CIRPASS
Digital Product Passport

D3.4

DPP System Roadmap

V2.0

May 2024

Funded by
the European Union

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Work Package	WP3
Due Date:	December 2023
Actual Delivery Date	March 2024
Abstract:	This report presents an expanded version of the DPP system roadmap which is also presented, but in summarized form, in CIRPASS report "Cross-sector and sector-specific DPP roadmaps". This roadmap will focus more specifically on the following topics: identification schemes, data carriers, DPP system components, dataspace integration and prototyping and deployment.
Citation	Jousse, A., (Ed.) (2024). DPP System Roadmap. CIRPASS Consortium. https://doi.org/10.5281/zenodo.11096973

Document Revision History			
Date	**Version**	**Author/Contributor/Reviewer**	**Summary of Main Changes**
01/05/2024	V1.0	Adrien Jousse, Staffan Olsson, Panagiotis Papadakos, Carolynn Bernier, Rigo Wenning, Sergio Gusmeroli, Abdelrahman Abdalla	Final draft available for review
30/05/2024	V2.0	Adrien Jousse, Sergio Gusmeroli	Final version after EC review

Dissemination Level and Nature of the Deliverable		
PU	Public	**x**
SEN	Sensitive, limited under the conditions of the Grant Agreement	
Nature	**R** = Report, **E** = Ethics or, **O** = Other	**R**

CIRPASS Consortium			
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22	SyncForce BV	SyncForce	NL
23	ASOCIACION DE EMPRESAS TECNOLOGICAS ES INNOVALIA	INNOVALIA	ES
24	Textile Exchange	TextileExchange	US
25	Responsible Business Alliance	RBA	US
26	WORLDLINE FRANCE	WORLDLINE	FR
27	RISE RESEARCH INSTITUTES OF SWEDEN AB	RISE	SE
28	IPOINT-SYSTEMS GMBH	iPoint	DE
29	Global Electronics Council	GEC	US/NL
30	Avery Dennison Atma GmbH	atma.io	AT
31	Global Battery Alliance	GBA	BE

Preparing the ground for the gradual piloting and deployment of DPPs from 2023 onwards, focusing on developing a roadmap for prototypes in three value chains: electronics, batteries and textiles.

Grant Agreement: 101083432
Theme: DIGITAL-2021-TRUST-01
Start Date of Project: 01 October 2022
Duration: 18 months

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List of Abbreviations and Acronyms	
AIDC	Automatic Identification and Data Capture
DEP	Digital Europe Programme
DID	Decentralised Identifiers
DNS	Domain Name System
DPP	Digital Product Passport
EBSI	European Blockchain Service Infrastructure
ERP	Enterprise Resource Planning (Software & System)
ESPR	Ecodesign for Sustainable Products Regulation
HEP	Horizon Europe Programme
HTTP	HyperText Transfer Protocol
IDSA	International Data Spaces Association
NFC	Near-Field Communication
PIM	Product Information Management
PLM	Product Lifecycle Management
REO	Responsible Economic Operators
RFID	Radio Frequency Identification
SHACL	Shapes Constraint Language
UHF	Ultra High Frequency
URL	Uniform Resource Locator

About CIRPASS

The European Commission has strong interest and ambition in relation to emerging technologies to support the 'twin', green and digital, transitions and specifically in the development of a **Digital Product Passport (DPP).** The DPP is defined by the European Commission as a structured collection of product related data with pre-defined scope and agreed data management and access rights conveyed through a unique identifier, and that is accessible via electronic means through a data carrier. The intended scope of the DPP is information related to sustainability, circularity, value retention for re-use, remanufacturing and recycling.

The aim of CIRPASS is to prepare the ground for a gradual deployment of DPPs, with an initial focus on the electronics, batteries and textile sectors. Spurred by the need to accelerate the transition to a more circular and sustainable economy, combined with new opportunities offered by a burgeoning data market, a large number of European and international initiatives have emerged recently. CIRPASS's methodology consists in uniting representatives from a large number of these early DPP pilots in order to build a balanced, open and transparent community dedicated to the design and roll-out of the upcoming European DPP.

To ensure a neutral and technology agnostic stance, CIRPASS relies heavily on the involvement of leading European Research and Technology organisations, supported by three standardization organisations, an experienced pool of circular economy and sustainability consultancies, several large European industrial associations, digital technologies and web experts, and digital solution providers. The CIRPASS consortium is made up of 31 partners in total.

By bringing together this community of expertise, the project will build consensus and momentum around the DPP concept and contribute to the development of common principles, prototypes and roadmaps to secure the interoperability of DPPs across value chains, sectors and market participants. Enhanced stakeholder dialogue will be achieved through extensive consultations addressing key DPP aspects such as ontologies, technical requirements and standardization needs.

1 Introduction and objectives

One of CIRPASS objectives is to create a high-level description of the fundamental functioning of the Digital Product Passport (DPP). This report collects and analyses the results from other CIRPASS reports[1], namely "Identification schemes", "DPP user stories", "DPP System Architecture" and "DPP Prototypes" to define a roadmap for the DPP system in the short term and midterm future (up to 5 years ahead).

This report presents an expanded version of the DPP system roadmap which is also presented, but in summarized form, in Chapter 4 of CIRPASS report "Cross-sector and sector-specific DPP roadmaps". This roadmap will focus more specifically on the following topics: identification schemes, data carriers, DPP system components, dataspace integration and prototyping and deployment.

This document is structured as follow. It starts with a summary of the CIRPASS proposal for the DPP system, to remind the reader of the status of the current proposal. Then, it presents the roadmapping methodology used for each of the following chapters. Four roadmapping chapters are then presented in this document. The first one is focused on identification schemes and data carriers. The second presents a roadmap for the development of the components of the DPP system and the protocols used to communicate in the DPP system. The third one deals with dataspaces and the final one with the real-world deployment of DPP prototypes.

2 Review of CIRPASS proposal for the DPP system

The CIRPASS proposal for the DPP system is described in a number of reports. This proposal not only targets a system that can ensure compliance to the needs of relevant regulations. The proposal aims to embed the regulatory DPP system into a much wider technological ecosystem. This present report builds on the results described in these other CIRPASS reports[2], namely:

- **Identification schemes**, which determines criteria for usable identification schemes for the DPP system with a focus on identifier interoperability;
- **DPP user stories**, which describes stakeholder interactions with the DPP system;
- **DPP system architecture**, presenting a component and data-flow view of the architecture;
- **DPP Prototypes**, focusing on semantic interoperability.

For reference, the high-level component view of the HTTP version of the proposed DPP system architecture is reproduced below.

[1] https://cirpassproject.eu/project-results/

[2] https://cirpassproject.eu/project-results/

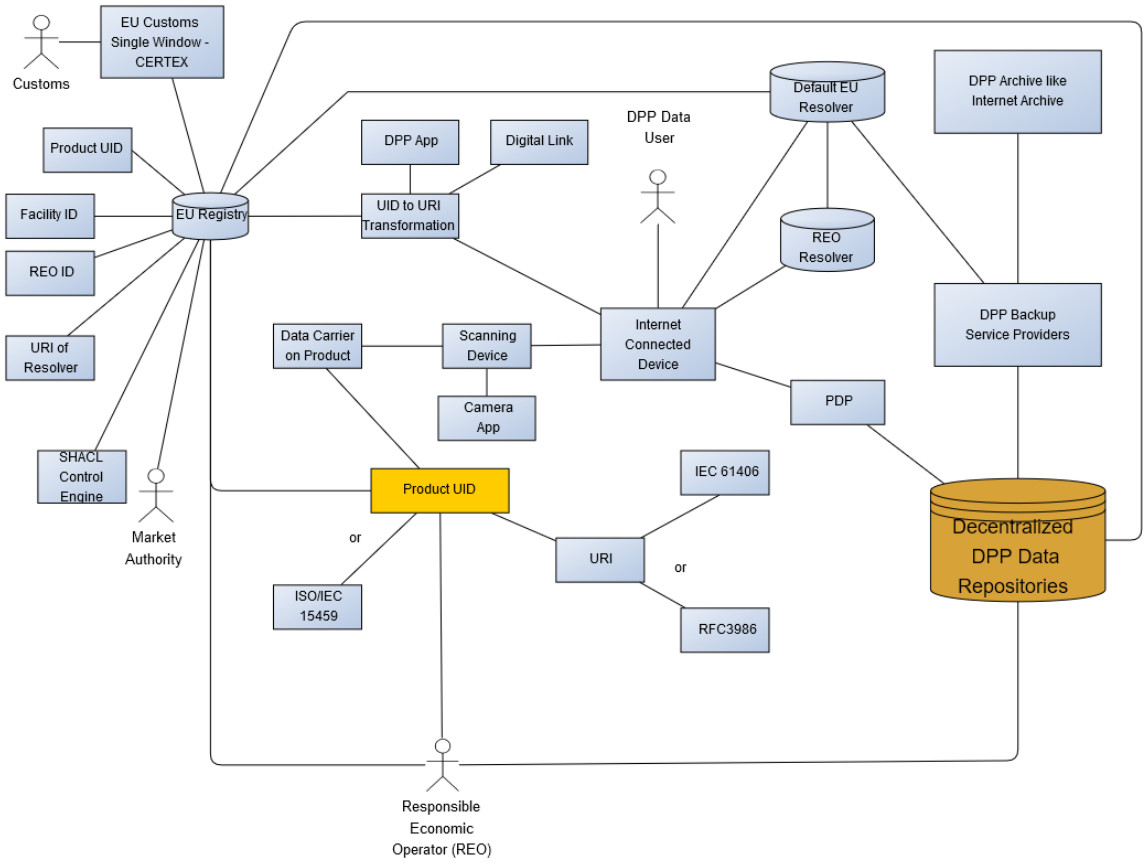

Figure 1: Structural view of the CIRPASS DPP HTTP system architecture[3]

3 Roadmapping Methodology

The CIRPASS project has produced numerous roadmapping reports, each one with its own focus. To ease the reading exercise, all the roadmaps share a common methodology which is described here.

The methodology used for the process of developing the roadmaps is based on the Advanced Technology Roadmap Architecture (ATRA) by De Weck 2022[4]. The core process after collecting the relevant information from other CIRPASS tasks for producing the roadmaps consists of four steps. In these four steps we filter and assess the available information from different perspectives based on guiding questions and criteria sets.

Step 1: Where are we today?

In this step, we explore the current state of the art in generic DPP systems and sectoral DPP solutions for batteries, electronics, and textiles.

Step 2: Where we are going!

Especially regarding the EC regulation and its EC market impacts, some key elements of a DPP system in the EU appear already to be predetermined with a high degree of certainty. The same applies to public-private investments in EU-level pilot projects, which cover key product groups that have been

[3] Figure extracted from CIRPASS report "DPP System Architecture"
[4] Olivier L. De Weck (2022), Technology Roadmapping and Development, p. 216

or soon will be regulated. In this step, we will summarize these mostly predetermined pathways and evaluate, which options they leave for stakeholders in the emerging European DPP ecosystem.

Step 3: Where could we go?

The regulation mandating the introduction of DPPs for different product groups leaves plenty of scope for different technological and organisational approaches in order to implement functioning DPPs in a compliant way. In order to highlight what is possible, we explore a small selection of different scenarios based on potential options and timelines for development and implementation of a generic DPP system.

Step 4: Where should we go?

Based on the exploratory work performed by CIRPASS regarding the DPP system architecture and the standardization requirements, we will describe some recommended pathways, which we aim to evaluate against envisioned key results of effective DPP systems.

4 Identification and data carrier roadmap

4.1 Step 1: Where are we today?

Due to the importance of the unique product identifier as the foundation of the DPP system, specific focus was placed on the criteria for assessing the suitability of product (and also operator and facility) identification schemes with respect to the essential requirements. To this end, an assessment framework was designed to evaluate a number of identification schemes according to the different criteria. The selected criteria are the following:

- Uniqueness
- Interoperability
- Granularity (Product)
- Representation in Data Carriers
- Linking Physical to Digital
- Current Scope of Use/Pervasiveness
- Online Selling (Product)
- Persistence
- Offline data Encoded in AIDC Data Carrier
- Delegated Act or Regulatory Direction (on Choice of Identification Schemes)

The above criteria were used to assess up to 6 identifications schemes for the identification of products, economic operators, and facilities.

In particular, this report proposes an inclusive definition of the concept of **product identifier interoperability**, allowing for the parallel use of a wide range of product identification schemes. This definition is reproduced below:

"Interoperability means that an identification scheme integrates well into the subsequent system accessing the DPP Information, and that various identification schemes can be used in parallel without causing disruption due to lack of uniqueness (see the UNIQUENESS criterion above). With this approach to interoperability, there will not be a risk that two completely different products are assigned the

exact same product identifier as a result of two or more different product identification schemes being used.

Furthermore, interoperability relies on product Identifiers that must either be in the form of a web URI or have a formal, specified and known transform into a web URI. If this URI is not present in the data carrier, this transform can be done within a dedicated application or as a cloud service. As soon as an identifier is in the form of a web URI, a web request to this URI will return DPP data or the link to the DPP.

If an application encounters an unknown identifier that it cannot resolve, and therefore who's DPP cannot be found, this does not affect or disrupt the other software running in the user's environment used, e.g. in a recycling plant."

More details can be found in CIRPASS report "Identification Schemes" available at https://cirpassproject.eu/project-results/.

4.2 Step 2: Where we are going!

Automatic Identification and Data Capture (AIDC) systems for products are currently evolving. The retail and consumer goods industries are in the beginning of a migration from the traditional GS1 1D barcodes, that were introduced in the 1970's, to the use of 2D barcodes, such as QR codes. These 2D codes will still contain the same GS1 product identifiers as the 1D barcodes, but the identifiers will be embedded in web addresses, enabling the connection to data on the web. In addition, the migration allows adding more information in the URI encoded in the data carrier, such as batch numbers or serial numbers enabling identification on item level. In the food sector (which is not in the scope of the ESPR), data attributes such as best-before-dates can be encoded enabling things like automatic mark-downs when the date is approaching. And it will still go 'beep' at checkouts across the world.

To favour openness and ease of integration of all actors, the CIRPASS proposal for the DPP system also works with other types of data carriers and identification schemes. As described in the definition above, any unique product identifier that can be resolved into a usable URI can be used in the DPP system.

4.3 Step 3: Where we could go?

Taking into account that sector-specific needs will also play an important role in the acceptance of the DPP system, the choice of data carrier type and placement has an important impact on usability of the DPP for a wide range of circular economy activities, particularly for any activity requiring high-speed sorting. In addition, consumers must be able to easily scan a data carrier, which should remain possible with any QR-code reading camera application in a smartphone. Smartphones able to read NFC (i.e. short-range RFID) tags are common today and will certainly become more so in the future. While NFC-enabled smartphones typically use the NFC embedded chip in a 'bank card emulation' profile, the default driver installed in most smartphone operating systems is also capable of executing the 'tag reader' profile that is capable of extracting an URL from a passive NFC tag. This means that most

smartphones could already read DPP-related URIs today[5], without the need to install any additional applications.

It is foreseeable that the use of longer-range RFID technology will be necessary in some domains to identify the product at the end of the life cycle (e.g. fashion and footwear). Future cell phones will likely be able to read not only NFC chips, but also UHF Gen 2 chips, making both short- and long-range RFID possible candidates as consumer-ready DPP data carriers. This would automatically lead to a broad application of UHF Gen 2 chips, simultaneously allowing for "theft protection ready" products (which use UHF RFID technology). In such a case the cost of RFID tagging may be lower than that of the financial damage associated with stolen goods.

If the European Commission decides to embed additional information in a QR code used as a DPP data carrier, in addition to the URI related to the unique identifier, specific smartphone DPP applications will be needed to read the DPP system components, symbol size will increase, and reading performance will decrease. More information on the impact of additional static data in the data carrier can be found in CIRPASS report "Identification schemes" Annex D available on CIRPASS website[6].

4.4 Step 4: Where we should go?

The development of new technologies for the embedding of persistent data carrier technologies onto products should be seen as an opportunity for innovation.

Also, as the adopted version of the ESPR now explicitly states that more than one data carrier may be required on the product, this is an opportunity to explore sectors in which specific data carriers are needed for specific uses (e.g. facilitating sorting). However, the choice of data carrier(s) should be frequently revised or left sufficiently flexible to follow innovations in reader technologies as they are increasingly disseminated.

With the dissemination of data carriers on high value products, it becomes evident that some malicious actors will try to impersonate those. As a result, authentication needs for data carriers should be clarified. The RAIN Alliance is one source of information that could help address authentication needs for RFID. By leveraging the expertise and insights provided by the RAIN Alliance, solutions should also be found for other types of data carrier ensuring the integrity and security of data transmission in the DPP system.

5 DPP System component development roadmap

5.1 Step 1: Where are we today?

A number of essential requirements for the DPP system are already known and mentioned in the ESPR:

[5] https://www.nfc-tag-shop.de/info/en/tutorials/reading-nfc-tags-with-ios-14/
https://www.google.de/books/edition/Take_Control_of_Find_My_and_AirTags_2nd/ku3XEAAAQBAJ?hl=de&gbpv=1&dq=How+to+read+NFC+URLs++with+smartphones&pg=PA1&printsec=frontcover
https://developer.android.com/develop/connectivity/nfc
https://developer.android.com/develop/connectivity/nfc/nfc
https://developer.apple.com/documentation/corenfc

[6] https://cirpassproject.eu/project-results/

- Decentralised storage of DPP data,
- Need for a unique and persistent product identifier embedded into a scannable data carrier placed on the product or its packaging,
- Use of open standards and interoperable formats,
- Semantic interoperability (including syntactical interoperability) to ensure that the meaning of the information in the DPP can be recorded and transmitted efficiently between economic operators,
- Confidentiality of specific data, that will only be accessible to specific users of the DPP system based on proper authentication of said users,
- Possibility for dynamic DPP data, to reflect the state of the product (update of battery state of health ...) and possibly lifecycle events (repair...), (The need for dynamic data must be justified for a specific product group and decided on in the delegated act).
- Existence of an EU operated, centralized registry for DPP registration, interconnected to the EU Customs Single Window Certificates Exchange System (EU CSW-CERTEX),
- Existence of a standardized API to access DPP data which will enable the development of other services such as web portals for different types of actors,
- Existence of DPP backup mechanisms.

Inspired by, but not limited to the above requirements, a vision of a working DPP system architecture including its necessary components, interconnections and associated data flows was proposed by CIRPASS. Concrete examples of alternatives for the implementation of the different components and associated data flows were provided, although this list is far from exhaustive.

This vision includes two approaches for connecting product identifiers to decentralized DPP data sources where associated product data is hosted. In the first of these, the unique product identifiers are embedded into HTTP URIs. The second scenario relies on the use of Decentralised Identifiers (DIDs) as product identifiers. In both cases, product identifiers can be linked to one or more sources of data associated with a given product identifier. The main difference lies in the issuing of the identifiers, in which the HTTP based scenario relies of the use of identification schemes either managed by Issuing Agencies or using self-minting approaches, while DIDs are generated without any governance structure.

The DPP architecture is a flexible and decentralized architecture, where the notion of decentralization revolves around two axes. The first one focuses on where the product DPP data are held and managed. In the proposed architecture the DPP data are held and managed by the DPP creator, the Responsible Economic Operator or REO, (or their appointee) on their own resources. As a result, the DPP data are not aggregated in a single, centralised location. The REO (or its appointee) is the only one responsible for managing and updating the data, and the data cannot be modified by any other actor without the REO's authorization.

The second axis focuses on managing the path to the online DPP data of the product based on the product UID, a concept that can be referred to as 'resolving' an UID to its associated data. The proposed architecture is extremely general and can support both centralized and decentralized approaches to DPP resolving. For example, if the data carrier does not hold a URI, a transformer is needed to transform the product UID to a URI. If the transformer is a centralized one, the path to the online information is managed by the centralized authority. An alternative approach for supporting decentralization in cases where the data carrier does not hold an URI is to provide means to locate dedicated transformers for each REO, which should be discoverable, verifiable, and integrated into

DPP dedicated applications. However, the recommended use of URIs in the Data Carriers provides a simpler means for decentralizing the process of discovering the path to the DPP data, giving the sovereignty of the route to the REO (or their appointee).

The vision proposed does not deeply detail the connectors needed to interface the DPP system with existing software in the economic operators' IT systems, nor does it discuss how the data is sourced over the supply-chain. However, the vision does show how the DPP system can be designed for maximum flexibility, in order that it can function seamlessly in a variety of situations (different product identification schemes, data hosted at numerous locations, changing data storage location, etc.).

More details can be found in the CIRPASS report "DPP system architecture", available on the CIRPASS website[7].

5.2 Step 2: Where we are going!

The European Commission is currently preparing the adoption of delegated acts to establish rules and procedures related to unique identifiers and data carriers' lifecycle management. It is also actively working towards the design and set-up of the DPP registry and web portal. This includes the setting-up of automatic DPP validation tools. This could be achieved through the use of a SHACL control engine as described in CIRPASS report "DPP System Architecture". This control engine could verify that a DPP contains all the mandatory information per the regulation. Similarly, the design of solutions for the archiving of DPPs for economic operators who have gone out of business is currently under consideration. This will impact the design of the mandatory resolving mechanisms.

For economic operators, including DPP-as-a-service operators, since the technologies that will be used to build the DPP system architecture are already relatively well-known and deployed, the development of DPP resolvers and associated DPP data repositories should be straight-forward. Experience shows that this can be implemented in a matter of hours. Slightly more complex may be the design of repositories that are directly linked to internal ERP, PLM, or PIM systems. For access to restricted DPP information, access control mechanisms need to be implemented and those require identity management. The identity management requires additional administrative overhead in order to identify the privileged actors. For example, a recycling facility needs to be identified as such. To do so, a company can use their normal enrolling procedures. Deploying access control technology itself is not expensive, it is the identity management inherently needed that is expensive. Alternatively, access control credentials can be issued by trustworthy public organisations. Finally, the economic operators responsible for the DPP (REO) will also have to choose among the options of managing DPP compliance tasks themselves, including the operation of the DPP data repository, or using alternative DPP data repositories such as those that might be provided by industry associations or by DPP-as-a-service providers taking care of this on behalf of the economic operators.

More complexity for manufacturers will undoubtedly arise from the embedding of DPP-compliant data carriers into manufacturing processes.

While the CIRPASS system architecture described in CIRPASS report "DPP system architecture" outlines a general technical direction, many details still remain underspecified. It is expected that the CEN/CENELEC standardisation mandate will fill in those technical details. The detailed technical

[7] https://cirpassproject.eu/project-results/

specifications for the implementation of the DPP system, that will result from the ongoing CEN/CENELEC standardisation work, will create further interoperability.

A key component of the DPP system that is currently underspecified is the DPP system ontology which should contain the minimum necessary vocabularies and semantics applicable across sectors. The "DPP system architecture" assumes the presence of a graph but does not specify that graph and its constraints expressed in an ontology. The design of such an ontology may be a useful tool to facilitate the later development of the sector-specific ontologies. More details on this aspect can be found in the CIRPASS report "DPP Prototypes", available on the CIRPASS website[8].

5.3 Step 3: Where we could go?

The vision for the DPP system architecture proposed by CIRPASS includes two interoperable options:

1. A DPP system based on HTTP URIs,
2. A DPP system based on DIDs.

Since the HTTP based approach is more mature and currently being implemented globally for many retail products, it will likely be adopted first. Indeed, DID technologies are not as known to IT service providers compared to HTTP technologies. Therefore, the adoption of a parallel, yet interoperable, DPP system based on DIDs will depend on if and when economic operators see an advantage to using DIDs as a product identification scheme over other schemes.

To provide useful services to actors, ideally beyond that of a mere regulatory obligation, the DPP system must be able to connect easily to economic operators' different IT systems while also ensuring data sovereignty. This could be achieved via using data-space connectors and widely promoting the use of semantic adaptors and ontology alignment tools.

5.4 Step 4: Where we should go?

The DPP system architecture using mainly HTTP protocols as specified in RFC 9110 is usable in the immediate. Thus, for the short term, going with the HTTP solution is highly recommended, not only because it is already used. The HTTP–centric web has existed for decades and has very widespread availability for tools, both commercial and open source. Most things will just work out of the box. There is also a lot of expertise and skilled personnel available in the market to help enterprises in fulfilling their compliance obligations. Thus, due to a constrained implementation time (first DPPs must be issued in 2027), the preferred route will likely follow the implementation of an HTTP URI-based DPP architecture. Because of the easy integration with the current mobile web infrastructure, this is also the preferred route for the issuing of DPPs that contain only public data. The technologies for this architecture all exist and are mature enough to be employed in such a large-scale system.

While this architecture works really well as a decentralized system for publicly available data, it has shortcomings in the areas of trust, identity management and proven reliability. As stated above, identity management requires costly administrative overhead to identify and issue credentials to actors that should have access to privileged data. The recently adopted eIDAS 2.0 'Digital Identity' Regulation 2024/1183[9] establishing the European Digital Identity Framework could be used to lower the cost of identity management and improve trust for access to sensitive data.

[8] https://cirpassproject.eu/project-results/
[9] http://eur-lex.europa.eu/eli/reg/2024/1183/oj

However, even looking beyond the issue of identity management, some of the shortcomings of the current web systems, especially the web of data, are related to the challenges around trust. In the past, data was mainly held in silos and use was regulated by access control systems that allowed to constrain the access to those silos. While the DPP issuer (REO) can be initially seen as operating such a 'silo', it can be expected that the circular economy will require a much larger flow of information between parties and that this flow will need to move beyond this siloed approach. Since this information can be sensitive, decentralized means to increase trust will likely be needed in the future to secure new circular data value chains.

The HTTP world relies on the Internet Domain Name System (DNS) to provide identification. But if a legal entity loses the Domain Name, others can pick up that domain name and provide different, even fraudulent, information under that Domain name. This is why initiatives such as Gaia-X have chosen to improve trust and reliability by refusing to rely on the DNS alone. They opted for Distributed Identifiers which are minted using a cryptographically secured method and which typically relies on distributed ledger technologies. This way, a legal entity can create identifiers under its own control and a secure and decentralized system of identity creation becomes possible. The European Blockchain Service Infrastructure (EBSI) tells us how to use distributed ledger technologies correctly. As long as the ledger continues to exist, even if the legal entity goes out of business, the identifier remains valid and operational. This means not any blockchain will do, but requirements from the EBSI should be followed.

In the long term, this infrastructure will provide additional security to the data value chains created via the DPP system and the availability of DPP Data. As identities can be used and reused, systems with the DID infrastructure as described in the CIRPASS architecture, will allow for easier identity management, more trust and advanced features. Looking even further ahead, this could and should go as far as every actor in the circular economy having their own little information repository with a DPP generated dynamically from all those sources. The development of the SOLID[10] technology in the area of personal data can be very inspiring here. The SOLID specification lets individuals and groups store their data, defined using interoperable formats, securely in decentralized data stores called Pods which operate as secure web servers for data. When data is stored in a Pod, its owner controls which people and applications can access any slice of data it contains.

To further improve trust in circular data value chains, parts of the DPP data can be secured via the use of verifiable credentials, which improves data reliability.

Independently of the question of whether a DPP system based on HTTP URIs or DIDs is used, seamless integration of the DPP into existing data and workflows remains a challenge. The concept of dataspaces can help with this respect. Data space connectors will need to be developed to interconnect existing enterprise data management systems (ERP, PLM, and PIM) with the DPP system directly. It would be preferable for the connectors to be open source in order to maximize widespread reuse by companies and improve confidence in these software components, even for high value or sensitive data.

The variety in the EU single market is near to infinite. This means any attempt for unification (i.e., a single platform, a single standards stack, a single toolchain, etc.) is bound to fail. But even an inclusive system like the one suggested by CIRPASS can benefit from some deliberate offering for unification. Every component of the CIRPASS architecture can be built as a service in a networked infrastructure.

[10] https://solidproject.org/

From experience, we know that this is best done by offering ready-made components in open source or by offering ready-made ontologies for certain sectors that will be free to use. A system builds up over time. The effort should start simple, with simple services, and allow for a maximum reuse of existing code and vocabularies. Those components can now be orchestrated and combined in new innovative ways.

Finally, because of its use and promotion of machine-readable semantically interoperable data, it is likely that the DPP will encourage European industry to further adopt such standards and thus increase data exchanges generally. This could potentially be done using the DPP itself. Indeed, the DPP could grow beyond a mere regulatory tool to become a vehicle for exchanging additional product data that is useful for enabling further circular use cases, supply chain use cases and use case cases that cannot be foreseen. The DPP itself integrates perfectly into Industry 4.0 and the paradigm of the European data economy and can play a role in their adoption.

6 DPP Dataspace integration roadmap

6.1 Step 1: Where are we today?

According to IDSA (International Data Spaces Association), a Data Space is "a virtual space that provides a standardized framework for data exchange, based on common protocols and formats, as well as secure and trusted data sharing mechanisms". Three elements therefore characterise a Data Space: i) a FAIR (Findable Accessible Interoperable Reusable) pool of high value Data Sources; ii) a secure and trusted ICT infrastructure for data exchange; and iii) a set of data sovereignty agreements ruling the access and the usage of Data Sources.

From a DPP perspective, this means i) that the envisaged Mandatory / Voluntary data model needs to be made **FAIR** by proper standard and semantic interoperability formalisms (**knowledge graph**); ii) that a B2B but also x2G and x2C **data sharing processes** and workflows needs to be designed and implemented along the lifecycle of a product (**data veracity**); and iii) that proper **access and usage rights** among the different stakeholders in the product value network need to be agreed (**data sovereignty**).

The second Staff Working Document on Data Spaces (SWD 24 Jan 2024) provides an overview of the current status of the common European data spaces, i) by giving an update on the enabling **EU legislative framework** for data spaces; ii) by presenting the state of play of data-space related EU support actions, the **Data Spaces Support Centre** (DSSC) the **cloud-to-edge** smart open-source **middleware** (Simpl), the relevant **European Digital Infrastructure Consortia** (EDICs and ALT-EDIC for language technologies and citiVERSE for city Digital Twins); iii) by illustrating progress of **14 domain-sector- specific data spaces** (e.g. Agriculture, Tourism, Public Administration , …).

Two main data space domains and initiatives are relevant for the DPP adoption in EU:

1. The **Common European green deal data space** (and the GREAT Digital Europe Programme (DEP) preparatory action), which provides the DPP / Circular Economy overall policy context for EU for Climate Change, Zero Pollution, and Biodiversity;
2. The **Common European industrial (manufacturing) data space** (and the Data Space 4.0 DEP preparatory action) which provides visibility on the industrial value networks where the DPPs will be implemented (e.g. Batteries, Electronics, Textile supply chains)

Several industrial Data Spaces do exist in Europe, at different levels of maturity, as indicated by the new version of the Data Space Radar, especially in the Manufacturing and Supply Chain sectors. Moreover, the Manufacturing-X initiative of the German Platform Industrie 4.0 is generating not just sectoral data spaces foundational frameworks (CATENA-X for Automotive, but also FACTORY-X, PROCESS-X, AERO-X, …), but also an International Council where national experiences could be shared and discussed together.

The **key challenge** to be met is therefore the following: is the introduction and full adoption of DPPs in the different industrial domains providing new requirements to existing sectoral Data Spaces (e.g. automotive, aeronautics, textile, machinery, white goods …)? Which are the new stakeholders (Responsible Economic Operators in the DPP jargon) joining the Data Space, not just the end-of-Life B2B actors for collection, sorting, de- re-manufacturing, re-cycling, but also Governmental Agencies (e.g. Customs, market surveillance, competition, anti-fraud agencies) and final consumers and citizens? Which are the new Data Sources and how to achieve their semantic interoperability? How to build trusted data networks based on data veracity and sovereignty principles?

6.2 Step 2: Where we are going!

Electronic data sharing started in the 90's, with Electronic Data Interchange (EDI) enabling peer to peer (B2B) exchanges to replace paper documents. Intermediation services (even in pre-internet era) emerged to help parties to connect. With growing complexity and specialisation in supply chains, the need for more advanced data sharing mechanisms emerged (many-to-many, real-time, API economy). Data governance and data sharing technologies became more advanced, powered by the Internet. In addition to the data sharing mechanisms mentioned above, which can be qualified as 'primary data use', with the increased use of machine learning new use cases are emerging, which also entail 'data reuse' (for purposes other than the primary use). Data governance and data sharing technologies are further evolving, data is becoming a product. **Data spaces** is the overarching concept that has emerged in support of this evolution, with data sovereignty as an important guiding principle.

Following this evolution, B2B Data Spaces have emerged (however maybe not in the standard form suggested by IDSA and DSSC building blocks) and are currently at the basis of several key applications for DPP-relevant sectors, such as Factory and Supply Chain Optimisation, Energy and Waste Management, Quality Control and Zero Defect, Health Monitoring and Predictive Maintenance. This is also closely related to the Edge-to-Cloud data distribution and computational continuum (CEI continuum) which focuses on the distribution of data sharing capabilities from the physical layer to the edge, then to the cloud. Smart devices and IoT as well as digital twins and robotics are likely to play an important role in this continuum. Key challenges regard data in motion vs. data at rest, dynamic (on-the-fly queries) vs. static (files) Data Sources, pull vs push data exchange business processes, compliance with Data Confidentiality agreements, Human interaction and decisional support.

On the other hand, DPPs introduce new requirements to those existing Data Spaces: mandatory vs. voluntary fields, assurance and certification needs, product identification challenges, data preparation vs. on-the-fly composition, real time performances, and consumers' privacy and protection.

At the moment, Data Space initiatives and DPPs are proceeding almost independently and with limited interactions. Also in DEP, two distinct pillars have been created, also at the level of preparatory actions (e.g. CIRPASS GREAT DATASPACE 4.0), where common principles and rules should be defined and agreed for all. While dialogues are ongoing, no concrete common strategic aims and actions have been undertaken.

Some initiatives, mostly in the Horizon Europe Programme (with lower TRL), are undertaking efforts to create this bridge between Industrial Data Spaces and DPPs. One of them (**DPP and Data Space Convergence in the Industrial Domain**) is pushed by IDSA, with the active participation of some HEP projects and the DEP relevant preparatory actions.

In a first Workshop (16 June 2023 *Data spaces for manufacturing and digital product passports for circularity: synergies, opportunities and challenges*), the debate was mostly at conceptual level to establish a link between HEP projects in the domain of circular data spaces (Circular TwAIn, DACAPO, RE4DY) and the two DEP preparatory actions in Data Spaces (Data Space 4.0) and Digital Product Passports (CIRPASS).

In a second Workshop (1 December 2023 How to drive business value with Digital Product Passports & data spaces), the emphasis was given to use cases and in addition to the previous initiatives, cases from the TRICK and DigiPrime projects have been presented covering batteries, electronics, textile and composite domains.

A White Paper is currently under preparation with the contributions of both communities, with the aim to find proper convergence paths between industrial and other data spaces like the Green Deal Data Space and DPPs.

For instance, in the recent call for proposals on the Green Deal Data Space, a use-case of interest was about a **DPP-ready** Information System for Producer Responsibility Organizations appointed to supervise the operation of post-consumer textile waste. PROs and policy makers need to develop traceability capabilities for several reasons: transparency on the "supply" of the emerging textile "waste market", calculation of operational costs for waste management, accountability to ensure for instance that waste is not "disguised" as re-usable textiles and shipped abroad. Such traceability capabilities can be multiplied by the Digital Product Passport (DPP). Along the same token it might be worth reflecting how other traceability capabilities required in other domains could be combined with DPP forming interesting "data spaces".

6.3 Step 3: Where we could go?

In the convergence path between industrial data spaces and DPPs, the main risk to avoid here is that DPPs, owing to new and original needs and requirements coming mostly from the regulatory aspects and different DGs involved, could create and develop their own Data Spaces completely disconnected from the existing ones. The "Greenfield" "Not Invented Here" syndrome could be a risk that will irremediably disconnect DPPs from Data Spaces and related EU level initiatives (e.g. the Data Space Support Centre DSSC). In the Greenfield integration mode, small-medium enterprises willing (or obliged by law) to implement DPPs could be facing excessive investments in the 'from scratch' digitalisation of their processes, data models and platforms, providing advantages to Large Companies and Multi-national organisations, able to afford the required investment.

It is however our conviction that DPPs, although addressing different aims and objectives than industrial B2B Data Spaces, should stem on the work done in the different domains (e.g. Manufacturing-X initiatives) and influence them so that they could meet the DPP expectations in a unified and harmonised green industrial data space. One way to mitigate the risk of disconnection, would be to work on use-cases demonstrating how DPP can leverage and multiply the capabilities of other IT information systems and data spaces meant to cover other sectorial needs.

The implementation of DPPs should therefore be a Brownfield integration effort and leverage on existing Enterprise Systems (e.g. ERP PLM SCM CRM), standards (e.g. OPC-UA, RAMI Asset Administration Shell, DPP4.0) to be adapted and evolved towards the new requirements of DPPs transparency, traceability and trust. We support the idea of a DPP as an evolutionary step in the enterprises' (SMEs) digital transformation towards a more sustainable and circular way to supply, manufacture and distribute goods and services.

6.4 Step 4: Where we should go?

The recommended pathway for the DPP data space integration roadmap is based on an evolution of the current industrial data spaces towards embracing circularity and green principles, to be ready to host the envisaged DPP implementations. DPP movement should therefore redirect existing data spaces (automotive, textile, electronics …) towards a more sustainable and circular awareness:

- **Data Sources**: DPPs introduce new data sources to be implemented in existing industrial Data Spaces in order to make them ready for supporting circularity processes and advanced applications.
- **Industrial Data Platform**: DPPs introduce new stakeholders to be involved in the industrial value networks, especially from governmental agencies' and from the consumers' perspective.
- **Industrial Agreements**: DPPs introduce new trust and sovereignty compliance requirements to be addressed in data spaces: in particular the veracity of the data and the privacy of human actors need to be preserved.

The DPP will encourage current manufacturing Data Spaces to evolve in the following three main directions:

- Enrich the current B2B perspective to a more holistic ecosystem, including governmental authorities and citizens, by including new innovative B2G and B2C circularity processes.
- Extend the current supply-chain focus to post-sales stakeholders and business processes, unleashing the potential of new servitisation business models linked to End-of-Life Management and Circular extended responsibility.
- Enlarge the current Data Sovereignty trust model (access and usage rights) with more sophisticated mechanisms aimed at implementing the Veracity V of the "5V" Big Data model (Velocity, Variety, Volume, Value, Veracity), introducing the "3 TR" model of Traceability Transparency and Trust in the business transactions, as well the human dimension of privacy and human rights preservation.

However, the DPP should benefit from ongoing data space developments:

- Because the DPP will impose new requirements on data capture and data sharing by industry players, data spaces can play a role in efficiently supporting these requirements, for example by leveraging data space governance principles and enabling services.
- As DPP data will become a new source of data for innovative applications (AI, digital twins, robotics, etc), data spaces can help to unlock this value by enabling parties to share data in a trusted and fair way, to the benefit of society and business.

7 Prototyping and deployment roadmap

7.1 Step 1: Where are we today?

Thanks to its benchmark of existing DPP-related initiatives, CIRPASS has shown that a huge number of companies and initiatives wish to be involved in the DPP. However, today, these solutions are not interoperable.

The current DPP-related solutions landscape comprises hundreds of initiatives. By studying these initiatives, we identified general trends. The initial 80 responses (collected through an online questionnaire) gave us useful insights on currently available approaches. From this benchmark, one of the lessons learnt is that 57% of the solutions already adopt decentralised data storage systems, similarly to the DPP system.

Regarding the data carrier used by these initiatives, QR codes are not only the predominant one, but associated with other data carriers, QR codes are supported by 95% of the surveyed initiatives.

Regarding other architectural choices, the study showed that a wide variety of implementations exist. This suggests that the DPP system should focus almost exclusively on providing a semantic interoperability layer and means to connect to a heterogeneous set of solutions.

More details can be found in CIRPASS report "Benchmark of existing DPP-oriented reference architectures" available at https://cirpassproject.eu/project-results/.

7.2 Step 2: Where we are going!

Because the DPP system standards will potentially not be available until the end of 2025, there is a risk that the ongoing work related to DPP prototyping and piloting, typically executed independently by different organizations, may lack the interoperability required the DPP system. This is of particular concern for the projects that are funded through public means, as described in this section.

7.2.1 Ongoing EU-funded piloting projects related to the DPP

In this section, we provide a non-exclusive list of ongoing projects funded either the H20202 Programme or the Horizon Europe Programme of the European Commission.

CIRCTHREAD - Building the Digital Thread for Circular Economy Product, Resource & Service Management https://circthread.com/

CE-RISE - A digital passport for critical raw materials

https://ce-rise.eu/news/breaking-silos-by-developing-a-shared-vocabulary/

DIGIPASS - Harmonization of advanced materials ecosystems serving strategic innovation markets to pave the way to a Digital Materials & Product Passport HORIZON-CL4-2023-RESILIENCE-01-39 https://www.hereon.de/about_us/eu_projects/horizon_europe/key/113621/index.php.en

BatWoMan – a validation testbed for DPPs in battery supply chains https://batwoman.eu/

Onto-DESIDE - Ontology-based Decentralized Sharing of Industry Data in the European Circular Economy: A shared vocabulary in the form of network of ontologies. https://ontodeside.eu/

TRICK - Defining a traceability platform to enable verifiable claims related to textiles circularity and other sectors https://www.trick-project.eu/

CISUTAC - Increasing Circularity and Sustainability in Textiles and Clothing in Europe https://www.cisutac.eu/

7.2.2 Upcoming EU-funded piloting projects

In 2023 and 2024, the European Commission issued a number of calls for projects related to the issuing and use of DPPs in several sectors. This will multiply the number of DPP prototypes and use cases exploring the use of DPPs in circular economy scenarios. A non-exhaustive list of these calls includes:

- HORIZON-CL5-2023-D2-02-03 Creating a digital passport to track battery materials, optimize battery performance and life, validate recycling, and promote a new business model based on data sharing (Batt4EU Partnership)
- DIGITAL-2023-CLOUD-DATA-04 -DIGIPASS - Digital Product Passport
- HORIZON-CL4-2024-TWIN-TRANSITION-01-41 Breakthroughs to improve process industry resource efficiency (Processes4Planet partnership) (RIA).
- HORIZON-CL4-2024-TWIN-TRANSITION-01-05 Technologies/solutions to support circularity for manufacturing (Made in Europe Partnership)
- HORIZON-CL4-2024-TWIN-TRANSITION-01-44 Digital transformation and ensuring a better use of industrial data, which can optimize steel supply chains (Clean Steel Partnership)
- HORIZON-CL6-2024-CircBio-01-3 Innovative circular solutions for furniture
- HORIZON-CL6-2024-CircBio-01-2 Circular solutions for textile value chains based on extended producer responsibility
- HORIZON-CL6-2024-CircBio-01-6 Digital information systems for bio-based products
- HORIZON-CL6-2024-CircBio-02-1 Circular solutions for textile value chains through innovative sorting, recycling, and design for recycling
- HORIZON-CL6-2024-CircBio-02-2 Increasing the circularity in plastics value chains
- HORIZON-CL6-2024-CircBio-02-3 Increasing the circularity in electronics value chains
- DIGITAL-2024-CLOUD-AI-06-GREENDEAL European Green Deal Data Space

7.2.3 Member State-funded projects

In parallel to the efforts of the European Commission, many member states have and are also funding research and deployment activities related to the DPP. A non-exhaustive list is provided below and it is expected that many more will emerge over the coming years.

This includes the TRACE4VALUE https://trace4value.se/ in Sweden and the Battery Pass https://thebatterypass.eu/ and the Product Information 4.0 projects in Germany.

Finland, through its Innovation Fund Sitra, funded a number of pilots related to the DPP in the batteries, steel and textiles value chains as summarized in a recent paper presenting their key learnings[11]. The FINPASS network project under the leadership of VTT will further serve to identify and gather Finnish actors and piloting activities. Finally, the Twinbase Research-to-Business project based

[11] Available: https://media.sitra.fi/app/uploads/2024/04/sitra_digital_product_passports_catalysing_europes_sustainable_growth.pdfffffffff (Accessed April 16, 2024)

at Aalto University and funded by Business Finland is developing a semantics-based digital twin management solution for streamlined digital product passport creation.

The Netherlands has identified DPPs as an exclusive key topic to receive national funding. In addition to this, many large IT projects include DPPs as a work package or task in the project. Some examples are:

- Centre of Excellence for Data Sharing and Cloud, includes a WP on DPPs (https://coe-dsc.nl/). The focus is to make data sharing technologies and DPPs accessible to Dutch SMEs.
- National Growthfunds, intended to keep the Dutch economy competitive by funding large sectoral programs. Examples in which DPPs are researched include:
    - Next Gen High Tech, in which DPPs for the (high tech) manufacturing industry are researched (https://nxtgenhightech.nl). In this programme, the use of DPPs is explored in ~7 different work packages and use cases.
    - Futureproof build environment, focusing on material passports for the construction sector (https://www.nationaalgroeifonds.nl/overzicht-lopende-projecten/thema-energie-en-duurzame-ontwikkeling/toekomstbestendige-leefomgeving).
    - Green Steel is aimed at enabling circular steel and containing DPPs in various aspects of the project.

7.3 Step 3: Where could we go?

The alignment of the above projects could be supported through an EU-level multiplier initiative similar to the existing Ecosystex mutiplier initiative for textiles sustainability and circularity projects (https://textile-platform.eu/ecosystex):

> *"ECOSYSTEX aims to become the central European knowledge hub and go-to resource for latest research work and technology state-of-the-art information on all matters related to textile sustainability and circularity.*
>
> *With 26 EU-funded member projects focusing on textile sustainability, ECOSYSTEX, the European Community of Practice for a Sustainable Textile Ecosystem, has been formally launched in early 2023, with a mission to accelerate collaboration in the textile sustainability and circularity field.*
>
> *As a joint initiative of the European Commission's Research Executive Agency (REA), the European Health and Digital Executive Agency (HaDEA – they are managing all DigitalEurope calls) and the Circular-Biobased Europe Joint Undertaking, and facilitated by the Textile ETP, this new network of textile circularity projects aims to create a long-term community of practice, ensuring collaboration across project consortia and lasting beyond the individual projects' durations."*

In addition, as EU member states will be responsible for supporting the deployment of the DPP in each country, and, again, because the DPP system standards will potentially not be available until the end of 2025, there is a risk that these deployments will lack the interoperability requirements of the DPP system. Again, ensuring that the content of this member-state-level support carries an aligned vision of the DPP system is essential. This could be facilitated through an EU-level "DPP implementation support centre", for example based on a similar structure as the Data Space Support Center (https://dssc.eu/). This Center could be mandated to:

- Serve as neutral expertise "bureau" providing contacts and financing expertise,

- Run training and information events,
- Collect success stories and share them for inspiration,
- Design and provide open-source training material for all.

7.4 Step 4: Where should we go?

In addition to funding mechanisms to ensure that existing and upcoming EU-funded DPP-related projects and future member-state support projects for DPP deployment are aligned, as discussed above, we make the following recommendations:

-To support economic operators in DPP compliance tasks, the EC should make a specific request to member states for generalized deployment support and industry should be involved in the design of these mechanisms.

-Implementing DPP pilots targeting SMEs and showcasing success stories can demonstrate how the DPP benefits companies, especially aiding SMEs that might lack experience or knowledge in implementation. Pilots showcasing the economic and sustainability benefits of the DPP should be put forward, even if these pilots go beyond the data sharing requirements of regulation. Use cases in need of more advanced features of the DPP system e.g., distributed ledgers[12], AI, reasoners, etc. should also be explored.

-Solution providers of enterprise IT systems (e.g. PLM, ERP, PIM) need to be encouraged to integrate DPP solutions into their systems as soon as possible.

8 Conclusion

This report gives a detailed view of the topics related to the definition of a DPP System Roadmap. For each topic, namely “Identification and data carrier”, “DPP System component development”, “DPP Dataspace integration” and “Prototyping and deployment” the adopted methodology starts by evaluating the current situation. It then describes the decisions that are already certain and will impact the DPP system roadmap. Then, possible paths are proposed for each topic with a description of the advantages and drawbacks. For each topic, we conclude on a description of recommendations for future work that must be achieved for the deployment of the DPP or that could be realized as long term evolutions of the DPP system.

12https://ec.europa.eu/digital-building-blocks/sites/display/EBSISANDCOLLAB/European+Blockchain+Sandbox+announces+the+selected+projects+for+the+first+cohort