

INNOVATIONS IN DIGITAL SOLUTIONS AND TRACEABILITY

Trainer Handbook



VERDEinMED

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PREFACE

This document aims to develop a skilled workforce through knowledge sharing, fostering experienced professionals in the Textile and Clothing Industry with a focus on circular strategies and textile waste management. It is a key outcome of the VERDEinMED project, specifically Activity 1.3 – Train the Trainers, which is part of WP1: Reforming the Industry through Sustainable and Circular Practices. In particular, this document aligns with the theme “Innovations in Digital Solutions and Traceability”, where it is possible examining and exploring innovative approaches and best practices for enhancing transparency, accountability, and data-driven decision-making across the textile and fashion value chain. The information is organized by:

1. Digital transformation in textiles;
2. Traceability systems and data management;
3. Transparency and consumer engagement;
4. Supply chain risk management;
5. Case studies and best practices;
6. Conclusion.



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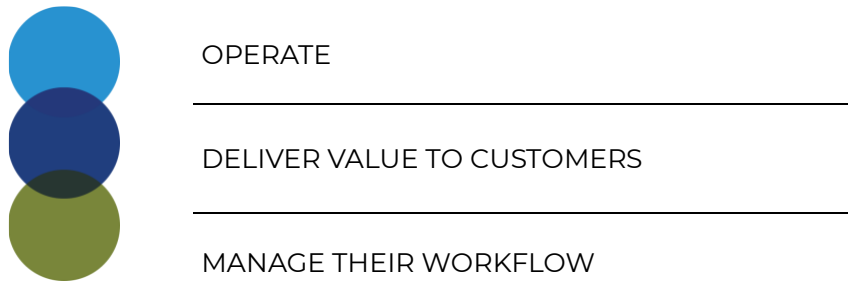
Digital Transformation in Textiles

The integration of Industry 4.0 technologies - such as the Internet of Things (IoT), Artificial Intelligence (AI), and big data - is transforming textile manufacturing, enabling the development of smart factories where automation enhances precision, reduces waste, and optimises energy efficiency. This digital transformation represents a significant shift for the textile sector, allowing companies to rethink their operations, streamline processes, and offer more customised experiences. Importantly, digital transformation goes beyond the adoption of new tools; it involves a comprehensive redesign of how businesses operate, create value, and manage workflows, with a focus on increasing agility, efficiency, and sustainability.

Process Digitalization and Automation

Digital transformation represents a fundamental shift in how organisations across all sectors, including the textile industry, operate and create value. By embedding digital technologies throughout the business, companies can rethink their processes, deliver more efficient and customised customer experiences, and optimise internal workflows.

Digital transformation involves the integration of digital technologies across all business areas, fundamentally changing:



One of the most compelling aspects of digital transformation is the conversion of manual workflows into fully digital and automated systems. The Internet of Things (IoT) plays a central role in enabling this transition. IoT technology connects physical devices—such as textile machinery, sensors, or even finished products—to digital networks, allowing them to communicate and exchange data autonomously. This connectivity transforms passive tools into active systems capable of monitoring, adjusting, and reporting on their operations in real time.

- Connecting Physical Devices to Digital Networks: Through IoT, traditional textile machines can be upgraded with sensors that transmit performance metrics to central monitoring systems. For example, looms equipped with IoT can alert technicians to maintenance requirements or automatically adjust their operations based on data inputs, ensuring optimal performance with minimal human intervention.
- Automated Data Collection: IoT devices enable automated data collection, eliminating the need for manual logging and significantly enhancing the accuracy of operational insights. Sensors embedded in production lines can continuously track energy consumption, material usage, and product quality metrics, feeding this data into analytics platforms to identify opportunities for improvement.

- Facilitating Autonomous Process Execution: IoT integration allows processes that were once reactive to become predictive or fully autonomous. Machinery can self-regulate using real-time data; for instance, automated dyeing units may adjust chemical mixes or temperatures in response to fabric characteristics detected by IoT sensors. This level of automation not only accelerates production but also reduces waste and improves product consistency.

In essence, digital transformation and technologies such as IoT are driving a paradigm shift in the textile industry. By automating processes, enhancing data-driven insights, and creating intelligent networks of connected devices, companies can deliver greater value, minimise their environmental footprint, and remain competitive in a rapidly evolving global market. Leveraging these advancements allows businesses to streamline operations and improve customer experiences. However, to maximise the benefits of IoT, it is essential to carefully implement and manage each component of the IoT infrastructure (Figure 1), ensuring seamless integration and continuous optimisation.

IOT INFRASTRUCTURE OVERVIEW

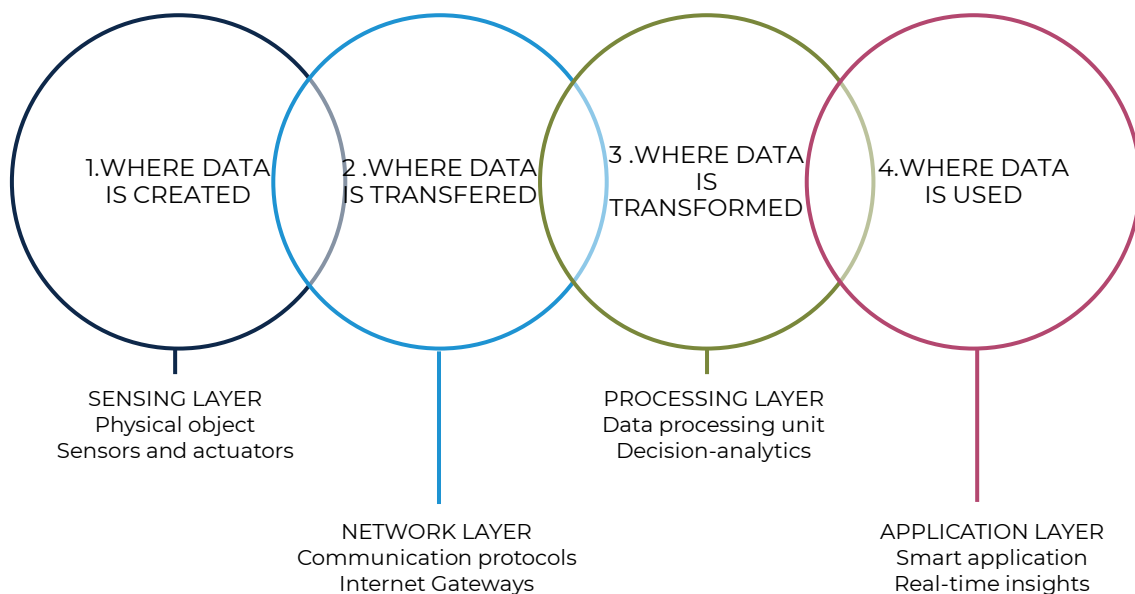


Figure 1 - IoT Infrastructure overview

Benefits and Challenges of Digitalization

The digitalisation of textile manufacturing delivers multiple benefits that significantly enhance industry performance (Figure 2). Foremost among these is operational efficiency: automation replaces manual tasks, streamlines production flows, and reduces machine downtime through real-time monitoring and data analysis. This ensures smoother and more effective production, minimising bottlenecks and delays.

Another major advantage is improved quality. By leveraging AI and IoT technologies, companies can uphold high standards through precise monitoring and automated quality control measures.

Business intelligence is also greatly enhanced through data-driven insights. Real-time data collection and analysis enable informed decision-making, optimise resource allocation, and improve demand forecasting. Access to comprehensive data supports better strategic planning and allows agile responses to market trends or disruptions.

Finally, digitalisation boosts profitability. Cost savings arise from resource conservation, reduced waste, and improved energy efficiency. Predictive maintenance decreases downtime and repair costs, while streamlined supply chains lower logistics expenses. Collectively, these efficiencies contribute to a more profitable and competitive business model, while simultaneously supporting sustainability objectives.

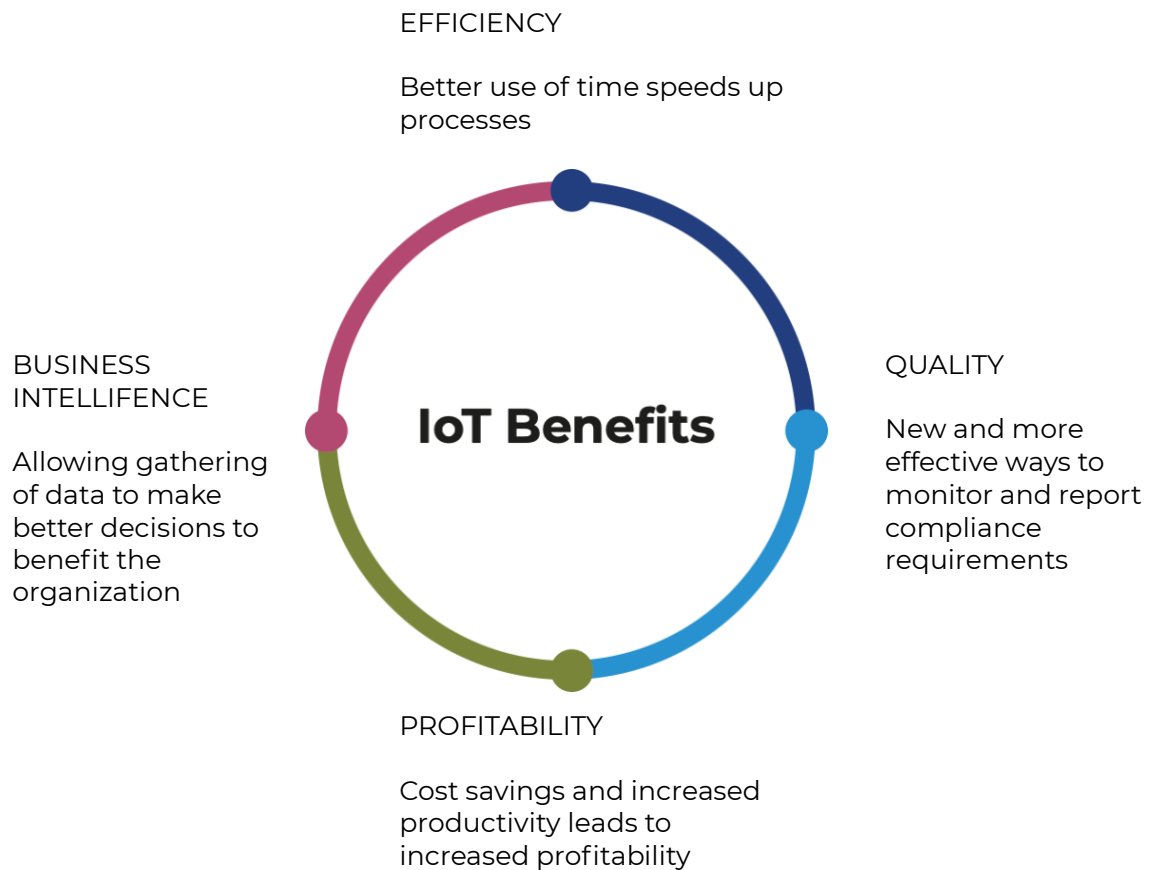


Figure 2 - IoT Benefits

Despite these promising benefits, the shift to digitalisation in textile manufacturing presents several notable challenges. One of the primary obstacles is the high cost of implementation, which can be prohibitive for small and medium-sized enterprises. Upgrading existing infrastructure, investing in advanced machinery, and developing customised software solutions all require substantial financial resources. Another critical issue is cybersecurity. As more devices and systems become interconnected, the risk of cyber-attacks and data breaches increases, making robust security measures essential to protect sensitive information.

The workforce also needs to be equipped with new skills to manage and operate digital systems effectively. This necessitates ongoing training and development programmes, which can be both time-consuming and expensive. Additionally, the rapid pace of technological change means that companies must continuously adapt and innovate to remain competitive, adding another layer of complexity to the transition.

Overall, while digitalisation presents a transformative opportunity to revolutionise textile manufacturing, it requires careful planning, significant investment, and proactive strategies to mitigate associated risks. The industry must balance the adoption of technological advancements with the need to address barriers to widespread implementation.

Traceability Systems and Data Management

The digital transformation of the textile industry has introduced a range of technological solutions that enable enhanced traceability and more efficient data management. Such solutions are essential for ensuring transparency, maintaining quality control, and supporting sustainability across the supply chain. This chapter explores key technologies for traceability, examines established data standards, evaluates the benefits these systems provide, and considers some of the challenges associated with their implementation.

Technology Comparison

Various technologies are employed for product traceability, each offering distinct capabilities and advantages:

- Passive RFID (Radio Frequency Identification): Passive RFID tags do not contain an internal power source and are activated when in proximity to an RFID reader. They are widely used for inventory management due to their cost-effectiveness and ability to scan multiple items simultaneously without line-of-sight. However, their limited read range makes them best suited for applications where close-range scanning is sufficient.
- Active RFID: In contrast to passive tags, active RFID tags have their own power source, allowing them to transmit data over longer distances. This makes them ideal for tracking items across large facilities or in real-time logistics. While highly effective for continuous monitoring, their higher cost and limited battery lifespan can be disadvantages.

- NFC (Near Field Communication): NFC is a short-range RFID technology, typically operating over a few centimetres. It is commonly used for consumer engagement, such as interactive product labelling or mobile payments. In the textile sector, NFC tags can provide detailed product information directly to consumers via smartphones, enhancing transparency and trust.
- QR Codes (Quick Response Codes): QR codes are two-dimensional barcodes that can be scanned with smartphones to provide immediate access to information. They are inexpensive, easy to implement, and widely accessible, making them suitable for consumer-facing traceability solutions. However, they require line-of-sight scanning and are more prone to damage or tampering compared to RFID technologies.

TECHNOLOGY	RANGE	COST	USE CASE	BENEFITS
Passive RFID	Few meters	0.10€/tag	Individual items	Cost effective
Active RFID	100m+	20€/tag	Warehouses	Long-range
NFC	Close range	0.30€/tag	Consumer interaction	Engagement
QR Codes	Visual	0.01€/tag	Marketing	Universal access

Data Standards

To ensure consistency and interoperability across the textile supply chain, several data standards have been established:

- eBIZ: An initiative designed to streamline digital data exchanges within the fashion and textile industries. eBIZ focuses on harmonising data processes, improving efficiency, and reducing errors in information sharing between supply chain partners.
- GOTS (Global Organic Textile Standard): GOTS is a leading standard for organic textiles, encompassing both ecological and social criteria. It sets stringent requirements for certification across the entire textile supply chain, ensuring transparency, sustainability, and compliance with organic production principles.
- GSI Standards: GSI provides globally recognised standards for supply chain management, including barcoding, RFID, and data exchange protocols. These standards are crucial for maintaining consistency, enhancing traceability, and enabling seamless data sharing among stakeholders in the textile industry.

eBIZ:

- Digital standard for textile, clothing, and footwear industries;
- Used for B2B communication and data exchange;
- Standardize electronic documents and business processes.

GOTS (Global Organic Textile Standard):

- Data standards for organic textile products;
- Standardized formats for material composition, processing methods, and chemical inputs;
- Provides traceability.

GS1 Standards:

- Universal product identification and barcode standards;
- Includes GTIN (Global Trade Item Number);
- Enables standardized data sharing and inventory management.

Benefits of Traceability Systems

Implementing advanced traceability systems in the textile sector offers several key advantages (Figure 3):

- **Quality Control:** Automated data collection and tracking technologies ensure that quality standards are maintained throughout production. Issues can be identified and addressed in real time, reducing the likelihood of defective products reaching the market.

- Supply Chain Transparency: Traceability systems provide end-to-end visibility of product journeys, from raw materials to the final consumer. This transparency helps brands manage supplier relationships, identify inefficiencies, and make informed decisions to enhance overall supply chain performance.
- Sustainability and Compliance: By tracking materials and processes, companies can verify that their operations adhere to environmental and social regulations. Technologies such as RFID, along with data standards like GOTS, enable brands to meet sustainability targets and demonstrate compliance to stakeholders.
- Consumer Trust: Providing detailed product information fosters consumer trust and loyalty. Tools such as QR codes and NFC tags allow consumers to access information about product origins, certifications, and ethical practices, thereby enhancing brand credibility.

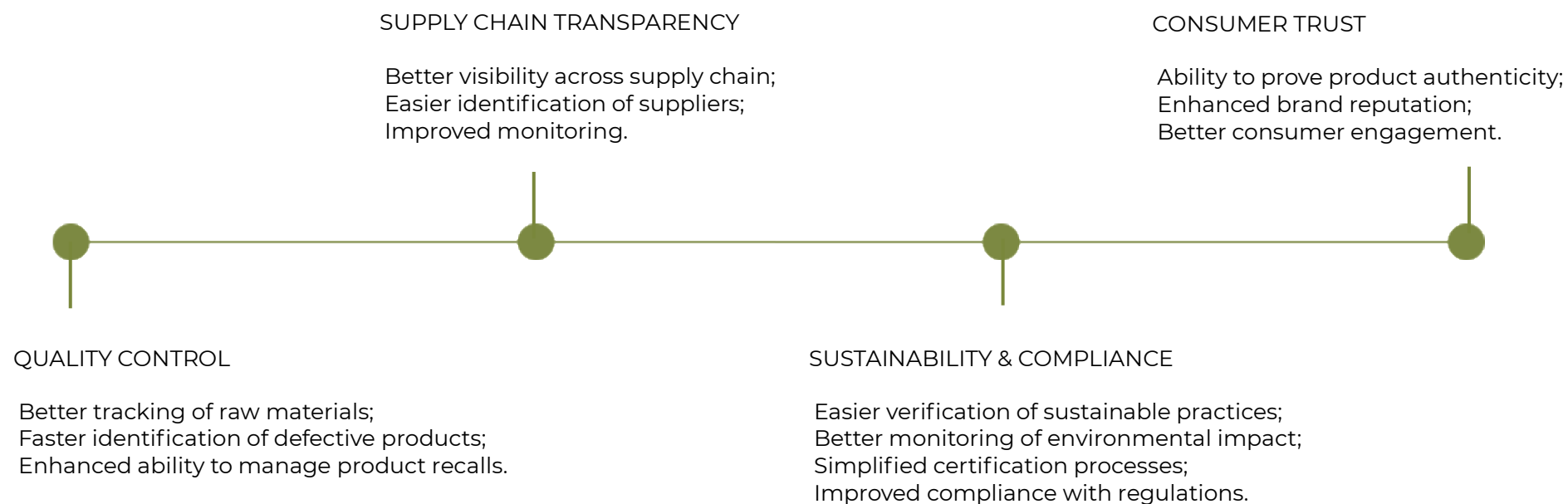


Figure 3 - Benefits of traceability systems

Challenges in Implementing Traceability Systems

Despite the clear benefits, the adoption of traceability technologies presents several challenges (Figure 4):

- **Technical Barriers:** Implementing advanced traceability systems requires significant investment in hardware, such as RFID readers or sensors, as well as in software and IT infrastructure.
- **Financial Constraints for SMEs:** Small and medium-sized enterprises (SMEs) may find the costs of implementing advanced traceability systems prohibitive, limiting their ability to adopt these technologies.
- **Product Transformation Complexity:** Textile products often undergo multiple processes from raw materials to finished goods. Accurately tracking these transformations requires robust data management practices.
- **Supply Chain Complexity:** Textile supply chains are frequently fragmented, involving numerous stakeholders with varying levels of digital maturity. Coordinating data sharing and ensuring compliance with traceability standards across all partners can be a significant challenge.
- **Data Management:** The large volumes of data generated by traceability systems require efficient storage, processing, and analysis. Companies must have the necessary infrastructure to handle big data while maintaining data security and privacy.
- **Implementation Challenges:** Transitioning to digital traceability systems necessitates careful planning, workforce training, and ongoing support. Resistance to change and the need for specialised skills can further complicate implementation effort.

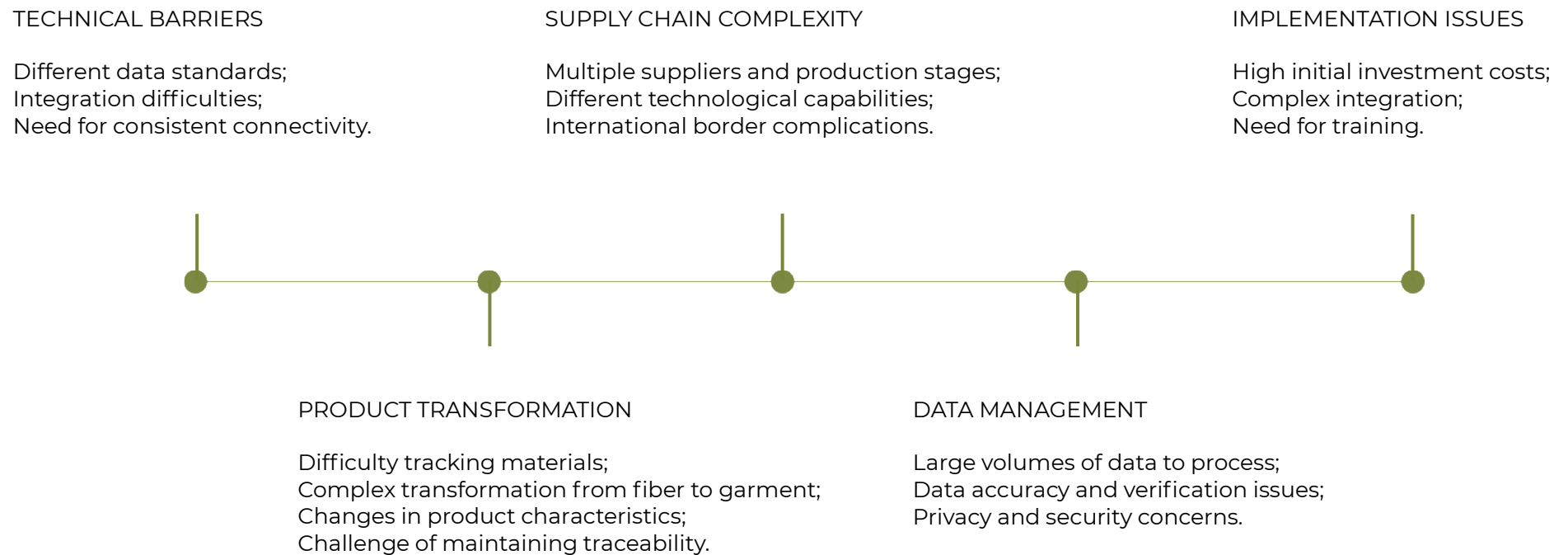


Figure 4 - Challenges in implementing traceability systems

Transparency and Consumer Engagement

Transparency and consumer engagement are increasingly central themes in the fashion and textile industry, driven by rising consumer awareness of ethical and environmental issues. Today, more consumers want to know the origins of the products they purchase, how they are made, and the impact of their consumption choices. As a result, brands face growing pressure to provide greater visibility into their supply chains and to communicate their sustainability practices clearly (Figure 5).

Transparency in this context refers to the open and honest disclosure of information relating to sourcing, production processes, and the overall environmental and social footprint of textile products. This goes beyond generic statements about sustainability, requiring detailed and verifiable information for each step of the supply chain, from raw material extraction to final product delivery. Technologies such as blockchain, RFID, and QR codes play a pivotal role in enhancing transparency, enabling real-time tracking and data sharing those consumers can easily access and verify.

Consumer engagement is equally crucial, as transparency alone is insufficient. To engage consumers effectively, brands must communicate their practices in an accessible and compelling manner. Digital tools, including mobile apps and interactive web platforms, can be used to tell the story of a product's journey. For example, a QR code on a clothing label might link to a digital platform where consumers can learn about the origins of the materials, the workers involved in production, and the environmental impact of each manufacturing stage. This level of engagement creates a narrative that resonates with ethically conscious shoppers and strengthens brand credibility.

Increasing transparency and consumer engagement in the fashion and textile industry involves leveraging innovative approaches that integrate digital technologies with physical product experiences. These methods include:

- **Digital Certificates:** These are verifiable, tamper-proof records that confirm a fashion product's attributes, such as the use of organic materials or adherence to ethical labour practices. Certification bodies like GOTS and OEKO-TEX issue digital certificates that brands can share with consumers - often via QR codes or websites - to validate sustainability claims. This third-party verification enhances transparency and fosters consumer trust.
- **Blockchain Verification:** Blockchain technology strengthens supply chain transparency by creating an immutable, decentralised ledger of all transactions involved in a product's lifecycle. This allows consumers to trace a garment from raw materials to sale, verifying compliance with ethical and environmental standards. Additionally, blockchain helps brands streamline regulatory compliance and combat issues such as counterfeiting and greenwashing.
- **Physical-Digital Links:** Technologies such as QR codes, RFID tags, and NFC chips connect physical products to digital information. By scanning or tapping a product, consumers can access detailed information about its supply chain, creating an interactive and immersive experience. These links also enable brands to provide real-time updates, making the consumer experience dynamic and engaging.

Moreover, increased transparency and consumer engagement help to strengthen the relationship between brands and their customers. By being transparent and inviting consumers to participate in their sustainability journey, brands foster trust and loyalty. Building consumer trust is essential in today's market, and transparency through verifiable information enhances brand credibility. It also helps combat greenwashing by enabling consumers to distinguish genuinely sustainable brands from those making misleading claims.

TRANSPARENCY CHALLENGES

IMPACT ON SALES

The fact of revealing the companies they work with can cause them to lose some competitive advantage.

IMPACT ON SALES

By sharing information about how the products, brands may lose business.

DATA COLLECTION EFFORT

Sharing information results in a great effort in collecting those data.

SUPPLY CHAIN RESISTANCE

Sharing information can be difficult, as companies may be unable or unwilling to share the necessary data.

Figure 5 - Transparency challenges

Supply Chain Risk Management

The key risk areas in textile supply chains typically encompass production, environmental, social, and economic factors (Figure 6). Identifying and managing these risks is essential for ensuring operational stability and supporting long-term sustainability.

RISK ASSESSMENT FRAMEWORK

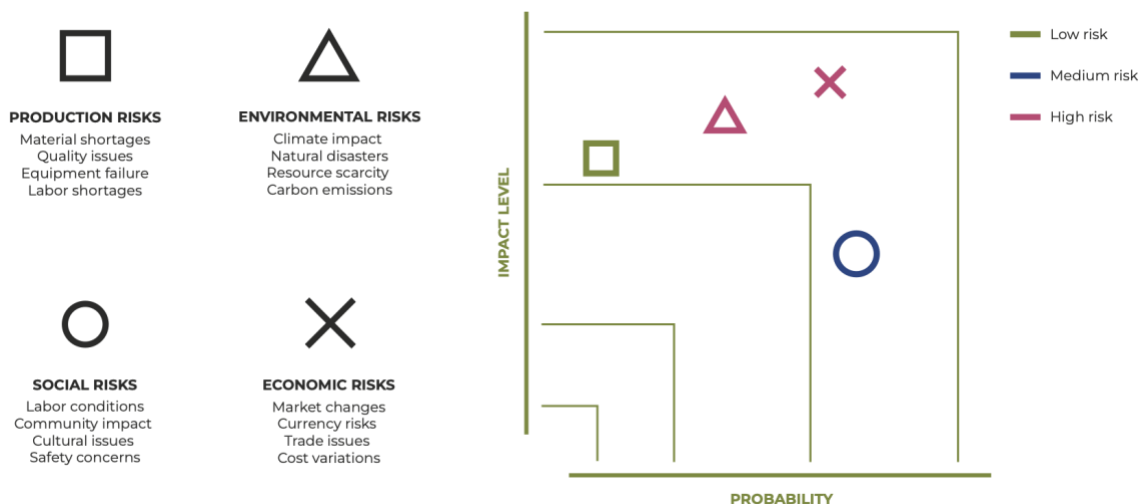


Figure 6 - Risk assessment framework

PRODUCTION RISKS

These arise from issues such as equipment failures, labour shortages, or delays in raw material supply. Companies can mitigate these risks by implementing predictive analytics, diversifying suppliers, and developing contingency plans to ensure continuity in production.

ENVIRONMENTAL RISKS

Climate change, resource scarcity, and natural disasters pose significant threats to supply chains, affecting both raw material production and logistics. These risks can be addressed through sustainable sourcing practices, investment in circular economy initiatives, and compliance with environmental regulations to minimise ecological impact.

SOCIAL RISKS

Labour-related risks, including unsafe working conditions or unethical practices, can severely damage a company's reputation. Regular audits, adherence to international labour standards, and transparent communication with stakeholders are essential to mitigate these risks.

ECONOMIC RISKS

Fluctuations in currency exchange rates, global trade policies, or market demand can destabilise supply chains. Companies can manage economic risks by monitoring relevant economic indicators, diversifying markets, and employing financial instruments such as hedging.

Case Studies and Best Practices

The objective of this section is to give each region the opportunity to present case studies and best practices that align with their specific objectives and requirements. By sharing these examples, the trainer can demonstrate the practical application of the concepts and information covered.

DIGITAL PRODUCT PASSPORT (DPP) BY CITEVE

The Digital Product Passport (DPP), led by CITEVE, represents a pioneering advancement designed to enhance transparency, accountability, and sustainability in the textile industry. The initiative goes beyond the conventional use of QR codes or basic product labels, driving a deeper shift towards comprehensive data sharing and circular economy practices. At its core, the DPP aims to transform how product information is managed and disclosed across the entire supply chain, enabling stakeholders and consumers to make more environmentally and ethically informed decisions.

Unlike traditional systems that provide limited product information, CITEVE's Digital Product Passport (DPP) offers a comprehensive repository of data, encompassing:

- Product Origin and Composition: Detailed insights into the sourcing and types of raw materials used.
- Environmental Footprint: Quantifiable data on emissions, resource consumption, and waste generated throughout the product lifecycle.
- Circularity and Care Guidelines: Instructions for product maintenance, repair, recycling, and responsible disposal.
- Supply Chain Transparency: A traceable overview of each stage of production, highlighting supplier locations, ethical compliance, and sustainability practices.

This extensive information framework ensures that every aspect of a product's journey is accessible and verifiable (Figure 7). For consumers, it enables purchasing decisions based on reliable evidence rather than marketing claims. For companies, it provides a means to substantiate sustainability efforts and reduce the risk of allegations of greenwashing.



Figure 7 - Product information in DPP

The conceptual foundation for the Digital Product Passport (DPP) was established as part of the EU Strategy for Sustainable and Circular Textiles, unveiled in March 2022. The strategy mandates a phased implementation, with key regulatory requirements expected to be finalised in the initial stages. The Digital Product Passport (DPP) is anticipated to become fully operational at a later stage, representing a significant shift in industry standards and practices.

In this context, CITEVE is committed to enhancing supply chain transparency by systematically collecting data that reflect not only the companies involved but also the environmental and social impacts of each stage of production. Through the be@t project, CITEVE is conducting a large-scale pilot in collaboration with various brands to test and validate these developments, with the ultimate aim of bringing products embedded with Digital Product Passports (DPPs) to market.

Furthermore, CITEVE seeks to raise consumer awareness and educate the public on making informed, sustainable decisions regarding product use, maintenance, and disposal. The initiative also promotes knowledge about product reuse and recycling, encouraging the reintegration of materials into the supply chain. This approach ensures a holistic commitment to sustainability, underpinned by a robust and transparent data collection process accessible to all stakeholders.

The Digital Product Passport (DPP) tool calculates an overall product index by assessing multiple components, including environmental and economic, while also incorporating circularity metrics. By quantifying these dimensions, the tool generates a comprehensive product sustainability index, providing a holistic understanding of a product's impact.

The system is designed to monitor every stage of the production journey, from the receipt of raw materials to the dispatch of the final product. Figure 8 illustrates the extensive data captured within the DPP, which remains consistent and adaptable across various industries beyond textiles, despite differences in production structures.

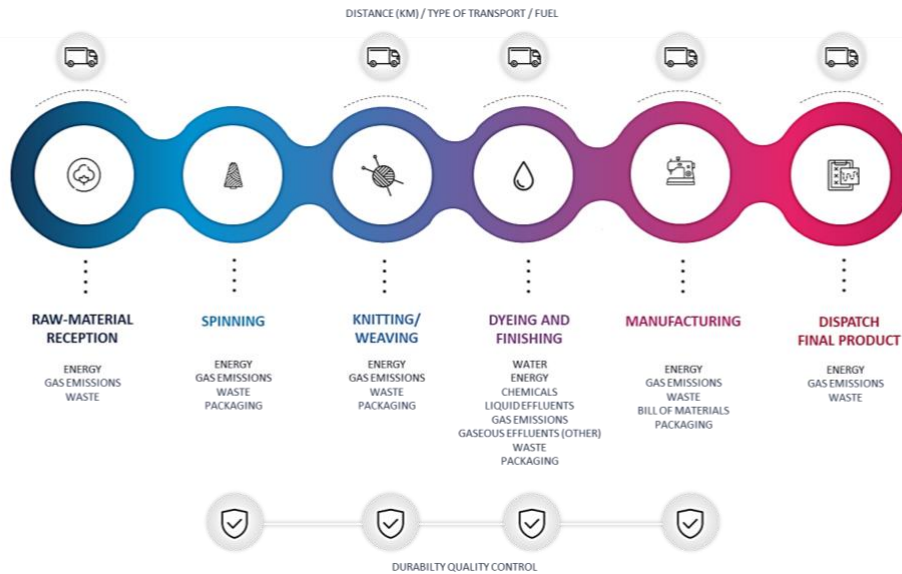


Figure 8 - Supply chain

By scanning the QR code shown in Figure 9, consumers can access CITEVE's Digital Product Passport (DPP) directly. The portal displays the overall product sustainability index, relevant certifications, and detailed information on production activities, including resource consumption and the geographic locations of suppliers. It also provides specific details on product properties, care instructions, repair and disposal guidelines, and a comprehensive bill of materials.

Furthermore, the interface offers recommendations for similar products, enhancing the consumer experience by providing relevant comparisons and supporting informed, sustainable purchasing decisions.

CITEVE's DPP is more than a technological innovation; it represents a strategic response to the urgent need for sustainability and circularity in the textile industry. By connecting product data to a wider framework of environmental and social responsibility, the DPP establishes a new benchmark for transparency. It enables businesses to navigate complex regulatory landscapes, enhance resource efficiency, and engage consumers in a meaningful way.

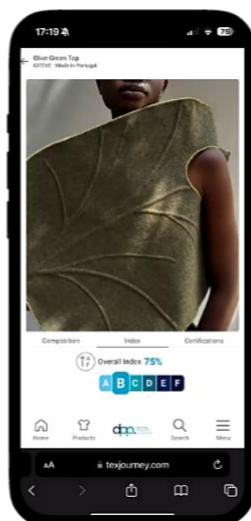


Figure 9 - DPP by CITEVE

Ultimately, the DPP constitutes a significant step forward, laying the groundwork for a more ethical, transparent, and sustainable future in textiles. As it becomes fully integrated into industry practices, the DPP is set to transform how products are perceived and interacted with, fostering a culture in which sustainability is a shared responsibility across the entire value chain.

KEY ACHIEVEMENTS	BEST PRACTICES
Comprehensive DPP system providing verified data on origin, composition, environmental impact, and supply-chain transparency.	Robust traceability framework ensuring accurate, harmonized data collection across all production stages.
Pilot implementation in the be@t project validating DPP functionality with multiple brands in real market conditions.	Consumer-focused transparency through QR-code access to product information, sustainability indicators, and care guidelines.
Integrated sustainability index combining environmental, social, economic, and circularity metrics into a single product score.	Circularity education and engagement promoting reuse, repair, recycling, and responsible disposal across stakeholders.
Website: https://texjourney.com	

Conclusion

The handbook's key conclusions and essential points can be summarised as follows:

- Digital Transformation is Essential: The adoption of Industry 4.0 technologies, including the Internet of Things (IoT), Artificial Intelligence (AI), and blockchain, is now critical for the survival and competitiveness of textile companies. These technologies enable smarter factories and more efficient workflows, reduce waste, and optimise resource use.
- Consumer Engagement Through Transparency: Modern consumers are increasingly informed and demand greater transparency from brands regarding the origin and impact of their products. Innovative solutions such as QR codes, NFC (Near Field Communication), and digital certificates provide consumers with easy access to detailed information on product sustainability and ethical practices. Engaging consumers through these digital touchpoints not only builds trust but also fosters loyalty and advocacy for sustainable fashion.
- Digital Product Passport (DPP): Developed by CITEVE, the DPP represents a transformative innovation that goes beyond traditional labelling. It offers comprehensive information on product origin, environmental footprint, and care instructions, accessible via QR codes. The DPP enhances supply chain transparency and engages consumers with verifiable sustainability data, laying the foundation for a more accountable and circular textile economy.



PreVEnting and ReDucing the tExtiles waste mountain in the MED area

Project overview

The VERDEinMED project is an initiative funded by the Interreg Euro-MED programme to promote the circular economy in the textile sector. VERDEinMED is a thematic project that will provide a support service to boost circularity in the textile value chain for businesses, consumers, policy makers and academia.

The project is part of the Innovative Sustainable Economy mission of the Euro-MED programme, which seeks cooperation between Mediterranean countries to promote smarter and greener business models. VERDEinMED project brings together 10 partners and 15 associated entities from Greece, Spain, Portugal, Italy, Slovenia, North Macedonia, Bulgaria, Tunisia, Turkey, Belgium and Lebanon.



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Consortium

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-Bulgarian Fashion Association
-CITEVE
-Confindustria
-Consorci de la Ribera
-Corporación Tecnológica de Andalucía.

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