

Valuing Modern Technologies to Boost the Circular Economy in the Fashion Industry

Oana MIONEL*

National University of Science and Technology Politehnica Bucharest, Bucharest, Romania

Faculty of Engineering in Foreign Languages

**Corresponding author, oana.mionel@upb.ro*

Mihaela ȘTEFĂNESCU

Ministry of Environment, Waters and Forests, Bucharest, Romania

mihaella.stefanescu@gmail.com

Abstract. *In the context of solving pollution problems, the circular economy appears to be a mandatory practice because it emphasises the principle of reuse - repair - reconditioning - recycle. In this context, the paper aims to analyse how modern technologies facilitate the implementation of circular economy principles through better traceability of goods produced and used in the fashion industry. In this way, our research is exploratory and the information on which it is based was gathered using the Google search tool, which identified brands who use Big Data, RFID and QR code tools, as well as online tools (cloud-based platforms) that offer integrated garment tracking services. Following detailed analysis of EU data, it was found that major companies have integrated QR Code technology into their products and cloud-based platforms are increasingly used.*

Keywords: modern technologies, circular economy, fashion industry, sustainability, traceability

Introduction

Between the first industrial revolution until today, much of the world economy has followed the linear production process model based on the take - make - consume - discard pattern. Still, due to the current situation of depletion of natural resources this expansive consumption perspective is no longer serving as a development trend. As a consequence, at the international level other sustainable approaches have gained interests. As such the one of circularity, which describes the framework supported by the principle of the circle that closes almost perfectly (Commoner, 1972): sharing, renting, reusing, repairing, refurbishing and recycling (Bourguignon, 2016), becomes the desirable long-term alternative. The circular economy is a term used in many fields to design future business models based on eco-innovation and eco-design (Centobelli, Cerchione, Chiaroni, Del Vecchio and Urbinati, 2020).

The present trends demonstrates to a certain level that the fear for increasingly scarce natural resources, global warming (Mineo, 2020) and environmental protection are equally important issues when it comes to the agenda of decision-makers to public policies and economic agents. According to Circularity Gap (2023) there is a global decreasing trend when it comes to circular resources being around 7.2% in 2023 as compared to 9.1% in 2018. There is space to further improvements at EU level, as well, because the average circularity rate for all 27 member countries increased by only 0.4 percentage points for the period 2015 – 2021 (European Court of Auditors, 2023).

The concept per se aims to extend the life cycle of products, optimise consumption of raw materials and energy, reduce waste and carbon footprint and encourage environmentally friendly activities (Haigh, 2022). The modern circularity (Maranesi and de Giovanni, 2020) is closely related to the quintessence of the previous principle summarizing the negative impact of the human-nature relationship. From this perspective, this problem should be solved by reducing the environmental impact and having better information accessible to market actors in terms of circular economy opportunities. Commoner (1972) had long ago observed that humans have torn themselves out of the circle of life not because of biological needs, but because of the social organization and the impact on nature in order to acquire wealth to satisfy conflictual governing demands. The result has been an environmental crisis of survival. Therefore, in order to survive, humans must close the circle.

In the "fashionopolis" era (Thomas, 2019), the production and consumption model will have to track both the biological cycles of decomposable materials and components that are not easy to recycle. Switching away from the linear model to the circular economy (Sariatli, 2017) offers multiple opportunities, such as reducing environmental impact, increasing security of supply of raw materials, competitiveness, innovation and job development. The opportunities are also accompanied by challenges, cultural, technological, market barriers associated with government policies (De Jesus and Mendonça, 2018) and criticisms (Corvellec, Stowell and Johansson, 2021) regarding funding, key economic factors, required skills, business models, essentially a myriad of structural barriers.

The modern technologies are the ones that steer a paradigm change (Dissanayake and Weerasinghe, 2021). They provide tools capable of reducing costs, automating tasks, increasing transparency and traceability, and creating added value for companies and customers (Lüdeke-Freund, Gold and Bocken, 2019). Furthermore, the uptake of modern technologies in the circular economy requires specialists to implement new projects (MAPFRE, 2021), especially in the textile and clothing industry, able to work with Big Data, RFID and QR code tools. Currently, there is an increasing demand for new skills, retraining and upskilling employees to allow companies to remain competitive in a changing market (World Economic Forum, 2018).

The above-listed research findings are incorporated to a certain extent in our paper. In our efforts to set the research background, we have observed that studied analyses are scarce as regards the status of companies that are implementing modern technologies and the existence of support platforms for their customers. From this perspective, our article aims to explore the status and extent of information tracking systems and utility of QR code-based technologies applied to the textile and apparel industry to achieve circular economy goals.

Literature review

Circular Economy, Technology and The Clothing Industry

The circular economy can offer many perspectives, but one of the most used aim to harmonise and reconcile economic activity with environmental well-being. It has a direct and important contribution to the sustainable development goals and actions. From the perspectives of Pearce and Turner circular economy was intended to create a movement to regenerate ecosystems damaged by industrial activity.

The practice of circularity transformed end-of-life goods into resources for other processes, closing industrial loops and reducing waste. Moreover, it changes the economic logic because it replaces production with sufficiency (Stahel, 2016), following the model: reuse what

can be reused, recycle what can no longer be reused, repair what is broken and restore what cannot be repaired (Figure 1). From this perspective, the circular economy aims to transform traditional patterns of production, economic growth and encourages the development of interdisciplinary economic sectors. There is potential for one sector to provide solutions for waste from other sectors (Provin, de Aguiar Dutra, de Sousa e Silva Gouveia and Vieira Cubas, 2021), additionally through the use of modern technologies currently available, from artificial intelligence to blockchain, Internet of Things (IoT) and Big Data (MAPFRE, 2021).

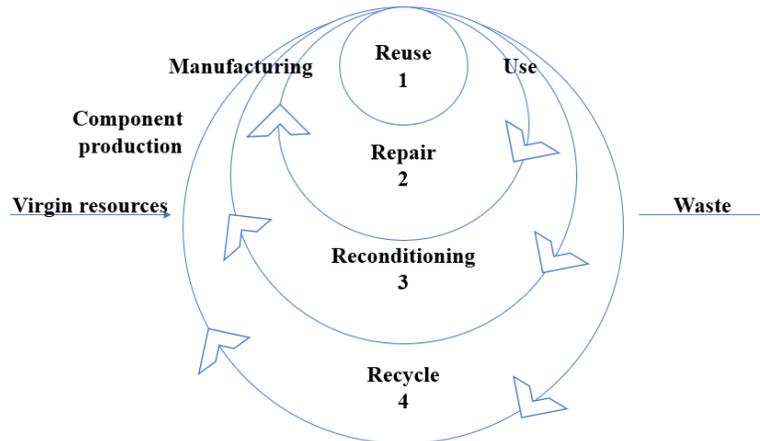


Figure 1. Stahel system for minimising material flows, energy and environmental impact

Source: Stahel (1981).

Since after oil, clothing is considered the most environmentally invasive industry, there is a need to change the mindset of both companies and co-consumers, and to realise the need to apply the technological potential in the circular economy in general, and in the clothing industry in particular.

According to estimates, this industry produces up to 10% of global CO₂ emissions (UN Climate Change, 2018) and is perceived as being the second largest consumer of water (Global Fashion Agenda and The Boston Consulting Group, 2017). Textile processing contributes to about 20% of industrial water pollution and 35% of primary microplastic pollution of the oceans (Niinimäki, et al. 2020). If applied, the circularity in the clothing industry will unlock economic opportunities worth billions of euros. According to the Ellen MacArthur Foundation, the apparel industry is worth \$1.3 trillion and employs over 300 million people. In some poor countries 7% of employees work in cotton production alone. In recent years the production of clothing has doubled and, very worryingly, the actual use of clothing has fallen by 40% due to the "fast fashion" phenomenon (Thomas, 2019).

According to a 2018 analysis by consulting firm Frost and Sullivan, the adoption of advanced technologies and digital solutions is having an impact on changing the circular economy mindset in the apparel industry: (1) IoT is present in smart containers, robotic sorting and mobile applications, combining analytics tools with optimization software; (2) state-of-the-art sensors and Radio Frequency Identification (RFID) enable real-time data tracking; (3) QR (Quick Response) code-based online platforms close the textile cycle by encouraging collaboration along the value chain and help track materials (Hedberg, Šipka and Bjerkem, 2019); (4) and Big Data (databases used for different types of analytics) contribute to the transparency of business models.

Accompanied by NGOs and several other political entities, the European Union (EU) is increasingly committed to implement principles of circular economy. Through the policies it promotes, the EU is funding new business models based on modern technologies and stimulating collaboration along the value chain to track materials used and 'close the loop' (Ellen MacArthur Foundation, 2022).

The EU and the circular (textile) economy

At the European level, textile use is the fourth most important environmental factor after food, housing and transport. Textiles also rank third in water consumption and land use, and fifth in the use of greenhouse gas-generating raw materials (Institute for European Environmental Policy, 2016).

In 2015, the EU came to the rescue of the circular economy with the new economy package which includes 3 key points: the action plan, the mapping of opportunities and the legislative proposals on landfill, reuse and recycling. The plan defines and measures progress towards a circular economy (Institute for European Environmental Policy, 2016) and involves both waste management and other actions related to production, consumption, creating markets for secondary raw materials and innovation through the formation of dedicated labour and textile platforms.

In 2020, the European Commission (EC) adopted a new action plan for the circular economy that aims to track the entire life cycle of products, trying to prepare its economy for a green future. The new action plan aims to build on the results of the first plan (2015) and focuses on keeping resources used in the economy for as long as possible (European Commission, 2020). The EC is also progressively introducing measures for resource-intensive industries, including textiles (European Commission, 2020). In order to strengthen competitiveness, innovation and stimulate material re-use in the textile industry, the EC has adopted the strategy for sustainable and circular products.

By monitoring the life cycle of textiles and proposing actions to change production and use, the European strategy proposes a new approach that integrates all aspects of product life (European Commission, 2022). It aims to create a sector that is green, competitive and more resilient to global shocks.

Until 2030, the EU believes it will be able to accommodate the following principles: (1) all textiles on the market should be sustainable, repairable and recyclable; (2) a significant proportion should be made from recycled fibres, free of hazardous substances and made with respect for society and the environment; (3) "fast fashion" should be out of fashion and consumers should benefit for a long time from quality textiles at affordable prices; (4) extensive repair and re-use services are available; (5) competitiveness, resilience and innovation exist in the textile sector; (6) producers take responsibility for their products throughout their lives, ensuring they have recycling capacities, reducing incineration and landfill (European Commission, 2022).

The European Commission also comes up with a set of measures aimed at textile industry players: design must be sustainable and products easy to repair and recycle. As a proactive measure, the EU has introduced a digital passport with standardised information for clothes to combat environmental misinformation, discourage the destruction of unsold products and eliminate overproduction. Harmonisation of EU rules on producer responsibility for textiles and financial incentives to make products more sustainable are also among the mechanisms to be implemented (European Commission, 2022).

An important measure is the application of the Digital Product Passport (DPP), which is a centralised, digital method of recording information or inventorying products in order to create an easily accessible and usable information bank. The DPP can provide information on product materials, possible repairs, maintenance and details on how to recycle (Stretton, 2022).

Therefore, the opportunity map (OECD, 2018) that the circular economy and technology are building emanates from the need to reduce pollution; to optimise supply and reduce dependence on imports; to increase the competitiveness of business and consumers through resource efficiency; to trigger the global innovation process due to the urgent need to redesign the textiles used; and to boost economic growth and reorganise jobs that can benefit the circular economy.

As expected, the implementation of the action plans has led to diverging views among those directly involved on the opportunities and challenges inherent in the circular economy (Bourguignon, 2016). The opportunities of the circular economy are, however, limited. Obstacles, which can be difficult to overcome, mean costs for funding research, development and innovation projects in the circular economy. There are also gaps in the collaboration of economic actors due to insufficient financial incentives and information to link the interests of producers and recyclers.

So far, the circular economy is also uncovered in terms of technical skills. Skills and workforce training need to move to other levels, to reskilling and upskilling (Circular Economy Alliance, 2022). These are what enable manufacturers to make goods that follow the circular economy model. Insufficient information for consumers and businesses is a major obstacle to behavioural change, which is making slow progress. Governance is still inflexible and needs to be adapted at all levels, as well as action by business area.

The EU proposals for the circular economy are being followed with attention and interest not only by associations and companies in the clothing industry but also in other sectors. However, those interested in fashion (companies, customers, decision-makers, etc.) and how to stay on trend for as long as possible will have every interest in understanding and applying circular economy principles to the fashion industry.

Circular fashion

Circularity is the solution that reduces the environmental impact of fast fashion (Voicu and Dumitru, 2022), focusing on resource reuse. "Fast fashion" is a modern phenomenon and follows the "take-make-dispose" model that allows manufacturers to produce a lot, retailers to sell quickly and shoppers to buy on-trend clothes.

The term circular fashion was first used in 2014 by Anna Brismar (Rathinamoorthy, 2019) that focused on sustainability and circularity issues in the apparel industry. She used the term at a sustainable fashion event in Stockholm, later to be called Circular Fashion - Show & Talk (Brismar, 2017). On that occasion, she explained that the term should be applied not only to fashion products, but to all categories of clothing: sports, outdoor, home, footwear and other similar products. Circular fashion looks at the entire life cycle of products, from design to use and end of life. In 2017, she proposes a new definition for circular fashion as follows: clothing designed, produced and supplied to be used and to circulate responsibly and efficiently in society for as long as possible, to be returned safely to the biosphere (Brismar Anna, 2017).

The definition of circular fashion is based on principles of circular economy and sustainable development. Thus, the circular fashion and, in extenso, the circularity of the clothing industry should aim to achieve the following aspects:

- clothes should be designed having in mind an approach based on resource efficiency, non-toxicity, biodegradability and recyclability perspectives;
- they should be produced giving priority to recyclable materials and ethical practices by encouraging the sharing of clothing with multiple users;
- the life cycle of the product should be environmentally friendly. When clothes are not suitable for recycling, the material should be biodegradable and used as compost for plants and other organisms;
- the ultimate goal of circular clothing is that the life cycle does not bring socio-economic or environmental damage (Rathinamoorthy, 2019).

Even if the economic models that support and encourage fashion circularity are not so many, the literature review describes at least three typologies: (1) *rental-based*, (2) *resale and reuse* and (3) *garment recycling*.

The rental model is mainly applicable to short-term needs, such as maternity and baby clothes, festive wear, fancy clothes, etc. Those who no longer like or need clothes can rent them and thus benefit from these fashion inconveniences. In addition, according to the Ellen MacArthur Foundation (2017), this model lends itself to retailers. Clothes can be rented for a fee, and the time and number of items can be defined according to factors such as the type of clothes and the season. This model allows individuals to respond to fast fashion challenges, to address multiple clothing styles, while providing a viable business for retailers.

The resale and reuse model is the best option from the perspective of increasing the life of the garment. It has been implemented around the world for some time, including in Romania being one of the countries where second-hand shops have its history. Little by little, resale could become the new norm in clothing. Similar to new products, strategies should be introduced to display the quality and hygiene of the renewed garment so that customers will understand that the resold garment also meets certain quality standards. Reuse can take the form of primary destination or it can take on a different meaning, a secondary reuse, i.e. for a purpose other than the original one (Rathinamoorthy, 2019). From a reuse perspective, most benefits are reaped from the environment as it does not involve any associated impacts. Clothing exchange is a simple way of reuse.

The recycling model has been well known for decades. Its application in the clothing and textile sector increases durability and increases life through recycling. The associated costs hinder the implementation of the corresponding implementation and limit the extent of applicability of the recycling process. The Ellen MacArthur Foundation (2017) report on the circular economy highlights a sad reality: less than 1% of clothing textiles are recycled, while 87% are used as stuffing for other goods or incinerated after first use. As a common practice, recycled textiles are found in the form of cleaning cloths, insulation material or fillers. Through recycling, fabrics are created from the blend without any information on its fiber and chemical composition while extending the life of the material, raises other practical problems. From this perspectives, materials have to follow a designed for recycling pattern.

An efficient solution to avoid the situation described above is the use of QR code technology along the value chain to record information that according to the transformation processes that textiles undertake through, degree of circularity by taking into account various factors, such as: pollution due to production, reuse and waste can be avoided. By putting QR codes

on clothing labels, companies offer customers transparency. Once the code is scanned, the consumer has access to all the information about the production, care system, cleaning and authenticity of the purchase, which has become increasingly necessary due to resource scarcity and counterfeiting.

Methodology

We frequently think that information is power, but it is more accurate to say that information owned and applied means more power and more resource efficiency. We have found from reviewing the literature that lack of information sharing is among the most pressing barriers to traceability (Ospital, Masson, Beler and Legardeur, 2022) and the circular economy.

As explained in the previous section, consumers and economic operators need information on the composition, maintenance, repair and recycling of materials. Therefore, standardised information on quality and durability encourages the reuse of textiles and clothing by other economic operators in the clothing industry.

The efforts are supported by innovations in traceability, payment and sales methods and the move to digitise the sector by applying modern tools, such as: Big Data, blockchain, Digital Product Passport (DPP), Radio-Frequency Identification (RFID) tags and readers and QR codes. Most recently, more and more online platforms contribute to easy, fast and clear tracking of the textile value chain. Sustainability is one of the reasons why more and more fashion companies have increased their investment in technology and innovation. For example, in 2016 only 7% of companies knew their cotton supplier (Ospital, Masson, Beler and Legardeur, 2022), today the percentage is increasing. As a result, according to a study by the Business of Fashion and McKinsey (2022), fashion companies are expected to double their investment in technology by 2030 (Layerise, 2022).

To trace and identify each item uniquely in the value chain, they are tagged as traceable resource units mainly using RFID and QR code technologies. Our research mainly focused on identifying online platforms and companies that, using QR code technology, have exact identity of clothing products, their textile composition and history starting from the moment when they were put on the market. The implementation of these codes is necessary to be analysed and discussed as they are not yet widely used among clothing companies. While QR codes have been around since the 1990s, their importance was only noticed with the outbreak of the COVID-19 pandemic, which brought humanity back to a point of environmental focus (Venkataraman, 2021).

The research's fundamental method is exploration. Our results are intended to open a new dimension in the research of economic circularity in the garment industry using QR codes. Brands using this traceability and transparency tool, online platforms and their customers were identified using the Google search engine. After gathering the information, we critically analysed their functionality, pointing out their role and usefulness in the context of EU approaches to the circular economy.

Results and discussions

The use of QR codes by companies contributes to increased traceability, providing customers with the following advantages: the possibility of permanently verifying the location and route of goods resold after the initial purchase; obtaining information on the manufacture of the product and the materials used, helping them to make the best purchasing decisions; customers can access

clear instructions on maintenance; last but not least, they can benefit from additional facilities, depending on the intention of each brand (Samsøe Samsøe, Diesel, Lacoste, Adidas, etc.).

One of the first add-on facilities for applying QR codes to products sold was the company Samsøe Samsøe, which started in 1993 when brothers of the same name opened a small jewellery shop in a Copenhagen neighbourhood. Today, the Danish brand is known internationally for the clothes it produces and for product labels that highlight its commitment to supporting sustainability and authenticity. The company's code of conduct is conditional on the sustainability and authenticity of the clothes and, to facilitate resale to other customers, it has incorporated QR codes on the product label. Furthermore, the company encourages its customers to resell their clothes when, for so-called reasons, they no longer use them. Each product's code is linked to Facebook and Instagram and automatically creates an ad that contains information about the garment (size, colour and age) and automatically generates images accompanied by text (Layerise, 2022).

In recently years, many clothing brands are using QR codes as an advertising and sustainability tool to raise awareness of the environmental impact of textile waste and attract young people to their products. A brief analysis on the QRCode Tiger website in July 2022 states that the number of smartphones accessing QR codes in the next 5 years will reach 1 billion, which is why more and more European fashion companies are adopting the strategy of those in Table 1.

Table 1. Large European companies that have integrated QR Code technology into their products

Company	Country	Commercialized Product	Year of QR code integration
Zara	Spain	Clothing	2014
Adidas	Germany	Footwear	2011
Burberry	United Kingdom	Luxury clothing, perfumes and accessories	2020
Diesel	Italy	Jeans	2018
Giorgio Armani	Italy	Clothing, watches, jewelry, accessories, eyewear, cosmetics, and home interiors	2020
Lacoste	France	Clothing and footwear	2019
Samsøe Samsøe	Denmark	Clothing	2022
Brunello Cucinelli	Italy	Clothing	2021
Prada	Italy	Clothing	2021

Source: Authors' own research.

When fashion brand Diesel adopted QR Code technology, it also added the "scan for authenticity" call, helping shoppers identify whether the jeans they purchased were genuine or not. Zara has also added such a code to clothing labels to direct customers, once scanned, to an online page with details of the product's manufacture. Adidas, Europe's largest sportswear company already has eleven years of using the QR code for multiple purposes (Lambert, 2011). Its ingenuity is boundless. In June 2019, it launched an innovation for urban runners called Pulse HD. The technology uses the QR code in partnership with Spotify. By placing the code on the shoe's tongue, Adidas directly connected the shoe wearer to a Spotify playlist customized to their location. The shoe has GPS coordinates embedded in the QR code. By scanning with the smartphone, the wearer accesses and listens to an exclusive playlist, motivating them to always be on the go (QRCode Tiger, 2022).

To support sustainability and traceability, Prada Group mentions in the Sustainability Report 2021 that the idea of applying RFID, NFC and QR code technologies on its products came from the International Master in Luxury Management (IMLux) a program of master for students, which it sponsored in 2019-2020 (Prada Group, 2021). Thus, by applying the QR code in the fashion industry in Europe, brands will be able to share information with consumers and consumers will be attracted to this new type of communication. In China, for example, people are so used to this system that the QR code can even be found on business cards.

Platform

Circular Content Management System (CCMS), the first online tool in the form of a cloud-based platform, developed in 2016 by the company Dutch Awearness and supported by the European Commission. The idea originated from a visit Rien Otto, the founder of the platform, made to Africa in the early 1990s for a humanitarian project to support farmers and children. The land needed to carry out the project was filled with textile waste from Europe, which is why Rien Otto noted that problems in Africa could never be solved unless Western problems such as dumping textile waste in countries such as Ethiopia and Tunisia are solved. Dutch Awearness therefore focuses on eco-friendly textile innovations, 100% recyclable materials and the control of a circular value chain.

The platform provides integrated clothing tracking services, allowing the customer to see the materials that were used in making the product, who manufactured the clothing and the environmental impact of clothing production. The products of Dutch Awearness are 100% recyclable and are leased to the consumer who returns them after use so that they can be reprocessed into raw materials. Initially, the company used the barcode system useful for tracking products and materials in manufactured products (JDS2248, 2016).

The CCMS online tool was considered essential in the clothing industry circular model in product return management to become a new material for the next production cycle. CCMS was designed for Dutch Awearness customers and partners to help them make the transition from a linear supply chain to a circular economy (Duch Awearness) (Table 2)

Table 2. Dutch Awearness - CCMS Contributors and Users Network

Supported by	Sales to customers	Sales to dealers	Rental to end users	The Dutch Circular Workwear Association
European Commission	Heigo	Tricorp	Berendsen	HAVEP
European Clothing Action Plan	Persu at Work	Latino Group	-	Wiltec
LIFE Programme	Intersafe Groeneveld	Jasmine Mode	-	Simon Jersey & Orcon Workwear
DA Inside	Wiltec	Orcon (Uniform Brands)	-	Van den IJssel Bedrijfskleding
True Colors DA Inside	BAS Bedrijfskleding	Simon Jersey (Uniform Brands)	-	Lasaulec
-	BTN	HAVEP	-	Van Wijngaarden VeiligGoed
-	Van Den IJssel	Concordia Textiles	-	Destil
-	Lasaulec	Alsico	-	Tricorp
-	Van Wijngaarden	-	-	Heido

Supported by	Sales to customers	Sales to dealers	Rental to end users	The Dutch Circular Workwear Association
	VeiligGoed			
-	Suit Up	-	-	-
-	Touchpoint	-	-	-
-	Proforto	-	-	-
-	VYLLIG.	-	-	-
-	Alsico	-	-	-
-	Kristels Fashion	-	-	-
-	HKV Ochten	-	-	-
-	Destil	-	-	-
-	VENDRIG	-	-	-

Sursa: <https://dutchawearness.com/>.

Circular.fashion is a German company that creates software and provides services that support innovations in fashion and the textile industry. In addition, the company offers an electronic tool, Circularity.ID, which after the scan provides digital information about the product history starting by the materials from which the product is made, and other product-related information that help tracking its circularity. Circular.fashion offers software for brands, material suppliers, sorting and recyclers. Brands benefit from a virtual library of circular materials, being the first digital showcase of fabrics, yarns, ornaments, etc, skins and leather alternatives that have been tested and validated for future recycling through the company's comprehensive process of circular material verification. In addition, brands benefit from a circular design guide that provides help in creating products with intelligent and responsible design and the possibility of checking the circularity of materials based on the concrete requirements of the European network of recyclers partners. Their vision focuses on 'Let's enable circularity!' and incorporating Circularity ID. into a brand helps to increase transparency regarding sustainability efforts in terms of increasing customer engagement and loyalty long after the time of product sale and provide data to facilitate circular business models such as resale, rental or end-of-life recycling of the product (Circular.Fashion, 2022). Circularity.ID includes the following features: a) circularity data (to encourage circularity and to provide information related to the materials used and the product, for six years research has been carried out, and, pilot projects have been carried out and collaborative dialogues with stakeholders have been maintained, all of which have been harnessed in creating the circularity.id data standard); b) the product identifier (it is integrated into a garment containing the product's circularity data. For example, for consumers it may be in the form of a QR or NFC code and can be scanned using the smartphone, thus obtaining all the information related to the product); c) the website of the digital product (following circularity.id scanning, the consumer is directed to the product website and all product related information is provided on the website); d) the intelligence of circularity (through circularity.id scanning, access to the entire supply chain can be obtained and the ideal system for taking, sorting, recordering and recycling of brand products can be configured).

Table 3. Circularity.id user network

Fashion brands that work with circularity.id	Material suppliers, sorters and recyclers	Funders and supporters	Collaborators
H&M Group	Canclini	Federal Ministry of Education and Research (Germania)	Circular Thinking
Zalando	Nuvolari Conceria	Das Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (The Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection)	Sqetch
GANNI	Santori Pelami SPA	Klimat-KIC	TrustTrace
BESTSELLER	Waste2Wear	DBU - Deutsche Bundesstiftung Umwelt (The German Federal Environmental Foundation)	Transition
ARMEDANGELS	We aRE SpinDye	ELIIT Project	
Silfir	Gren. Reduce, Reuse, Recycle	FASHION FOR GOOD	
OTTO	Recover	HEREWEAR	
Vretena	Renewcell	IBB Business Team	
Monkl	Valérius 360	World Circular Textiles Day	
The Slow Label	I:CO		
	Fair Wertung		
	Texaid		

Sursa: <https://circular.fashion/en/about/about-us.html#ourclients>.

"Tell me" brand based in Brussels, Belgium, was the first European online wardrobe that aimed to rent clothing for maternity (during pregnancy and breastfeeding periods) and for children up to 6 years old. Tell me launched these trends, being seen as a new way of ethical and sustainable consumption. The Tell me platform operated between January 2015 and January 2018, was supported by the European Circular Economy Stakeholder Platform and financed through crowdfunding. According to the information published by the European Circular Economy Stakeholder Platform in the article Clothes rental - helping to reduce textile waste, greenhouse gas emissions and water footprint, thanks to gaining an increasing number of customers, the business of renting, repairing and returning clothes continued after the closure of the project.

MUD Jeans was created by Bert van Son in 2012 in the Netherlands. MUD Jeans is the only circular denim brand in the world. The company's main business concept is to rent to customers the clothing it produces. After renting for one year at the cost of 9.95 Euros per month, users have the option to either switch to another pair and continue leasing, retain the current pair, or return the worn pair. In the case of returning, MUD will wash, repair, and subsequently sell the jeans on the vintage market (Ellen Macarthur Foundation). The lease comprises unlimited repair services, and the initiative introduced in 2013 is identified as "Lease a Jeans." For MUD Jeans, leasing involves paying a monthly fee instead of the direct EUR 119 purchase, providing an eco-friendly method to reclaim the cotton utilized in jean production. Furthermore, the company extends discounts for subsequent leases, reducing the customer's monthly payment to 8.95 euros from the regular 9.95 euros. To celebrate Earth Day, in April 2022, MUD Jeans launched The Voice for Good platform. The purpose of the platform is to give entrepreneurs visibility and bring them into contact with other entrepreneurs. For the public it is an online place where they discover and share new and emerging initiatives (fashionunited.nl, 2022). Under the slogan

"Discover real projects by real people, tackling real planet problems", only a few months after its launch, The Voice for Good platform provides visibility for companies such as World Changer Co., The Shore and Mended.

Table 4. The platform Voice For Good

Entrepreneurs present on The Voice for Good platform	Activity carried out by entrepreneurs	Company motto
World Changer Co	Shows shopping options that include clothing brands, coffee, chocolate, cosmetics, etc.	"Sustainable fashion stands up for the life of the factory worker, the farmer, the human."
The Shore	It is a surf school and a meeting place dedicated to those who love nature.	"Surfen is natuur, en spelen met de elementen"
Mended	The company's mission is to reduce barriers to extending the life of clothes by making aftercare as easy as purchasing a new product.	"Care and repair everything you wear!"

Source: <https://www.worldchangerco.com/>, <https://www.theshore.nl/>, <https://www.mendedwear.com/en>.

Lalaland, a company founded in 2019 in Amsterdam, is a Dutch start-up that offers companies services such as ODM (Original Design Manufacturer) or in other words, through the created platform is responsible for designing and building a product according to the specifications of the demanding companies, the so-called production on demand (end-to-end). With two major goals, fostering social self-determination and sustainability in fashion, the company uses artificial intelligence to drive inclusion and diversity in digital fashion. By using artificial intelligence, the Lalaland platform enables brands and retailers to use hyper-realistic models of any body type, size and skin tone in the form of Avatars (Patricia Allen, 2022) and provides a single source of truth among designers, merchandisers, sellers and buyers, eliminating guesswork by presenting garments on avatars that match buyers ' preferences, before the products are physical samples, thus eliminating clothing waste (Lalaland, 2022). With digital avatars, companies in the clothing industry can present and validate their 3D clothing models.

Table 5. Users of the Lalaland platform

The largest retailers in Europe	Brands PVH (Phillips-Van Heusen Corporation)	Strategic investors
Zalando	Tommy Hilfiger	Google
Wehkamp	Calvin Klein	Bart De Wilde (former CEO of Nike)
Otto	Warners	-
-	Olga	-
-	True & Co	-
-	AdoreMe	-

Sursa: <https://seedblink.com/en/2022-04-18-streamlining-content-production-for-digital-fashion-brands-michael-musandu-founder-of-lalaland>.

The creation and development of the Lalaland platform are based on the trends that have been evident in recent years worldwide. (1) Creation of the metaverse or to put it another way, synthetic models that exist only in the digital world have come to allow brands and consumers to control images in cyberspace. (2) Digital fashion houses (the Fabricant) are at the top, and digital fashion is on the rise. More and more fashion brands are using 3D design (Clo, Grosso Moda, BROWZWEAR) and web stores for product presentation. The willingness of fashion brands to

use end-to-end (production on Demand) Solutions is high, which contributes to the reduction of overproduction and the development of fully digital solutions. (3) Digital influencers or avatars in the fashion world, such as Shudu and Lil Miquela who changed the world, in the same manner manages Lalaland to impose himself in the fashion world. (4) NFT in fashion is increasingly popular, with major brands embracing the idea of the existence of this opportunity to be able to dress various avatars with 3D created clothing. (5) Sustainable fashion pursues the growing awareness of fashion's environmental impact. (6) The COVID-19 pandemic has allowed the clothing industry to completely rethink the value chain of the industry, especially in the area of fashion photography. Fashion brands sought alternative solutions to the lack of limitations that face-to-face photo shoots implied.

In order to launch a new collection, brands had to do between 2 and 8 photo shoots in a year, needing human models, photographers, makeup specialists, hairstylists, amazing locations, all of which meant huge costs, the creation of the Lalaland platform for the fashion industry massively reduced costs with: the opportunities missed by customers because they can not see someone who looks like them; the high rate of Return of products that most of the time did not match the end customer, which in most cases did not resemble the model; impact on the environment because 2.3 million kilograms of waste are generated annually from fashion returns that end up in landfills or incinerators; the speed with which the market moves because most of the time brands cannot keep up with production during the shooting process, there is the option of presenting the product without a model (Bianca Iulia Simion, April 18, 2022). Lablaco is a French start-up created in 2016 that offers a digital platform and mobile app and aims to trace second-hand clothes using blockchain. The Start - up offers brands the opportunity to value their products at different levels of the supply chain, and consumers the opportunity to identify the actions of marketers on sustainability in the fashion industry.

SPIN is an app that allows consumers to tokenize products, identifying, for example, that clothes they once purchased belonged to a favorite influencer. The application makes it possible to apply the circular model, allowing consumers to become active buyers in the supply chain, and in the end to be able to communicate to traders the desire to recycle products that will no longer be used, thus avoiding the circulation of counterfeit parts (Jess Redgrave, 2021). Since October 2021, the Lablaco company and the H&M Mitte Garten store in Berlin have been collaborating and, through the new technology based on blockchain and the Internet of Things (IoT), allow customers to rent and Exchange textile products (Fibre2Fasion, 2021).

Table 6. European platforms supporting the circular economy

Platform	Purpose	Geographical area	Year of creation
LAMASMODA	Online platform that rents used dresses to women in Spain	Spain	-
Reverse Resources	Streamlines the transfer, reuse and recycling of Textiles, connecting manufacturers, waste handlers and recyclers.	Europe, North and South America, Asia, Africa	-
Haikure	Italian sustainable fashion Brand that provides customers with product information through QR code application	Italy	-
A-GAIN GUIDE	Supporter of the idea that clothing can be repaired, reused, recycled.	Germany	2021
TEXAID	Recycling of textile waste	Germany	-
Recytrader	Textile waste trading platform	Germany, Hungary,	-

Platform	Purpose	Geographical area	Year of creation
		Austria	
Dutch Circular Textiles Platform	Track circularity in the textile industry	Netherlands	2016
Palanta	Rental of clothing for women, future mothers and babies	Netherlands	-
Reversed Loop	Resale of second-hand clothes	Spain and Estonia	-
Resell platform of the COS brand, owned by H & M	Supports second-hand sale of clothes	Germany and Great Britain	2020

Sursa: <https://knowledge-hub.circle-lab.com/>

Using the SPIN platform, with a click, the clothes are booked, paid and ready to be worn, and at the time of return to the store, the clothing is checked, cleaned and prepared for the next customer who wants to rent the product. Along with those identified and presented, at the level of the European Union, the following platforms of local/ regional importance have been created that have developed as supporting the circular economy in the fashion industry.

Conclusion

From our perspective, the circular economy focuses on the resource management dimension and it is directly contributing to sustainable development goals. The aim is to close the loop of resource consumption in the case of materials incorporated in products because there is a lot of space to be filled when it comes to global circularity.

The paper offers an overview on the role of modern technologies in traceability of goods in fashion industry and their contribution to the implementation of circular economy. The methods focused on data collected through Google search tool aiming to identify brands who use Big Data, RFID and QR code tools, as well as on online tools (cloud-based platforms) in order to offer insights regarding future trends implemented by major companies.

From this perspective the fashion industry has an important role to play as part of efforts to reduce its impacts throughout supply chain. A paradigm shift is more desirable to be implemented starting from design stage till waste. The so-called design for recycling is more than welcome to be implemented in the case of fashion industry. Thus, the paper advocates for several typologies of case studies. These new business models and innovative emerging technologies offer not just market opportunities, but also an important contribution to tackling the current environmental crisis and increasing awareness and transparency in relation to consumers.

The findings focus on the role of transformative fashion products. Firstly, it is important to change perceptions about production systems in terms of materials used, labour force, etc. Increasing circularity can steer performance when it comes to inputs and outputs used in production and products' traceability process.

Secondly, transparency and integrity will play an essential role in the global supply chain. From this perspective, additional research is further needed, especially in terms of new emerging business models that are focused on environmental and social standards, as well.

Thirdly, partnerships can be the new collaboration system in the fashion industry. The cross-sectoral initiative, such as the Circular Fashion Partnership can ensure the implementation of effective circular fashion systems in various areas (e.g. in textile, garment and footwear manufacturing regions, including waste management).

Innovation and technologies are the key driving forces for meeting strategic circular potential sectors in terms of actions and targets included in the public policy. Creating a more sustainable fashion industry capable of reducing environmental impacts and promoting new friendly approaches in terms of production will trigger the development of new business models. Reuse of textiles needs to allow the creation of market opportunities (e.g. industrial symbiosis clusters), but to respect specific standards such as the ones on sanitation.

Building upon these drivers of change can steer the transformation of the fashion industry towards a more sustainable one. In terms of current limitations, we believe that new research is needed, especially related to global impact of information included to digital product passports in the supply chain in terms of traceability of fashion products. Still, as future concerns we believe that there is a need to improve the transparency as part of a collaborative approach between policy-makers and stakeholders for building successful approaches.

References

- Alan, M, Skene, K., Haynes, K. (2017). The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context, *Journal of Business Ethics*: 369–380. <https://doi.org/10.1007/s10551-015-2693-2>.
- Allen, P. (2022). Amsterdam's Lalaland bags €2.1 million to empower inclusion and diversity in the fashion industry, June 10, <https://www.eu-startups.com/2022/06/amsterdams-lalaland-bags-e2-1-million-to-empower-inclusion-and-diversity-in-the-fashion-industry/>
- Barry, C. (1972). *The Closing Circle: Confronting the Environmental Crisis*. London: Cape.
- Bert van Son (2022). *MUD Jeans winnaar van de Plaquette Duurzaam Ondernemerschap van de Koning Willem I Stichting*, 18 mei, Retrieved from <https://www.linkedin.com/in/bertvanson/?originalSubdomain=nl>
- Bourguignon, D. (2016). Closing the loop. New circular economy package, *European Parliamentary Research Service*, Janury, PE 573.899
- Brismar, A. (2017). What is Circular Fashion? Green Strategy. <https://greenstrategy.se/circular-fashion-definition/>
- Browzwear (2023), *Accelerate Workflows, from Sketch to Store*, Retrieved from <https://browzwear.com/>
- Circular Economy Alliance (2022), Working together for the upskilling and reskilling of the global workforce, may 4, <https://circulareconomyalliance.com/working-together-for-the-upskilling-and-reskilling-of-the-global-workforce/>
- Circular fashion (2023). *Let's enable circularity!*, Retrieved from <https://circular.fashion/en/software/circularity-id.html>
- Circular fashion (2023). *Let's design circular products!*, Retrieved from <https://circular.fashion/en/software/brands.html>
- Clo (2022). *Changing the world with virtual garments*, Retrieved from <https://www.clo3d.com/en/>
- Comisia Europeană (2020), *Schimbarea modului în care producem și consumăm: noul Plan de acțiune pentru economia circulară deschide calea unei economii competitive, neutre din punctul de vedere al impactului asupra climei, în care consumatorii sunt responsabilizați*, 11 martie 2020, https://ec.europa.eu/commission/presscorner/detail/ro/ip_20_420
- Comisia Europeană (2022), *Strategia UE pentru produse textile sustenabile și circulare*, martie, https://environment.ec.europa.eu/strategy/textiles-strategy_ro

- Crandall Brianna (2018). *5 waste management trends in smart buildings*, April 20, Retrieved from <https://www.fmlink.com/articles/frost-sullivan-5-digitalization-trends-recycling/>
- Circular Fashion Partnership, <https://globalfashionagenda.org/circular-fashion-partnership/>
- De Jesus, A., Mendonça, S. (2018). Lost in transition? Drivers and barriers in the eco-innovation road to the circular economy. *Ecological Economics* 145, 75-89.
- Deloitte & The circular economy Foundation (2023), *The circularity Gap Report 2023* <https://www.circularity-gap.world/2023>
- Departamentul pentru Dezvoltare Durabilă (2022), *Strategia Națională privind Economia Circulară*, <https://dezvoltaredurabila.gov.ro/strategia-nationala-privind-economia-circulara-13409762>
- Departamentul pentru Dezvoltare Durabilă (2023), *Planul de Actiune pentru Strategia națională privind economia circulară* <http://www.mmediu.ro/app/webroot/uploads/files/Planul%20de%20actiune%20pentru%20Strategia%20Nationala%20privind%20Economia%20Circulara%20-%20varianta%20finala.PDF>
- Dissanayake, D.G.K, Weerasinghe D. (2021). Towards Circular Economy in Fashion: Review of Strategies Barriers and Enablers, *Circular Economy and Sustainability*: 25–45. <https://doi.org/10.1007/s43615-021-00090-5>.
- Dragomir Voicu D, Dumitru M. (2022). Practical Solutions for Circular Business Models in the Fashion Industry, *Cleaner Logistics and Supply Chain*. <https://doi.org/10.1016/j.clscn.2022.100040>.
- Duch Awareness (2022), *In Pursuit of Circular*, Retrieved from <https://dutchawareness.com/>
- Ellen MacArthur Foundation. (2022). Fashion and the Circular Economy. <https://archive.ellenmacarthurfoundation.org/explore/fashion-and-the-circular-economy>
- European Commission. (2022). EU strategy for sustainable and circular textiles, March. https://environment.ec.europa.eu/strategy/textiles-strategy_en
- European Court of Auditors (2023), *Special report 17/2023, “Circular economy: slow transition by member states despite EU action* https://www.eca.europa.eu/ECAPublications/SR-2023-17/SR-2023-17_EN.pdf
- European Environment Agency, (2022), *Circular economy country profile – Romania* https://www.eionet.europa.eu/etc/etc-ce/products/etc-ce-products/etc-ce-report-5-2022-country-profiles-on-circular-economy/romania-ce-country-profile-2022_for-publication.pdf
- European Union (2023), *Green Deal Circular Festivals: striving for a circular and climate neutral festival industry*, Retrieved from <https://circulareconomy.europa.eu/platform/en/good-practices/clothes-rental-helping-reduce-textile-waste-greenhouse-gas-emissions-and-water-footprint>
- Fashionunited.nl. (2022). MUD Jeans launches Voices For Good, a platform sharing environmental initiatives founded by MUD Jeans wearers, 22 april, <https://tekdeeps.com/mud-jeans-launches-voices-for-good-a-platform-sharing-environmental-initiatives-founded-by-mud-jeans-wearers/>
- Fibre2Fashion. (2021). Europe's H&M & Lablaco launch blockchain-based rental service, 22 oct., <https://www.fibre2fashion.com/news/retail-industry/europe-s-h-m-lablaco-launch-blockchain-based-rental-service-276980-newsdetails.htm>
- Florian, L.-F., Gold, S., Bocken, Nancy. (2019). A Review and Typology of Circular Economy Business Model Patterns, *Journal of Industrial Ecology*: 36–61. <https://doi.org/10.1111/jiec.12763>.

- Global Fashion Agenda, The Boston Consulting Group. (2017). Pulse of the fashion industry. [globalfashionagenda.com https://www.globalfashionagenda.com/wp-content/uploads/2017/05/Pulse-of-the-Fashion-Industry_2017.pdf](https://www.globalfashionagenda.com/wp-content/uploads/2017/05/Pulse-of-the-Fashion-Industry_2017.pdf).
- Haigh, L. A. (2022). 21 circular economy solutions: changing how we eat, live and travel for a more sustainable world, World Economic Forum, 09 March. <https://www.weforum.org/agenda/2022/03/21-circular-economy-solutions/>
- Hedberg, A., Šipka, S., Bjerkem, J. (2019). *Creating a digital roadmap for a circular economy*, European Policy Center.
- Hervé, C., Stowell, A., Johansson N. (2021). Critiques of the Circular Economy, *Journal of Industrial Ecology*: 421–432. <https://doi.org/10.1111/jiec.13187>.
- Institute for European Environmental Policy (2016), Limits to the circular economy?, 25 november, <https://ieep.eu/news/limits-to-the-circular-economy>
- JDS2248 (2016), Circular Content Management System (CCMS): Track and Trace Tool for Supply Chains, June 16, <https://makeasmartcity.com/2016/06/16/circular-content-management-system-ccms-track-and-trace-tool-for-supply-chains/>
- Kirsi, N., Peters, G., Dahlbo, H., Perry, P., Rissanen, T., Gwilt, A. (2020). The Environmental Price of Fast Fashion, *Nature Reviews Earth & Environment* 189–200. <https://doi.org/10.1038/s43017-020-0039-9>.
- Knowledge Hub (2022), *Discover and contribute practical examples of the circular economy*, Retrieved from <https://knowledge-hub.circle-lab.com/>
- Lablaco, J. R. (2021) A Digital Platform for Circular Fashion, 13 aug, <https://knowledge-hub.circle-lab.com/wctd/article/3937?n=Lablaco-A-Digital-Platform-for-Circular-Fashion>
- Lalland (2022). *Your 3D designs on lifelike AI-models*, Retrieved from <https://lalaland.ai/>
- Layerise (2022). Samsøe Samsøe introduces QR clothing labels. 30 June. <https://www.layerise.com/resources/blog/post/samsøe-samsøe-introduces-qr-clothing-labels>
- MAPFRE. (2021). How can technology help achieve a circular economy? 10 June. <https://www.mapfre.com/en/insights/sustainability/technology-circular-economy/>
- Maranesi, C., Pietro De G. (2020). Modern Circular Economy: Corporate Strategy, Supply Chain, and Industrial Symbiosis, *Sustainability*. 12 (9383): 9383.
- Mineo, L. (2020). What scares you most about climate change? *The Harvard Gazette*, April 22. <https://news.harvard.edu/gazette/story/2020/04/harvard-experts-discuss-climate-change-fears/>
- Mud Jeans, *Lease your circular jeans*, Retrieved from <https://mudjeans.eu/pages/lease-page>
- OECD (2018). Business Models for Circular Economy. Opportunities and Challenges from a Policy Perspective, <https://www.oecd.org/environment/waste/policy-highlights-business-models-for-the-circular-economy.pdf>
- Pantxika, O., Dimitri, M., Cédric, B., Legardeur J. (2022). Toward total traceability and full transparency communication in textile industry supply chain, *INCOSE International Symposium*. Vol. 32: 1-7. <https://doi.org/10.1002/iis2.12866>.
- Pearce, D., Turner, K.. (1990). *Economics of Natural Resources and the Environment*. New York: Harvester Wheatsheaf.
- Piera, C., Cerchione, R., Chiaroni, D., Pasquale Del Vecchio, Urbinati, A. (2020). Designing business models in circular economy: A systematic literature review and research agenda, *Business Strategy and the Environment*. 29 (4): 1734-1749.

- Prada Group (2021), *Sustainability report*, Retrieved from https://www.pradagroup.com/content/dam/pradagroup/documents/Responsabilita_sociale/2022/e-Sustainability%20Report%202021.pdf
- Provin A. P., Ana Regina de Aguiar Dutra, Isabel Cristina Aguiar de Sousa e Silva Gouveia, and e Anelise Leal Vieira Cubas. (2021). Circular Economy for Fashion Industry: Use of Waste from the Food Industry for the Production of Biotextiles, *Technological Forecasting & Social Change* 169. <https://doi.org/10.1016/j.techfore.2021.120858>.
- QRCode Tiger. (2022). Fashion and luxury brands that are using QR Codes for marketing. 11 July. <https://www.qrcode-tiger.com/top-10-luxury-brands-that-are-using-qr-codes-for-marketing>
- Rathinamoorthy, R. (2019). "Circular fashion". In Muthu, S.S. (ed.), *Circular Economy in Textiles and Apparel*. Cambridge: Woodhead Publishing, pp. 13–48
- Sam, L. (2011). Adidas replaces recruiters with QR codes, 12 September. <http://www.qrcodepress.com/adidas-replaces-recruiters-with-qr-codes/855410/>
- Sariatli, F. 2017. Linear Economy Versus Circular Economy: A Comparative and Analyzer Study for Optimization of Economy for Sustainability, *Visegrad Journal on Bioeconomy and Sustainable Development* 6 (1), 31–34. <https://doi.org/10.1515/vjbsd-2017-0005>.
- Simion B. I. (2022), Streamlining content production for digital fashion brands - Michael Musandu, Founder of Lalaland, <https://seedblink.com/en/2022-04-18-streamlining-content-production-for-digital-fashion-brands-michael-musandu-founder-of-lalaland>
- Stahel, W. (2016). The circular economy, *Nature* 531, 435–438. <https://doi.org/10.1038/531435a>
- Stahel, W., (1981) The product-life factor. In Grinton Orr, S. (ed.). *An Inquiry into the Nature of Sustainable Societies: The Role of the Private Sector*. HARC, Houston, TX, 72-96.
- Stretton, C. (2022). Digital product passports (DPP): what, how, and why?, *Circularise*, April 20. <https://www.circularise.com/blog/digital-product-passports-dpp-what-how-and-why>
- The Business of Fashion and McKinsey & Company. 2022. *State of Fashion: Technology*. May. <https://www.mckinsey.com/industries/retail/our-insights/state-of-fashion-technology-report-2022>
- The Shore Scheveningen, <https://www.theshore.nl/>
- Thomas D. (2019). *Fashionopolis: The Price of Fast Fashion & the Future of Clothes*. London: Head of Zeus.
- United Nations Climate Change. (2018). UN helps fashion industry shift to low carbon, [unfccc.int https://unfccc.int/news/un-helps-fashion-industry-shift-to-low-carbon](https://unfccc.int/news/un-helps-fashion-industry-shift-to-low-carbon).
- Venkataraman, D. (2021). QR codes are the next step in fashion supply chain transparency, *GQ Australia*, 24 June. <https://www.gq.com.au/style/news/qr-codes-are-the-next-big-thing-for-fashion-supply-chain-visibility/news-story/afdf1a3beb02754005ffa9d6e7006b55>
- World Changer (2022), *Sustainable fashion stands up for the life of the factory worker, the farmer, the human*, Retrieved from <https://www.worldchangerco.com/>
- World Economic Forum. (2018). *The Future of Jobs Report*, <https://www.weforum.org/publications/the-future-of-jobs-report-2023/>