TEX4.0

Enabling Industry 4.0 Skills in Textile SMEs

Digital Product Passport

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1. Objectives

This course is designed to teach how the European Union's Digital Product Passport (DPP) initiative enhances product transparency, sustainability, and compliance in the modern economy. Participants will gain an overview of how the DPP improves traceability, durability, and certifications while leveraging 4.0 technologies like RFID and data security. Understanding these elements is crucial for businesses aiming to meet evolving regulatory demands and for consumers seeking more informed purchasing decisions.

2. Outcomes

2.1. Knowledge

By the end of the course, participants will know how the European Union's initiatives drive sustainability through the Digital Product Passport (DPP) framework. They will understand the purpose and structure of the DPP, including its role in improving traceability, durability, and certifications of products. Participants will learn about the advantages for both consumers and businesses, the challenges of implementation, and how 4.0 technologies like RFID chips and data security are integrated. Additionally, they will gain insights from real-world case studies, such as Renoon and Temera, showcasing different approaches and objectives for the DPP.

2.2. Skills

The participants will be able to:

- Comprehend the framework and functionality of the Digital Product Passport (DPP)
- Articulate the benefits of DPP regarding traceability, durability, and certifications
- Understand DPP benefits for consumers and businesses, as well as its implementation challenges
- Analyze and assess real-world DPP applications through case studies

3. The Basis for Digital Product Passports in Europe

3.1. Introduction

The textile industry is facing a pivotal moment with a growing need to confront challenges related to supply chain transparency, sustainability, and ethical production. While we recognize the importance of transparency and data sharing in the transition towards circular economies, the Fashion Transparency Index 2023 reports that only 8% of major fashion brands disclose information about their raw material suppliers and just 42% report progress on sustainability targets. Also of great concern are working conditions which as of now remain largely undocumented throughout the supply chain, leaving millions of garment and textile workers vulnerable to exploitative labor practices that favor a linear economy with fast turnover rates. While the industry is struggling to update practices to match evolving sustainability needs consumer awareness is rising. Research shows that 38% of consumers actively switch brands in favor of companies with credible social and environmental commitments. At the same time, EU policymakers are confronting to these challenges by establishing new regulatory frameworks to improve traceability and circularity within the textile industry.

One promising tool that has emerged from these efforts is the Digital Product Passport (DPP)—a digital record providing detailed information about a product's material compositions, geographic origins, production processes, and environmental impact. As part of the EU's Ecodesign for Sustainable Products Initiative, DPPs aim to enable the establishment of a circular economy by improving data transparency, supporting reviews for more efficient design, and ultimately creating increased accountability for companies selling products on the European marketplace. Industry 4.0 technologies such as RFID, NFC, QR codes, and blockchain allow DPPs to conduct real-time tracking, verification, and sharing of product data across the supply chain. By implementing DPPs, textile companies can not only comply with evolving legislation but also enhance consumer trust, optimize resource and design efficiency, support the credibility of their claims, improve their processes, and drive sustainability efforts all while opening the door for new industries and economic opportunities. This module will explore the

legislative landscape, benefits, challenges, technology involved, and real-world applications of DPPs in the textile sector.

3.2. European Union Initiatives

The European Union is taking steps to address growing concerns about the state of the climate and working to transform Europe's economy to a system that works for the future of the planet. This shift is happening at the same time as a widespread transition within the European Economy that focuses on embracing digital technologies such as AI, blockchain, data sharing, and cloud computing as a means to support innovation and increase productivity across all sectors. This simultaneous shift towards sustainability and digitization is seen as deeply intertwined and referred to as the "**Twin Transition**". While the green transition relies on digital tools to track, optimize and improve the management of resources, the digital transition must be sustainable to avoid creating a new kind of digital environmental burden, highlighting their interdependent nature. There are currently several initiatives to support the adoption of digital technologies as a way to build and foster sustainable and circular economies, particularly within the clothing and textile sector. 4.0 technologies will be a key part of this transition that is fueled by EU legislation. To understand how the industry has arrived at the critical point of mandatory DPP implementation, and how it can be implemented it is crucial to understand the legislation that serves as the foundation for DPP creation.

European Green Deal

In December of 2019, the European Commission announced the **Green Deal** initiative aimed at making Europe the first climate-neutral continent by 2050, recognizing the competitive advantages of investing in sustainability through a fairer, greener, and **more digital Europe**. It includes policies to reduce greenhouse gas emissions, promote renewable energies, improve energy efficiency and encourage the shift to a competitive circular economy all while leaving nobody behind. The Green Deal initiated a new era of product-related economic policies within the EU aimed at achieving this goal including the **Circular Economy Action Plan**, **Ecodesign for Sustainable Products Regulation**, and

– specific to the clothing and textiles sector – the **Strategy for Sustainable and Circular Textiles**.

Timeline of European Union's Legislation leading to digital product passport implementation

Circular Economy Action Plan (CEAP)

In order to achieve the goals outlined in the Green Deal, Europe needs to cut its consumption and double its circular material use rate in the next decade. The **Circular Economy Action Plan** is a European Commission strategy to promote the establishment of a circular economy to ensure that resources are used more sustainably. It proposes measures to reduce waste, recycle materials, and encourage the reuse and repair of products. This plan highlights the need for circular economy initiatives to consider the entire life cycle of products, from raw materials to recycling and end-of-life disposal. Digital technologies are at the heart of tracking product lifecycles, and data will play a critical role in improving economic systems to become more circular. The information collected through the supply and value chain will be accessible as **digital product passports (DPP)**.

Ecodesign for Sustainable Products Regulation (ESPR)

The **Ecodesign for Sustainable Products Regulation (ESPR)** is a proposal by the European Commission to establish sustainability requirements for products throughout their life cycle. This includes the design, production, use, and end-of-life of products in an effort to reduce their environmental impact. It aims to establish a framework for the

eco-design of products, making the approach applicable for the broadest possible range of products and set new eco-design requirements to improve product durability, reliability, repairability, upgradability, maintenance, reusability, refurbishment and recyclability, performance and safety. The ESPR aims to reduce waste and ensure that products that are made or sold in Europe are fit for a climate-neutral, resource-efficient and circular economy. It is important to note that this will affect raw materials and components as well, including those that are not manufactured in Europe, but that are part of products sold in the European market. A key principle of this regulation is that it aims to end the practice of destroying unsold consumer products, which to monitor and enforce will require the transparent communication of product lifecycle tracking through the phases of recyclability and end-of-life treatment. The focus of this framework is on reducing the impact of the entire lifecycle of the product, and requires supply chain tracking and transparency to monitor and improve. The ESPR serves as a dedicated legal basis for detailed, digital tracking and recording of each phase of the product lifecycle in a DPP. It stipulates that DPP will be mandatory for textile products sold in the EU starting in 2027. The ecodesign requirements mentioned here should be included in the DPP.

Strategy for Sustainable and Circular Textiles

One key industry identified as having a high environmental impact within the European economy is the clothing and textiles sector. The global production of textiles is on the rise, and it is predicted that the consumption of clothing and footwear is expected to increase by over 60% by 2030. Because of this, there is a particular focus on reducing textile waste and formulating strategies to make textile production more efficient, and its products more sustainable. The EU **Strategy for Sustainable and Circular Textiles** was adopted in March of 2022, and is a part of the **Green Deal** and **Circular Economy Action Plan**. This strategy aims to address the environmental and social aspects of the textile industry and simultaneously promote circularity within the value chain with the wider goal that by 2030 textile products in the EU market will be longlife and recyclable. 4.0 technologies such as leveraging AI to improve the eco-design of products and predict scenarios of environmental impact, advanced recycling techniques and smart materials,

and the use of blockchain and digital tag tracking to generate transparency within the supply chain from the point of raw materials to end of life recycling and disposal (in other terms, the introduction of a DPP) are crucial to the plan's implementation and success. Together these measures are meant to give credible foundation to sustainable claims and support circular business models by enabling the adoption of more effective and widespread reuse, repair, and recycling services based on collected data leveraged for improval.

The **European Commission** has planned for the mandatory introduction of DPP in the textile and electronics sectors from 2027, in line with the **Circular Economy Action Plan (CEAP)**. This strategy uses the **Ecodesign for Sustainable Products Regulation (ESPR)** to define DPP requirements. According to EU legislation, the information contained in the DPP must be based on open standards, developed in an interoperable format and easily accessible via a common smartphone.

4. Digital Product Passports (DPP)

4.1. An Introduction

A **Digital Product Passport (DPP)** is a digital document that provides comprehensive information about a product's origin, materials, manufacturing process, and lifecycle. It aims to enhance transparency, traceability, and sustainability in supply chains, benefiting both consumers and businesses. The European Commission defines a DPP as a structured collection of product-related data with a pre-defined scope and agreed data management and access rights conveyed through a unique identifier, or **tag**, and that is electronically accessible through a data carrier. An agreed upon, clearly defined, and regulated implementation of a DPP will be a fundamental step in tracking the lifecycle of products from the conception of design and raw materials to end of lifecycle and recycling steps. Not only will it reinforce the credibility of a company's sustainable claims and build increased trust with industry stakeholders and consumers, it will serve to provide detailed information regarding the environmental impacts throughout a product's lifecycle to manufacturers allowing them to make more informed decisions in order to continuously improve future practices. The rich collection and sharing of data will improve the efficiency of design in making products less wasteful and promote reuse, easier recycling, and avoid decisions that lead to overproduction. For this reason, a DPP will be a fundamental tool in the twin transition of circularity and digitization. It is important to note that the transparency of supply chain and product lifecycle data does not in itself mean sustainability, but we can use transparency to collect large amounts of data to then analyze to improve the efficiency of systems and supply chains, reworking them to establish circularity and create more sustainable products. Data is a commodity, and a tool for growth and achieving goals in meaningful ways. This is a key factor why digitization and DPP will be crucial in creating a circular economy and driving new business opportunities. It will be implemented via digital platforms but also through meaningful collaboration amongst players in the supply chain. The key elements included with in a DPP should be compliant with the ESPR and include:

- Information regarding raw materials and composition
- A unique product identifier
- Compliance documentation

- User manuals
- User Instructions
- Information regarding durability and maintenance
- Warnings or safety information (as required by other EU legislation applicable to the product)
- Information related to the manufacturer, such as its unique operator identifier
- Information related to the person or company placing a product on the EU single market

Companies will benefit by preparing now for the introduction of mandatory digital product passports, beginning with grasping an understanding of what will be required of them and how to implement the passports in their product supply chain.

The Digital Product Passport therefore has three key properties: it is capable of providing all the information required concerning traceability, durability and certifications and standards during product quality testing.

The Digital Product Passport will let you know where and how the **raw materials** were harvested, as well as the production processes, i.e. the locations and methods used. The DPP will therefore be able to trace a product's journey along the supply chain.

This passport can have an impact on **sustainability**, as it will contain key data on the product's environmental impact, such as its **carbon footprint**, **water use** and **energy consumption,** allowing businesses to evaluate and better manage their use of resources with improved manufacturing and sourcing methods. It will also provide information about the **product's end-of-life** (recycling, disposal or reuse).

DPPs can provide consumers with information regarding a product’s care instructions and durability. This could include laundering, storage, and usage guidelines to maximize the life of the product. Educating consumers about a product’s lifespan and use can help them to make more informed purchasing decisions. Making this information easily accessible via electronic means is crucial for it to be effective.

Naturally, the passport will contain information on **certifications** and compliance with standards and regulations in the sector concerned. It will provide details of product quality checks and testing procedures followed during production throughout the supply chain. It is important to note that DPPs themselves are not an ecolabel or

sustainability claim. They contain the foundational information that substantiates any ecolabels or sustainability claims.

Companies will benefit by preparing now for the introduction of mandatory digital product passports, beginning with grasping an understanding of what will be required of them and how to implement the passports in their product supply chain.

4.2. Benefits for Consumers and Businesses

The DPP offers advantages for both consumers and companies. The aim is to provide consumers with better information about the products they are buying, but also to enable companies to better manage their supply chain. Consumers are demanding information about the origin of products, their sustainability and also their ethics. They want to have confidence in the information they are given, and for product information to be verifiable and transparent. This consumer demand has an impact on the way companies produce. They can no longer lack information about their partners and not inform the consumer. The DPP therefore has the following advantages for companies:

- Create new data sources to drive sustainable investment
- Optimize the supply chain by helping to identify inefficiencies and areas for improvement
- Builds trust with and improves reputation amongst consumers
- Gives credibility to sustainability claims
- Mitigate risks regarding legal compliance
- Protect public image of the company against scandal
- Motivates and informs investors

The previous point is perhaps not what will motivate companies to make efforts in this area, but on the other hand, and this may be of more interest to them, the DPP could improve their reputation with consumers. In fact, if as well as having a good brand image, they can prove their investment in the transparency and sustainability of their products, they have everything to gain. The DPP will also help them to comply with regulatory requirements and industry standards.

4.3. Challenges for Implementation

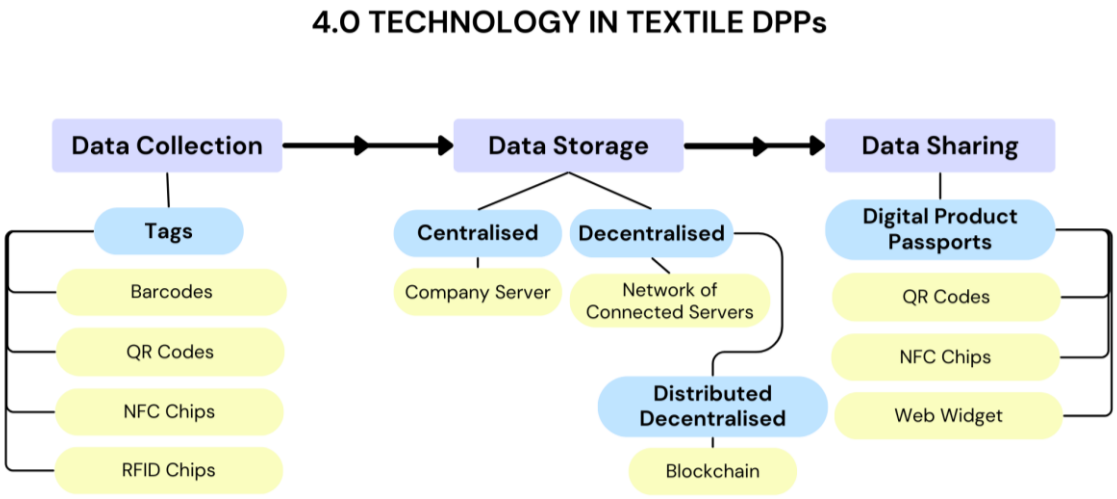
For the DPP to be taken seriously, the data it contains must be 100% accurate and reliable. To achieve this, each collaborator within the supply and manufacturing chain must be checked and the information provided by each must be honest and transparent. This means using digital mechanisms to check and verify the authenticity of the information transmitted. One particular challenge is that companies may be reluctant to provide detailed information regarding their suppliers and processes because it could threaten their competitive edge. This raises the question about what information should be accessible by who. Different stakeholders have different information needs. Customers shopping for garments in-store might want information regarding materials used, care, usability and durability whereas potential investors or new industries might be more interested in information about the manufacturing chain, sustainability certifications, and the end-of-life treatment of products.

Successful implementation of the DPP will depend on good collaboration between manufacturers, suppliers, distributors and certification bodies. To facilitate the sharing of information between collaborators and systems, it will be necessary to adopt **standardized digital formats** and protocols for product passports. It must be possible to communicate between two or more systems, devices or IT elements to ensure the **compatibility and interoperability of systems** used along the supply chain. A standardized, broadly applicable DPP approach and framework has not yet been identified, which poses significant challenges in the initial phases of its implementation. Another major consideration for the adoption of digital product passports and their integration into the business is the initial cost of installation. This shift will be a major undertaking and require monetary and personnel resources to implement, which many small and medium-sized businesses do not readily have at their disposal. While this is a challenge, it does open the possibility for new businesses to fill these service gaps and create new positions.

5. 4.0 Technologies in the DPP

4.0 technologies are at the very heart of the DPP. The product 'passport' will take the form of a label or an easily accessible digital tag, giving instant access to information about a product's sustainability factors. DPP will contain all the relative information about a product, including a unique identifier, and act as its **digital twin** – a digital representation of a physical object. The technologies used to obtain this information are based on **interconnectivity** and the **heavy security of the data**.

The DPP will use blockchain technology to ensure that product information is recorded securely and immutably and will be accessible via **web widgets**, **QR codes** or **NFC chips** that can be easily scanned and allow instant access to stored information. The digital record will link data sets from different sources (steps in the supply chain) but will not own the data. To arrive at the point of a sharable DPP, data must first be collected throughout the supply chain and stored in a secure and trustable manner before being disseminated electronically. Let's further explore the 4.0 technologies involved in this process.



The flow of data in creating a DPP

5.1. Data Collection and Tracking

Throughout the supply chain, data is collected and transmitted using different types of **tags** that are either physical or embedded. **Physical tags** include **barcodes** and **QR codes** that are attached to product tags and packaging or even printed, embroidered or woven

directly onto the product. **Embedded tags** are integrated into the garment during manufacturing such as **NFC tags** that are embedded into garments or **RFID chips** that can even be spun into yarn and embedded in a garment. Each tag, whether physical or embedded, contains a product ID, or unique identifier that allows us to access corresponding information for that object stored in a backend system or platform which has been gathered from key events throughout the supply chain.

Quick response (QR) codes are a physical tag that stores information in a two-dimensional barcode, readable by most smartphones without the need for any additional apps. They can be printed on labels, tags or products, making them easy to spot. While they can store significant amounts of data, the information linked to the code cannot be changed once the code is generated. This means that one QR code cannot be modified with additional information as a product moves through the lifecycle. One benefit to QR codes is that they are relatively easy and inexpensive to generate. There are several online websites that generate QR codes, you can generate them directly in Microsoft Office Suite by installing a QR code add-in, or for more advanced programmers, a Python script can be run to generate a code. One negative aspect about using QR codes is that because they cannot be modified after generation, the information stored on them must be transferred to other systems and locations to be added to as the product lifecycle continues.

QR Code Icons

Source: https://www.flaticon.com/free-icons/qr-code

Radio-frequency identification (RFID) technology uses electromagnetic fields to automatically identify and track tags attached to objects. The system consists of an **antenna**, **transceiver** and **transponder**. When the antella and transceiver and combined in one device it is called a **reader**. The reader transmits radio frequencies that activates

the tag (the transponder) to send information back to the reader which translates it into data. **Active RFID tags** get their energy from a battery, where **passive RFID tags** get their energy from the reader itself. The three main types of RFID systems are categorized by the type of frequency they run on:

- **Low-Frequency RFID** functions on a frequency of 30-500KHz and have a readable range of less than 1 meter. This is often used in livestock tracking, and differences in frequency and power across the world do not make it fit for global application.
- **High-Frequency RFID** functions on a frequency of 3-30MHz and have a readable range of less than 2 meters. This is often used for ticketing, payment, and data transfer.
- **Ultra-High Frequency RFID** functions on a frequency of 300-960MHz and has a readable range of over 8 meters with faster data transfer than low and high-frequency RFID. It is commonly used in retail inventory management. The UHF frequency is regulated by a global standard, not only making it the fastest, but the most applicable for world-wide data sharing.

RFID chips can be embedded into threads that are used to make garments, making their presence nearly invisible from an aesthetic standpoint. Data can be updated in real-time and they can identify individual objects without the direct line of sight required for QR and barcodes. They can pose a security question because they can be read by anyone with a compatible reader without a direct line of sight.

Smartrac Belt RFID tag

Source: https://www.atlasrfidstore.com/rfid-resources/rfid-beginners-guide/

Near field communication (NFC) chips, or tags, are a short-range wireless technology that allows devices to communicate by touching or being within close proximity to each other (typically 10cm or less). While functioning from a much closer distance, technology

behind it is based on RFID technology: the system consists of a reader and a chip. The reader generates a magnetic field which activates the chip and enables data exchange. Simply tapping an NFC tag with a smartphone opens a link with the stored information without the need for any additional effort on the part of the consumer. Concerning DPP, the smartphone acts as the reader while the embedded NFC tag is the chip. This is a **single-interface NFC chip** because the sharing of data flows one way. From the chip to the smartphone. Other NFC technologies include:

- **Dual-interface NFC chips** which is coupled with a microcontroller through a wired interface offering a second communication interface. It enables two-way communication between two electronic systems. We see this in action when a phone automatically pairs with Bluetooth speakers in close range.
- **NFC controller chips** combine both reader and tag for an integrated solution. We see this in smartphones where in some scenarios the phone acts as the reader, and in other scenarios it acts as the tag. Tapping your or smartphone in close proximity to a creditcard reader allows you to make a payment transaction between the two devices. In this case, the smartphone is acting as the tag. When a smartphone comes into contact with an NFC tag attached to a garment to access care instructions it is acting as the reader.

NFC tags store information similar to QR codes but are more dynamic in that they can be reprogrammed with new information after they have been produced. This allows for the modification and addition of information as the product moves through its lifecycle without needing to create a new NFC tag at every stage. They are more expensive to produce than QR codes but can enhance product authenticity with encryption and unique identifiers. NFC tags are often embedded into products and are less visible than QR codes. This can be both a positive and a negative feature. While it may make information less visibly accessible, it does not affect the aesthetic appeal of products in the same way that QR codes often do. NFC tags can be applied to track the movement and processing of materials in the production cycle or after manufacturing as access to the DPP final product itself. While consumers can access product information via NFC tags at the time of purchase, the technology opens up the future possibility for further

tracing past the point of consumer purchase as the information on the tags could potentially continue to be modified tracking consumer use, repair and recycling habits.

NFC tag on Monobi Studio garment

Source: https://monobistudio.com/blogs/notizie/monobi-digital-product-passport?srsltid=AfmBOooiCKJAPMiCxpdQMBGPd2eiPiv1vSzIvtmn7qctCMrWMh_GCl2r

Embedded tags like NFC chips and RFID tags are most commonly used for commercial shipping and logistics. They are often attached to larger packaging units, such as pallets, but can also be embedded into the individual textile products themselves. An RFID tag can be embedded into a thread which in turn is used to create the garment in the manufacturing stage. This has the potential for one RFID chip embedded at the stage in which raw materials are spun into yarn or thread, to track the product lifecycle from a relatively early stage. While they are promising technologies for tracking the events in the value chain of textile products, embedded tags can pose additional challenges for the recycling phase as metal components are integrated into textile products and regardless of the type of tag used to collect data one critical hurdle remains – the **interoperability of software and data storage systems.**

5.2. Data Storage, Security and Interoperability

Data security is critical in ensuring that the information stored within the DPP is trustworthy and has not been tampered with. If we cannot trust the integrity of data in the DPP it will be of little use to companies and stakeholders. Let's evaluate the efficacy of centralised, decentralised, and decentralised distributed data storage systems. While

both centralised and decentralised systems function on cloud-based technology, there are notable differences.

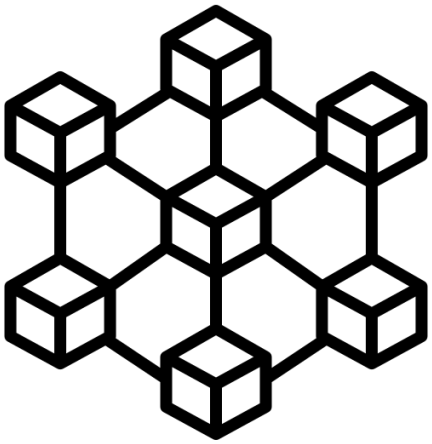
Centralised systems store data in one central location such as a company server that is managed by one entity. While they tend to be relatively simple to implement, they cannot be accessed by other servers limiting their accessibility and are more vulnerable to breaches and a potential loss of data as it is stored only in one place. Centralised systems are also more susceptible to corruption because data can be modified or tampered with easily.

A **decentralised system** has multiple owners and the same data is stored and accessible by all of them. While they are more complex systems to implement and require data consistency across all **nodes** (computer, server, or device that participates in the system), they also offer better protection of data from singular points of failure, scalability for system expansion, and accessibility from multiple points. While security requires that you protect each node rather than focusing on one singular point, they are less susceptible to cyber attacks than centralised systems. Overall, decentralised systems offer better privacy, security, control and scalability, and are recommended in the initial phases of DPP implementation.

Decentralised distributed systems are a peer-to-peer network of nodes where no single member owns all the data. A well-known example of a decentralized, distributed system is **blockchain.** When data is recorded or uploaded in the system a block is created. Blockchain uses **distributed ledger technology (DLT)** that ensures each of the participants in the network (nodes) agree on the validity of the data. The data, or block, is split into encrypted fragments and distributed across the network of **nodes** (computers or devices running software for the blockchain in different locations). This distribution creates repetition or redundancy because each device in the network stores a copy of the ledger. When it is validated, the block is added to the chain and is then executed. Data is secure from tampering because no single node can modify existing data without the other nodes' approval. Changes are recorded across all nodes. Each one publishes its version with the latest transactions, and if they reach an agreement about its validity, transactions are finalized, encrypted, and used as a basis for the following transactions. This creates a sort of chain of transactions and is how blockchains

develop. Each block contains encrypted information about the block before it, which makes them immutable.

This is why blockchain is considered to be so secure, the data stored on it is verified as valid by multiple other parties in the system, rendering it very difficult to modify or falsify without detection. Blockchain is recommended as the best data storage system for use in DPPs because it ensures the highest amount of data security and integrity compared to other decentralized, and particularly centralised, systems.



Blockchain Icons

Source: https://www.flaticon.com/free-icons/blockchain

While digital mediums can generate large amounts of data, it is not useful unless it is accessible. Right now, most data is centralized to companies which leads to ambiguity. Sharing data can lead to the further developing of transparency and traceable systems for circular economies.

Establishing interoperability across various platforms and stakeholders for **sharing DPP data** requires establishing **standardized data formats** that everyone in the value chain adheres to. This is currently considered to be one of the greatest technical challenges in DPP implementation. While interoperability is important in establishing supply chain transparency and analyzing collected data to create circular economies, there is currently no established standard. There are however several proposals and things to consider as we work towards establishing interoperability in the context of sharing data needed to create a DPP. Decentralized systems create less administrative burden for companies because they can insert and control data in their own systems that connect

to a central platform by **application programming interfaces (APIs)**, a mechanism that works as an intermediary, allowing two software components or servers to communicate with each other.

One interesting proposal is the **DIDChain**: a framework for tracing a product's supply chain that is based on using **decentralised identifiers** and blockchain technology. Like we saw the decentralization of data storage systems, this framework proposes the decentralization of identifiers which are currently centralized and managed mainly by governments or companies. This would allow users, or members of the supply chain (raw material providers, manufacturers, distributors, etc.) to control the ID and associated data. Each DID would consist of a unique identifier and a DID document including public keys for cryptographic verification, authentication methods, and service endpoints for interactions. Each raw material, component, and entity would get its own unique DID linking back to critical data required of the DPP. The information from each step in the supply chain would be stored as a block on a public blockchain, creating an immutable chain that traces each key event in production. Because DIDs are machine-readable, cryptographically verifiable, and interoperable, they could serve as a standardized data format for DPPs. This is still a theoretical proposal and would take advanced, high-functioning systems to implement. While it is an interesting approach worthy of further exploration, it is doubtful that this would be doable within the timeframe required for DPP implementation.

Fortunately, there are several companies filling the tech space with a faster solution to interoperability. **Tech providers and platforms** can act as intermediary services between material suppliers, manufacturers and distributors gathering and verifying data in the supply chain while making it accessible to platform users ultimately compiling all relevant data collected into one DPP. Two of these providers, Renoon and Temera, we will examine within real-life scenarios in our case studies.

5.3. Communicating and Using DPP Information

Data sharing and communication is the most important step in the DPP process. Without the means to share the data that has been collected and stored, our efforts become useless. A **DPP shares the stored data in a way that is electronically accessible to**

stakeholders. This can take various digital forms such as information embedded on a product webpage, or via physical tags like QR codes and NFC chips. Webpages make DPP information available to customers or stakeholders before or even without purchasing or handling a physical product. Physical tags such as QR codes on tags in-store or NFC chips embedded or attached to garments give access to DPP information when a stakeholder comes into contact with the physical product itself.

To access information stored in a QR code, you can simply scan the code with a phone camera, which will open a webpage that contains all relevant data. To access information stored on NFC chips, you can hold your mobile phone in close range to the embedded chip to access information. We will look at this more closely in the case study examples.

DPP contain information and compile large amounts of data from throughout the supply chain that is incredibly usefull for business as well. **Artificial Intelligence (AI)** systems can be used to analyse and manage DPP data to make sure that companies and products are in compliance with regulatory standards and to improve operational efficiency and product sustainability by analyzing life cycle data. The atomization of DPP data analysis minimises the risk of human error and creates less disruption to company's current operational systems.

6. Conclusion

In summary, the **European Commission's Circular Economy Action Plan (CEAP)** and its strategy using the **Ecodesign for Sustainable Products Regulation (ESPR)** to define the particular needs of **Digital Passport Products** has already enabled several companies to

develop ways of meeting both the EU and consumers' needs for **transparency**, **sustainability** and **certification** in the products they buy. The use of 4.0 **technologies** make this information more **accessible** to consumers, while at the same time making it **secure** and **trustworthy**. Today, the Digital Product Passport can take many different forms, but it offers a necessary step forward, particularly in the **textile industry**: visibility over the supply chain and the choice of **climate-responsible** and **sustainable** alternatives.

While the digital product passport already serves an honorable purpose, there are many prospects for the future. The trend should be towards increasing regulatory pressure for greater transparency and sustainability and establishing standards for data formats and interoperability. Technological advances should simplify the creation and management of product passports. Growing consumer demand for more ethical and sustainable products along with increasing regulatory measures from the European Union will enhance DPP uptake over the next several years.

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