Enabling Industry 4.0 Skills in Textile SMEs

Social Implications of Textile 4.0

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1. Introduction to Textile 4.0

The term “Textile 4.0” refers to the transformation of the textile industry to a constantly higher level by utilizing the maximum technological advancements in automation, digitalization and interconnected systems. It is directly associated with concepts such as artificial intelligence (AI), Internet of Things (IoT), 3D printing, robotics and big data that allow customization and promote sustainability while promoting efficiency.

The social implications of Textile 4.0 present a wide range as they cover various aspects of society such as employment, environment, economy, culture and consumer behaviour. In terms of labour, there is a great chance that automation and AI could lead to the displacement of traditional, low-skilled jobs and the simultaneous rise in the number of job roles that require above-average technological skills and knowledge. Regarding the environmental impact, Textile 4.0 and its methods of deliverance seem to have a positive effect as advanced technologies promote a circular economy, waste management and resource-efficient production methods. Economically speaking, the revolution that Textile 4.0 brings can have negative ramifications for small businesses as they struggle to adopt costly technological advancements. On the other hand, this forward motion can offer cost reductions and increased productivity to the industry. Additionally, such technological development in the industry allows personalization in production and drives customer demand for more sustainable methods and materials and therefore undermines the “fast-fashion effect”.

There is a new landscape forming in the textile industry. The sector faces significant challenges and opportunities at the same time as it must ensure that the technological advancements used to benefit workers, businesses and consumers on the same level while retaining their ability to drive innovation and promote sustainability.

1.1 Objectives

This course aims to explore how Textile 4.0 has affected the industry and society from a social aspect, especially in terms of employment, workforce rights and working conditions, consumer behaviour, sustainability, cultural identity and socio-economic inequalities. The course has been designed in a way that will help learners:

- Understand the concept of Textile 4.0
- Examine the impact it has on employment and labour market changes
- Investigate how emerging technologies influence workplace conditions and labour rights
- Analyze how digitalization, automation and AI are reshaping consumers’ environmental consciousness and preferences

- Explore the contribution of technological advancements in promoting a circular economy within the industry
- Examine how technological innovations of the sector influence cultural heritage
- Explore the ethical considerations Textile 4.0 brings to labour exploitation, equal access to new technologies and fair distribution of socio-economic benefits.

2. Impact on employment

2.1 Reskilling/Upskilling of the workforce

As the textile sector embraces the technological innovations of Textile 4.0, the need for reskilling and/ or upskilling is imperative. Automated systems, robotics, and AI are about to replace traditional roles as they perform faster, more accurately, and overall more efficiently. Employees in the sector need to be willing and able to adapt to the change quickly by acquiring or updating their technical skills. They need to be capable of efficiently operating and maintaining sophisticated machinery, using and programming advanced production lines or 3D printing software systems, and managing real-time data from IoT devices. It's likely, that this shift towards an advanced technologically skilled workforce will enhance the demand for training programs in relevant areas such as robotics, data analytics, computer science, and machine learning or machine maintenance, which used to be in low demand in the past years.

Moreover, textile employees will need to develop another key factor: adaptability. Adaptability is tightly connected to upskilling as it urges employees to combine newly acquired knowledge with past traits and experience and implement the mix in constantly changing situations. The former concept that people working in the industrial sector are required to perform tasks by doing the same movement repeatedly without thinking or the need for any specific skills has long passed. In the new era, textile employees must develop critical thinking that allows them to implement their skills and knowledge efficiently in each working challenge.

Additionally, the skillsets required within the sector are now being influenced by the interdisciplinary approach that Textile 4.0 has, meaning that it requires collaboration and cross-industry skills from several fields such as engineering, materials science, data analysis, supply chain management, etc. Therefore, employees within the industry need to be able to understand the principles of almost all sectors to enhance their performance and maximize the effect of continuous professional development acquired via training programs.

The need for reskilling/upskilling can lead to socio-economic implications if not implemented carefully. More specifically, training programs and upskilling opportunities need to be equitable,

in other words, they will have to be offered to all levels of the workforce and with special consideration to lower-income regions or economies that depend on textile manufacturing to a great extent to avoid income inequalities or gaps in the global labour market. This is why there needs to be policies in place that will regulate the reskilling/upskilling procedure by forcing companies and training providers to collaborate to provide the sector's workforce with enough resources and opportunities to adapt to the industry's technological transformation successfully and at the same time foster inclusion and sustainability.

2.2 Job transformation: New roles emerging

Reskilling/upskilling is one aspect of the changes that Textile 4.0 brings to the sector. There is another aspect though that is directly routed to the technological transformation taking place: the emergence of new job roles whose description focuses on robotics maintenance, AI programming, data analysis, and digital design. The level of sophistication that materials, machines, and methods used in manufacturing become progressively higher up to the point that upskilling/reskilling is not enough. The sector is in immediate need of people who are well-trained in specific fields such as robotics engineering, mechatronics, IoT, and AI in manufacturing. For example, an employee within the industry may be able to get additional training on how to use a 3D printing machine but developing the software that the machine runs is a skill that can be acquired via extensive studies in the respective field and thus creates a new role. In the same way, new positions have been created that cover specific needs and require a more sophisticated range of skills.

From a social aspect, the development of new roles within the sector is beneficial as one would expect, as it raises the standards of the manufacturing process and drives people to seek expertise. More particularly, the creation of such new roles within the industry is a sign that it is progressing in the right way and in line with modern demands for adaptation to technology. On the other hand, people realise that the stakes are higher and push themselves to gain in-depth knowledge and advanced skills in related fields of study, allowing them to evolve professionally and thus secure employability. Active employment is a crucial element for people as it provides financial stability and enables them to focus on social interactions. Moreover, since tech-savvy skills are a characteristic of new generations, youth employment may benefit more. Overall, the creation of high-skilled, tech-driven roles changes the socio-economic profile of the textile workforce and reshapes the idea of industrial roles being monotonous.

Figure 1: Source: Freepik.com

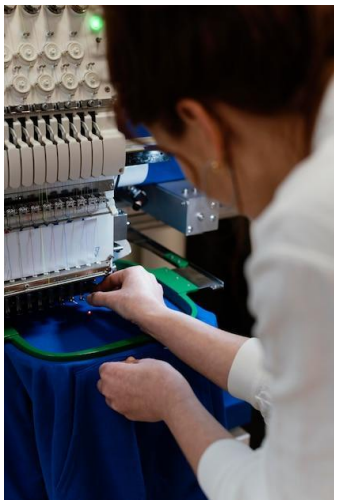


Figure 2: Source: Freepik.com

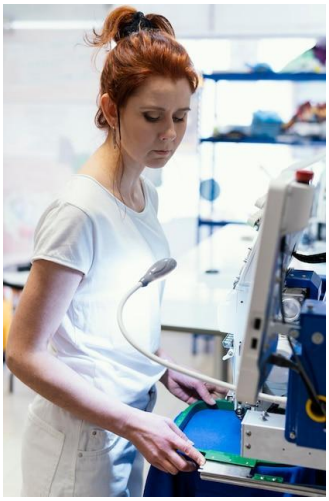


Figure 3: Source: Freepik.com

2.3 Textile workforce statistics

Data from EURATEX (the European Apparel and Textile Confederation) in their 2024 annual edition of the Key Figures report, provides information on the industry's labour demographics. Let's have a look at the numbers:

a) Women have always been a key factor in the textile industry's workforce. They now represent more than 70% of all employees in the sector.

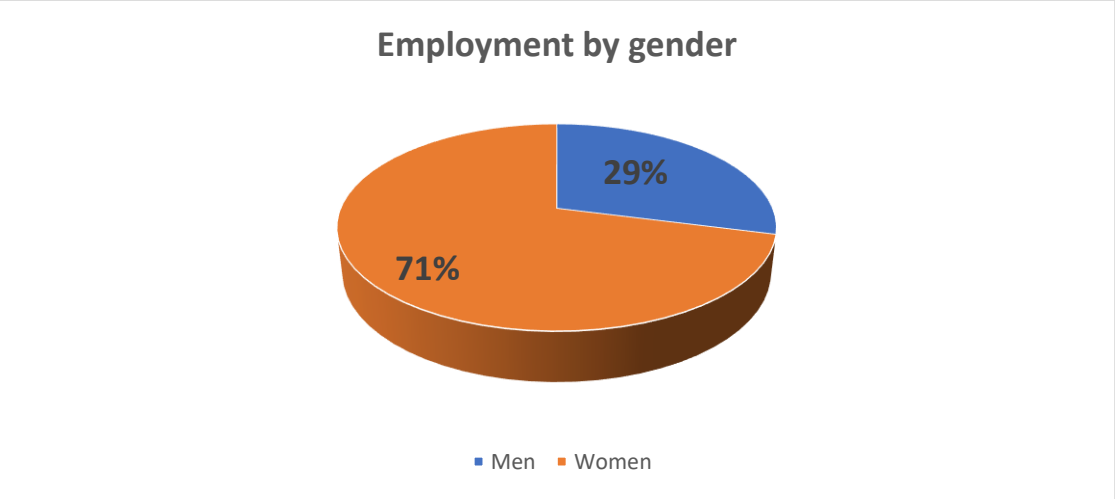
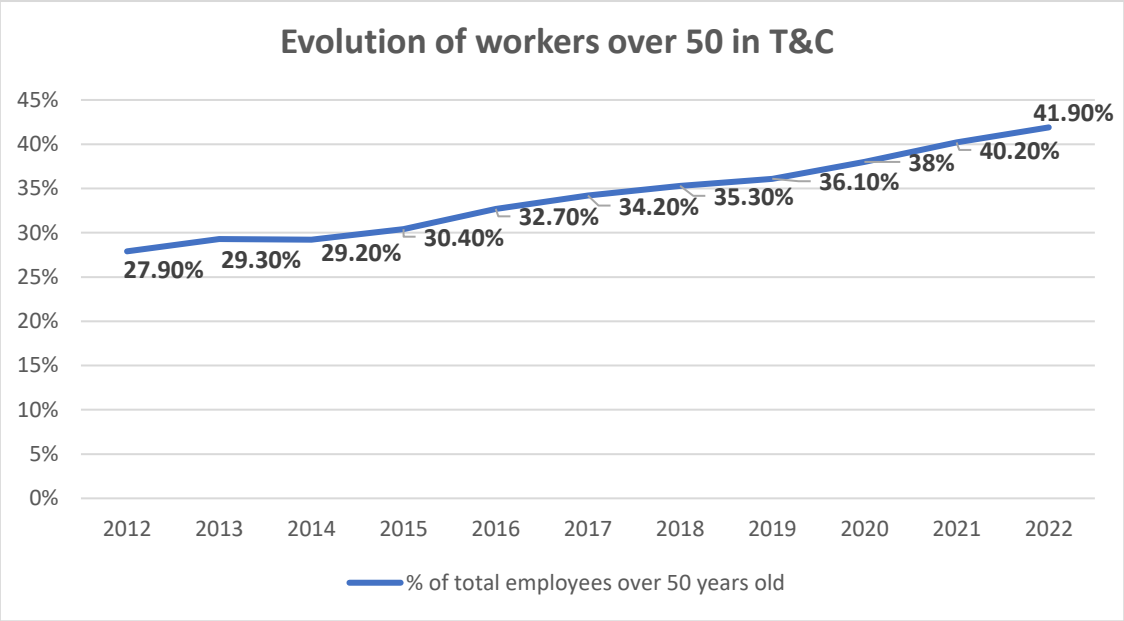


Figure 4: Source: euratex.eu

b) The chart below shows the evolution of employees over 50 years old in the textile sector. As you can see, the textile industry is being characterised by an ageing workforce.



c) Textile 4.0 has led to the progression of the employees' skills and academic knowledge. Below is a chart portraying the evolution of graduates (master's and bachelor's) by programme orientation. It's easy to understand when studying it that the sector is in urgent need of engineers.

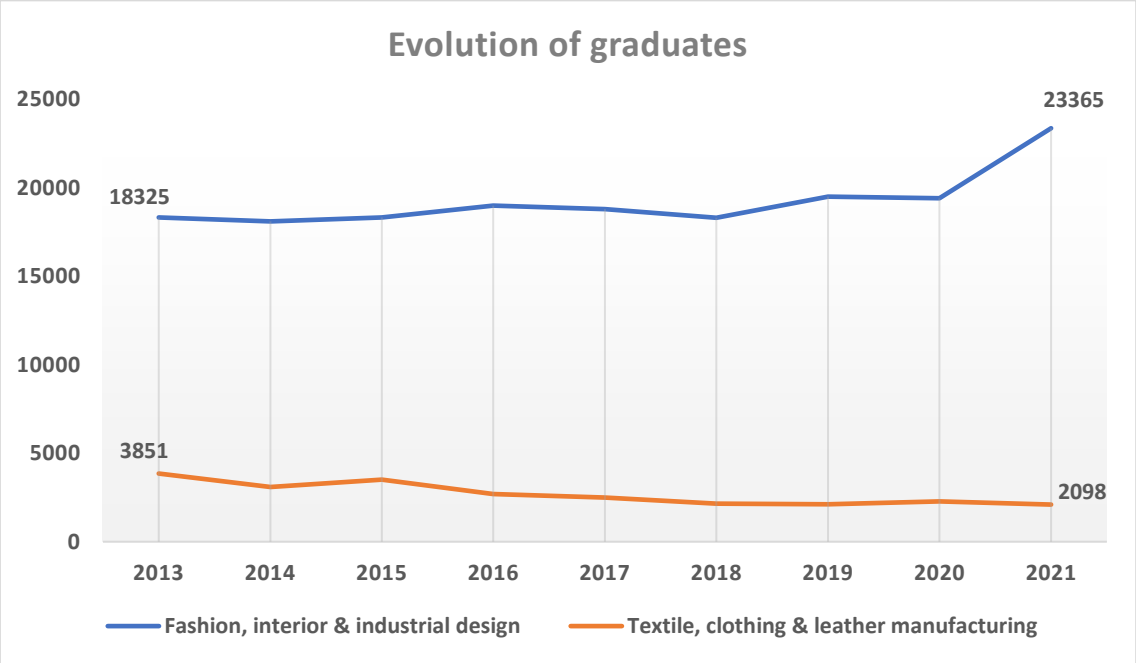


Figure 6: Source: euratex.eu

The data presented in the above charts is evidence of the module's references regarding the way that Textile 4.0 has transformed the sector's workforce and the need for more technologically skilled workers.

3. Economic Impact

There are several social and economic implications of the 4th industrial revolution in the textile industry. Following, you will be presented with a more detailed guide on the socioeconomic disparities caused by Textile 4.0:

1) Skills gap and job displacement

- Impacting low-skilled employees: the introduction of automation and robotics in production lines can lead to the replacement of manual labour. Robots and automated machines can do the same job without taking breaks, needing benefits or pay, and guarantee consistency.
- Need for up-to-date skills: traditional skills will fade away as the need for people with high skills in AI, computing, engineering, and robotics has become imperative. Unfortunately, not all workers have access to education or training programs relevant to the above which means that certain areas and communities will face higher levels of unemployment. Eventually, this will widen the skills gap and cause social disparities and turbulence.

2) Accessing technology

Small and medium-sized textile companies cannot afford technologies such as IoT, purely automated machines, or AI-driven analytics and thus cannot compete against mega companies within the sector. As a result, prices may rise and we might witness a further concentration of wealth and power among big players in the textile market, a circumstance that will deepen gaps in economic growth. These gaps may be more visible on a larger scale. Instead of comparing companies within the textile sector, try to imagine how things would be on a European level from one country to another. Italy for example which is the leader of textile production in Europe based on the EURATEX 2024 report, will strengthen further while countries like Poland, Portugal, or Austria will continue to struggle.

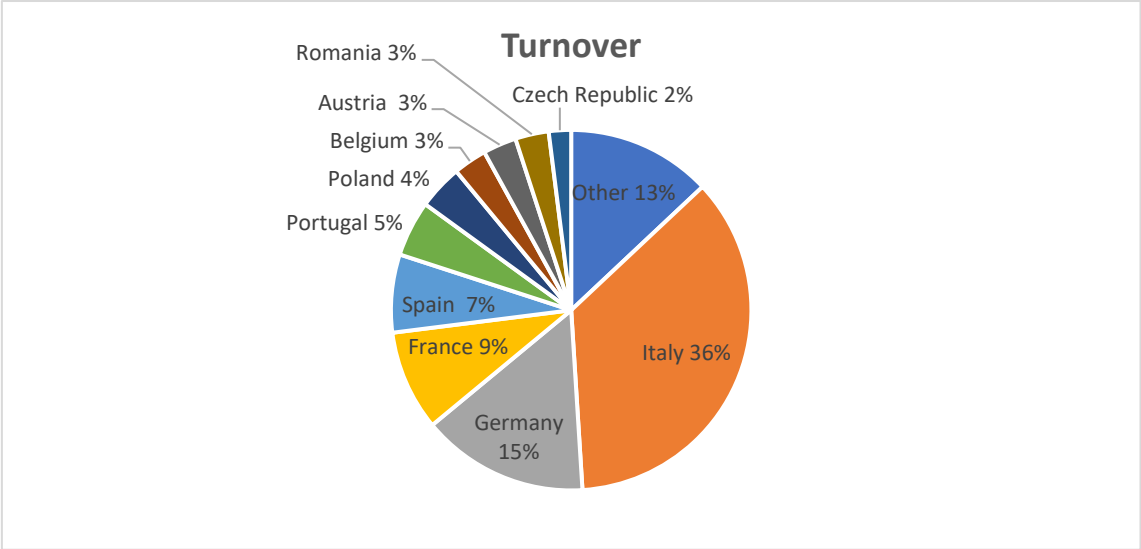


Figure 7: Facts & Key Figures 2024: euratex.eu

3) Labour rights and working conditions

Especially in countries where working conditions for textile workers are already poor, the shift towards automation in production might lead to even worse exploitation of labour. This could eventually become a reason for strikes or protests and result in social unrest which in turn will deepen inequalities. To prevent such a turnout of events, labour laws should be in place to prevent further exploitation of the rights of workers and force employers in the industry to create safe and inclusive working environments.

4) Ethical consumption and responsible consumer behaviour

Textile 4.0 technologies benefit fast fashion and uncontrolled mass production but can also benefit the circular economy and responsible use of raw materials and resources. It's simply a matter of how stakeholders within the sector choose to use the technological advancements at their disposal. This is why companies must raise awareness regarding sustainability in the sector among their workforce and consumers. Artisanal and ethically resourced and manufactured products must be offered at affordable prices otherwise there is a risk that will become a privilege of wealthier individuals and thus create a bigger gap in socio-economic inequalities.

5) Equal chances in sustainability

Technologically and financially advanced countries or regions have better chances of approaching production in the textile sector from an eco-friendly point of view. They can provide companies with funding for shifting their production methods closer to a circular economy leading poorer countries or regions to experience implications due to non-compliance with relevant EU regulations.

The best chances that the European textile sector has in mitigating these socio-economic inequalities are:

- by investing in upskilling and reskilling of its workforce
- by establishing and following a regulatory context that promotes sustainability and social equality
- by exchanging knowledge and experiences to maintain effective collaboration and establish a robust supply chain (e.g. fair-trade frameworks, and environmental standards).

The textile industry has managed to overcome and flourish in the years since its development, overcoming hurdles and challenges that other industries failed to face successfully. Nowadays, with the support of technology and the revolution it brings, the textile sector can become a role model for all other industries to look upon simply by adjusting the inequalities in the suggested manner.

4. Environmental Impact

4.1 Waste and energy management: a key benefit of Textile 4.0

The emerging technologies of Textile 4.0 have brought some promising advantages to the sector. Waste management is the most beneficial one. There are several ways in which it helps minimise waste and therefore promote sustainability with the support of automation and digitalisation as presented below:

a) Optimisation of digital cutting and choosing appropriate fabrics and patterns

Figure 8: Source: Freepik.com

Traditionally, fabrics in the textile industry are being cut manually leading to discarded remnants from improperly cut pieces or oversized cuts. The use of AI-powered tools and machines for digital fabric cutting minimises fabric scraps and improves cost-efficiency and speed of production.

b) 3D Printing

Also known as additive manufacturing, 3D Printing is an innovative method used widely today in textile manufacturing that can lead to waste reduction. The way it works (by adding 3D printing material layer by layer) enables precision and total control of the amount of the material used. Moreover, it enables the use of all sorts of materials which means that it allows the use of eco-friendly and recyclable materials. Lastly, it allows on-demand and customizable production and therefore minimises unsold stock.

c) AI-driven energy efficiency

Due to AI's ability to process vast amounts of data, the sector has the potential to analyse real-time energy needs and proceed with effective solutions. Additionally, energy-efficient algorithms can predict future needs and thus act proactively in covering the energy needs of today and tomorrow.

d) Supply chain transparency

Blockchain technology can offer a solution to the environmental challenge of the textile industry regarding tracking and managing the environmental impact of its production process. Data collected throughout the process make it easier for the sector to maintain high standards in sustainability while ensuring that consumers gain a better insight into the manufacturing process and therefore can make informed choices.

Figure 9: Source: Freepik.com

e) Use of eco-friendly materials and manufacturing methods

By leveraging digital tools manufacturers can track, source, and use sustainable materials like organic cotton or recyclable polyester in combination with methods such as waterless or low-impact dyeing to produce textiles that are characterised as ethically sourced. Smart textiles fall under this category as the technology embedded in them (e.g. sensors, climate-adaptive properties) makes them more durable and reduces their waste. These materials and production methods enhance resource efficiency and pollution across the entire production lifecycle.

All the above considerations, allow the textile sector to become more sustainable and reduce the need for raw materials while minimizing waste across all stages of manufacturing. By reducing waste, companies within the sector can lower production costs, minimize excessive stock, and thus make the end product more affordable for consumers. This can be beneficial specifically for small-scale businesses that struggle with unsold inventory. Moreover, the need to manage waste in relation to sustainability leads to the creation of green jobs complementing not only employability but also social stability.

4.2 Closed-loop economy

The term "closed-loop economy" (or circular economy) in the textile sector refers to the key component of Textile 4.0, a model aiming to reduce waste throughout the process of production. In a closed-loop recycling system, all materials are kept within the system and when the production ends waste products are diminished to a minimum level. A basic component of

the system is that the materials used are ethically sourced and the efforts made to create products that are characterized by longevity, repairability, and recyclability to prevent them from being sent to the landfill.

The social implications of Textile 4.0. in relation to a closed-loop economy touch a variety of areas in life and to different extents. Following there is a brief analysis of these implications.

Figure 10: Source: Freepik.com

Figure 11: Source: Freepik.com

Figure 12: Source: Freepik.com

4.2.1 Advantages of a closed-loop system in Textile 4.0

The textile industry is known for its environmental impact. A closed-loop economic system in the sector benefits sustainability and socio-economy by incorporating eco-friendly design and manufacturing processes. In more detail:

- Prioritizing sustainability: products are designed to be recycled, reused, and remanufactured. This minimises the need for new material sourcing and thus reduces the amount of waste generated.
- Minimizing the carbon footprint: by reducing new material sourcing and production, greenhouse emissions are minimised. This is an excellent example of the optimization of energy use leading to the minimization of waste.
- Leveraging resources accordingly: the textile industry uses resources at its disposal but it's the closed-loop system that ensures that these are being used effectively. That means that there is a need for researching and planning regarding the materials to be used as they need to be recyclable and repurposed (e.g. wool, cotton).
- Leveraging innovations: adopting smart materials (e.g. sensors, knitting techniques that provide breathability), technological advancements in recycling/ reusing (e.g. waterless dyeing techniques), and sustainable design principles (e.g. using the textile's pattern or texture effectively). By combining technological advancements in the industry and traditional knowledge companies can create products that respond to consumers' preferences and are sustainable at the same time.

- Cost-efficiency: when recycling/repurposing products there is maximum need for sourcing raw materials. Just like that, by utilising existing fabrics and fibres the companies lower their production costs and are able to offer competitive prices to consumers.
- Promoting eco-consumerism: the idea of circulating products is appealing to consumers who are looking for a way to contribute to sustainability and ask for the ability to make informed choices when purchasing (they seek transparency and full recording of the materials and methods used in making the product they wish to purchase). Companies leverage these consumers' eco-consciousness and promote their closed-loop production methods to gain their customers' loyalty and thus maximize profit.
- Resilient supply chains: companies within the sector shield themselves from supply chain disruptions when using the closed-loop economy system. The need for newly-sourced raw materials is less and so are the chances of the companies facing hurdles in obtaining them. This ensures a smoother production process and can also lead to competitive prices.

Regardless of how beneficial a circular economy system can be, industries in the sector seem to hesitate to implement it in their environment. EURATEX surveyed 326 textile companies in 2023 to measure the level of engagement the sector has in promoting sustainability via a circular economy. It compared the existing technologies within the industry that promote closed-loop systems to the number of companies that are actually taking advantage of these:

Available eco-friendly technologies	Companies that use it already
Recycled materials	32.0%
Energy-saving technologies	27.8%
Recycling technologies	24.3%
Clean production	24.3%
Bio-based materials	23.3%
Renewable energies	18.0%
Biotechnology	8.3%
Additive manufacturing	6.8%
Carbon capture technologies	6.0%
Hydrogen	1.3%

Figure 13: Facts & Key Figures 2024: euratex.eu

The results showed that despite the effectiveness of the sustainable technologies in place, only 42% of the surveyed companies adopted these or a green business model. As it becomes clear, sustainability in the textile sector faces challenges and barriers. Following we will briefly present you with the most common ones.

4.2.2 Challenges and barriers to adopting a closed-loop economy system in the textile sector

Even though the benefits of a closed-loop economy system in the sector are undeniable, companies face certain challenges in adopting it due to challenges such as:

a) Limitations in recycling technology and materials

Textile recycling technologies still lack knowledge on how to recycle complex fabrics like cotton-polyester blends into high-quality fibres. On many occasions, recycled fibers are lower in quality compared to virgin fibers and this harms the end product's quality and performance. Moreover, the complexity in the design of certain products makes the recycling process impossible as the fibres can't be recovered. For example, some textiles undergo chemical treatments or dyeing processes that make their recycling difficult.

b) High costs and limitations in infrastructure

Recycling and sorting textiles requires effective collection, sorting, and processing infrastructure elements which can be very expensive or require excessive needs in terms of space. Especially for medium-sized or small companies in the sector, implementing closed-loop systems is very challenging in terms of costs as they lack funding for the necessary infrastructure. On the other hand, the market demand for recycled products is still low, not enough to justify investing in recycling infrastructure for textile companies. As a result of the above, small and medium-sized companies often can't afford to implement a closed-loop system in their environment while big ones lack the market motivation.

Figure 14: Source: Freepik.com

c) Complexity of the supply chains

Establishing effective communication and collaboration among all stakeholders in the textile sector can be very challenging. Its supply chain involves fibre producers, manufacturers and retailers among others who work in a fast-paced environment. It can be very tricky to implement standardised procedures or proper tracing and monitoring of the products which makes it hard to initiate and maintain a circular economy system.

d) Lack of policy and regulations

In Europe, textile industries are obliged to comply with the Extended Producer Responsibility (EPR) directive and translate it into national laws by 2025 at the latest. EPR for textiles, forces manufacturers to take responsibility and monitor the entire lifecycle of the products placed in the market from their ethical sourcing to their collection, sorting, production, and re-use/ recycling. While some countries and their textile industries have begun to implement EPR policies, others still struggle with it.

e) Social factors and consumer behaviour

Recycled or second-hand materials are still perceived as lower quality in the consumers' eyes. For many, buying them is a social stigma, a sign that they can't afford items of a better quality and a degradation in their social status. Those who are more aware of the concept of sustainability and choose to follow its principles when purchasing a textile product face ethical dilemmas due to the general perception that the textile sector is characterized by harsh working conditions (long hours, labour-intensive, unfair pay). Moreover, consumers are bombarded daily with fast-fashion ads prompting them to invest in buying cheap textile products that are in style, and without checking their sourcing, quality, or any other element. It's a well-organised marketing strategy by fast-fashion mega-manufacturers that leaves no space for sustainability.

4.2.3 Social implications of the closed-loop economy in Textile 4.0

Based on the information presented above, it is easy to understand that the implementation of a closed-loop economy in Textile 4.0 can be a beneficial but challenging task from a social perspective that requires a multifaceted approach.

A key factor to achieve the best results is leveraging emerging innovations which in the long run will lead to social mobility by introducing new types of working positions into the sector such as designers specialised in circular economy products, specialists in recycling systems, and waste management, entrepreneurs in eco-design, experts in manufacturing and maintenance. These new circumstances boost employability levels and can become a means for social stability,

especially in regions that are marginalised but foster textile companies. Additionally, it can lead to the development of a whole new area of studies and training, focused on the textile sector and sustainability. If we think about the fact that the textile sector is one of the most complicated and damaging sectors in terms of environmental pollution, developing specialists in the sector that will transform it radically aiming to strengthen its sustainability, seems like an excellent idea.

New job positions within the industry will raise the skill levels of the sector's workforce. Already existing workers will have to catch up with upskilling or reskilling. Down the road, they will have to gain a better understanding of the concept of a circular economy. In a closed-loop economy, all stakeholders must be aware of its key factors, possible challenges, and ways to overcome these. As mentioned earlier, companies need to raise awareness about the circular economy among their consumers but it's a priority to educate their labour first. Imagine working in a textile company and despite all your skills and experience being clueless as to what a closed-loop system is or how it works. It would be impossible to act sustainably without specific knowledge. Would you be able to design, for example, clothes using already-used material or would you simply order a new batch from your supplier? Would you keep in mind to use waterless dyeing techniques for your designs? If you were a machine maintenance mechanic, would you make efforts to fix broken down machines effectively, and fast, following health and safety protocols, and using components already in the inventory?

A closed-loop circular economy is a system that works best only when all those involved in the sector have a high level of awareness of its principles and objectives. It is more than just organised efforts to recycle or upcycle products. It is a philosophy tightly connected to sustainability, an ethical approach to manufacturing, and the promotion of social stability. When integrated into the industry effectively it can transform it to its core and benefits companies not only from a cost-efficiency perspective but also from a point of helping them with promoting eco-consciousness for consumers.

5. Ethics of Textile 4.0

5.1 Health and safety of the workforce

The textile industry has always been characterised by hard working conditions that include long working hours, repetitive tasks, poor ergonomics, and exposure to harmful toxic materials (e.g. dyes, and chemicals). Thanks to Textile 4.0 those days seem to fade as implementing smart

technologies into the manufacturing process allows an enhanced sense of health and safety in the workplace.

In more detail, the integration of automation and AI in production has benefited the textile industry in terms of health and safety in the following ways:

- Improvement of ergonomics: Like in every other production line, textile employees perform repetitive tasks which progressively lead to musculoskeletal issues. These disorders are being minimised thanks to the introduction of ergonomic machinery and robots assigned to perform repetitive tasks. Workers are no longer required to work long hours standing, stretching, or bending over all of which are associated with manual labour injuries or long-term health issues.
- Minimisation of hazardous tasks performed by workers: Automated machines and robots perform tasks that have a high risk of leading to injuries and therefore minimise workers' exposure to hazardous material or actions (e.g. chemicals when dyeing fabrics, sharp tools like scissors).
- Minimisation of physical and mental stress: Concerning the previous aspects, by minimising workers' exposure to hazardous or monotonous (repetitive) tasks, their physical and mental state is improved. They feel less tired because their work is not as labour-intensive and in addition, they feel less stressed as their daily working routine is well structured and aligned with their skills.
- Enhancement of risk assessment and management: The use of AI and data analytics allows risks to be monitored, evaluated, and managed proactively and by drawing real-time data. Sensors and monitors in the working environment analyse factors such as air quality, temperature, or noise levels and perform real-time evaluations of the risk probability for each. Moreover, the data collected can be stored and used for future references or exchanged with similar environments to gain insight into future adjustments, ensuring that working conditions are mint.

Risk assessment and risk management have never looked better for the textile industry. With the support of technology, health, and safety in the workplace, it has evolved into a separate section that constantly gathers data and analyses numbers to produce results that promote workers' well-being both physically and mentally. This allows the production process to carry on without unforeseen events but also boosts labour morale as it sends the message that the health and safety of the workforce are a priority.

5.2 Fair labour practices

Figure 15: Source: Freepik.com

While Textile 4.0 can lead to inclusive and safe working conditions the same doesn't apply in terms of ethical labour practices. The use of advanced technology in textile manufacturing calls for labor regulations which in some cases require additional funding or a shift in focus from pure profit making. This can lead to the outsourcing of production to countries with weaker labour regulations or lower standards in terms of worker-friendly and protective working environments. Many companies choose to relocate their production to such regions causing a domino of effects such as the following:

- *Unfairness in wages:* countries with lax labour laws are a manufacturing paradise as textile companies can use cheap labour. The term "cheap labour" refers to the amount of payment that workers gain for their labour in relation to the working conditions they experience and their rights. In such low-cost production countries, workers have minimum or no working rights and might work for very long hours, under extremely hazardous conditions for very little money.
- *Unregulated use of automation and AI:* despite the positive effects that automated systems and AI have in the textile industry when implemented in an unregulated way they can lead to implications in fair labour distribution. In more detail, certain companies choose to replace high-skilled (and higher-wage) workers with robots and automated machines or programs while maintaining low-skilled (and lower-wage) staff.

Such changes in the labour market scenery can easily lead to social turbulence. They disrupt the smooth development of the global supply chain and reshape the societies involved as they tamper with employability or labour rights. To ensure that fair labour practices are in place and the textile industry progresses without posing a threat to socio-economic stability, the sector ought to adopt fair trade standards on a global level. Governments and international organisations need to create a global standard for the industry's workforce that ensures dignified treatment of labour, transparency in pay schemes, safe working conditions, and protection of employees' rights. Employees, on the other hand, need to unionise and drive bargains with the industry's highest forces in a collective form, via trade unions, and advocacy groups and by raising awareness about their rights and experiencing working conditions.

Figures 16 & 17: Source: Freepik.com

5.3 Eco-conscious consumerism

Environmental issues like climate change have affected society in a variety of ways. Consumers now are well-informed on sustainability and the implications that unethical sourcing of materials or unregulated production can have on the planet. The textile sector's consumers are now interested in blockchain technology which allows transparency in recording and tracking every transaction and interaction along the textile supply chain. Before making a purchase, they need to know whether the materials and methods used in the manufacturing process of the product adhere to ethical and eco-friendly practices. Ethical sourcing becomes intertwined with sustainability as consumers ask companies to source raw materials whose processing can be done with minimal environmental impacts such as organic cotton and hemp, recycled polyester, and bio-based fibres (e.g. tencel).

This rise in consumers' eco-consciousness forces textile companies to follow practices that promote sustainability. Not only do they use materials that respond to consumers' demands and are ethically sourced, or maximize the use of technological advancements aiming for eco-friendly production processes, but they are also looking into ways of promoting a circular economy. In detail, they are researching ways of recycling/reusing production materials. The most common methods are fiber-to-fiber and chemical recycling which allow textile companies to break down fibers into their raw material or base components and re-use them to produce new textiles.

Consumers have the power to change global market trends at will and luckily their minds nowadays are focused on sustainability. Their take on eco-friendly consumerism fuels a positive change in the textile sector and the use of technology, automation, and AI seems to act as an

accelerating agent toward the sector's transformation into an industry that promotes eco-friendly practices.

5.4 Digitalisation and customization of the end products

Figure 18: Source: Freepik.com

Textile 4.0 has introduced innovative ways for consumers to engage with the industry, specifically with the fashion industry. Consumers now have the opportunity to personalise the products they wish to purchase via digital platforms. They can choose the fabric, colour, pattern, design, and even quality of the end product for it to respond well to their personalised preferences and needs. Many platforms even allow consumers to upload their images and conduct virtual try-ons to maximise their shopping experience. Such an innovative way of shopping enhances convenience for the consumers and strengthens the bond between them and the companies in the sector. By involving consumers directly in the design process, companies create a more engaging shopping experience that promotes brand loyalty and, in the long run, maximisation of profit.

From a different point of view, the customisation of end products by the consumers is like a free collaboration for the companies of the sector and one of the best marketing methods. Consumers contribute with their ideas without even realising the pool of designs that the fashion industry has at its disposal. While this is beneficial for the sector, it is also beneficial for the consumers' world as it promotes diversity and multi-cultural influences.

Extensive research of the consumers' customisation preferences guarantees that textile production responds efficiently to their needs. This is a reality that fosters inclusion and leads to sustainability as it dictates the effective use of materials by minimising the manufacturing of products that don't cover consumers' needs and therefore would end up in recycling processes. Additionally, the need to conduct extensive research and the use of digital platforms for shopping leads to the creation of additional job positions in the sector. These roles vary from the traditional ones in the sense that require extensive digital and technical skills which are usually a trait of younger generations. Therefore, young people gain more opportunities in employability while the sector overall benefits from their fresh ideas and up-to-date skills.

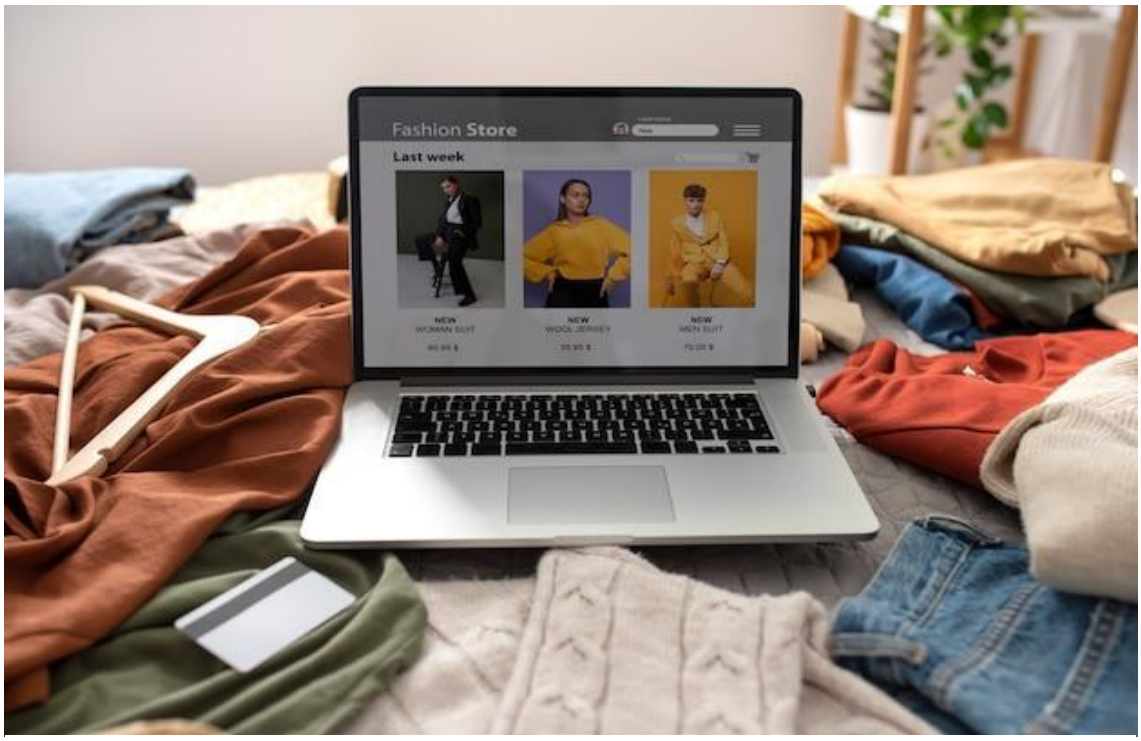


Figure 19: Source: Freepik.com

Although online shopping and customization of products boast of innovation and customer satisfaction and even though it can benefit the environment by producing the exact amount and style of products needed, there are rising concerns regarding data privacy. When shopping online or during virtual try-ons consumers are guided into providing sensitive details regarding their demographics, personal preferences, and geographical stigma. All these can easily be harvested by maleficent companies that use false marketing methods.

Moreover, there's another aspect concerning the digitalisation of consumers' shopping in the textile sector. It leads to uncontrollable sales chain management as consumers can choose to purchase a product from anywhere in the world. Transporting the product contributes to carbon emissions, especially in the case of the fast-fashion industry, which means a huge impact on the environment. There is no golden rule when it comes to online shopping and the digitalisation of products and the effect they have on sustainability efforts. Perhaps, there is a solution; providing consumers with options for customisation but limiting these options to a local range.

The pros and cons of digitalisation and customisation of products in the textile sector vary as presented above. There is one standard truth though that as technology progresses the market and its consumers will lean more and more towards similar innovative methods of purchasing products which call for measures on an international scale to avoid hurdles in efforts for sustainability.

5.5 Cultural Identity and Craftsmanship

Artisanal craftsmanship has always been a big part of the social dimension of the textile sector. With the introduction of technological advancements in the industry such as 3D printing and smart textiles, artisanal craftsmanship suffered a heavy strike. Additionally, modern technologies in the sector somehow swallowed the cultural identity and textile traditions in certain areas, leading to a new globalised sense of heritage.

The impact that Textile 4.0 has on cultural identity refers to the way it is almost wiped off from the manufacturing process's traditional methods of production, techniques, and designs. As the sector leans towards mass production and the incorporation of innovative technological means of production and design, traditional ways are fading. Still, the revolution that Textile 4.0 brings is not an element of destruction but rather a tool for progress based on previous knowledge and history. Efforts are being made to produce textiles of high quality using a blend of traditional methods and modern technology. These products are considered artisanal, come in limited numbers, and can be very costly for the average consumer. Such examples are textiles dyed using traditional techniques (e.g. use of pressed flowers for design or natural dyes deriving from plants). The labour-intensiveness they require makes them inconvenient for mass production, which in this case is a blessing as it drives their quality to high levels.

Figure 20: Source: Freepik.com

Figure 21: Source: Freepik.com

It's understandable that the constant progression of the textile industry using technology as a vessel, raises concerns about the future of craftsmanship. Just like in the case of cultural identity, craftsmanship in the textile sector can be salvaged if technological advancements are being used in its favour. To better explain this, think of an artisan textile designer using 3D printing methods or digital weaving to enhance their designs. The possibilities to produce artisanal products that highlight their exceptional craftsmanship are now endless. Moreover, the use of digital platforms for promoting artisanal products enhances their marketing and provides access to markets that otherwise would never be approachable or would be reached up to a base minimum level.

Figure 22: Source: Freepik.com

The shift of the industry from heavily relying on traditional methods and craftsmanship production to the manufacturing of artisanal products using technologically advanced methods and on a bigger scale has social implications for local communities and their workforce. In the past, the skills and knowledge of traditional textile manufacturing would be passed down from generation to generation involving the local community. Now, the introduction of automation and robotics in the manufacturing process often leads to job displacement and the need for highly skilled people whose knowledge and skills are gained not through experience but through studies.

From all the above, one can easily comprehend the extended risk that cultural identity and craftsmanship face from the success of Textile 4.0. In conclusion, whether these fundamental elements of the textile industry survive or not in time, depends on the sector's desire to highlight them by combining their historical value and quality with modern technology and by raising awareness about the importance of their preservation.

6. Conclusion

The new technological era and the revolution it brought to the textile industry marked a pivotal moment in the evolution of the textile sector. The innovation it brings is a promise for development, maximisation of consumption and manufacturing via automation, customisation of products, and digitalisation.

Along with the progress though, Textile 4.0 brings some challenges to the social sector such as job displacement, possible diminishment of traditional methods and cultural identity, socio-economic inequalities in poorer regions, and a negative environmental impact. All these challenges are possible scenarios that could become a reality if the stakeholders of the sector fail to understand the importance of adaptation and leveraging the Textile 4.0 technologies in a way that benefits them and their surrounding environment.

As presented in the module, there are ways for the textile sector to respond to the changes it faces from rapid technological and digital progress but the core element for successfully overcoming obstacles is the level of engagement that the industry will show in creating the

necessary circumstances for further development. Companies in the sector must invest in training their workforce and improvement of the working conditions they offer. Additionally, more intense and well-organised efforts should be made by companies to invest in a circular economy. Once they have established a robust closed-loop system, they should invest in raising awareness among consumers regarding sustainability within the textile sector.

By considering human and environmental dimensions equally with their growth and profit, companies of the sector can contribute to a more sustainable, inclusive, and equitable future for the global textile industry.

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