[152] Chertow, M.R. 2000. Industrial symbiosis: Literature and Taxonomy. Annual review of energy and the environment, 25(1), 313-337. https://doi.org/10.1146/annurev.energy.25.1.313

[153] Cainelli, G.; Mazzanti, M.; Montresor, S. 2012. Environmental Innovations, Local Networks and Internationalization. Industry and Innovation, 19(8), 697-734. https://doi.org/10.1080/13662716.2012.739782

[154] Cainelli, G. 2008. Spatial agglomeration, technological innovations, and firm productivity: Evidence from Italian industrial districts. Growth and Change, 39(3), 414-435. https://doi.org/10.1111/j.1468-2257.2008.00432.x

[155] http://www.conseronline.it/?page_id=120

[156] Mazzoni, F. 2020. Circular economy and eco-innovation in Italian industrial clusters. Best practices from Prato textile cluster. Insights into Regional Development, 2(3), 661-676. https://doi.org/10.9770/IRD.2020.2.3(4)

[157] CONSER 2009. Rapporto ambientale e sociale anno 2009. http://www.arpat.toscana.it/notizie/arpatnews/2010/allegati/086-Conser-rappambsoc.pdf

[158] https://www.ananas-anam.com/about-us/

[159] http://orangefiber.it/impact/

[160] Genovese, A., Acquaye, A.A., Figueroa, A., Koh, S.C.L., 2017. Sustainable supply chain management and the transition towards a circular economy: evidence and some applications. Omega 66 (Part B), 344–357.

[161] Muhammad Farooque, Abraham Zhang, Matthias Thürer, Ting Qu, Donald Huisingh (2019) Circular supply chain management: A definition and structured literature review, Journal of Cleaner Production, Volume 228, Pages 882-900, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2019.04.303.

[162] Zhang, A., Zhong, R. Y., Farooque, M., Kang, K., & Venkatesh, V. G. (2020). Blockchain-based life cycle assessment : An implementation framework and system architecture. *Resources, Conservation & Recycling*, *152*(May 2019), 104512. https://doi.org/10.1016/j.resconrec.2019.104512

[163] https://www.ellenmacarthurfoundation.org/explore/the-circular-economy-in-detail

[164] https://www.ico-spirit.com/en/services/

[165] Pal, R. (2017), "Value creation through reverse logistics in used clothing networks", International Journal of Logistics Management, Vol. 28 No. 3, pp. 864-906.

[166] Zamani, B., Sandin, G., & Peters, G. M. (2017). Life cycle assessment of clothing libraries : can collaborative consumption reduce the environmental impact of fast fashion ? *Journal of Cleaner Production*, *162*, 1368–1375. https://doi.org/10.1016/j.jclepro.2017.06.128

[167] https://about.puma.com/en/sustainability/environment/measuring_environmental_footprint

[168] https://www.stellamccartney.com/cloud/smcwp/uploads/2020/09/EcoImpact_2020.pdf

[169] Shen, L., Worrell, E., & Patel, M. K. (2010). Resources , Conservation and Recycling Environmental impact assessment of man-made cellulose fibres. "Resources, Conservation & Recycling," 55(2), 260–274. https://doi.org/10.1016/j.resconrec.2010.10.001