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# Requirements for a Digital Product Passport to Boost the Circular Economy

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**Abstract:** The Digital Product Passport (DPP) is a concept to collect and share product-related information along a product's lifecycle. The aim is to provide all stakeholders during the product lifecycle with the information they need such that a successful Circular Economy can be implemented. At the moment, several varieties of DPPs are being developed, most of them sector-specific. As of today, however, there is no common standard as to what a DPP should look like. This paper collects requirements for the DPP from different perspectives that must be fulfilled to make it broadly applicable.

**Keywords:** Digital Product Passport; Circular Economy

## 1 Introduction and Motivation

The Circular Economy (CE) tries to counter the over-exploitation of resources by keeping materials in the loop for as long as possible by reusing, repairing, refurbishing, and recycling products or their components, with the ultimate goal of our living within earth's ecological limits [1]. The CE is promoted by the European Green Deal [2] and the Circular Economy Action Plan [3] in the EU and via the Digital Policy Agenda for the Environment [4] by the German Federal Environmental Ministry at the German national level. An important means to facilitate the development of a true CE is the concept of the Digital Product Passport (DPP) [5]. Its aim is to create transparency along a product's lifecycle and to enable the collection and sharing of product-related data among various stakeholders. The DPP allows to exchange information such as material flows, instructions for disassembly, or whether a product contains hazardous materials. Thus, it can inform recyclers which materials or compounds to expect, enable feedback to producers about the recyclability of their products, and educate customers about the environmental impact of their purchases, to name just a few applications. Furthermore, value-added services and applications can be built on top of the information contained in the DPP, such as AI-based lifecycle assessment (LCA) [6].

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This can benefit the field of environmental informatics and enable new business models. Several approaches to the DPP are recently being conceptualized, implemented, and tested. A systematic requirements analysis for the DPP, however, has not yet been published. Our paper aims to close this gap. Aligning the requirements of different stakeholders and sectors can foster discussion and steer the evolution of the DPP towards improved interoperability.

The following methodology has been used to derive the requirements: Starting with a review of existing scientific and grey literature on the DPP (which is presented in Section 2), we identified the key goals (Section 3) and most important stakeholders (Section 4) of the DPP. From the literature we also extracted those requirements that were most often mentioned. We furthermore elicited requirements from practitioners from various sectors by means of a questionnaire, which was filled in by 10 manufacturers and 9 end-of-life actors. In addition, we took part in various initiatives, meetings, talks, and discussions with experts on the DPP, and incorporated the experts' opinions into our requirements analysis. We present the results in Section 5. Section 6 summarizes and concludes the paper.

## 2 Existing Approaches to the Digital Product Passport

| Name | Developed by | Sector | Description | Reference |
|---|---|---|---|---|
| Product Circularity Data Sheet | PositiveImpaKT | all | exchange of standardized, verified circularity data for products | [7] |
| Resources Passport | Excess Materials Exchange | all | standardized format to enable sharing of resource-related data | [8] |
| Digital Lifecycle Passport | ReCircE consortium | all | sharing of human and machine readable data along the product lifecycle based on Asset Administration Shell | [9] |
| Digital Product Passport | GS1 | all | machine readable product data based on persistent identity of the product | [10] |
| Digital Product Passport | iPoint | all | enables manufacturers to record sustainability data about products in a standardized format | [11] |
| Digital Product Passport | R-Cycle | plastic packaging | storing of production information for recycling based on GS1 standards | [12] |
| circularity.ID | circular.fashion | textiles | open data standard to enable circularity in the fashion industry | [13] |
| GBA Battery Passport | Global Battery Alliance | batteries | tracking lifecycle data for batteries of electric vehicles | [14] |
| Battery Identity Global Passport | UT-Battelle | batteries | tracking lifecycle data for batteries to improve recycling | [15] |
| Materials Passport (BAMB) | BAMB EU project | buildings | recording data about materials in buildings for recovery and reuse | [16] |
| Madaster | Madaster Foundation | buildings | recording data about materials in buildings to enable circularity | [17] |
| International Material Data System (IMDS) | several car manufacturers | automotive | recording data related to materials used in the automotive industry for compliance checking | [18] |
| Product Lifecycle Management (PLM) | PLM research | all | management of all product related information and processes across the enterprise through its lifecycle | [19] |

Tab. 1: Different approaches to the Digital Product Passport.

Several endeavours exist that are concerned with DPPs or similar concepts (see Table 1). Some pursue a cross-sectoral approach [10, 9], while others are conceptualized in a sector-oriented way [14, 17]. Table 1 gives an overview of some of the most prominent approaches that currently exist. All of them are either at the conceptual level [15], in a prototypical stage

[7, 9] or are being tested in first pilots on the market [13]. Technology readiness will likely increase in the coming years when the DPP becomes mandatory in more and more sectors in the EU, starting with battery passports in 2026 [20]. To foster practical DPP uptake, however, several non-technological challenges must be tackled as well, i.e., stakeholders must agree on common standards, new business models around the DPP must be explored and regulatory conditions must be clearly stated so they can be addressed. This paper is intended to contribute in this regard and will hopefully bring the discussion forward.

## 3 Goals of the Digital Product Passport

Analyzing the existing literature, we extracted the goals associated with DPP concepts. In detail, the DPP should fulfill the following goals:

- ensure that all stakeholders in the product lifecycle can access and share product-related data [9, 10, 7]
- improve collaboration in the value chain [11, 7, 13]
- foster transparency and traceability of products, materials, components [11, 10, 7, 14]
- enable compliance checking and facilitate certification procedures [10, 18]
- enable tracking of critical materials/substances [10]
- improve circularity of products in terms of the R strategies [9, 7, 13, 16, 17]
- allow to benchmark different products [14]
- track progress in the development of sustainable products [14]

As can be seen, most goals were mentioned multiple times; the improvement of the circularity of products being the most frequently mentioned goal, followed by the goal of fostering transparency and traceability of products, materials, and components.

## 4 Stakeholders

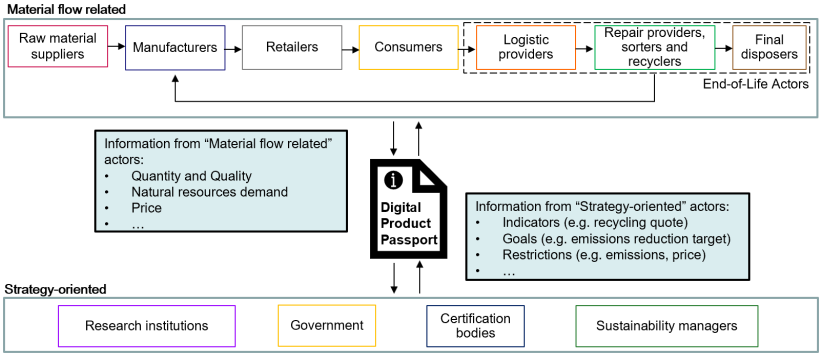


Fig. 1: Potential users of the DPP (based on [21]).

The following section gives an overview of potential users of the DPP. The users are based on and adapted from [21]. They can be divided into two general groups: the material flow related actors and the strategy-oriented actors (see Figure 1). The distinction is based on the *type of interaction* with the DPP, the *type of information* contributed, and the respective *goals of the interaction* with the DPP.

The material flow related actors (e.g., industries, retailers, recyclers) interact physically with the material flow and the necessary processes to handle it. Examples of information provided by the material flow related actors include quantity, quality and composition of a product or material and the energy, water and raw material demand in the production process.

The strategy-oriented actors comprise for example the government, research institutions, certification bodies and sustainability managers. Such actors are able to access material flow information via the DPP for, e.g., better definition of targets, developing strategies, initiating measures and calculating indicators. Such aggregated information is fed back to the DPP, where it serves as a basis for decision makers and for the optimization of processes. This can lead to greater resource efficiency, the reduction of needed resources, or even sufficiency, the elimination of unnecessary processes or reduction of primary resource consumption.

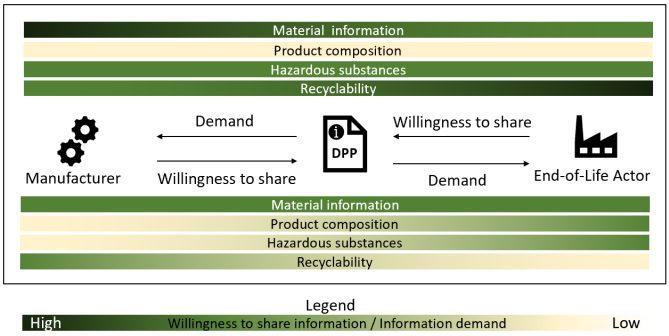


Fig. 2: Results of our questionnaire survey regarding mutual information requirements.

When it comes to mutual information requirements, the results from our questionnaire survey show that demand for information corresponds to willingness to share among manufacturers and end-of-life actors (see Figure 2), with some exceptions: End-of-life actors desire information on product composition and hazardousness, but only some manufacturers are willing to share this information. This may hint at different interests and possible conflicts.

## 5 Requirements for a Digital Product Passport

The requirements presented in this section were elicited based on our literature review, the results from the questionnaire, talks given by experts and discussions with experts, as mentioned in Section 1.

### 5.1 Information Requirements

The DPP allows value chain stakeholders to map information and obtain a better understanding of the *composition* of the product, the *environmental impact* of the production and use phase, and the *recycling solutions* at the end of the lifecycle [22]. In most DPP concepts existing so far, the DPP is generated during the production phase of a product by default. However, for recycling-oriented use cases, the DPP can also be generated at a later phase, e.g., during collection or sorting. Depending on the use case, one DPP per individual product might be required (e.g., to record individual manufacturing or usage/repair data). For simple products, one DPP per product model or per batch might be sufficient.

The requirements on a product's DPP depend on a number of criteria, including:

- complexity of the product, i.e., material mixtures, joining techniques, disassembly efforts
- complexity of the lifecycle, i.e., type of use, number of stakeholders during each lifecycle, number of lifecycles
- value of the product or the targeted fractions, i.e., monetary (residual) value or ecological indicators such as embodied energy and material scarcity
- harm potential, i.e., product hazardousness or material toxicity

**Manufacturing Data** The main responsibility for the subsequent value chain lies in the manufacturing process and its documentation. This should contain the product's composition, the materials and weights used in each component [23]. Additionally, technical data is also significant to be included. This contains details about the manufacturing process (e.g., joining technique, binder), the physical and chemical properties of the materials employed as well as information regarding non-hazardousness or hazardousness to human health or to the environment (e.g., hazard class) [24]. A product's and its components' performance and durability should also be stated. This, together with information on component removeability and replaceability, can help users extend the product's life expectancy and enable optimal product use. The inclusion of the batch number in the DPP is beneficial because it allows to track all products that were manufactured under the same conditions.

**Usage Data** During the use phase of complex products, all changes to the product should be documented. This includes the documentation of any parts that have been replaced or repaired. The person or organization who makes these adjustments is also responsible for updating the DPP. Frequent product-specific damages and damage to components, especially those that are critical to health and environmental safety, should be recorded to ensure proper handling and enable optimization of the product [25]. Ideally, users will indicate how they intend to dispose of the product when it reaches the end of its life. This, in turn, aids in better planning of the CE and better targeting of waste collection campaigns.

**End-of-Life Data** The DPP should include documentation on collection, sorting, and treatment during the End-of-Life (EoL) phase. These data, when combined with user input, can help improve waste management. The recording of the achieved collection fraction of the product can be compared with the sales volume. This provides information on how many products are still in use, how many have left the geographical boundary of the sales region or have been otherwise displaced. Furthermore, the applied recycling method should be specified, and the process's output streams should be recorded. This information can also be fed back to the manufacturer to facilitate product (re-)design for improved circularity.

**Lifecycle Data** Sales volume can be used to anticipate how much waste to expect at any given time and the amount of resources that could be recycled. This facilitates economic and CE planning. However, these are variable figures that depend on a variety of factors such as the life expectancy of a product, user behaviour, and recycling potential. Furthermore, the DPP should include guidelines for storage and usage of the product, which are provided to users in order to minimize potential health or environmental risks. The DPP also serves as a tool for achieving the Sustainable Development Goals (SDGs) [26]. Therefore, information on the environmental impact of a product should be disclosed, which aids consumers with their purchasing decisions [27]. Moreover, a social lifecycle assessment (SLCA) can be incorporated to assess and identify potential social impacts throughout the lifecycle [28].

### 5.2 Requirements for Successful Collaboration

Collaboration, trust and transparency are the most difficult aspects of the CE. Therefore, all stakeholders in the value chain must work together with openness to achieve long-term success [29]. Data availability and transparency are essential throughout a product's lifecycle to indicate its origin, location, material properties and characteristics as well as end-of-life treatment and recycling, among other things – especially if a global CE is to be realized. In resource planning and sustainable procurement practices, materials traceability is critical. In many circumstances, tracking information is limited, particularly in developing countries with weak governance structures. Digital technologies such as a DPP aim to enhance transparency and traceability [30].

### 5.3 Identification

A challenge in the pursuit of digitization of product information is the linkage between the physical product and the associated information that resides with various stakeholders. A unique product identification is critical for storing product-related information because it allows the physical products to be connected to their specific information. Additionally, this identification must be recognizable on a global scale [19]. Ideally, the identifier should not only be able to be carried on a data carrier like a QR code but also have a uniform

resource locator (URL) on the internet. Moreover, linking the identifier with other common existing identifiers such as the European Article Number (EAN) or other GS1 standards [10] ensures traceability of the information added to the DPP from production to disposal of the product. In addition, such information should be linkable to certain stakeholders (e.g., manufacturers) to achieve accountability [24]. The storage of the DPP and access to it are further topics that need to be considered, but are not the focus of this paper.

### 5.4 Incorporation of Legal Obligations

The legal and regulatory framework for the DPP is slowly emerging. At present, the main driver for this is the European Commission. The DPP has been mentioned and conceptualised in various strategies and other documents relating to the twin transition – the European Green Deal and the EU's industrial strategies.

The key document is the Proposal for Ecodesign for Sustainable Products Regulation (ESPR) [31] published in March 2022. In this document and its annexes, the European Commission proposes a definition of the DPP, its scope, and the informational requirements of the DPP, which specifically relate to CE purposes and the declaration of substances of concern (i.e., all substances that may negatively affect reuse or recycling of a product). According to the current proposal, every product containing substances of concern that is being introduced to the EU's market will be obliged to have a DPP. There is, however, little mentioning of technological specifications for the DPP system in the ESPR. The current proposal suggests a central registry which will at least contain a unique identifier per product, item series or batch, respectively, but does not make explicit which other information needs to be contained within a DPP. However, other rules and standards can be used for this, such as DIN SPEC 91406 [32], which provides the normative background for unique identifiers.

While the regulatory framework is still sketchy and at an early stage, there are also some further aspirations for obligatory content and use beyond CE. One of them refers to the DPP as a single point of reference and entry for information that companies have to declare. Hence, instead of having to fill in a number of databases, like SCIP [33], REACH, RoHS [34] or EPREL [35] in the European context, which can be cumbersome and costly, the DPP would gather and provide the required information at one single point of truth. Likewise, the provision of information on social compliance and greenhouse gas emissions could be part of a DPP's obligatory content. Another legal item that could be covered by the DPP is the enablement and support of market surveillance via DPPs – they might be used to counter plagiarism and other illegal practices in product manufacturing, for instance.

## 6 Conclusion and Outlook

In this paper, we have compiled requirements for the DPP based on identified goals and stakeholders. Our compilation constitutes a first proposal and is by no means complete.

Furthermore, the results from our questionnaire are based on a comparatively small number of participants and deserve further investigation. This paper can thus be seen as a basis for a discussion across sectors and industries as to what a broadly applicable DPP concept should look like. Once such a DPP concept has been realized, various applications and services can be built on top of it that can bring the CE forward. Very promising applications are being developed in the field of Artificial Intelligence. Examples are AI-based lifecycle assessment [6] and neural network based waste sorting informed by data from the DPP as proposed by [9]. Future work includes a requirements analysis of the data handling system for the DPP.

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## References

[1] European Parliamentary Research Service (EPRS). *Circular economy*. 2021. URL: https://www.europarl.europa.eu/thinktank/infographics/circulareconomy/public/index.html (visited on 06/15/2022).

[2] The European Commission. *The European Green Deal*. 2019. URL: https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF (visited on 06/15/2022).

[3] The European Commission. *A new Circular Economy Action Plan For a cleaner and more competitive Europe*. 2020. URL: https://eur-lex.europa.eu/resource.html?uri=cellar:9903b325-6388-11ea-b735-01aa75ed71a1.0017.02/DOC_1&format=PDF (visited on 06/15/2022).

[4] German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection. *Digital Policy Agenda for the Environment*. 2020. URL: https://www.bmu.de/DL2444-1 (visited on 06/15/2022).

[5] Thomas Götz, Thomas Adisorn, and Lena Tholen. *Der digitale Produktpass als Politik-Konzept*. Wuppertal Institut, 2021. URL: https://epub.wupperinst.org/frontdoor/deliver/index/docId/7694/file/WR20.pdf (visited on 06/15/2022).

[6] José Oduque de Jesus, Karla Oliveira-Esquerre, and Diego Lima Medeiros. "Integration of Artificial Intelligence and Life Cycle Assessment Methods". In: *IOP Conference Series: Materials Science and Engineering*. Vol. 1196. 1. 2021.

[7] The Circularity Dataset Initiative. *Product Circularity Data Sheet (PCDS)*. 2022. URL: https://pcds.lu/pcds-system/%5C#pcds (visited on 06/15/2022).

[8] Excess Materials Exchange (EME). *Resources Passport*. 2022. URL: https://www.resourcespassport.com/ (visited on 06/15/2022).

[9] Christiane Plociennik et al. “Towards a Digital Lifecycle Passport for the Circular Economy”. In: *Procedia CIRP* 105 (2022), pp. 122–127. ISSN: 2212-8271. DOI: 10.1016/j.procir.2022.02.021.

[10] GS1 in Europe. *Proposed Architecture and Principles for Digital Product Passports*. The Global Language of Business. 2022. URL: https://www.gs1.eu/news/eu-digital-product-passport-revealed-time-to-act (visited on 06/15/2022).

[11] *Digital Product Passport*. 2022. URL: https://www.ipoint-systems.com/de/loesungen/digital-product-passport (visited on 06/15/2022).

[12] R-Cycle. *Projekt R-Cycle*. 2022. URL: https://www.r-cycle.org (visited on 06/15/2022).

[13] circular.fashion UG. *circularity.ID® Open Data Standard Version 2.0*. 2020. URL: https://circularity.id/static/circularity.ID-Standard-Specification-v2.pdf (visited on 06/15/2022).

[14] Global Battery Alliance (GBA). *Battery Passport*. 2022. URL: https://www.globalbattery.org/battery-passport/ (visited on 06/15/2022).

[15] Yaocai Bai et al. “Energy and environmental aspects in recycling lithium-ion batteries: Concept of Battery Identity Global Passport”. In: *Materials Today* 41 (2020). ISSN: 1369-7021. DOI: 10.1016/j.mattod.2020.09.001.

[16] EPEA Nederland BV and SundaHus i Linköping AB. *Framework for Materials Passports*. Buildings as Material Banks (BAMB) European Union project. 2017. URL: https://www.bamb2020.eu/wp-content/uploads/2018/01/Framework-for-Materials-Passports-for-the-webb.pdf (visited on 06/15/2022).

[17] Madaster Foundation. *Madaster*. 2022. URL: https://madaster.de/ (visited on 06/15/2022).

[18] Voith. *IMDS Leitfaden*. 2022. URL: https://voith.com/corp-de/IMDS-Leitfaden.pdf (visited on 06/15/2022).

[19] Kary Främling, Mark Harrison, and James Brusey. “Globally unique product identifiers–requirements and solutions to product lifecycle management”. In: *IFAC Proceedings Volumes* 39.3 (2006), pp. 855–860.

[20] European Commission. *Proposal for a Regulation of the European Parliament and of the Council concerning batteries and waste batteries*. 2020. URL: https://ec.europa.eu/environment/pdf/waste/batteries/Proposal_for_a_Regulation_on_batteries_and_waste_batteries.pdf (visited on 06/15/2022).

[21] Erik G. Hansen, Florian Lüdeke-Freund, and Klaus Fichter. “Circular business models: a typology based on actor type, circular strategy and service degree”. In: *Product Lifetimes and the Environment (PLATE)*. 2021.

[22] TANNER AG. “Der digitale Produktpass, Treiber für die digitale Dokumentation”. In: *ABZ-Magazin* (2021). URL: https://www.tanner.de/wp-content/uploads/2021/08/ABZ_01_2021_web.pdf (visited on 06/15/2022).

[23] Thomas Adisorn, Lena Tholen, and Thomas Götz. “Towards a Digital Product Passport Fit for Contributing to a Circular Economy”. In: *Energies* 14.8 (2021). URL: https://www.mdpi.com/1996-1073/14/8/2289.

[24] Susanne Guth-Orlowski. *The digital product passport and its technical implementation*. 2021. URL: https://medium.com/@susi.guth/the-digital-product-passport-and-its-technical-implementation-efdd09a4ed75 (visited on 06/15/2022).

[25] Conrad Tucker and Harrison Kim. “Predicting emerging product design trend by mining publicly available customer review data”. In: *DS 68-6: Proceedings of the 18th International Conference on Engineering Design (ICED 11)*. 2011.

[26] United Nations Development Programme (UNDP). *Sustainable Development Goals (SDGs)*. 2015. URL: https://www.undp.org/sustainable-development-goals (visited on 06/15/2022).

[27] Otmar Lell, Viola Muste, and Christian Thorun. *Förderung des nachhaltigen Konsums durch digitale Produktinformationen: Bestandsaufnahme und Handlungsempfehlungen*. 2020. URL: https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/2020_11_17_texte_212_2020_digitalisierung_nachhaltiger_konsum_wirtschaftkonsum.pdf (visited on 06/15/2022).

[28] Andreas Moltesen et al. “Social life cycle assessment: An introduction”. In: *Life Cycle Assessment*. Springer, 2018, pp. 401–422.

[29] Dawei Zhang et al. “Sustainable Circular Business Model for Transparency and Uncertainty Reduction in Supply Chain Management”. In: *J. Theor. Appl. Electron. Commer. Res.* 16 (2021), pp. 959–975. DOI: 10.3390/jtaer16040054.

[30] *OECD workshop on international trade and the circular economy*. 2020. URL: https://www.oecd.org/env/workshop-trade-circular-economy-summary-report.pdf (visited on 06/15/2022).

[31] European Commission. *Proposal for Ecodesign for Sustainable Products Regulation*. 2022. URL: https://environment.ec.europa.eu/publications/proposal-ecodesign-sustainable-products-regulation_en (visited on 06/15/2022).

[32] DIN. *DIN SPEC 91406: Automatic identification of physical objects and information on physical objects in IT systems, particularly IoT systems*. 2019. URL: https://dx.doi.org/10.31030/3114151.

[33] European Chemicals Agency. *SCIP*. 2022. URL: https://echa.europa.eu/de/scip (visited on 06/15/2022).

[34] Eva Hink and Hans-Jochen Lueckefett. “REACH and RoHS compliance in the supply chain”. In: *2012 Electronics Goes Green 2012+*. IEEE. 2012, pp. 1–4.

[35] European Commission. *EPREL – European Product Registry for Energy Labelling*. 2022. URL: https://eprel.ec.europa.eu (visited on 06/15/2022).