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Digital Product Passport trials to support the concept's introduction in industry

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Abstract: The European Union is introducing the concept of the Digital Product Passport (DPP) to the manufacturing industry. The first domain areas are batteries and textiles, but regulation will soon reach all manufacturing domains. In this paper, we briefly discuss the requirements of the DPP and its contributions to the circular economy and sustainable decision making through the product lifecycle and manufacturing value chain. Some preliminary architectural viewpoints are explained, aligned with the intention to exploit the International Data Spaces (IDS) reference architecture for secure data sharing among various actors. A practical way to manage the complex innovation process of how to co-create and implement the DPP via several iterative minimum viable DPP deployments is also outlined. It contains the proof-of-concept process with the build-measure-learn circles and the sprint model.

Keywords: Digital Product Passport; data sharing; open innovation; minimum viable product; proof-of-concept; innovation management; sustainability; circular economy; R strategies

1 Introduction

Companies are struggling with overwhelming requests to proceed with digitalisation, contribute to the UN sustainability development goals (SDG) and stay competitive with their limited resources. Furthermore, the European Union (EU) is pushing towards data economy, green transition, ecodesign and adoption of the Digital Product Passport (DPP).

The first manufacturing sectors requiring a DPP comprise textiles and batteries, but in the future, the DPP will be required for any product provided to European markets. The concept of the DPP is still under construction although some partial solutions already exist. According to the EU, the DPP provides information about a product's environmental sustainability. A dynamic DPP evolves during the product lifecycle.

Initiatives for federated data sharing such as GAIA-X,[1] Industrial Data Spaces (IDS) reference architecture model (RAM)[2] and fair data economy are emerging as Europe wishes to keep data ownership (Otto, 2022). The IDS RAM provides secure data-sharing services between industrial partners that have their own private data space or lake. In case the DPP is based on the IDS RAM, the data ownership can be granted and correct datasets provided to the end users for sustainable decision making. The successful minimum viable DPP trials motivate industry to implement and deploy the DPP and make progress with the UN SDGs.

2 Background

In this section, the circular economy (CE) and R strategies are defined before presenting the DPP concept. Data sharing, IDS and the Data Spaces Innovation Lab (DSIL) are mentioned before delving into the architectural requirements of a DPP. Finally, the

[1] https://www.data-infrastructure.eu/GAIAX/Navigation/EN/Home/home.html

[2] https://internationaldataspaces.org/publications/ids-ram/

complexity of this kind of innovation process is highlighted, and the development practices for DPPs are introduced.

Circular economy

The CE transforms the linear take-make-waste economy via the return loops, such as recycle, repair and reuse. Here, the definition formulated by Korhonen et al. (2018) is adopted: *"CE is an economy constructed from societal production-consumption systems that maximizes the service produced from the linear nature-society-nature material and energy throughput flow. This is done by using cyclical materials flows, renewable energy sources and cascading type energy flows."* (Korhonen et al., 2018)

Furthermore, sustainable decision making should decrease the environmental footprint of the product lifecycle and the manufacturing value chain, implement new R strategies (recycle, remanufacture, etc.) and boost the CE (Saari et al., 2021).

Digital Product Passport (DPP)

The DPP is one of the key concepts of the EU in the pursuit of sustainability and climate neutrality. Figure 1 displays the expected objectives of the EU DPP concept.

Figure 1 Objectives of the EU DPP concept.

The DPP will provide visibility to the product information through the entire lifecycle (Figure 2). The product information may contain data on materials, chemicals and components, as well as instructions related to the repair, recycling, dismantling and disposal of the product. The data should help actors make sustainable decisions over the product lifecycle. The DPP can also support the implementation of R strategies in many ways (Figure 3) (Saari et al., 2022).

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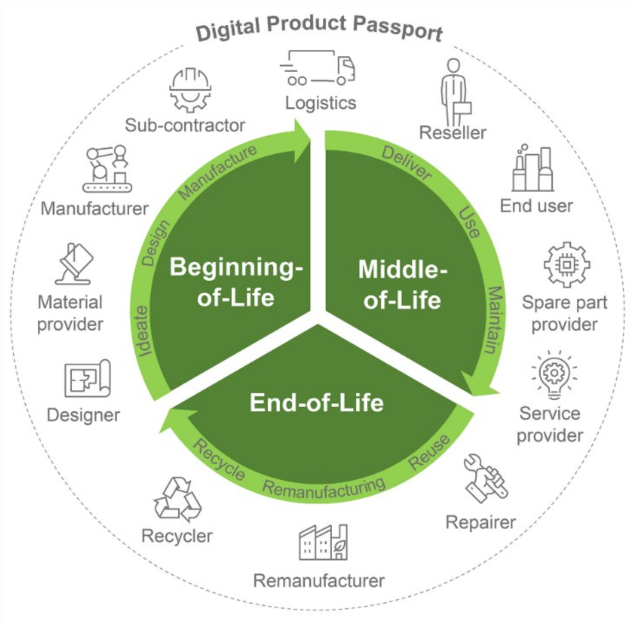

Figure 2 DPP links the product-related information produced and consumed by various actors during the entire product lifecycle (Saari et al., 2022).

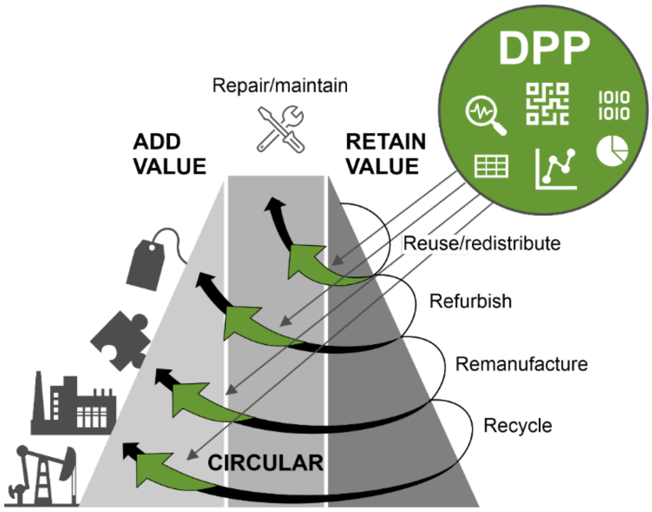

Figure 3 DPP facilitates the implementation of R strategies (modified from Achterberg et al., 2016; Saari et al., 2022).

Data sharing

The fair and sovereign exchange of data has increased in importance across all sectors of the economy and enhanced the visibility of the enormous potential of data sharing for spurring cross-sector innovation and the development of new business models (Nagel and Lycklama, 2021). The IDS initiative aims at enabling sovereign and self-determined exchange of data via a standardised connection across company boundaries (Pettenpohl et al., 2022).

In IDS-based data exchange, the data remains with its owner until it is needed by a trusted business partner, and when the data is shared, the terms of use can be linked to the data itself. This means that the participants can both share data with business partners in an interoperable way and retain self-determination regarding these data assets (Otto and Jarke, 2019). IDS defines a technology-agnostic architecture, which is described and continuously updated in the International Data Spaces Association's (IDSA's) RAM (Otto, 2022).

The IDS RAM defines the required standards, control and enforcement rules for data exchange among different participants in a data space, specifying their components and mechanisms (Solmaz et al., 2022). The key components and roles specified in the IDS-RAM are depicted in Figure 4.

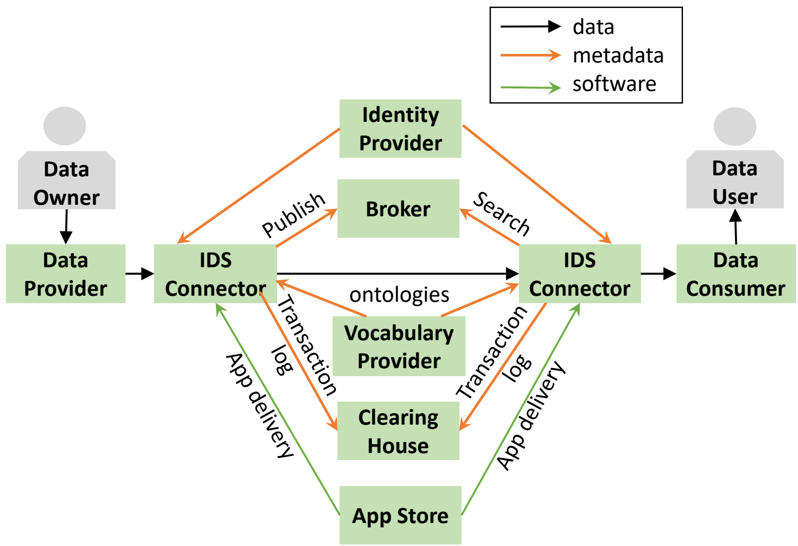

Figure 4 Basic principle of federated data sharing
modified from (Otto and Steinbuß, 2019; Nagel and Lycklama, 2021).

DSIL supports the development, utilisation and testing of data space concepts, based on the IDSA's reference testbed components, and preserves data sovereignty in confidential data sharing between companies and organisations. The DSIL provides piloting services as part of the IDSA hub hosted by the VTT Technical Research Centre of Finland.[3] The DSIL defines the needed components for creating an experimental data space (e.g., identity provider, metadata repository) and is offered (as a service) for companies and project partners interested in business-to-business data economy and data sharing.

System architecture aspects

To maximally promote building the CE, the DPP system architecture needs to be as holistic and inclusive as possible – meeting requirements from heterogeneous stakeholders and integrating numerous independent, and in many cases legacy, technical systems.

[3] https://www.idsa-finland.fi/

Interoperability of the systems must be realised on legal, organisational, semantic and technical layers (King et al., 2023).

CIRPASS[4] aims at standards-based DPPs aligned with the Ecodesign for Sustainable Products regulations.[5] In CIRPASS, technical implementations of various DPP initiatives have been benchmarked, for example, considering product identification, data carriers and several IT architecture aspects (Bernier et al., 2023).The study reveals significant divergences in nearly all classification categories, which substantiate the urgency for common standards and further definition of the level of DPPs' architectural decentralisation.

CircThread[6] provides an IDSA-based approach to DPPs. As shown in Figure 5, CircThread leverages IDSA connectors for easier interoperability in exchanging product information between ecosystem participants in a trusted manner (Koppelaar et al., 2023). Furthermore, CircThread Data Space also deploys the IDS identity provider, Metadata Broker and Clearing House services for orchestrating DPP data sharing so that participants, their roles and their IT infrastructure are verified and data can be shared exclusively if necessary.

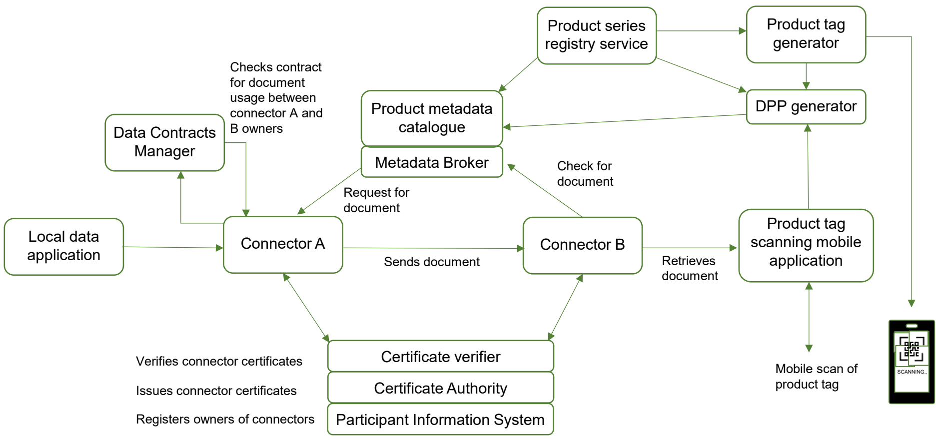

Figure 5 IDS-based IT architecture for DPP developed in the CircThread project (Koppelaar et al., 2023).

As mentioned, DPP architecture also requires semantic interoperability. Linked Data technologies[7] provide a solution for connecting product data to entities specified in the DPP with the uniform resource identifier URI link, and Linked Data recommends HTTP URIs. A standard model for describing the entities is the Resource Description Framework (RDF)[8] as subject-predicate-object triplets. The RDF can be presented as JavaScript Object Notation for Linking Data (JSON-LD[9]), which is a JSON-based RDF format containing links in a machine-readable way. A DPP can contain public datasets but can also restrict

[4] https://cirpassproject.eu/
[5] https://commission.europa.eu/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/sustainable-products/ecodesign-sustainable-products_en
[6] https://circthread.com/
[7] https://www.w3.org/standards/semanticweb/
[8] https://www.w3.org/RDF/
[9] https://json-ld.org/

access to other datasets. In case access control is required, IDS provides the means to achieve this.

Innovation management

Innovations profit from data in many ways. The new value enabled by data utilisation can result in new inventions, business ventures and sales. Utilising data may require working with different types of businesses to develop a combined product. However, businesses encounter several difficulties when utilising vast quantities of data and working with new players (Erevelles et al., 2016).

In this paper, the focus is on innovating the DPP and the ways in which it is implemented. DPP development requires many actors for both providing data and developing sustainable decision-making services. Therefore, the process requires open innovation and thus becomes more complicated. In this paper, we present a highly complex case for open innovation (Chesbrough et al., 2014) and sustainable innovation (Cillo et al., 2019) as it comprises both the DPP and sustainability, which are broad in scope, in their early development stages and require practical cases.

Trials towards minimum viable DPPs

While agile software (SW) development focuses on creating operational SW solutions, the Scrum methods support the management of product planning and implementation (Laanti et al., 2011). The constant experimentation guides the development process with the build-measure-learn circles and identifies the next development actions (Zorzetti et al., 2022).

Usually in EU-funded projects, SW development is distributed among partners. To enable cocreation regular online meetings, development facilities, such as Git repositories and communication channels, are requested, as well as face-to-face integration camps, where SW developers jointly solve emerging problems (Bendas et al., 2018). In a national project,[10] the proof-of-concept (PoC) process was organised in five phases: i) identification, ii) formulation, iii) proposal, iv) implementation and v) closure (Kääriäinen et al., 2021). The management of PoCs was then organised as sprints (Khan et al., 2022).

The Lean Product Playbook (Olsen, 2015) promotes rapid customer feedback when developing minimum viable products (MVPs). The steps for creating an MVP are as follows: i) specify the MVP feature set, ii) create the MVP prototype, and iii) test the MVP with end users. When developing the MVP, reliability, usability and delightfulness should also be achieved, in addition to functionality (Figure 6).

[10] https://rebootiotfactory.fi/

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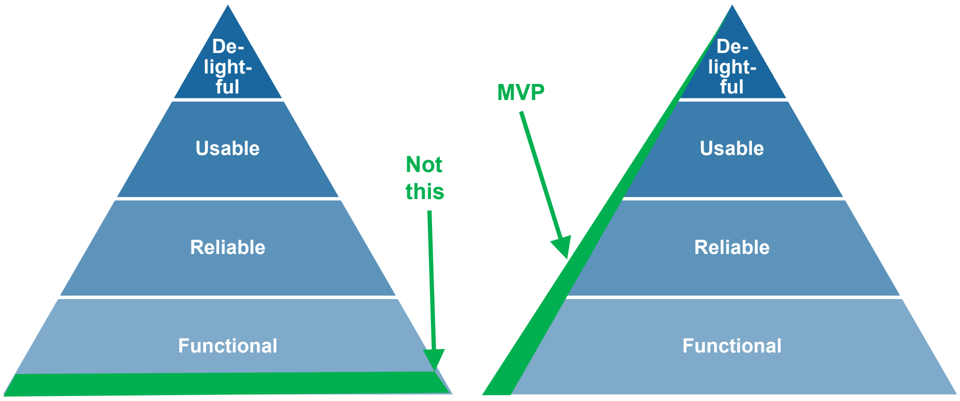

Figure 6 Each MVP implementation fulfils reliability, usability and delightfulness requirements in addition to the (partial) functional ones (Olsen, 2015).

3 Research process

The research will be conducted in an EU project called DaCapo.[11] The development will be guided with three pilot cases from industrial domains, including aerospace, electronics and logistics. In the consortium, the way of working will be agile, focusing on the objective to boost sustainability and implementation of the CE and R strategies.

The development does not try to solve the overall architecture of a DPP suitable for any product or manufacturing process but aims to build the first MVP solutions for the use cases. In the iterative development, the DPP continuously evolves and grows, still trying to focus on the functionalities requested by the user. The development of the minimum viable DPP applies the PoC process (Kääriäinen et al., 2021) managed in sprints. A sprint allocates the resources, that is, a task force group covering both the industry (the case owner and solvers) and the research representatives assigned to the PoC development (Khan et al., 2022). Additionally, the build-measure-learn circle identifies the next development actions (Zorzetti et al., 2022).

4 Expected findings

The findings will reveal which datasets are required for a DPP that can support actors in their sustainable decision making in the manufacturing value chain or the product lifecycle. Moreover, the applicability of federated data sharing – especially IDS RAM – will be proven, or the problems will be identified. Probably, we will also find out that data sharing enables the progress with the CE.

We expect that datasets, data-sharing architectures and cognitive decision support can be integrated with the R strategies and verified with industrial pilot cases via agile ways of

[11] https://www.dacapo-project.eu/

working, gaining the best practices from the PoC process (Kääriäinen et al., 2021) and the build-measure-learn circles (Zorzetti et al., 2022) managed via the sprint model (Khan et al., 2022). Innovations will focus on core DPP solutions for industrial pilot cases, supporting the most relevant phase of their product lifecycles or the manufacturing value chain.

5 Areas for feedback and development

The DPP is a concept that is essential for sustainable decision making in manufacturing in Europe. For successful DPP deployment, the following questions are addressed:

- Which datasets are required to boost the CE and R strategies in manufacturing companies?
- How can the data about a product or a process be shared securely, without creating enormous centralised data lakes or spaces?
- What are the roles and responsibilities of actors in the DPP value chain?

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