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Digital Product Passport within Boundaries

Consumer Information Requirements for the EU Digital Product Passport and Boundary Conditions for its Implementation

TU Delft

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Executive Summary

The continuous growth of material consumption places a high burden on the Earth's systems, causing harm to both humans and nature. Transitioning to a circular economy, in which all products and materials retain in cycles, has been promoted by the European Union as a countermeasure to this threatening development. However, progress in the circular economy transition is minor and needs to be accelerated. Therefore, reducing material consumption by implementing the highest level circular strategies, such as product-as-a-service models or reusing, is crucial.

The European Union (EU) proposes the implementation of a cross-sectoral EU Digital Product Passport (DPP) to accelerate the transition to the circular economy. The EU DPP is a standardized dataset of product-specific lifecycle information that is electronically accessible with a product. It is anticipated to benefit all actors along a product's value chain by creating transparency and trust, enabling access to more comprehensive information, and facilitating informed decision-making for sustainability.

However, research around this concept is still emerging, and it needs to be clarified how exactly the EU DPP should be designed to be impactful. Notably, actor- and product-specific information requirements are missing for the technology's near-term implementation.

This thesis research addresses the societal challenge by contributing to the called needs from the DPP research. It aspires to shed light on the contextual DPP development by eliciting information requirements for the EU DPP that addresses the information deficits of EU consumers hindering them from acquiring the most circular mobile phone alternative.

For this purpose, rigorous Design Science Research is performed through desk research and based on scientific literature to explicate the information deficits of consumers. They are translated into design principles that guide the purposeful elicitation of information requirements. Furthermore, by conducting expert interviews, the information requirements are evaluated and revised to bring value to the EU DPP's development in practice. However, as the EU DPP is a new technology that will intervene in the complex consumption system of mobile phones, uncertainties about its implementation exist. Thus, with expert input, boundary conditions are identified that determine the implementation of an EU DPP. They are structured in a Boundary Condition Framework to inform further research and development.

A total of 50 information requirements are elicited that ensure the relevance, soundness, and accessibility of the EU DPP's information provided so that consumers' information deficits are addressed. Whether the EU DPP developed based on these information requirements can mitigate consumers' information deficits is determined by four boundary conditions that need to be in place and are partly dependent on the heterogeneity of consumer needs. They are:

Suitability of the DPP	The development process and the resulting DPP is suitable to serve the objectives (e.g., material consumption reduction) and address the consumer needs in the research's context.
Information Efficiency	The information and its provision to the consumer are most effective in serving the DPP objectives and addressing the consumer needs while using the least possible data.
Data Governance	The data for the DPP is governed in a way that supports the intended information provision (including, for instance, roles and rights or trust mechanisms), also considering the lifecycle of the DPP's data and the implementation of third-party applications.
Data Provision	The data and its governance required to serve the consumer needs are in accordance with the interests and capabilities of the data provider (including private persons if necessary) and incorporate standards ensuring information validity.

These findings contribute to the overall understanding and development of the EU DPP and, simultaneously, the mitigation of potential risks associated with its implementation. Focusing on mobile phone acquisition from a consumer perspective informs the purposeful design of the EU DPP in a specific context. Furthermore, the identification of relevant boundary conditions facilitates its successful implementation. Ultimately, the EU DPP developed further based on this research's outcome can assist consumers in making informed decisions and fostering a more circular economy in the mobile phone industry.

Hence, it can contribute to the needed acceleration of the circular economy transition in the EU to tackle the societal challenge of continuous material consumption growth.

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List of Abbreviations

CE	Circular Economy
CET	Circular Economy Transition
DPP	Digital Product Passport
DSR	Design Science Research
EKB	Engel-Kollat-Blackwell
ESPR	Ecodesign for Sustainable Products Regulation
EU	European Union
ICT	Information and Communication Technology
IPCC	Intergovernmental Panel on Climate Change
KG	Knowledge Gap
LCA	Lifecycle Assessment
SQ	Sub-Question

Contents

1. Introduction

This chapter lays the foundation for the thesis research by elaborating on the societal and scientific relevance and establishing the main research question. In addition, the relation to the researcher's study program and the thesis outline are provided.

1.1 Societal Challenge & Motivation

Continuous material consumption growth – A high burden for the earth's system

The way humanity has been treating the earth, the basis of their existence, is alarming. Particularly in high-income countries, human material consumption continuously and significantly increases over the ecosystems' capacity to recover, as the United Nations (2022, p. 50), the OECD (2019), and renowned scientific organizations (e.g., Earth4All, 2022, p. 5; International Resource Panel of the UN, 2019, pp. 42–45) point out.

This development harms humans and nature tremendously (e.g., Earth4All, 2022; European Commission, 2019; Hanemaaijer et al., 2021; International Resource Panel of the UN, 2019; United Nations, 2022; WWF, 2020). The demand for technology products and the associated increase in material consumption cause pollution, waste generation, and habitat pressure over a product's lifecycle (OECD, 2019, pp. 184–185). Also, the ongoing increase in global CO_2 emissions, reported by the Intergovernmental Panel on Climate Change (IPCC), is directly linked to the material consumption required for our everyday lives (IPCC, 2022).

Transitioning towards a circular economy – A countermeasure by the European Union

To counter these issues, the IPCC calls for more sustainable consumption and production patterns, which a circular economy could support (IPCC, 2022, pp. 117–124). Based on the Ellen MacArthur Foundation (2019), in a circular economy (CE), all materials retain in a technical or biological cycle, wherein products circulate as long as possible, and material flows are closed. Also, it creates just as much waste, pollution, and other negative externalities as can be handled by the earth's ecosystem.

Taking on their responsibility, the European Union (EU) has already for years been promoting the transition from a linear to a CE (European Commission, 2015, 2020; Council Directive 75/442/EEC, 1975). Moreover, as the European Green Deal pointed out, implementing a CE is one central element of the EU's environmental ambitions (European Commission, 2019, pp. 2–3). In this context, the focus of the planned CE measures is on transforming "resource-intensive sectors such as textiles, construction, electronics, and plastics" (European Commission, 2019, p. 7), thus on the above-mentioned technical cycle.

Need to accelerate the EU circular economy transition

Despite the efforts and planned legislation, the European Environment Agency registers hardly progress in the circular economy transition (CET), particularly regarding the consumption footprint[1], as Figure 1 shows (European Environment Agency, 2022). This aligns with the global trend in material consumption growth outlined before. In that respect, it is also important to point out that consumption in the EU also contributes to adverse environmental impacts outside the borders of the EU, undermining global justice (Bruckner et al., 2023).

[1] "The consumption footprint refers to the environmental and climate impacts resulting from the consumption by EU citizens of goods and services, whether produced within or outside the EU." (European Environment Agency, 2022; webpage)

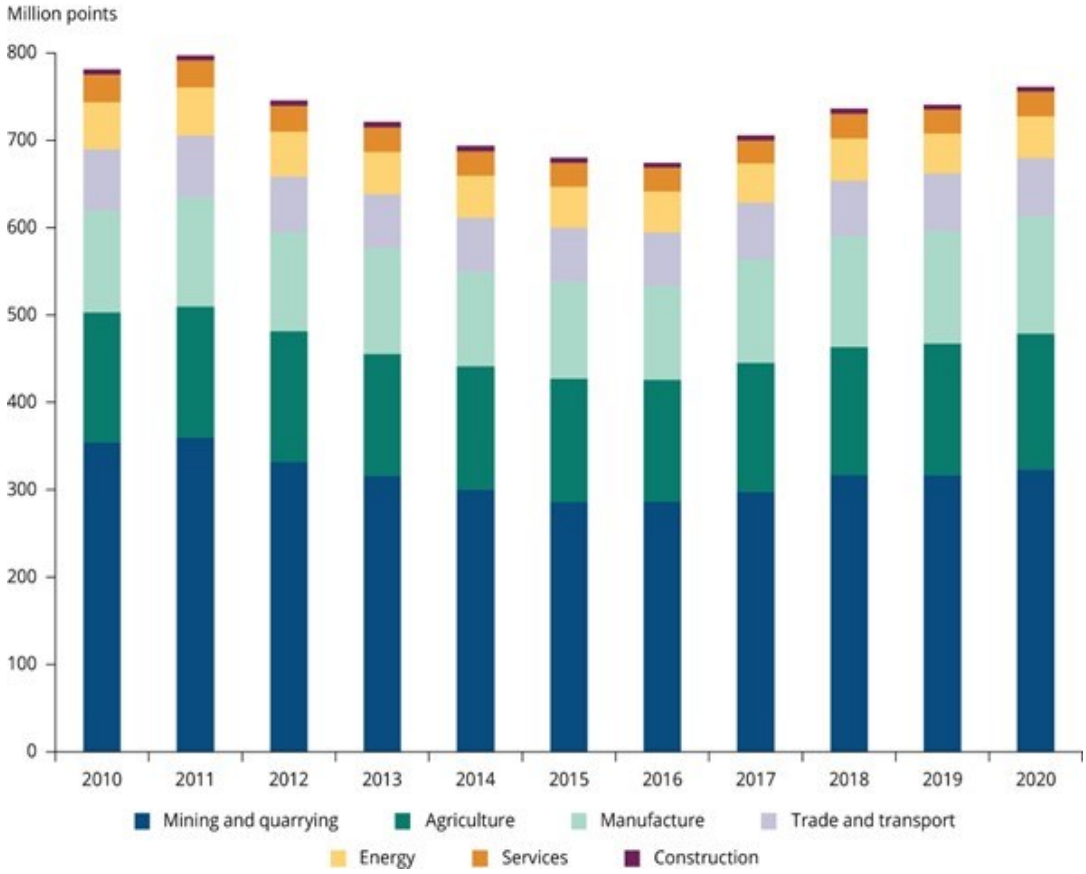


Figure 1: Europe's consumption footprint from 2010 to 2020 (European Environment Agency, 2022); The point scale comprises 16 normalized and weighted environmental and climate impact indicators. It allows the aggregation of the different indicators in one single score. (European Environment Agency, n.d.)

Reduction of material consumption through the highest CE strategies

The European Environment Agency (2022; webpage) acknowledges that "the EU would need to make significant efforts to reduce its overall consumption of goods and services or to shift to the consumption of goods and services that have a lower impact on the environment, or both". This objective is also backed by the introduction of the EU's "Circular Economy Action Plan" (European Commission, 2020, p. 4) and the recently introduced "8th Environment Action Programme" (European Parliament & Council of the European Union, 2022). Also, researchers see the impossibility of decoupling the continuous economic growth from the environment's exploitation as the real cause of the outlined developments (e.g., Baldé et al., 2017; Earth4All, 2022; Hickel & Kallis, 2019; Timothée et al., 2019).

The European Environment Agency (2022) calls for promoting the highest circular strategies (see Figure 2), like sharing or product-as-a-service business models, to reduce material consumption. This is also relevant, as the PBL Netherlands Environmental Assessment Agency (Hanemaaijer et al., 2021) and scholars (e.g., Castro et al., 2022; Horvath et al., 2019) often identify a sole focus on recycling regarding CE actions. They argue that this leads to deviating from the objectives and support the call for highest-level circular strategies.

Consequently, this thesis research is motivated to contribute to promoting the highest-level CE strategies to reduce overall material consumption and thus accelerate an effective CET in the EU.

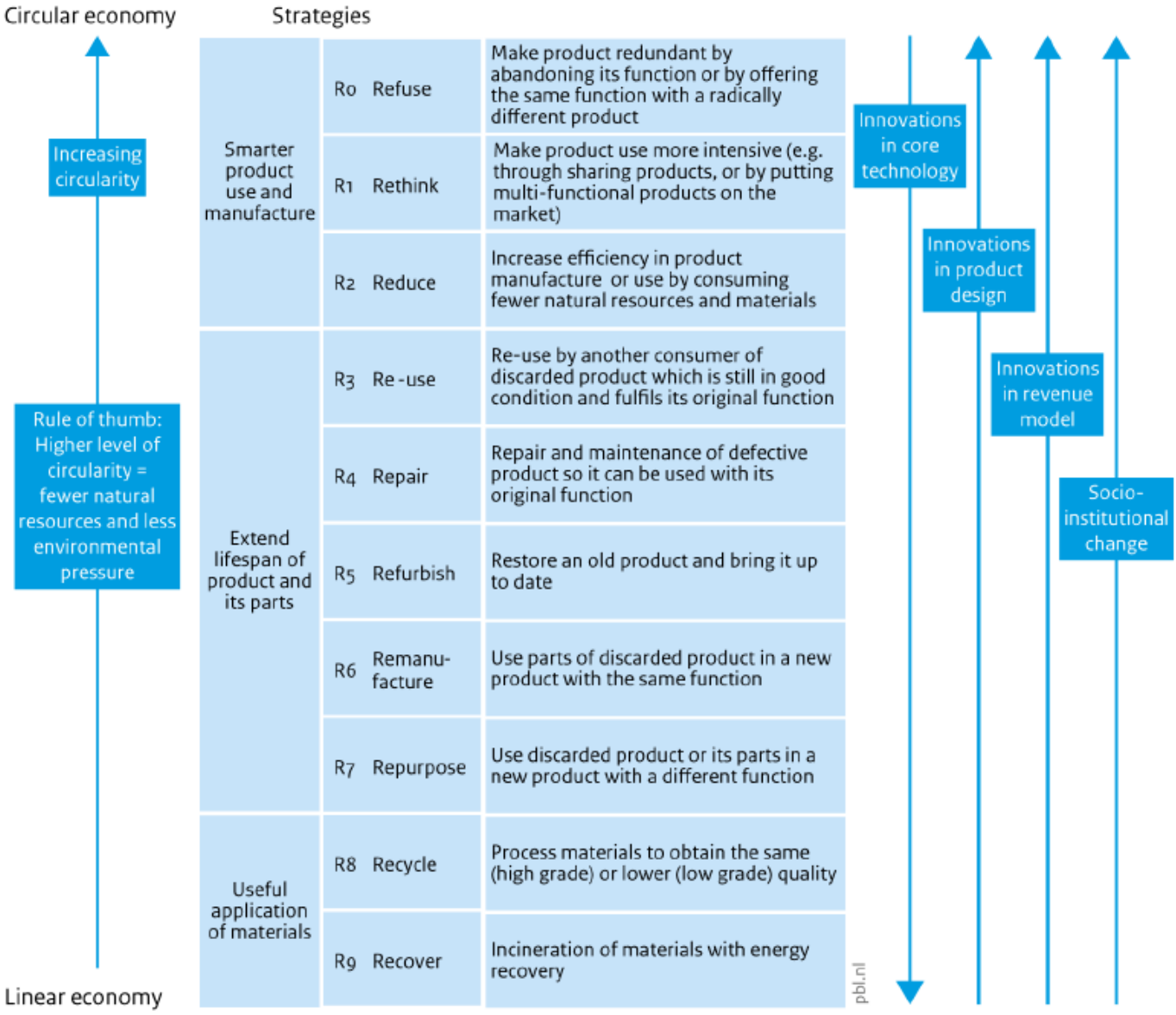


Figure 2: Circular Strategies (Potting et al., 2017, p. 5)

1.2 Knowledge Gaps

In this section, scientific knowledge gaps are identified gradually to examine the scientific relevance of the research in light of the societal challenge. The identified knowledge gaps are the basis for the main research question and scope.

First, the Digital Product Passport (DPP) is presented, a technical solution proposed by the European Union to accelerate the circular economy transition. Afterward, its development status and the state of scientific knowledge are examined based on an initial literature review.

1.2.1 Digital Product Passport

Introducing the EU DPP

Aiming at accelerating the transition to a CE, the EU identified the need for developing a cross-sectoral EU[2] Digital Product Passport (DPP) (European Commission, 2022a). Accordingly, it is introduced in the proposed "Ecodesign for Sustainable Products Regulation" (ESPR) (Directorate-General for Environment of the European Commission, 2022) as the supporting technical solution, which will be accompanied by other policies, for instance, regarding product design.

The ESPR proposal states that the DPP is used to "[…] electronically register, process and share product-related information amongst supply chain businesses, authorities, and consumers" (Directorate-General for Environment of the European Commission, 2022, p. 9).

By doing so, the DPP should bring several advantages for all actors along a product's value chain by creating transparency and trust, enabling access to more comprehensive information, and facilitating informed decision-making for sustainability (European Commission, 2022c, pp. 584–588). Consequently, the DPP is a relevant digital technology in the CE Action Plan, the EU's strategic roadmap in the circular economy transition (European Commission, 2020).

DPP – an information system

From a technical viewpoint, the DPP is a standardized dataset of product-specific lifecycle information electronically accessible with a product through a data carrier (machine-readable data capture medium, e.g., bar code) (Directorate-General for Environment of the European Commission, 2022). The DPP should complement the information on the product packaging instead of replacing it (European Commission, 2022c, p. 594). In addition, it is intended that third parties can develop additional applications based on the DPP to further facilitate, for example, consumers' information processing and decision-making (European Commission, 2022c, p. 595).

In general terms, I define the DPP as an information system. An information system is "a system which assembles, stores, processes and delivers information relevant to an organization (or to society) in such a way that the information is accessible and useful to those who wish to use it, including managers, staff, clients and citizens" (Buckingham et al., 1987, cited by Avison & Myers, 1995, p. 44). Based on the international standard ISO/IEC 25012:2008, this not only comprises "computer systems and communication systems, [but also] associated organizational resources such as human, technical, and financial resources" (ISO & IEC, 2008, Chapter 4).

Figure 3 by Ducuing & Reich (2023) shows a conceptualization of the DPP and its ecosystem, in line with this socio-technical definition of the DPP as an information system.

[2] The adjunct "EU" may be left out to facilitate reading throughout the report. If not explicitly stated, the entire thesis research concerns the DPP concept proposed by the European Commission that will be deployed in the EU for EU consumers.

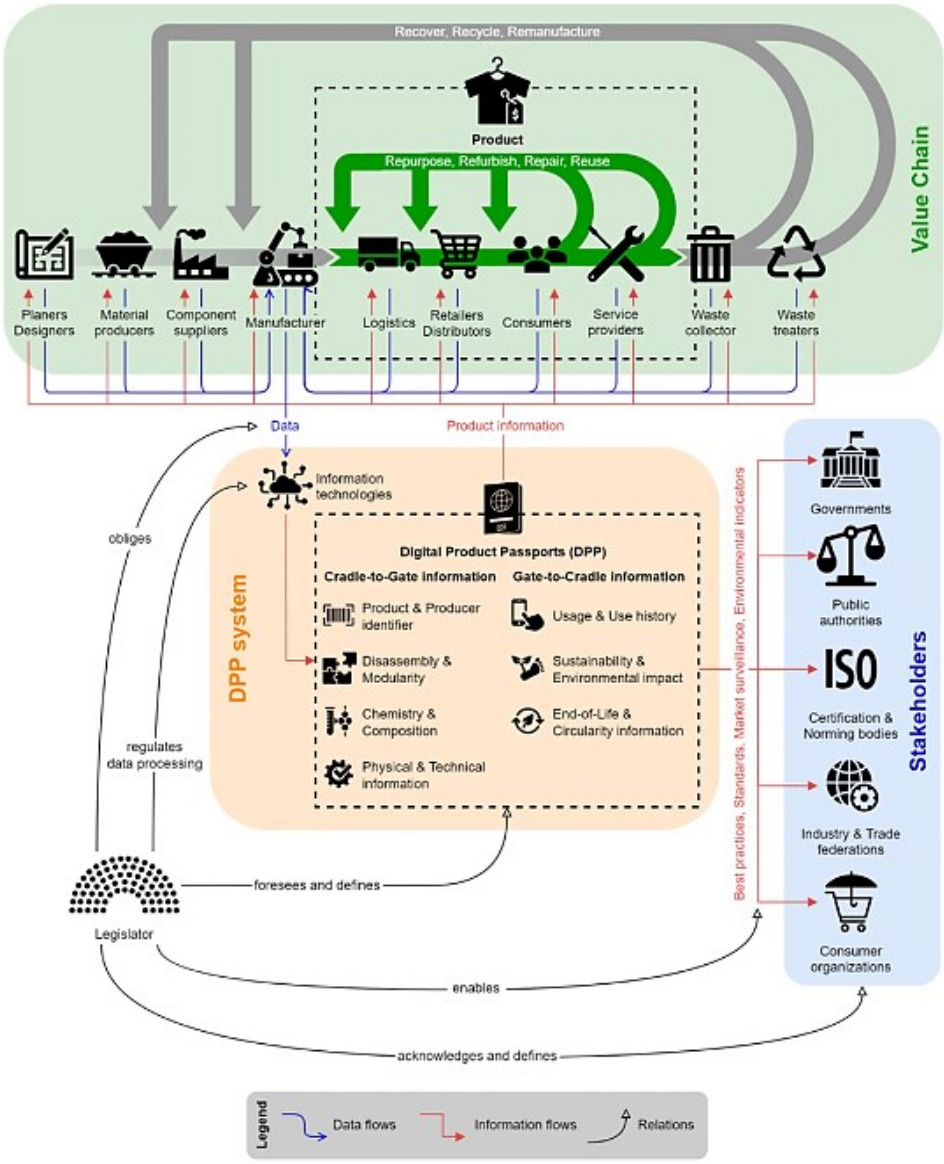


Figure 3: DPP Ecosystem (Ducuing & Reich, 2023, p. 10)

EU research efforts

The EU-funded research project "CIRPASS" was set up at the end of 2022 to "prepare the ground for the gradual piloting and deployment of a standards-based Digital Product Passport (DPP) aligned with the requirements of the Proposal for Ecodesign for Sustainable Product Regulations (ESPR), with an initial focus on the electronics, batteries, and textile sectors" (CIRPASS, n.d.). Based on this project, the expected roll-out of the EU DPP in the market will be in 2026/2027, focusing on the mentioned sectors. Furthermore, the CE Action Plan highlights these sectors as key sectors (European Commission, 2020).

In order to contribute to this EU effort in light of the societal challenge, the outlined scope of the CIRPASS project and the ESPR proposal are the baselines for this research. This also means that the development of applications by third parties is outside the research scope. Considering the novelty of the EU DPP concept and the expected near-term roll-out, I conclude the first main knowledge gap, which sets the general purpose of my research.

Knowledge Gap 1 (KG1): The EU DPP, related to the ESPR proposal and CIRPASS project, is intended to address the societal challenge of continuous material consumption growth. However, further research is required to explicate the novel concept and prepare its near-term implementation.

1.2.2 Initial Literature Review

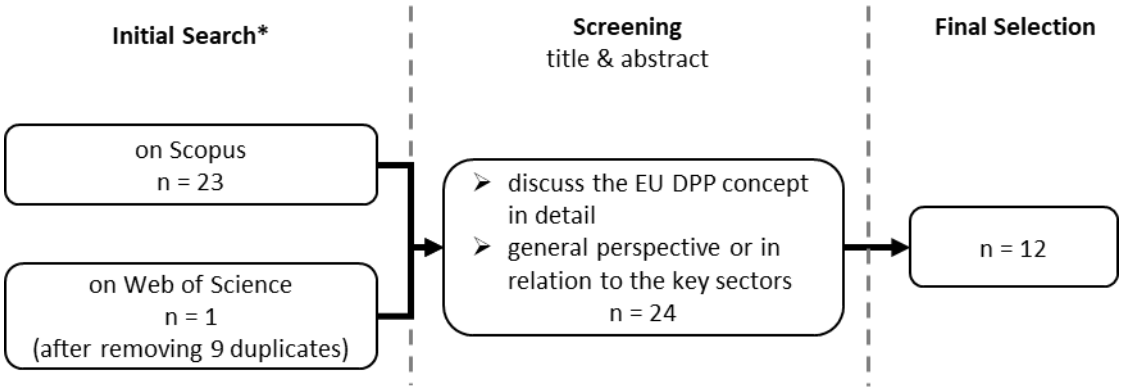
An initial, systematic literature review is conducted to identify specific knowledge gaps in the EU's development of the DPP. The literature analysis mainly focuses on how the DPP concept has been approached so far to identify what common research need exists.

In the following, the document selection process and general findings are provided.

Selected documents

A total of 20 documents were selected, presented in Table A. 1 (see Appendix A).

Based on a literature review on Scopus and Web of Science (see Figure 4), 12 documents come from peer-reviewed scientific literature. They are identified by screening the abstracts regarding whether the papers discuss the EU DPP concept in detail, either from a sector-independent perspective or in relation to the key sectors mentioned.



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TITLE-ABS-KEY ("product passport" OR "lifecycle passport" OR "life cycle passport" OR "circularity passport" OR "textile passport" OR "electronics passport" OR "battery passport") further filter: article, review papers, conference papers; English, German; final version

Figure 4: Literature selection process – DPP research

In addition, the ESPR proposal and papers or reports by research institutes active in the DPP research (n = 7) are included. The latter are relevant, as they are active in the DPP development, among others, as part of the CIRPASS project. From the selected 12 scientific papers, the affiliated research institutes were chosen. Relevant documents are retrieved from their institute's public databases. The same criteria as for the literature review on Scopus and Web of Science are applied to assess their relevance.

Moreover, 104 identified scientific research and business initiatives related to the EU DPP are considered to further assess the current state of the EU DPP development in the following two Sub-Sections 1.2.3 and 1.2.4 (72 initiatives identified by Jansen et al. (2022) and 32 identified by CIRPASS, see Bernier et al., 2023).

General research approaches for the DPP development

General findings are made based on the analysis in Table A. 1 (see Appendix A).

The research and development regarding the DPP are still emerging (earliest publication = 2021).

Most documents (14 of 20) lay the conceptual foundation by defining and/or reviewing the concept (n = 8), or by describing possible use cases and system designs (n = 6). 7 of the 20 documents define system requirements from a general perspective for the cross-sectoral DPP system (n = 4) or in a particular sector- or product-context (n = 3).

I conclude that the current research in the EU DPP so far rather frames the general cross-sectoral concept, instead of working towards more context-specific requirements for the implementation.

Demand for specific information requirements

Reviewing the documents more in detail reveals a particular call for the development of information requirements from an actor- and product-specific perspective (Adisorn et al., 2021; Bernier et al., 2023; Directorate-General for Environment of the European Commission, 2022, p. 25; Durand et al., 2022; European Commission, 2022c, p. 604; Götz et al., 2021; King et al., 2023; University of Cambridge Institute for Sustainability Leadership (CISL) & Wuppertal Institute, 2022; Walden et al., 2021).

The investigation of information requirements based on actor needs is proposed as a near-term task to adjust the DPP and prepare pilot projects in practice, as Götz et al. (2021, p. 34) state in their elaborate research and implementation roadmap.

On the other hand, a product-specific perspective is seen as necessary to elaborate on relevant product groups and their specifics for implementation by taking into account their variety in (ecosystem) complexity (Adisorn et al., 2021, p. 13; King et al., 2023; University of Cambridge Institute for Sustainability Leadership (CISL) & Wuppertal Institute, 2022). Also, referring to the ESPR proposal, the specific requirements for the key target sectors still need to be defined (Directorate-General for Environment of the European Commission, 2022).

Additionally, considering the work packages of the EU DPP project CIRPASS, they rather take a technical perspective, i.e., the identification and classification of data and technical systems already existing (Bernier et al., 2023, pp. 10–12).

From the general analysis of the current state of scientific knowledge, I conclude the second main knowledge gap, which directs my research effort in the DPP context.

Knowledge Gap 2 (KG2): Information requirements from an actor- and product-specific perspective are hardly investigated yet but are required in the near term to inform the overall DPP development and set up context-specific pilots.

The second knowledge gap is further concretized in the following two sub-sections to identify which actor and product perspective is relevant for an information requirement elicitation. The perspectives are analyzed by further reviewing the DPP literature, the related initiatives, and additional related literature.

1.2.3 Actor-perspective: Consumers

Although the reviewed DPP literature outlines the advantages of the DPP for all actors along a product's value chain, only a minor focus on the consumer perspective can be noticed (Table A. 1, Table A. 2; see Appendix A). Specifically, only 1 of the 20 reviewed documents and 18 of 88 relevant[3] initiatives address the consumer. Other than that, they mainly address businesses.

Relevance of the consumer role

In contrast to the DPP research focus, research in CE highlights the consumer's significant role in the transition to a circular economy, besides the government and businesses (e.g., Castro et al., 2022; Grafström & Aasma, 2021; Kirchherr et al., 2017; Nazlı Köseoğlu, 2022; Rizos et al., 2015; Tan et al., 2022; Wieser, 2016).

Shevchenko et al. (2023, p. 6) define the consumer role as tri-fold within the CE, as they are: customer, user, and End-of-Life Product Holder.
This research particularly focuses on the consumer's role as a customer[4], as I assume this role to have the most impact on the discussed societal aim of (material) consumption reduction. The choice to acquire a more circular alternative could be decisive for facilitating circular practices in the use phase and at the end of use. For instance, acquiring a product that is durable, repairable, and/or has good recyclability characteristics.

[3] Only initiatives that are beyond the proposal stage are considered. They are at least in the "requirements elicitation" phase and are thus being actively developed. Moreover, the 18 mentioned initiatives only comprise initiatives that are stated to address the four key sectors of the EU DPP deployment and the consumer.

[4] Throughout the report, I just use the term "consumer" to avoid confusion. I noticed that the role-specific distinction is not commonly used.

To pursue the highest CE strategies in the CET, customers need to acquire products and services in the most circular way possible. Moreover, to further specify the scope of this research, I only consider private persons as a consumer. Other than that, I do not limit my consumer perspective to a particular consumer group, as the ESPR policy mix, including the DPP, is also not targeting one specific consumer group.

As a customer – (not) acquiring products or services (Shevchenko et al., 2023) –, consumers stimulate the development and market presence of circular business models with their awareness, acceptance, and involvement (Kirchherr et al., 2018; Mostaghel & Chirumalla, 2021).
For instance, the global Platform for Accelerating the Circular Economy (government, research, and business network) calls for transforming consumption practices to create the required demand for circular products and services in the electronics sector (PACE, 2021, p. 33). Hanemaaijer et al. (2021, p. 119) also see the need for stronger demand for circular business models in the only slight growth in the number of circular businesses in the Netherlands.

At the same time, still just a minor part of the total population is expected actually to acquire, for instance, refurbished products and particularly leasing offers (e.g. Hanemaaijer et al., 2021, p. 23; LE Europe et al., 2018, p. 48). Also, Kirchherr et al. (2018), investigating barriers in the CET of the EU, found a lack of customer engagement to be an impediment but also mentioned that market barriers drive this phenomenon.

Need for information requirements

With regard to the ESPR proposal and the associated empirical stakeholder consultations, the European Commission identifies a deficit in information affecting consumers' acquisition choice for sustainable products (Directorate-General for Environment of the European Commission, 2022, p. 98; European Commission, 2022b, pp. 6–8, 2022a, pp. 63–64; LE Europe et al., 2018, p. 179). They assume a deficit of relevant, clear, and available information. Moreover, they base their argumentation on the reasoning that

(1) some consumers declare to take environmental sustainability into account during their acquisition and that
(2) consumers would buy more environmentally friendly products if they had the necessary information to identify them (European Commission, 2022a, p. 63).

Hence, the European Commission concludes that providing information can be an effective measure to help consumers in their choice of environmentally sustainable products, including products with circular economy-related characteristics (e.g., repairability) (European Commission, 2022b, pp. 14, 65).

In this context, the DPP is expected to assist in a sustainable acquisition choice by providing sustainability information (King et al., 2023, p. 6).
Nevertheless, the DPP research and development does not elaborate sufficiently how exactly the information provision with the DPP can address their information deficits. Also, Adisorn et al. (2021, p. 12) call for further research in the consumer context. Among others, regarding what and how data needs to be provided so that it facilitates the intended sustainable choice-making.

Outlining the relevance of the consumer in the CE and taking the ESPR proposal as a baseline for this research, I identify that further research from the EU consumer perspective is required for the DPP. Thus, I conclude the following specification of the second knowledge gap.

Knowledge Gap 2.1 (KG2.1): EU consumers face potential information deficits hindering them from acquiring the most circular product alternatives. These could be resolved with the DPP. However, research and information requirements are missing in that respect.

1.2.4 Product-perspective: Mobile phones

Examining the current EU DPP research, the key sector of electronics (e.g., mobile phones, laptops, tablets) appears to be hardly addressed (see Table A. 1 in Appendix A). In the EU DPP-related literature, only 1 of 20 documents considers this sector, and only 2 of the 18 consumer-related initiatives. In addition, no electronics focus was found in a general product passport review by van Capelleveen et al. (2023),.

Relevance of the electronics sector & mobile phones

However, electronics are one of the key products the EU needs to address (European Commission, 2020). They are a particular example of the discussed need to accelerate an effective CET by reducing material consumption.
Not only the stock of electronics in use and the amount put on the market continuously increase (Eurostat, 2022b; Mazzarano, 2020), but also its resulting waste is growing, with less than 40% getting recycled on average in the EU (European Commission, n.d.-b; Eurostat, 2021). What makes the latter even more serious is, on the one hand, the high toxicity of electronic waste (European Parliament, 2022b). On the other hand, the dissipation of contained critical materials leads to negative environmental impacts due to the mining of virgin materials and the EU industry's dependency on mainly non-EU suppliers (Bobba et al., 2018; European Commission, n.d.-a).

In specific, mobile phones appear relevant in the context of my research.
On the one hand, they are relevant to address from a circular economy perspective because of their high usage[5], relatively short replacement cycles[6], complicated and material-rich design[7], and environmentally harmful lifecycle[10].
On the other hand, EU consumers already have today the possibility to choose mobile phones with a more circular product design (e.g., Fairphone, SHIFT), acquire refurbished phones (e.g., Backmarket, Apple, local electronic stores) or lease/rent them (e.g., Swapphone, Nokia, Grover). This circumstance could support the DPP's piloting and adoption in a sector where consumers can actually choose circular business model alternatives. Thus, I expect market barriers to be lower.

Noticing the need for further research regarding the application of the DPP in the electronics sector, particularly for mobile phones, the following specification of the second knowledge gap is concluded.

Knowledge Gap 2.2 (KG2.2): The key sector of electronics, particularly mobile phones, is important in the transition towards a circular economy and for the DPP deployment. However, research on the DPP's application for the product of mobile phones is missing.

[5] The amount of unique mobile subscribers as a percentage of the entire European population (penetration rate) is expected further grow to around 87% in 2025 (GSM Association, 2022; Statista, 2022).

[6] The average in-use lifespan of mobile phones in European countries is 2-4 years (Magnier & Mugge, 2022; Prabhu N & Majhi, 2023). In comparison, the average in-use lifespan of washing machines is around 8 years (Magnier & Mugge, 2022). Furthermore, while the total amount of mobile phones newly sold in the EU is seen to decline, with 176 million units sold in 2022, (Rizos et al., 2019, p. 12; Stryjak, 2023) the still rising penetration rate and new developments like the 5G network are expected to stimulate new phone sales (GSM Association, 2022).

[7] New mobile phones have a high impact on the environment (Jardim, 2017; Rizos et al., 2019) due to their extensive material composition (over 60 different elements, incl. critical raw materials), complex supply chains, and energy-intensive manufacturing processes. Moreover, mobile phones' functioning depends on complicated hardware and software.

1.3 Main Research Question

Thesis Objective

The initial literature review revealed that research around the EU DPP concept is still emerging and that the consumer perspective and the electronics sector have not yet been studied explicitly in this context.

Consequently, this thesis research aims to lay the foundation for further research and the implementation of the EU DPP in the consumer and electronics context. Moreover, by contributing a novel actor- and product-specific perspective, this research can uncover aspects that are disregarded in the more general discussion of the current EU DPP research.

Based on the identified knowledge gaps, the objective of the thesis research is:

To elicit a set of information requirements for an EU DPP (KG2) that addresses the information deficits of EU consumers hindering them from acquiring the most circular mobile phone alternative (KG2.1/2.2). These information requirements are meant to inform the near-term EU DPP implementation with the aim of addressing continuous material consumption growth (KG1).

By eliciting these context-specific information requirements, I intend to create scientific value by gaining additional knowledge regarding the DPP concept and how to research it further (e.g., identifying/establishing relevant scientific perspectives, theories, or tools). Furthermore, I aim to lay the ground for a broader scientific discussion by facilitating the generalizability of my research approach and findings and by informing domains besides the technical perspective (e.g., policy-making). These scientific objectives result mainly from Knowledge Gap 1.

Main Research Question

To summarize, society in the EU needs to transition rapidly towards a CE to reduce material consumption through the highest levels of circular strategies and thus to counteract human's negative, lasting environmental impacts from material extraction and waste generation. One specific product group of particular interest regarding consumption reduction is mobile phones.

The EU plans to introduce a Digital Product Passport (DPP) to accelerate the circular economy transition by providing transparent, comparable, and comprehensive (sustainability-related) product information and thus address information deficits that are assumed to hinder EU consumers from making most circular acquisition choices regarding mobile phones.

However, the research on the EU DPP concept is still emerging and is missing the outlined actor- and product-specific perspective. Hence, the discussion of information requirements in that context is relevant, as it can guide further research and near-term implementation of the EU DPP.

In conclusion, the main research question of this master thesis research is:

Main Research Question

What information requirements can be elicited for an EU DPP that addresses the information deficits of EU consumers hindering them from the acquisition of the most circular mobile phone alternative?

1.4 Link to CoSEM Program

Stimulating the development of an EU Digital Product Passport (DPP) for consumers to address their information deficits in choosing the most circular mobile phone alternative presents an intervention into a complex socio-technical system. Therefore, it is critical to set correct system boundaries to study the effect of this policy intervention.

Furthermore, the DPP has effects beyond consumer decision-making and the mobile phone industry. For instance, if only consumer decision-making is analyzed, the DPP may appear beneficial for providing relevant and accessible product information. However, suppose the system boundaries are enlarged to consider other aspects of the mobile phone's consumption system. In that case, the DPP benefits are no longer straightforward, for instance, if one considers its dependency on boundary conditions shows. The applied Design Science Research approach is a methodology often used by information system designers to rigorously design and evaluate artifacts with practice relevance.

Moreover, the results are relevant for various parties: consumers, policymakers, manufacturers, and the mobile phone industry. This underpins the interconnectedness of the system and the public and private values that are at play, which is typical for a CoSEM thesis. The social context and the need for a more effective circular economy transition are drivers of this research. Thus, the results need to be evaluated with great care and consider the possible socio-technical issues that could arise if the EU DPP is implemented for consumers. Given these complexities, the topic at hand presents an example of a CoSEM thesis.

1.5 Thesis Outline

This thesis report is structured into eight chapters.

Chapter 2 presents the general methodology used to approach the main research question. The following chapters represent each of the defined sub-questions of the Design Science Research Approach.

First, Chapter 3 identifies the consumer's information deficits in the acquisition process. Afterward, in Chapter 4, design principles are defined that translate the information deficits into the information requirements. Then, in Chapter 5, the initial information requirements are elicited. In Chapter 6, these initial information requirements are evaluated and revised to provide a final list of information requirements. Afterward, in Chapter 7, possible boundary conditions are identified that determine the implementation of the EU DPP based on the elicited information requirements. Finally, in Chapter 8, the conclusion to the main research question is provided, as well as the contribution of this research, the limitations, possible further research, and recommendations for the DPP development.

2. Methodology

This chapter presents the research methodology, which is applied to answer the identified main research question. The methodology structures and supports the elaborations in the subsequent chapters 3 to 7.

In the first section, the overall research approach is defined. Afterward, the guiding sub-questions and the used research methods are presented. Finally, the research flow diagram provides an overview of the research approach.

2.1 Research Approach

The research approach provides the framework for creating the intended outcome and answering the main research question. It informs the establishment of a systematic and rigorous research process and the selection of appropriate methods.

Design Science Research

The general outcome of my research are information requirements for an EU DPP that address information deficits of EU consumers in their acquisition of circular mobile phone alternatives. They are meant to lay the foundation for further research and development of the EU DPP.

The Design Science Research (DSR) approach by Hevner et al. (2004) is applied to achieve this outcome.

DSR aims to design or develop an artifact, a human-made object, to solve a problem in practice and generate knowledge through the design process itself (Johannesson & Perjons, 2021, p. 16).
In this research's case, the artifact to be designed is a list of information requirements, which should help practitioners and researchers better understand the EU DPP concept in general and in the consumer and mobile phone (or electronics) context (see also Knowledge Gaps, Section 1.2). Specifically, the information requirements provide particular starting points and directions for implementing the DPP and initiate further discussion through the theories and perspectives considered in this research's design science approach.

Moreover, the DSR approach ensures the scientific and practical relevance of this research by requiring the consideration of the practical and scientific foundation and contribution of each DSR process step (introduced in the following paragraph) (Hevner et al., 2004). So, on the one hand, I incorporate the practical perspective by using appropriate information sources (e.g., empirical studies, information input from practice). On the other hand, I ensure the scientific value by identifying and applying relevant scientific theories and methods and by considering the generalizability of the findings, particularly before and after the design of the context-specific artifact (see design principles and the consideration of the DPP's implementation stated in the following paragraph regarding the DSR process).

Consequently, incorporating the practical and scientific relevance, the knowledge from the design process and the final outcome of this research can inform the further discussion and development of the EU DPP. This is required according to the first identified knowledge gap.

DSR Process

I apply the DSR process model developed by Peffers et al. (2007) as a guideline for my research. Adapting this process to the main research question and research objective, Figure 5 shows my main research steps assigned to the process model.

First, the DSR process provides a rigorous and systematic procedure to explicate the problem and identify consumers' needs toward the anticipated DPP solution. This is relevant, as I found in the initial literature review that the DPP's added value for consumers is still considered broadly, and addressing their potential information deficits is not clarified yet (Sub-Section 1.2.3).

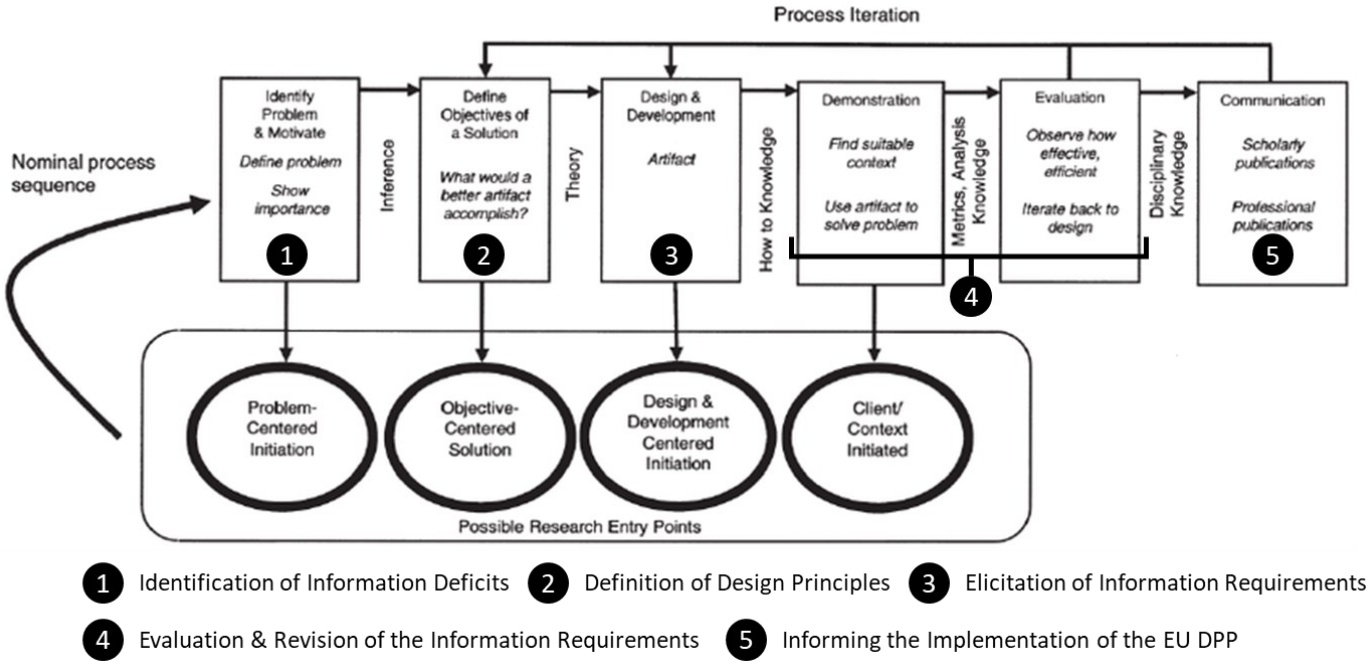

Figure 5: Design Science Research process by Peffers et al. (2007), including the associated main research steps performed in this research

Second, the design principles guide the requirement elicitation. In this research not a physical but a knowledge artifact is designed, namely information requirements. Therefore, I do not use "requirements" in the second DSR step that instead usually define the design of physical artifacts. (see also Johannesson & Perjons, 2021, pp. 34–36)

Third, the rigorous DSR process ensures the elicitation of appropriate and complete information requirements by translating the problem explication into design principles and using these to guide the requirement elicitation.

Fourth, the steps of demonstration and evaluation are combined, as they were performed in parallel (see evaluation method, Sub-Section 2.2.4). With the final evaluation step, an additional revision of the information requirements is performed. Meaning the requirements are adapted based on the findings from the evaluation.

Finally, the research step of communication addresses the underlying purpose of the information requirement elicitation, namely informing the implementation of the EU DPP (Knowledge Gap 1).

By applying systematic and established methods for each research step, the necessary rigor and reasoning are created to facilitate rationality. Moreover, the final evaluation also mitigates possible bounded rationality and bias of the researcher.

The following section defines the sub-questions and the required research methods following the DSR approach.

2.2 Sub-Questions & Research Methods

Five sub-questions (SQ), that are related to the DSR process steps, and the applied research methods are defined in this section. The sub-questions guide the research steps and contribute to the answer of the main research question. The research methods are used to answer the sub-questions.

Table 1 shows the sub-question for each research step, and the type of research method used to develop an answer for them. In general, desk research is used for the requirement elicitation and empirical information gathering for the evaluation and communication.

Table 1: Research steps with guiding sub-questions and type of research method

No	Research Step	Sub-Question	Type of Research Method
1	Identification of Information Deficits	What are potential information deficits in the EU consumer's acquisition process of most circular mobile phone alternatives, that could be addressed by the EU DPP?	Desk research
2	Definition of Design Principles	What are the design principles ensuring that the elicited information requirements address the potential information deficits of EU consumers?	
3	Elicitation of Information Requirements	What initial information requirements can be elicited based on the design principles, so that the EU DPP can address the potential information deficits of EU consumers?	
4	Evaluation & Revision of Information Requirements	What revised information requirements result from the requirements' evaluation regarding their utility for the practice and research?	Empirical information gathering
5	Informing the Implementation of the EU DPP	How can boundary conditions inform the implementation of an EU DPP based on the elicited information requirements?	

Hereafter, the rationale for the usage of these two types of research methods is provided, that are used for multiple sub-questions. Subsequently, in the following sub-sections, the purpose of each sub-question and the applied specific research method are described successively.

Desk research

The first three DSR steps are based on desk research, which is reflected in their methods. This type of research method comprises the consultation of literature and argumentative analyses. Although I here also consider the literature from the initial literature review used to identify the knowledge gaps (Sub-Section 1.2.2), I mainly draw on additional literature and conduct specific reviews.

Desk research is appropriate, as the objective is to lay the foundation and provide understanding and guidance for further EU DPP research and development (see Section 1.3). In particular, as the consumer and electronics sector perspective is hardly researched yet, using existing scientific knowledge helps to get one's bearings in the research process, but also regarding further research (also see Johannesson & Perjons, 2021, p. 113). Thus, relevant aspects to consider for the further advancement of the DPP concept are pointed out, and orientation for the actor- and product-specific DPP development is provided.

Moreover, as the scope of this research is quite large (e.g., EU consumer in general, the entire EU, all possible CE strategies), due to the intended application of the DPP and the objective of this research, drawing on literature allows me to consider different perspectives to establish a general understanding. For instance, this comes in handy for identifying the consumer's relevant information in Section 5.1. Empirical consumer studies on this scope level are expected to be resource-intensive and thus not feasible for this research. Nevertheless, while selecting and reviewing the literature, it was ensured that the literature is suitable for the given context, for instance, is relatable to the EU. Also, it was attempted to consult empirical studies as much as possible to consider the practical relevance.

The credibility of the selected references for the desk research is considered, and preferably peer-reviewed scientific literature is used. The exact literature selection process is stated where applied in the chapters.

Empirical information gathering

For the last two DSR steps, the evaluation and communication, empirical information is gathered.

Considering the practical perspective, empirical information gathering enhances the practical relevance of the research results by evaluating and enhancing the findings from desk research. Thus, the research's objective of contributing to the implementation of the EU DPP (Knowledge Gap 1) is incorporated into the research approach.

Regarding the evaluation of the information requirements, the consultation of researchers and practitioners allows the assessment of whether the requirements comply with practice and can be used for the further development of the EU DPP. This approach also reduces potential misinterpretations or uncertainties from the desk research (e.g., bounded rationality). Thus, the rigor of my findings can be ensured.

Furthermore, the practical perspective can provide information not yet available in scientific research to inform the implementation of an EU DPP based on the context-specific information requirements.

2.2.1 Sub-Question 1 – Identification of Information Deficits

SQ1:	What are potential information deficits in the EU consumer's acquisition process of most circular mobile phone alternatives, that could be addressed by the EU DPP?

First, the problem of information deficits in the consumer's acquisition process is explicated, which should be addressed with the DPP. In particular, it is aimed at gaining understanding of what comprises potential information deficits as it does not become clear from the initial literature review.
The outcome of investigating this sub-question are information deficits to be considered in the information requirement elicitation. In addition, the generated knowledge about the problem and its context can inform the subsequent research steps.

A **decision analysis** is applied, with respect to Davis (1982), to derive the potential information deficits.
This method is appropriate for this research. On the one hand, referring to the ESPR proposal, the consumer's acquisition of a circular mobile phone alternative appears to be a decision-making problem of making the "right" choice. On the other hand, research on consumer behavior has been soundly studied (Reina Paz & Rodríguez Vargas, 2023), which is a prerequisite for applying a decision analysis (Davis, 1982).
Deriving the information deficits based on the system (acquisition process) in which the DPP should intervene is also meant to mitigate possible uncertainties and ensure rigorous research (Davis, 1982). These uncertainties exist regarding the research process and the system under investigation. For instance, uncertainties arise from the possible bounded rationality of the researcher, the heterogenic and large population of DPP users (EU consumers), and the lack of experience with the usage of the DPP by consumers.

The information required for the analysis is obtained from additional literature and theories to define, describe, and analyze decision-making regarding consumers' acquisition activities.

Table 2 shows the other possible strategies by Davis (1982) to derive the knowledge to inform a requirement elicitation. Moreover, the reasoning for their exclusion is provided.

Table 2: Not selected strategies by Davis (1982, pp. 12–19) *and reasoning for their exclusion*

Strategy	Description	Premises contradicting to the research context
Asking	Requirements based on user consultation.	Requires users to be able to structure their problem space and problem and to be able to overcome or compensate for biases due to concreteness, recency, and small sample size.
Deriving from an existing information system	Requirements based on information from existing information systems that have been implemented and have an operational history.	Requires that similar systems applied for the same type of organization or with the same application already exist.
Discovering from experimentation	Requirements evolving with the experimentation and continuous development of the system.	Requires the existence of a (minimum viable) system to experiment with.

2.2.2 Sub-Question 2 – Definition of Design Principles

SQ2:	What are the design principles ensuring that the elicited information requirements address the potential information deficits of EU consumers?

Second, the design principles to guide the requirement elicitation are identified, which ensure that the information requirements address the consumer's potential information deficits. Therefore, the information deficits are systematically translated into design principles.
The outcome of investigating this sub-question are design principles and their definition.

The design principles are established rigorously based on an additional **systematic literature review**. With the literature review, the most appropriate scientific concept is selected to identify the design principles and inform the methodic approach of the subsequent requirement elicitation.

By considering established scientific concepts, I ensure that the used design principles are grounded in theory while reflecting the information deficits derived from the decision analysis. Moreover, the design principles are evaluated in the evaluation phase, as they are the link between the information deficits and the information requirements, thus build the foundation of the research's outcome.

2.2.3 Sub-Question 3 – Elicitation of Information Requirements

SQ3:	What initial information requirements can be elicited based on the design principles, so that the EU DPP can address the potential information deficits of EU consumers?

Third, the information requirements are elicited using the design principles as a guideline. Thus, it is defined with the information requirements how the DPP can address the identified potential information deficits.
The outcome of investigating this sub-question is a list of initial information requirements. This list of initial information requirements is demonstrated and evaluated by experts (see next paragraph regarding evaluation).

For this purpose, an appropriate **literature study and/or systematic analysis** is performed for each design principle to elicit the information requirements.
The appropriateness of desk research for the requirement elicitation is argued in the introduction of Section 2.2. In general, it is meant to identify relevant aspects to consider, which are translated in the provided general requirements.

2.2.4 Sub-Question 4 – Evaluation & Revision of Information Requirements

SQ4:	What revised information requirements result from the requirements' evaluation regarding their utility for the practice and research?

Fourth, the elicited requirements are evaluated regarding their utility for the practice and research
The outcome of investigating this sub-question is an evaluated list of information requirements, which serve as the final research outcome to the main research question.

When comparing the possible goals of an DSR evaluation by Venable et al. (2016) (see Table 3), the goal of uncertainty and risk reduction appears most appropriate for this research's context. Potential uncertainties regarding this research and the DPP development exist because of the novelty of the concept, the first-time investigation of the DPP's use for the consumer in the electronics sector, the DPP's implementation on a large scale addressing a critical societal issue, and the societal need to minimize negative impacts by the DPP itself in light of the urgency of mitigating human's pressures on the environment.

Table 3: Evaluation goals by Venable et al. (2016, pp. 82–83)

Evaluation Goal	Description
Rigor	establishing that the artifact causes an observed outcome and that it works in a real situation
Uncertainty and risk reduction	establishing that design uncertainties and consequential risks (e.g., human social/use risks, technical risks) are considered as early as possible, resulting in the development of a higher quality artifact
Ethics	establishing that the artifact does not pose risks to, for instance, animals, people, organizations, or the public
Efficiency	balancing the other mentioned goals against resources available for the evaluation (e.g., time, money)

These practice-related risks and uncertainties underline the necessity to evaluate the information requirements utility for the practice and research. I define the information requirements as relevant for practice if they cover all the essential aspects for consumers (= they are appropriate to address the information deficits) and are understandable to inform further DPP development (= they are of use for the further DPP development; Knowledge Gap 1).

Consequently, the evaluation strategy of "Human Risk & Effectiveness" by Venable et al. (2016, pp. 81–82) is applied as being the most appropriate to serve the intended goal of the evaluation. Following this evaluation strategy implies formative, rather artificial evaluation at the beginning of the DPP development to inform subsequent formative and summative naturalistic evaluations[8]. Thereby, a further understanding of the DPP's purpose and implementation is required and should be fed back into its further development.

For this reason, I see the necessity to evaluate the requirements from a practical perspective and revise them to enhance their practical relevance and mitigate research uncertainties.
On the other hand, to mitigate the uncertainties and potential risks in implementing an EU DPP based on my elicited information requirements, possible implementation issues and resulting boundary conditions need to be investigated. This can even more inform the further research and development of the concept (Knowledge Gap 1).

As a research method, **semi-structured expert interviews** are most appropriate for both purposes. This research lays the ground for further DPP research and development, particularly in the consumer and electronics (mobile phones) context. Thus semi-structured expert interviews provide a quick and rigorous way to evaluate the information requirements and, at the same time, investigate them in more depth (e.g., regarding implementation issues). Moreover, this method allows the consideration of views from different, context-related fields of expertise and can enhance the practical relevance of desk research. Furthermore, a semi-structured approach is meant to mitigate the potential influence of the researcher on the interviewees by following a standard interview protocol (see Appendix D).

Detailed information regarding the interview procedure and analysis are provided in Section 6.1.

2.2.5 Sub-Question 5 – Informing the Implementation of the EU DPP

SQ5:	How can boundary conditions inform the implementation of an EU DPP based on the elicited information requirements?

Finally, resulting from the research's objective to inform the implementation of the DPP and the necessity to mitigate implementation uncertainties and risks (see previous Sub-Section 2.2.4), possible implementation issues and resulting boundary conditions need to be investigated.
The outcome of investigating this sub-question is the presentation of boundary conditions in a manner that can inform the implementation of the EU DPP.

Regarding this last DSR step of communication, Peffers et al. (2007) state the necessity of "[communicating] the problem and its importance, the artifact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences such as practicing professionals, when appropriate." (p. 56). Seeing the first aspects inherent in this report and the elicited information requirements (as the artifact), I focus on the effectiveness of the research findings for the relevant audience (researcher and practitioners).

Although the information requirements themselves can already provide a basis for the DPP's implementation, they may not be able to inform the implementation process, including the possible uncertainties. Hence, considering implementation issues and boundary conditions can provide additional guidance for the implementation.

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[8] Definitions based on Venable et al. (2016, pp. 78, 80–81):

Formative	= empirical evaluations to improve the artifact design
Summative	= empirical evaluation to create meaning about the artifact in different contexts
Artificial	= evaluation to test design hypothesis, understand why an artifact works, or (dis-)proving the utility of an artifact; it is mainly scientific/rational and brings stronger scientific reliability in the form of better repeatability and falsifiability
Naturalistic	= evaluation to assess the performance of the artifact in its real environment; its interpretative character brings benefits of stronger internal validity

For this purpose, possible implementation issues regarding the elicited information requirements are discussed with the experts during the requirement evaluation **interviews**. Those implementation issues can be synthesized to provide an overview of what boundary conditions to be addressed and inform the research and development process in the DPP's implementation.

In addition, this approach allows me to finally widen the perspective after solely taking the consumer's view into account and thus answering the main research question under consideration of the broader context of this research.

The rationale for applying expert interviews is provided in the previous Sub-Section 2.2.4 regarding Sub-Question 4.

2.3 Research Flow Diagram

The research flow diagram in Figure 6 provides an overview of the described research process. It includes the main research steps and their purpose, the related sub-questions, the performed research tasks and applied methods, and the outcomes of each research step.

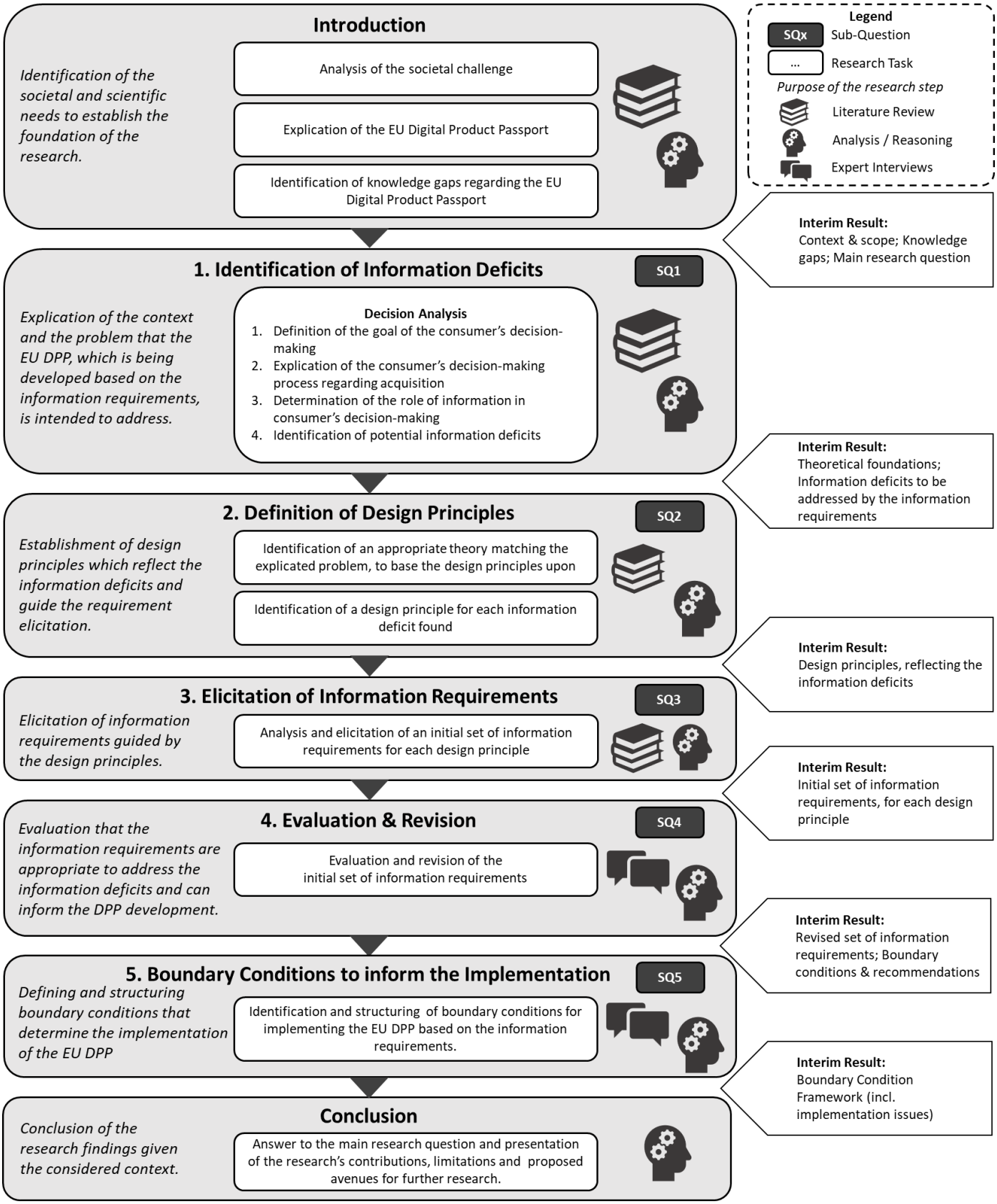


Figure 6: Research Flow Diagram

3. Information Deficits

In this chapter, the consumer's problem of information deficits is explicated, that should be addressed by the EU DPP. In the process, it is aimed to understand what comprises information deficits and thus how the DPP could assist.

The outcome of this chapter are potential information deficits that consumers face, which can be addressed with the DPP. These information deficits need to be considered in eliciting the information requirements.

Thus, Sub-Question 1 is answered:

SQ1:	What are potential information deficits in the EU consumer's acquisition process of most circular mobile phone alternatives that could be addressed by the EU DPP?

A rigorous analysis based on desk research is performed to answer this question. First, a systematic decision analysis based on Davis (1982, p. 17) is applied to determine how information is used in the consumer's acquisition process. Afterward, this understanding is used to identify what potential information deficits could arise.

Based on Davis (1982), the first step of the decision analysis is the prescription of the decision. According to the elaborated context of this research, it is the consumer's decision for the most circular acquisition alternative, thus the alternative with the least impact on material consumption. In this respect, the hierarchy for circular economy strategies can be used as a guideline (see Section 1.1). Although the refusal of consumption would be the most desirable regarding the hierarchy, concluding to the ESPR, the DPP takes effect when the consumer has already decided to make an acquisition.

In the first section of this chapter, I orient myself on the remaining two steps in the decision analysis by Davis (1982, p. 17):

1. Explication of the consumer's decision-making process regarding acquisition
2. Determination of the use of information in consumer's decision-making process

In the second section, the information deficits are identified by analyzing the elaborated context, consulting additional relevant literature, and considering the mobile phone context.

Finally, the answer to Sub-Question 1 is provided (see Section 3.3).

3.1 Acquisition Process & Information

In this section, the consumer's decision-making in the acquisition is established as a process. By selecting a suitable acquisition process model, it is possible to determine the use of information in this process. Thus, in the following section, it can be analyzed how information deficits may arise. Furthermore, the here established understanding informs the requirement elicitation phase.

First, the selection of the appropriate acquisition process model is presented. Afterward, it is elaborated on how information is used by the consumer in its acquisition process.

3.1.1 Consumer Behavior Model

Decision theory mainly distinguishes between normative and descriptive decision theory (Jonassen, 2012, pp. 343–347; Takemura, 2021, pp. 10–12).
The normative theory views decision-making as a rational process "to identify the optimal choice" (Jonassen, 2012, p. 344).
The descriptive theory describes "how people actually make decisions" (Takemura, 2021, p. 10). This usually follows only to a minor extent a rational process and is, among others, influenced by bias or the tendency towards seeking satisfaction instead of optimization (Jonassen, 2012, pp. 346–347).
According to Takemura (2021 Part VI), decision-making can be described as a process toward a final choice, whether the decision-making rather follows the normative or descriptive theory perspective.

A rational, processual model is required for this research, which illustrates the consumers' behavior and decision-making in the acquisition. Using such a model allows me to determine when during the acquisition process, information is used that could be provided by the DPP. It improves understanding of the consumer's behavior, explicates the DPP's implementation in practice (e.g., how to provide/apply the DPP), and thus facilitates the decision analysis.

Model selection

To select an appropriate consumer behavior model, the recent literature review by Reina Paz & Rodríguez Vargas (2023) is consulted. It provides an overview of consumer behavior models from 1935 to 2021.

Comparing the consumer behavior models gathered by Reina Paz & Rodríguez Vargas (2023), the *Engel-Kollat-Blackwell (EKB) Model* by Engel et al. (1990)[9] appears most suitable for this research.

On the one hand, it illustrates comprehensibly the process of consumer decision-making, as well as their information intake and processing (e.g., compared to the *theory of reasoned action* by Ajzen & Fishbein, 1980 or *the theory of buyer behavior* by Haines et al., 1970). Thus, it provides a framework that facilitates analyzing the information's use in the acquisition process. On the other hand, the model appears applicable to a heterogenic consumer group – as should be addressed with the DPP – with different driving factors in their acquisition – because the model does not only consider information-related factors (e.g., compared to the *Information Processing Model* by Bettman, 1979). Moreover, Engel et al. (1990, p. 475) state that their model applies to different decision-making situations, whether they are more rational and systematic or emotion-driven and impulsive.

Santos & Gonçalves (2022, pp. 13–14) and Van Weelden et al. (2016, p. 745) argue that the decision-making for acquiring mobile phones is rather a cognitive process. That is, consumers consciously gather information and evaluate acquisition alternatives. Thus, I assume in this research that the consumer sees relevance in information for their decision-making processes when acquiring a mobile phone. This backs up the DPP's relevance in the mobile phone context.

Although the EKB model was initially developed for the acquisition of products, it is also applicable for services or product-service systems. To investigating consumer behavior in the context of services and compare it with the behavior regarding products, Gabbott & Hogg (2010) applied the same consumer behavior phases as Engel et al. (1990). They found that consumers face different challenges throughout the process, inherent in the services' nature (e.g., intangibility or difficult comparability due to heterogeneity).

[9] Reina Paz & Rodríguez Vargas (2023) refer to the first version from 1968. I use the authors' revised version from 1990 (Engel et al., 1990).

Engel-Kollat-Blackwell (EKB) Model

The EKG Model by Engel et al. (1990) originates from a marketing perspective but aims to synthesize the evolving knowledge around consumer behavior from a holistic scientific and practical standpoint. Consequently, the knowledge base of the associated book underwent several revisions over time, also leading to minor adaptations of the original model from 1968. Moreover, they establish consumer behavior as a decision process and base the model on literature reviews and major theories, such as by McGuire (1976) (information processing process).

The model is shown in Figure 7. They argue that the consumer goes through five main phases when acquiring a product:

1. **Need Recognition:** The consumer recognizes a consumption need that can be initiated by a complex set of factors (e.g., changes in circumstances, marketing influences).
2. **Search:** The consumer seeks to satisfy their needs by consulting their existing knowledge (internal search) or, if it is not sufficient or retrievable, by gathering external information (external search). The outcome of the search phase is a set of possible choice alternatives (incl. their characteristics) the consumer evaluates and chooses from in the evaluation phase.
3. **Alternative Evaluation:** In practice, the search and the evaluation phase are usually highly intertwined. So, during and/or after the search for and compilation of a set of choice alternatives (incl. their characteristics), the alternatives are evaluated against a set of evaluation criteria regarding their level of satisfaction. The set of evaluation criteria can comprise several factors, among others, product information (e.g., product features). The decision made, finally depends on the decision rule the consumer applies. This phase results in a choice for a particular acquisition alternative and the intention to acquire it.
4. **Purchase:** Based on the consumer's intention, the consumer mainly plans their acquisition, for instance, regarding the time and location/channel of acquisition. The result of this phase is the actual acquisition of the chosen alternative.
5. **Outcome (incl. Dis-/Satisfaction):** Informing future purchases, the outcome phase entails the consumer's evaluation of the made acquisition during the use phase.

In the context of this research, the consumer's need includes the choice of the most circular acquisition alternative.

This understanding of the consumer's acquisition process is used in the following sub-section to define the use of product information in the process.

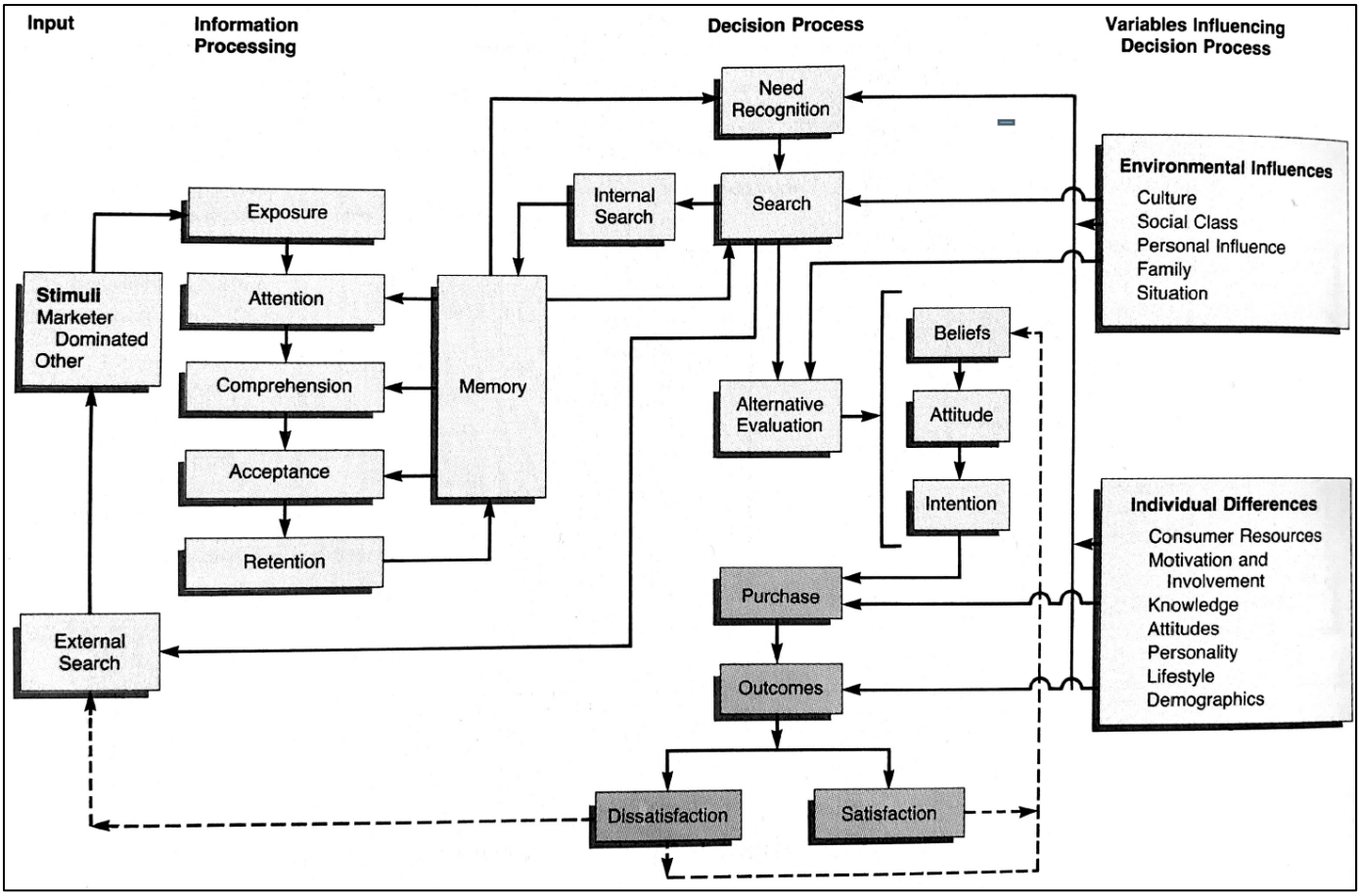


Figure 7: Engel-Kollat-Blackwell (EKB) Model (Engel et al., 1990, p. 482)

3.1.2 Information in the Acquisition Process

Based on the selected consumer behavior model, the use of information in the consumer's acquisition process is determined. Based on this, the following section analyzes which information deficits may arise.

Use of product information

Repeating the statement in the ESPR proposal, the DPP is used to "[…] electronically register, process and share product-related information amongst supply chain businesses, authorities, and consumers" (Directorate-General for Environment of the European Commission, 2022, p. 9).
Consequently, product information is considered for this research, meaning information that describes the product and its life cycle. For instance, regarding the product's features, its functional condition, or its life cycle performance (e.g., environmental impact, durability). To simplify reading, only the word "information" is used throughout the report when speaking about information provided by the DPP.

With reference to the *EKB Model*, product information is particularly important in the consumers' **search** (trying to find information) and their **evaluation** (evaluating choice alternatives against certain criteria). Product information can thus be part of the consumer's evaluation criteria relevant to their choice-making. While product information thus seems more important in the evaluation, I consider it together with the search phase. Both phases are highly intertwined, and the search phase is decisive for the consumer to establish the evaluation criteria and find related information.

In the context of acquiring circular mobile phone alternatives, it is assumed that the consumer is actively searching for the product information they need for the evaluation (= external search). This is argued by referring to the ESPR proposal, identifying a lack of needed information, and the mentioned cognitive process of mobile phone acquisition (see previous sub-section).

Further following the model along the external search, the stimuli would represent product information. What can be noticed then is the decisive role of information processing which determines to what extent the product information enters the knowledge of the consumer and thus contributes to their decision-making (Engel et al., 1990, pp. 363–365). Hence, from the assumption that consumers nowadays cannot use the right product information for their acquisition choice, investigating the consumer's information processing can yield further insights into how information deficits can arise.

Information processing

According to the theory by McGuire (1976), which is used in the model by Engel et al. (1990), there are in general five steps in the information processing, literally stated:

1. **Exposure:** the achievement of proximity to a stimulus such that an opportunity exists for one or more of a person's five senses to be activated
2. **Attention:** paying the allocation of processing capacity to the incoming stimulus
3. **Comprehension:** the interpretation of the stimulus
4. **Acceptance:** the degree to which the stimulus influences the person's knowledge and/or attitudes
5. **Retention:** the transfer of the stimulus interpretation into long-term memory

To determine which information processing steps could be best assisted with the EU DPP, it is referred to the main added value it should bring. To repeat, the DPP is meant to be of value by creating transparency and trust, enabling access to more comprehensive information, and facilitating informed decision-making for sustainability (European Commission, 2022c, pp. 584–588).

On the one hand, "creating transparency and trust" could serve possible issues regarding the **acceptance** of product information. On the other hand, "enabling access" could benefit the **exposure**. Thus, these two processing steps are concluded to be most relevant for the DPP's application.

Hence, the steps of *acceptance* and *exposure* need to be considered in identifying information deficits.

The other steps can be excluded from the consideration because of the following reasons:

Under the assumption of the ESPR proposal that the consumer is actively looking for information to make a choice towards circularity, it is concluded that the information does not need to attract their attention (see Sub-Section 1.2.3).

According to Engel et al. (1990, p. 376), comprehension depends on the consumer's existing knowledge, which is outside the influence of the DPP. Moreover, while comprehensive information is important to the consumer, this is not seen as a unique value that can be provided by the EU DPP (see added values mentioned after the information processing steps).

Finally, I expect the retention of the information not being under main influence by the information provision as it is dependent on multiple factors not related to the DPP (see Engel et al., 1990).

3.2 Information Deficits

In this section, the potential information deficits of the consumer are established. The identified information deficits need to be addressed by the DPP and thus inform the definition of the design principles and the elicitation of information requirements.

According to the established understanding of the acquisition process, I define the term information deficits for this research as:

Information deficits are the mismatch between the product information a consumer needs to identify and evaluate mobile phone alternatives for choosing the most circular one and the information the consumer actually gets provided.

Thus, it is the mismatch between the product information actively searched for and the consumer's ability to process it for their decision-making. In particular, the information processing steps of exposure and acceptance are considered. They are argued in the previous Sub-Section 3.1.2 to be most relevant regarding the EU DPP.

Drawing on the previous findings and consulting literature, it is analyzed which main information deficits could arise regarding the exposure and acceptance of information. Especially the as-is situation regarding information in the acquisition process and (circular) life cycles of mobile phones is considered.
Important to mention that information deficits are only considered from a consumer perspective. Meaning, for instance, reasons that lead to the information deficits on the provider side are not discussed. Those are addressed in the investigation of boundary conditions in Chapter 7.

Three potential information deficits are identified, which are reasoned in the following. I associate the first two information deficits with the acceptance and the third one with the exposure of information within the consumer's information processing.

In general, it shows that information deficits can not only arise through not having the right information for decision-making but also through information not being reliable or accessible.

In the following sub-sections, each information deficit is identified and described successively.

3.2.1 Information Deficit 1

Information Deficit 1: The amount and/or type of information provided may not match the consumers' needs regarding evaluation criteria for their choice of the (most) circular mobile phone alternatives.

The first potential information deficit is derived from the initial assumption that consumers lack certain product information for making their acquisition choice for a more circular alternative, see Sub-Section 1.2.3.

Suppose the amount and/or type of information provided with the mobile phone does not match the consumer's needs for evaluation criteria. In that case, information deficits can arise, and the choice for a (more) circular option might be hindered. Thus, the consumer would not accept this information for their decision-making.

Discrepancy regarding the amount of information

First, according to the ESPR proposal (see sub-section 1.2.3), I assume that the consumer actively searches for relevant information. However, although consumers may want to gather information, scholars argue that an information overload can lead to poor decision-making, depending on each person's capabilities (e.g., Chen et al., 2009; Houdek et al., 2018). Consequently, the right amount of information is also essential.

Also, because many factors can influence the required amount of information and thus expectedly influence the sensitivity against information overload, finding an appropriate scope for the information provided with the DPP appears even more relevant. For instance, as Engel et al. (1990, pp. 517–519) outline, there are multiple personal (e.g., motivation) and contextual (e.g., time pressure) factors that can determine the set of used evaluation criteria. This also becomes clear when viewing the multitude of consumer behavior models seeking to navigate through the factors that can influence a consumer's choice (Reina Paz & Rodríguez Vargas, 2023).

Discrepancy in information's utility

Moreover, I assume that an information deficit can arise if the provided information does not match the information the consumer needs for their evaluation. For instance, studies found that consumers focus on different evaluation criteria (e.g., Bovea et al., 2018; Eurostat, 2022a; LE Europe et al., 2018). As a result, if the information is not useful to the consumer, they might unable to choose the most circular mobile phone alternative.

Also, considering the hierarchy of CE strategies, I assume that consumers require different information to assess the product's standing regarding its circular economy contribution. Not to mention that the information should also serve the different requirements that consumers can have regarding a product, for example, concerning used as opposed to new mobile phones (e.g., information about the used mobile phone's condition).

For the EU DPP, the aspect of different consumer preferences in evaluation criteria has additional weight. As mentioned in the introduction of the concept, the EU DPP is intended to be used by a large, heterogeneous population in the different contexts of the EU member states. Hence, this aspect also needs to be considered in the DPP development.

3.2.2 Information Deficit 2

Information Deficit 2: The information provided may not be reliable (e.g., comparable, trustworthy) over the mobile phone's lifecycle to be considered in the consumer's evaluation of acquisition alternatives.

In addition to the usefulness of information for the consumer, the reliability of information is also important for the consumer's information acceptance, according to Engel et al. (1990).

The consumers' uncertainty regarding the reliability of the provided information, which is particularly considered regarding comparability and trustworthiness, can cause information deficits. I anticipate that consumers are less likely to accept this non-reliable information for their evaluation.

Discrepancy in comparability of information

First, reliability is related to the degree to which consumers can expect to get the same, comparable information regardless of the use cycle of the mobile phone. Potential issues in that respect become noticeable in the outline of the information flow in the prevalent linear economy, provided in the ESPR impact assessment (European Commission, 2022c, pp. 583–584) (see Figure 8). It supposes several potential issues within the flow of product-related information, among others: limited information sharing before the use phase, non-standardized information sharing with the consumer, and information loss during the use phase.

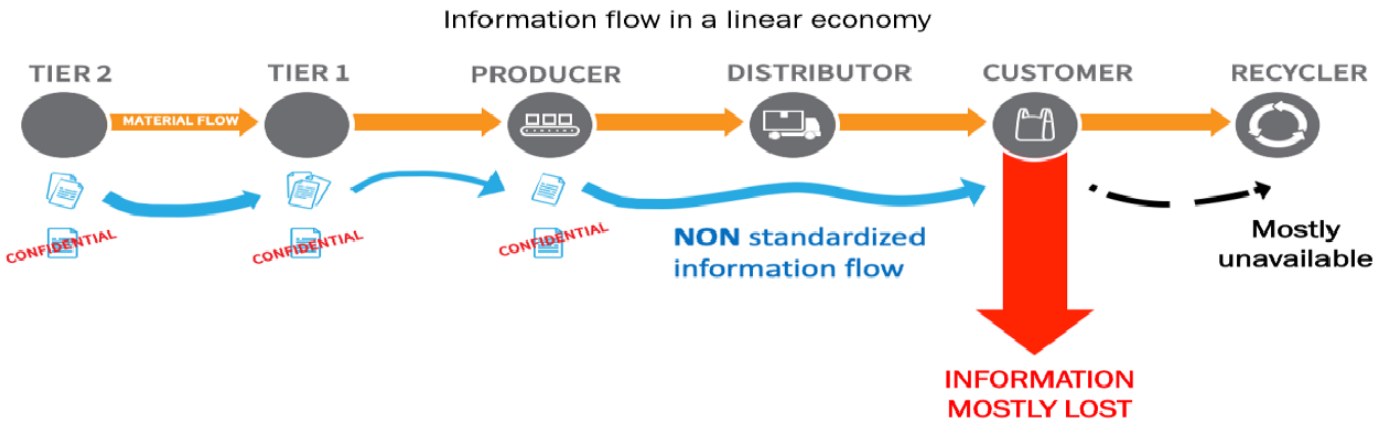


Figure 8: Issues in the information flow of the linear economy (European Commission, 2022c, pp. 583–584)

Particularly regarding pre-owned mobile phones, information complementing the initial set of product information becomes relevant, for instance, the product's condition. However, information about the mobile phone use phase, which a consumer may consider in their evaluation, could get lost over multiple use cycles. For instance, information about what parts of the mobile phone have been replaced.

This issue also depends on what information the previous owner shares with the subsequent owner and how well it is documented. Thus, the information available could differ for each pre-owned mobile phone.

Moreover, exemplarily comparing the online adverts by Backmarket (https://www.backmarket.com/) and Rebuy (https://www.rebuy.de/) (state 14.05.2023), two different providers of pre-owned mobile phones, also reveals differences in how information is defined, for example, regarding the classifications and criteria used to describe the condition of the mobile phone's outer appearance.

These factors could impair the comparability of different alternatives.

Discrepancy in trustworthiness of information

Second, a potential lack of reliability is related to whether the provided product information is trustworthy.

On the one hand, distrust may arise regarding the information provided to consumers if they want to acquire a pre-owned mobile phone. Based on the consumer study by Nepa & Klarna (2023)[10], distrust in the quality of a product and the information provided is a relevant issue for consumers towards purchasing pre-owned goods. On the other hand, Hirschmeier et al. (2016) found that accuracy and believability were noticeably rated as most relevant when studying what information qualities are important for consumers regarding product reviews by private persons. According to Santos & Gonçalves (2022), product reviews are a relevant source for consumers' information gathering when acquiring mobile phones. This finding can be a particular concern for the CET, the pursuit of the highest CE strategies (e.g., reuse), and the emergence of new circular mobile phone alternatives. I assume that less established sellers play a role in the CE, for example, start-ups, small and medium-sized enterprises, or private sellers. Thus, they may have less credit of trust compared to established business actors.
This distrust could result from the loss of information during the use phase and the higher dependency on the trustful information provision by the seller in the case of pre-owned mobile phones (European Commission, 2022c, pp. 583–584).

On the other hand, distrust may exist regarding information indicating the mobile phone's circularity or environmental performance. For instance, in the context of consumer protection, unfair business practices or claims, that can lead to this distrust, are recognized as a problem by EU legislation (European Commission & Directorate-General for Justice and Consumers, 2022). Also, an EU-wide study by the European Commission found that only 56% of consumers agree (incl. 9% "strongly agree") with the statement that "Most environmental claims about goods or services are reliable" (European Commission, 2023, p. 4). From this, I suppose that similar circumstances apply to circular economy-related information.
This distrust could result from the non-standardized information flow, particularly among manufacturers, distributors/sellers, and consumers (European Commission, 2022c, pp. 583–584).

3.2.3 Information Deficit 3

Information Deficit 3: The information provided in different contexts and over the mobile phone's lifecycle may not be accessible for consumer's identification of acquisition alternatives and product information.

Regarding the third potential information deficit, the exposure of consumers to the needed information is considered.

Discrepancies in the accessible information can arise depending on the context of the information search and throughout multiple use cycles of mobile phones. This could lead to information deficits, as the consumer cannot identify or access the required information for choosing the most circular mobile phone alternative. Thus, exposure to information is hindered.

[10] Klarna, an online payment company, conducts quarterly consumer research studies across 17 countries (mainly in the EU). 17,218 consumers participated in Q1 2023. The sample sizes are equally distributed among countries, are representative, and include both Klarna users and non-users selected by the research agency Nepa. The study aims to gain insights into consumer behavior and preferences. (Nepa & Klarna, 2023)

Discrepancy of accessible information in different contexts

In their external search for information, consumers nowadays make use of many different online and offline information sources (e.g., Akalamkam & Mitra, 2018; Ibáñez-Sánchez et al., 2021; Nepa & Klarna, 2023; Voramontri & Klieb, 2019). Barwitz & Maas (2018) and Santos & Gonçalves (2022) identified the usage of multiple information and acquisition channels as dependent on various factors. Regarding the search for choice alternatives and evaluation criteria information, they mainly see the consumer's motivation in the desire to get as complete a picture as possible and to get assurance about the information. This backs my argumentation for Information Deficits 1 and 2 as well.

For the specific case of acquiring mobile phones, Santos & Gonçalves (2022) examined the combination of common information channels and individual consumer preferences by means of an empirical consumer journey mapping in Portugal. Figure 9 shows the synthesis of their findings and clarifies the complexity of information gathering particularly for the pre-purchase phase, which can be related to the considered search and evaluation phase. For instance, they identified four different consumer types according to their information source usage (namely: online-prone, offline-focused, omnichannel enthusiastic research, and third-party dependent shopper) and 31 different touchpoints (e.g., website, loyalty program) over nine distinct information channels (e.g., online, TV) (Santos & Gonçalves, 2022, p. 6). While they identify online sources to be mainly consulted, offline information access in the pre-purchase search is still relevant to a group of consumers (Santos & Gonçalves, 2022, pp. 6–8).
This also corresponds to the findings of the study by Nepa & Klarna (2023), which shows that, in general, many purchases are still preferred to be done offline in a store, even though online shopping is rising.

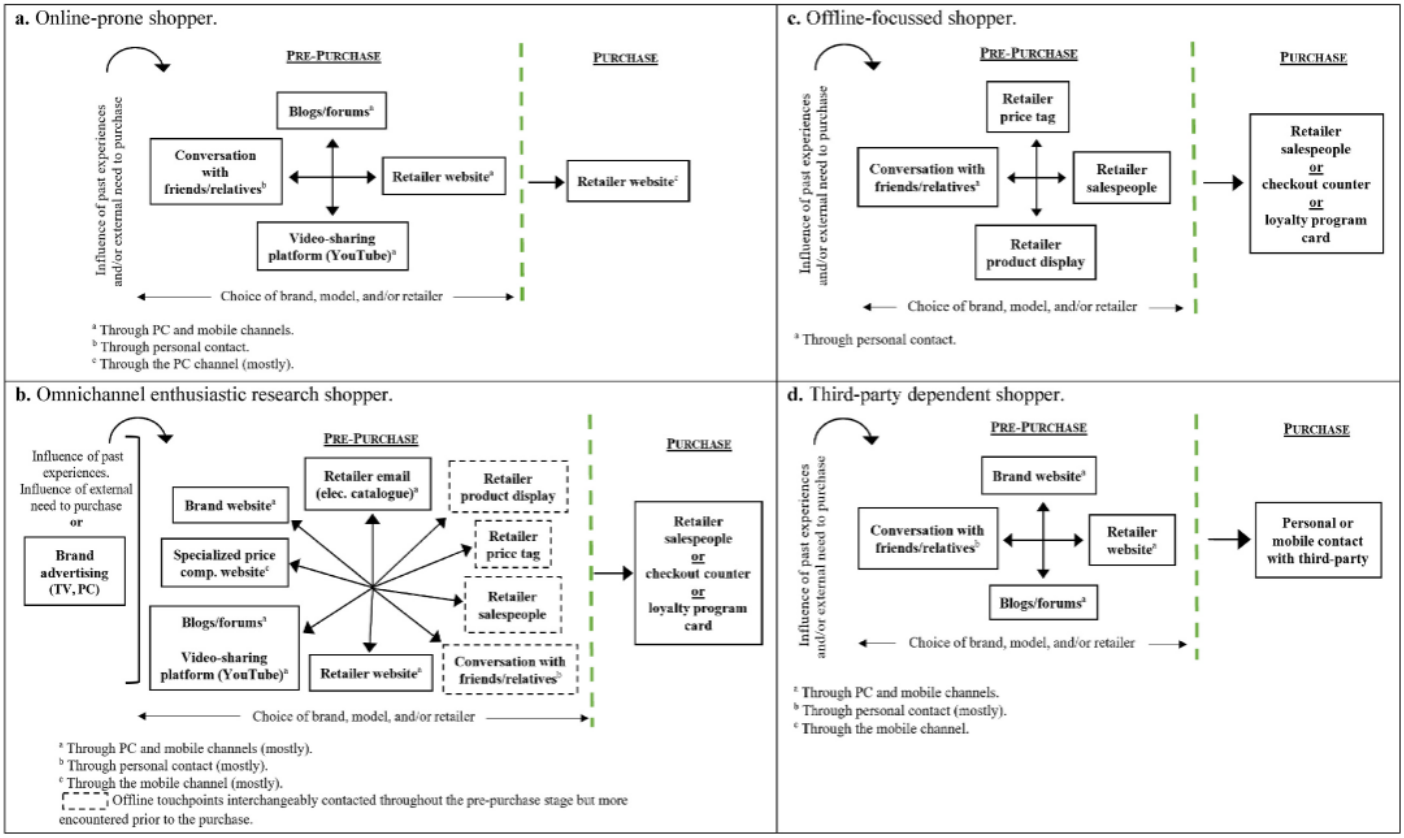


Figure 9: Consumer journey maps regarding mobile phone purchases (Santos & Gonçalves, 2022, p. 10)

Consequently, referring to this outlined variety of different information channels and preferences, I assume that the extent of accessible information can vary as well. For instance, if comparing information on a stand-up display in a store versus information from web sources.

Moreover, the consumer may not be aware of possible information sources that provide them with the needed information for their identification and evaluation of the most circular mobile phone alternative. Thus, they are also dependent on the information provided to them by the seller. For instance, this can be an issue in second-hand online marketplaces (Hallem et al., 2021) and is intensified by information loss in the use phase (see Information Deficit 2).

Furthermore, as used devices or circular business models are predominantly offered online today (e.g., marketplace platforms, eCommerce sites), and online sources can provide a variety of additional product-related information (e.g., product reviews), consumers with a preference or restriction to shop in-store could have limited access to available choice alternatives and their product information.

Discrepancy of accessible information over use cycles

As the consumer searches for and wants to identify possible choice alternatives in their external search phase (Engel et al., 1990), it requires that they can find and have access to the information they need. However, it can be seen that the scope of available information can vary depending on which phase the mobile phone is in or by which party it is sold. This is particularly the case for use-phase information about one specific mobile phone. (see also Information Deficits 1 &2)

In addition, information may not be provided in a collected, accessible manner once the packaging and documents of the mobile phone are removed. So, this variance of directly accessible information over the mobile phone's lifecycle can also lead to information deficits. This issue may intensify if the consumer is unaware of where to find additional information and thus depends on which information is directly provided (as mentioned before).

3.3 Answering Sub-Question 1

To recap, this chapter approached Sub-Question 1, namely:

What are potential information deficits in the EU consumer's acquisition process of most circular mobile phone alternatives, that could be addressed by the EU DPP?

To answer Sub-Question 1: Three main information deficits are identified, which could hinder consumers from making an acquisition choice towards the most circular mobile phone alternative.

Information Deficit 1: The amount and/or type of information provided may not match the consumers' needs regarding evaluation criteria for their choice of the (most) circular mobile phone alternatives.

Information Deficit 2: The information provided may not be reliable (e.g., comparable, trustworthy) over the mobile phone's lifecycle to be considered in the consumer's evaluation of acquisition alternatives.

Information Deficit 3: The information provided in different contexts and over the mobile phone's lifecycle may not be accessible for consumer's identification of acquisition alternatives and product information.

For the research's outcome, the information deficits represent the problems that the EU DPP should resolve, and thus they need to be addressed by the information requirements.

The next chapter identifies design principles that represent the information deficits and ensure the information requirements address them.

4. Design Principles

This chapter establishes design principles that ensure that the DPP developed according to the information requirements addresses the consumer's information deficits.

The outcome of this chapter are design principles and their definition. On the one hand, they reflect the identified information deficits from the previous chapter. On the other hand, their definition informs the elicitation of the information requirements in the next chapter.

Thus, Sub-Question 2 is answered:

SQ2:	What are the design principles ensuring that the elicited information requirements address the potential information deficits of EU consumers?

To answer this question, it is intended to link

- the information deficits, whose mitigation is the consumer's need from practice regarding the DPP, with
- the information requirements that are meant to describe the design of an information system (the EU DPP).

Consequently, as the design principles are applied to establish this link, they need to be based on a concept that can help to reflect the practical needs (mitigating the information deficits) and translate them into the information requirements.

For this purpose, the definition of the design principles is gradually approached in three steps based on desk research.

First, the information deficits are described as information quality problems, which provides the rationale for using an information quality framework for the definition of the design principle. Moreover, a differentiation between the terms *data* and *information* is made to ensure the appropriate information quality framework is chosen.

Second, the most appropriate information quality framework is selected to identify and define the design principles.

Third, categories or criteria from the information quality framework are selected that best reflect the consumer's information deficits. They are used to define the design principles and guide the requirement elicitation in the next chapter.

Finally, the answer to Sub-Question 2 is provided (see Section 4.4).

4.1 Information Quality Problem

In this section, the theoretical foundation is laid to select the most appropriate information quality framework that can be used to define the design principles based on the information deficits.

First, the information deficits are reasoned to be information quality problems. This provides the rationale for using the information quality framework.

Afterward, *information* is differentiated from *data* to ensure the most appropriate information quality framework is selected in the next section.

4.1.1 Information Deficits as Information Quality Problems

The use of information quality for defining the design principles can be reasoned with my definition of information deficits[11]. Accordingly, the DPP would be effective if it could resolve the information deficits, i.e., provide consumers with the information they need in their decision-making process. This is in line with the definition by the international standard ISO 9000:2015, to which the DPP's information provision would be of quality if it fulfills "[…] the needs and expectations of customers [consumers in this case] and other relevant interested parties" (ISO & IEC, 2015, p. 2).

In conclusion, information deficits can be seen as information quality problems.

To resolve these quality problems, quality criteria can be used to define what constitutes quality information. Thus, the DPP's information must comply with the consumers' needs and effectively address the information deficits. Consequently, quality criteria are used for the identification of design principles.

However, a multiplicity of possible criteria can be found in the literature (Eppler, 2006, pp. 70–71). Thus, it appears appropriate to use an information quality framework to get a structured overview of possible criteria and have a basis for analyzing which criteria are most suitable regarding the identified information deficits. Moreover, it is anticipated that the development of frameworks by scholars is usually based on an extensive review of existing information quality criteria and/or frameworks and follows a rigorous process.

4.1.2 Information vs. Data

Deucing & Reich (2023, p. 16) have found, when considering information and data governance in the DPP context, that the terms *data* and *information* are often equated in legislative texts, although there are arguments for differentiation (p. 11). The same was generally identified in the scientific literature regarding information and data quality (e.g., Baškarada, 2009).

To make sure that the selected information quality framework is appropriate for the specific consumer perspective, a differentiation is made in the following.

As I defined the DPP as an information system, the definitions according to the international standard ISO/IEC 25012:2008 can be used. It defines *data* a "reinterpretable representation of information in a formalized manner suitable for communication, interpretation, or processing [that] can be processed by humans or by automatic means" (ISO & IEC, 2008, Chapter 4). Eppler (2006), who distinguishes information and data in his consideration of information quality, sees *data* as "'raw,' unconnected, quantitative or qualitative items" without context (pp. 21-22).

In contrast, the ISO/IEC 25012:2008 states *information* as "<information processing> knowledge concerning objects, such as facts, events, things, processes, or ideas, including concepts, that within a certain context have a particular meaning", with the annotation that "although information will necessarily have a representation form to make it communicable, it is the interpretation of this representation (the meaning) that is relevant in the first place" (ISO & IEC, 2008, Chapter 4). According to Eppler (2006), *information* is an interrelated set of data related to "answers to questions, statements about situations or facts" (pp. 21-22).

To conclude, while data is a formalized object being meaningless in its "raw" nature, information is the meaning a person attaches to it by combining different data based on their knowledge within a specific context.

[11] Information deficits are the mismatch between the product information a consumer needs to identify and evaluate mobile phone alternatives for choosing the most circular one and the information the consumer actually gets provided (see Section 3.2).

For instance, the data digit 24 alone might not have any meaning to the information receiver. However, if further data is added (e.g., degree Celsius, Delft, 2 pm) and in a specific context, it can become meaningful information to the receiver to answer their question: "What is the temperature in Delft in the afternoon?". Although the concepts of *data* and *information* are very much related, differentiation is important for this research. From the consumer perspective, the notion of *information* is more relevant based on the provided definitions and my definition of information deficits[11].

Thus, it is adopted for this research and has the following consequences:

1. In general, when speaking about information, it is about what information the consumer wants to receive to answer their questions in the evaluation and choice for the most circular purchase alternatives.
2. In formulating the information requirements, it is attempted to consider this distinction (see Section 5.2).
3. In the following selection of the appropriate information quality framework, attention is paid to this differentiation.

4.2 Information Quality Framework

In this section, the most appropriate information quality framework is identified. This framework is used in the following section to define the design principles.

First, the method to select the framework is provided.

Afterward, the framework is presented in detail, including defining relevant information quality categories and criteria.

4.2.1 Framework Selection

In this sub-section the identification procedure and evaluation of possibly suitable frameworks is presented first. Afterwards, the selection of the most appropriate framework is made.

Literature selection process

To identify an appropriate framework, a systematic literature review is conducted by searching for relevant review papers and specialist books on Scopus (see Figure 10).

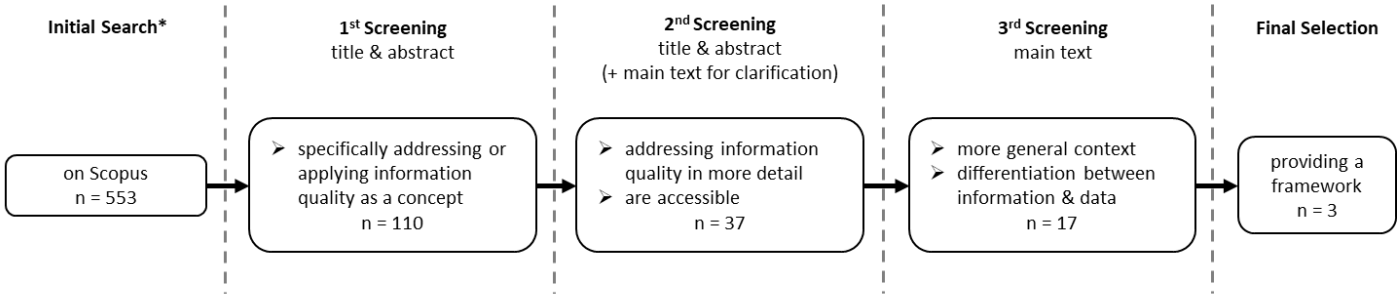


Figure 10: Literature selection process – Information quality frameworks

Review papers and specialist books are meant to provide the needed overview of existing knowledge regarding information quality (criteria). In addition, it was searched for literature that

- addresses the concept of information quality in more detail,
- is more general to be applied to this research's context, and
- makes a differentiation between data and information (according to the elaborations before).

Evaluation of identified frameworks

From the literature review, three frameworks are identified. They are evaluated systematically to select the most appropriate framework for this research. The selected literature and the framework evaluation results are summarized in Table 4**.**

For the framework evaluation, it is considered whether the framework can be applied to the specific context of this research (applicability), if it is developed scientifically sound (scientific soundness), and to what extent the framework can facilitate the analysis of the information deficits to derive design principles (useability). The latter is important to derive suitable information categories or criteria that define the design principles.

For each evaluation criterion, guiding questions are established, and the strengths and weaknesses of each framework regarding these questions are considered.

Table 4: Evaluation table – Information quality frameworks

Evaluation Criteria	Frameworks		
	Information Quality Framework (Eppler, 2006)	**Information Quality Ontology** (Rogova, 2016)	**Semiotic Information Quality Framework** (Price & Shanks, 2016)
Applicability Is the framework universal to adapt to the research context? Is information quality comprehensively addressed from an information receiver perspective? (incl. distinction between data and information)	+ general applicability (scientific & practical relevance); clear focus on the information receiver/user (incl. survey), with elaboration on distinction and relation between data, information, and knowledge - developed in the context of knowledge-intensive processes (in business)	+ general applicability; incorporating information user perspective; clear distinction between information and data - developed in the context of information fusion of crisis management;	+ general applicability; incorporating information user perspective; clear distinction between information and data - developed in the context of databases; information user perspective is quite technical and data oriented
Scientific Soundness Is the framework developed in a rigorous manner? Is the framework current?	+ grounded in theory; empirical study to identify information quality issues in practice; comprehensive review of existing information quality frameworks & criteria (incl. addressing shortcomings); rigorous, comprehensive process of framework development - based on literature from before 2006	+ discusses shortcomings of existing frameworks - process of framework development is not comprehensible and mainly argumentations by the author are used without references; mainly draws on literature from before 2000 or early 2000s	+ rigorous process of framework development, incl. evaluation with focus groups; discusses shortcomings of existing frameworks - mainly draws on literature from before 2000 or early 2000s; not every step is completely transparent
Useability Are there categories of quality criteria or other guidance that facilitate using the framework for analysis? Are the categories and criteria of quality clearly defined?	+ consideration of pedagogic design; link to processing by information receiver; accurate definition of information quality criteria and categories (glossary based on literature review); demonstration of framework in use cases	+ accurate definition of information quality criteria - no definition of the quality categories; no additional guidance in how to use the framework for analysis	+ accurate definition of information quality criteria and categories - no additional guidance in how to use the framework for analysis; many different criteria; categories and criteria are just provided in form of a table, so no conceptual framework

Selection of the most appropriate framework

Referring to the framework evaluation (see Table 4), it is examined which framework appears to be most suitable for the purpose of identifying the design principles. A brief rationale for the selection is provided below.

The **Information Quality Framework** by Eppler (2006) is concluded to be most suitable in the context of this research. The framework is characterized by a clear focus on quality criteria relevant to the information receiver, a comprehensive process for developing the framework (including scientific and practical relevance), and its ease of use for the analysis in the next section.

In contrast, for the framework of Rogova (2016), especially the scientific soundness is unclear and the usability seems to be difficult, for instance, due to missing definitions of the quality categories.

The framework of Price & Shanks (2016) has the advantage of having accurate definitions of information quality criteria and categories, and it was revised with focus groups. However, the disadvantage of this framework is the focus on rather a technical or organizational context: the usage of databases in organizations. Thus, the applicability in this research context is doubted.

4.2.2 The Information Quality Framework

The selected Information Quality Framework by Eppler (2006) (see Figure 11) and its comprising information quality categories and criteria are presented for a general understanding.

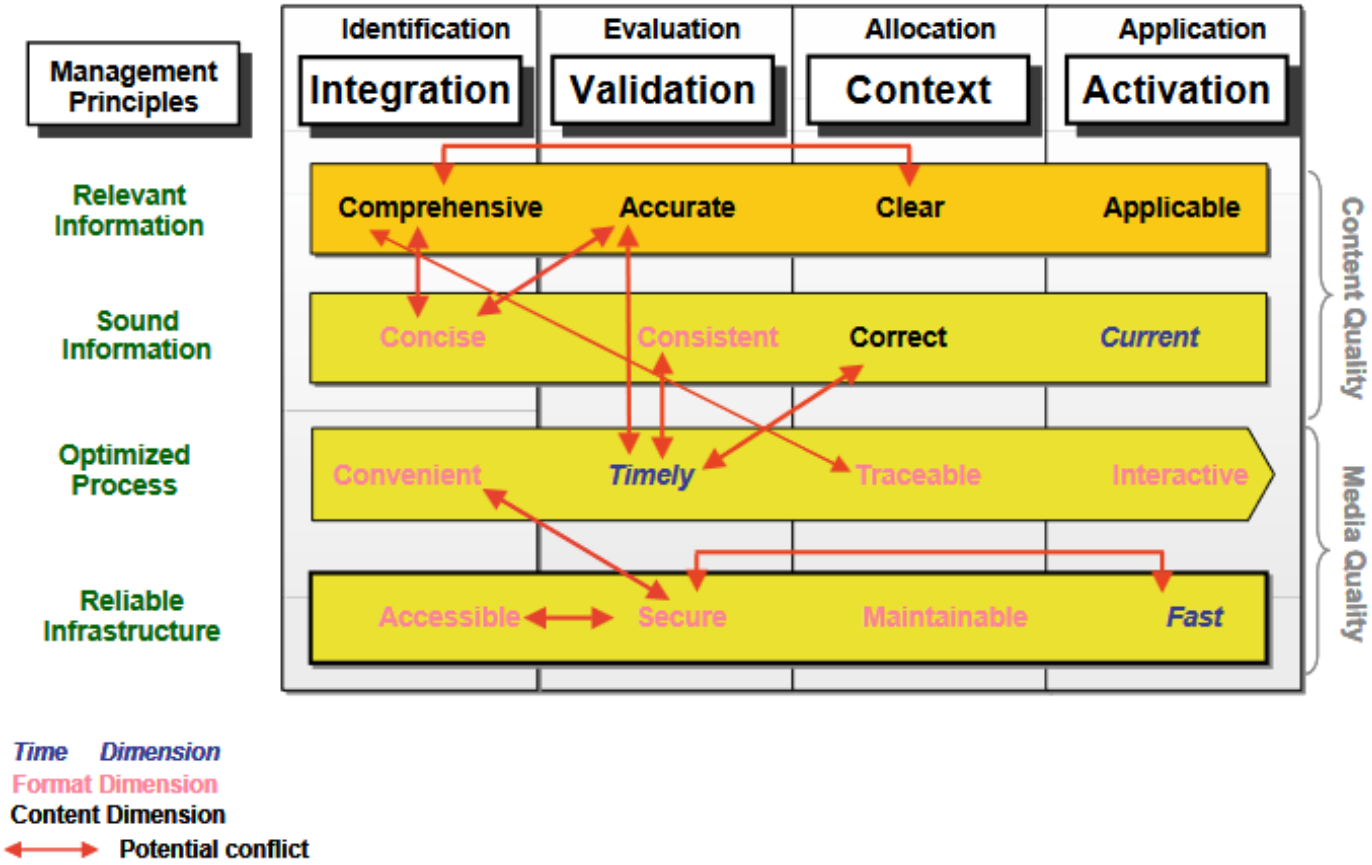


Figure 11: Information Quality Framework (Eppler, 2006, p. 68)

Main elements of the framework

The information quality framework comprises four key elements Eppler, 2006 (pp. 65–69):

First, the vertical structure categorizes information quality criteria based on their relation to the target community (*Relevant Information*), the information product (*Sound Information*), the process (*Optimized Process*), and the infrastructure (*Reliable Infrastructure*). While the upper two of these categories comprise the quality of the information's content (*Content Quality*), the lower two categories address the quality of how the information is provided to the information receiver (*Media Quality*).

Second, the horizontal structure consists of four phases representing the user's information processing: information search and retrieval, evaluation, adaptation to a new context (allocation), and application.

Third, the information quality criteria are assigned to the corresponding rows and columns accordingly (cells).

Fourth, the management principles within the framework provide guidance for improving information quality across all phases in practice (boxes under the column headers: *Integration*, *Validation*, *Context*, *Activation*).

As argued, mainly the information quality categories and their criteria are considered for identifying the design principles in the next section. Thus, their definition according to Eppler (2006) is provided.

Definition of Information Quality Categories

The definitions of the information quality categories are partly shortened as follows (based on Eppler, 2006, p. 67):

- **Relevant information:** This category relates to whether information is comprehensive, accurate, and clear enough for the intended use, and whether it is easily applicable to the problem at hand. This category is also called the community view, since the relevance of a piece of information depends on the expectations and needs of a certain community (e.g., user).
- **Sound information:** This category contains criteria which describe the intrinsic or product characteristics of information, such as whether it is concise or not, consistent or not, correct or not, and current or not. Whereas the criteria in the first category (relevance) are subjective (indicated through the term „enough") the criteria in this category should be relatively independent of the targeted community (indicated through the term „or not").
- **Optimized Process:** This category contains criteria which relate to the content management process by which the information is created and distributed and whether that process (or information service) is convenient, and whether it provides the information in a timely, traceable (attributable), and interactive manner.
- **Reliable Infrastructure:** This category contains criteria which relate to the infrastructure on which the content management process runs and through which the information is actually provided. Reliability in this context refers to a system's easy and continuous accessibility, its security, its maintainability over time and at reasonable costs, and its high speed or performance.

Definition of Information Quality Criteria

The definition of the information quality criteria is provided in Table 5.

Table 5: Definitions of Information Quality Criteria by Eppler (2006)

Information Quality Category	Information Quality Criteria	Definition
Relevant Information	Comprehensiveness	The quality of information to cover a topic to a degree or scope that is satisfactory to the information user.
	Accuracy	Degree of conformity of a measure to a standard or a true value. Level of precision or detail.
	Clarity	Void of obscure language or expression, ease of understanding, interpretability.
	Applicability	The characteristic of information to be directly useful for a given context, information that is organized for action.
Sound Information	Conciseness	Marked by brevity of expression or statement, free from all elaboration and superfluous detail.
	Consistency	The condition of adhering together, the ability to be asserted together without contradiction.
	Correctness	Conforming to an approved or conventional standard, conforming to or agreeing with fact, logic, or known truth.
	Currency	The quality or state of information of being up-to-date or not outdated.
Optimized Process	Convenience	The ease-of-use or seamlessness by which information is acquired.
	Timeliness	Coming early or at the right, appropriate or adapted to the times or the occasion.
	Traceability	The quality of information to be linked to its background or sources.
	Interactivity	The capacity of an information system to react to the inputs of information consumers, to generate instant, tailored responses to a user's actions or inquiries.
Reliable Infrastructure	Accessibility	Capable of being reached, capable of being used or seen.
	Security	Measures taken to guard information against unauthorized access, espionage or sabotage, crime, attack, unauthorized modification, or deletion.
	Maintainability	The characteristic of an information environment to be manageable at reasonable costs in terms of content volume, frequency, quality, and infrastructure. If a system is maintainable, information can be added, deleted, or changed efficiently.
	Speed	Here relatable to response time: The delay between an initial information request and the provision of that information by the information system. *(Exact definition is missing but meant to be linked to Response Time, p. 84)*

4.3 Design Principles

In this section, the design principles are established that guide the requirement elicitation.

For this research, design principles are defined as prescriptive principles that guide the elicitation of the information requirements. Moreover, referring to Johannesson & Perjons (2021, p. 34), they are generic and thus applicable to similar artifacts in different contexts. The latter seems important to this research in the context of the DPP development, as the DPP is to be used for many different consumer products. The design principles defined here can therefore be applied for their requirement elicitation as well, thus beyond the acquisition of mobile phones.

To establish the design principles, each of the three identified information deficits is considered and the most appropriate information quality category or criteria is selected from the Information Quality Framework by Eppler (2006). The argumentation for the quality category or criteria selection is provided with the design principles in the following sub-section. The definitions of the quality categories and criteria are provided in Sub-Section 4.2.2.

In general, as the first two information deficit concern the consumer's acceptance of the information, they can be related to the *content quality* categories/criteria. On the other hand, the third information deficit describes issues in the way the information is provided. Thus, it can be related to the media quality categories/criteria.

Figure 12 shows the selected information quality categories and criteria within the Information Quality Framework.

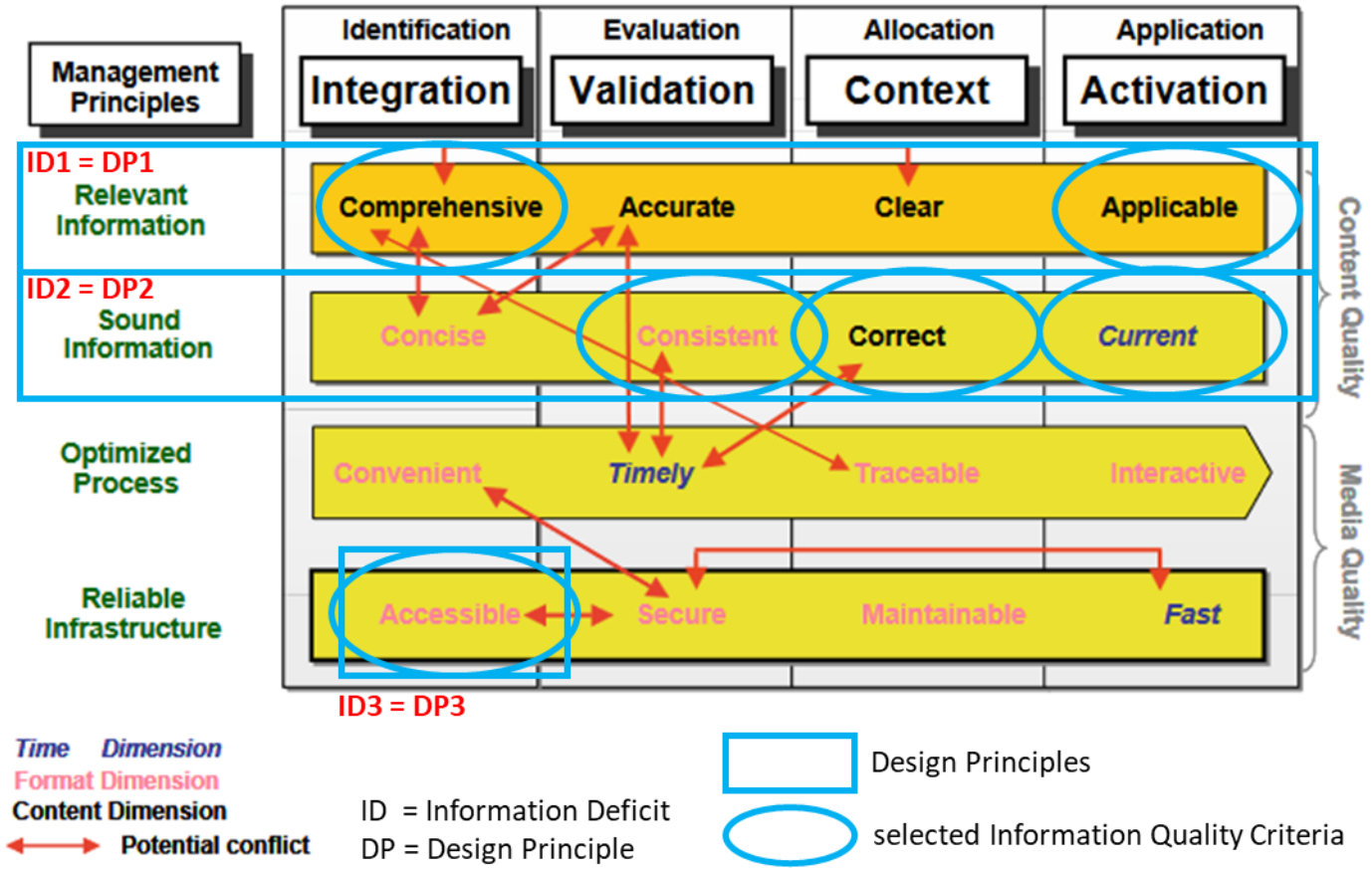


Figure 12: Selection of Information Quality Categories/Criteria in the framework by Eppler (2006, p. 68)

As can be noticed, the category of *Optimized Process* is not considered regarding the information deficits. With regard to the ESPR and the resulting value of the DPP in the consumer acquisition process (see Sub-Section 3.1.2), information issues were rather identified relating to the content of the information and its accessibility in general. This quality category can be investigated in further research.

In the following sub-sections, each design principle is defined in more detail, successively, to inform the requirement elicitation in the next chapter.

4.3.1 Design Principle 1: Relevance

Information Deficit 1: The amount and/or type of information provided may not match the consumers' needs regarding evaluation criteria for their choice of the (most) circular mobile phone alternatives.

Regarding the first information deficit, it is noticed that the DPP should provide the right type and amount of information that the consumer needs to evaluate different acquisition alternatives and choose the most circular one. Thus, referring to the framework by Eppler (2006), the information content needs to be of quality.

I conclude for the first design principle that, in general, the information provided by the DPP needs to be relevant. Thus, it corresponds to the first row in the framework by Eppler (2006), which is the information quality category of *Relevant Information*. The entire quality category is considered as it best reflects the information deficit as a whole, and multiple criteria appear to be applicable (further argued below).

Design Principle 1: Relevance
The DPP should provide relevant information to the consumer that is comprehensive and applicable.

The information needs to satisfy the expectations and needs of the consumers (Eppler, 2006, p. 67). Meaning the consumer values the information as useful for the choice of the most circular mobile phone alternative.

Considering the different information quality criteria that Eppler (2006) assigns to the quality category of *Relevant Information*, the criteria of *comprehensiveness* and *applicability* are selected to be most important regarding the main issues identified in Information Deficit 1 (discrepancies regarding the type and the amount of information). Therefore, the information provided with the DPP should be of an appropriate scope not to be overwhelming (*comprehensiveness*) and, at the same time, useful (*applicability*) for the consumer.

Using these two criteria as a guide for eliciting the relevance-related requirements means that the proper scope of information should be defined (*comprehensiveness*). Furthermore, it needs to be ensured that the information (requirements) elicited can be useful to consumers to evaluate and choose the most circular mobile phone alternative (*applicability*).

In addition, I acknowledge that the other two criteria of the relevance category (*accurate* and *clear*) are also important for consumers' acceptance of the information. However, additional empirical consumer studies based on my identified set of information are required to define the accuracy and clearness of the provided information. This is beyond the scope of this research.

4.3.2 Design Principle 2: Soundness

Information Deficit 2: The information provided may not be reliable (e.g., comparable, trustworthy) over the mobile phone's lifecycle to be considered in the consumer's evaluation of acquisition alternatives.

Regarding the second information deficit, it is noticed that the DPP should also safeguard that the consumer can rely on the provided information. In this respect, particularly, comparability and trustworthiness were considered in identifying the information deficit (see Sub-Section 3.2.2).

Applying the framework by Eppler (2006), this information deficit is best linked to the second row of the framework, which is the information quality category of *Sound Information.* The entire quality category is considered as it best reflects the information deficit as a whole, and multiple criteria appear to be applicable (further argued below).

Design Principle 2: Soundness
The DPP should provide information that is sound, thus based on consistent, current, and correct data.

So, the information is objectively appropriate to be used by the consumer, independent of their subjective opinion (Eppler, 2006, p. 67). Consequently, here the link to data is established considering its objective character (see definition in Sub-Section 4.1.1).

Considering the two main issues of Information Deficit 2 (discrepancies regarding the comparability and the trustworthiness of information), the most suitable quality criteria of the category of *Sound Information* can be selected. Thus, on the one hand, the information would be comparable if the data is not contradicting other information in the DPP (*consistency*) and is up-to-date (*currency*) (Eppler, 2006, p. 365). On the one hand, the trustworthiness of the information can be related to the *correctness* criteria, stating that the information is "conforming to an approved or conventional standard [or] conforming to or agreeing with fact, logic, or known truth" (Eppler, 2006, p. 365).
It can be noticed that the criteria are highly interwind in the context of the identified information deficit. For instance, the correctness of the information can also contribute to the comparability between information. Nevertheless, these three selected criteria should be used separately to facilitate the elicitation of requirements related to the information's soundness.

Hence, the quality criteria of *consistency, currency, and correctness* guide the elicitation of the soundness-related requirements.

In addition, I acknowledge that the fourth criterion of the soundness category (conciseness) can also be important for consumers' acceptance of the information. However, additional empirical consumer studies are required to define the necessary degree of the information's conciseness, which can use my identified set of information as a basis. This is beyond the scope of this research.

4.3.3 Design Principle 3: Accessibility

Information Deficit 3: The information provided in different contexts and over the mobile phone's lifecycle may not be accessible for consumer's identification of acquisition alternatives and product information.

Regarding the third information deficit, it is noticed that the DPP should improve the accessibility to information in different contexts and over the mobile phone's multiple use cycles. The consumer needs a reliable DPP system that provides access to the needed information.

Consequently, this information deficit is linked to the fourth quality category by Eppler (2006) regarding a *Reliable Infrastructure*. However, by comparing the information deficit with the criteria in this quality category, it is noticed that it can exclusively be linked to the criteria of *accessibility*.

Design Principle 3: Accessibility
The DPP should ensure that the information can be seen, reached, and used by the consumer throughout the different information contexts and the use cycles of a product.

This design principle is in line with the criteria definition of *accessibility* by Eppler (2006, p. 364), which states that information is accessible if it is "capable of being reached [and] capable of being used or seen". This needs to be guaranteed with the DPP.

Considering the specific aspects provided regarding accessibility in the definition by Eppler (2006, p. 364) – namely, the *capability to be seen, reached, and used* (logically ordered to the expected process of a consumer approaching the information) – can further help to guide the elicitation of the accessibility-related requirements. In specific, considering the main issues identified regarding Information Deficit 3 (discrepancies of information accessible in different contexts and over use cycles), the DPP should, on the one hand, be visible to consumers (*be seen*) and support the information provision (*be reached*) in different contexts. On the other hand, the DPP information should be accessible for use over the mobile phone's multiple use cycles (*be used*).

In addition, I acknowledge that the other three criteria of the reliable infrastructure category (*secure, maintainable,* and *fast*) are also important, particularly from a more technical, system provider perspective. However, this research focuses on the consumer perspective. Thus, these aspects can be investigated in further research regarding the technical infrastructure.

4.4 Answering Sub-Question 2

To recap, this chapter approached Sub-Question 2, namely:

What are the design principles ensuring that the elicitation of the information requirements considers the potential information deficits of EU consumers?

To answer Sub-Question 2: Three design principles are established, which reflect the three information deficits of the consumer and can provide guidance for the information quality elicitation. The respective sub-sections provide an elaboration of the design principles (4.3.1 Design Principle 1, 4.3.2 Design Principle 2, 4.3.3 Design Principle 3).

Design Principle 1: Relevance (addressing Information Deficit 1)
The DPP should provide relevant information to the consumer that is comprehensive and applicable.

Design Principle 2: Soundness (addressing Information Deficit 2)
The DPP should provide information that is sound, thus based on consistent, current, and correct data.

Design Principle 3: Accessibility (addressing Information Deficit 3)
The DPP should ensure that the information can be seen, reached, and used by the consumer throughout the different information contexts and the use cycles of a product.

For the research's outcome, the design principles ensure that the DPP developed based on the information requirements can address the consumer's information deficits.

In the next chapter, the established design principles are used as a guideline to elicit the information requirements.

5. Information Requirements

This chapter elicits the initial information requirements using the established design principles (*Relevance*, *Soundness*, *and Accessibility*). The requirements are meant to address the consumer's information deficits, and thus benefit the development of an EU DPP that serves the EU consumer in acquiring the most circular mobile phone alternative.

The outcome of this chapter is a list of initial information requirements.

Thus, Sub-Question 3 is answered:

SQ3:	What initial information requirements can be elicited based on the design principles, so that the EU DPP can address the potential information deficits of EU consumers?

To elicit the information requirements, analyses based on desk research are conducted for each design principle. The appropriateness of desk research is argued for in the introduction of Section 2.2.
Generally, the detailed elaboration of the design principles, including appropriate quality criteria (see Section 4.2), is used as a guide for each elicitation process method. Moreover, when eliciting the requirements, it was intended to provide them with a breakdown structure numbering (e.g., 1., 1.1, 1.1.1,…) according to system engineering practices (Dym et al., 2014, pp. 70–72). This provides structure to follow the line of reasoning and inform further research. While the higher-level requirements provide the general functions the DPP should serve, the lower-level requirements specify them. I want to provide higher-level requirements to guide the discussion in the development of the DPP and allow the elicitation of different lower-level requirements in further research.

For the relevance-related requirements it is intended to identify the information that is relevant to the consumer. For this purpose, it can be drawn on existing knowledge, meaning a systematic literature review of empirical studies is conducted. The exact literature review procedure is established in Sub-Section 5.1.1.

The soundness- and accessibility-related requirements are rather seen to be DPP-context dependent, and thus the existing knowledge base is limited (see Section 1.2). Thus, systematic analyses are performed guided by the design principles' quality criteria and with respect to the knowledge established regarding the information deficits. Moreover, according to the quality category definitions by Eppler, 2006 (p. 67), while the relevance of information is more subjective, the quality of soundness and accessibility is relatively objective, and thus desk studies are appropriate.

In the following three sections, the requirements for each of the three design principles (*Relevance*, *Soundness*, *Accessibility*) are elicited, respectively.

Finally, the answer to Sub-Question 3 is provided (see Section 5.4).

5.1 Relevance

This section elicits the information requirements regarding the *Relevance* (Design Principle 1) of the DPP information. Table 6 shows the link between Information Deficit 1 and the relevance-related requirements.

Table 6: Link between Information Deficit 1, Design Principle 1, and the Relevance Requirements
** Definition of Information Quality Criteria by Eppler (2006)*

Information Deficit 1	**Design Principle 1: Relevance** The DPP should provide relevant information to the consumer that is comprehensive and applicable.	**Relevance Requirements**
Acceptance Issues	**Information Quality Criteria***	**Incorporation in the Requirement Elicitation**
Discrepancy regarding the amount of information	*Comprehensiveness:* The quality of information to cover a topic to a degree or scope that is satisfactory to the information user.	Consideration of the right scope of information in the DPP.
Discrepancy in information's utility	*Applicability:* The characteristic of information to be directly useful for a given context, information that is organized for action.	Consideration of information that is actionable. This is, acquiring factors that influence consumers in their decision-making for circular alternatives and derive the information requirements from there.

Concerning the quality criteria identified for Design Principle 1, a *comprehensive list* of *applicable* information provided with the DPP has to be obtained so that the information provided with the DPP is relevant to the consumer (Information Deficit 1).
As the research's objective is to lay the foundation for further research, I attempt to provide a complete list of applicable/relevant information instead of selecting the "right amount" of information. I argue that the definition of the "right amount" of information would require an additional, extensive consumer study (based on my findings), which is beyond the scope of this research. Furthermore, my approach complies with the ESPR proposal. The proposal does not address a specific consumer group yet (e.g., environmentally conscious consumers). However, this particular focus is necessary to determine the "right amount" (see consumer's heterogeneity regarding Information Deficit 1).

For this purpose, a systematic literature review is conducted to derive the information relevant to the consumer from multiple peer-reviewed empirical studies. Using a literature review for this purpose is appropriate, considering the objective mentioned before and the argumentation made in Section 2.2.

In specific, to derive the relevant information, empirical studies are examined which identified factors influencing consumers regarding their identification and selection of circular mobile phone alternatives.
This approach allows me to start from a wide scope of factors that are decisive for consumers' decision-making and then identify the factors related to information that can be addressed with the DPP. Thus, it is expected to derive a more comprehensive list of evaluation criteria that consumers actually apply in their acquisition choice-making. Scientific studies solely focused on required information were not found during the literature acquisition process.

In the first section, the performed literature selection and reviewing process is presented.

In the second section, the relevance requirements are elicited from the found information-related factors.

Finally, the elicited initial set of relevance requirements for the DPP is presented (see Sub-Section 5.1.3).

5.1.1 Identification of Influencing Factors

As mentioned before, to elicit the information requirements that define the information that is relevant to the consumer, a systematic literature review is conducted.

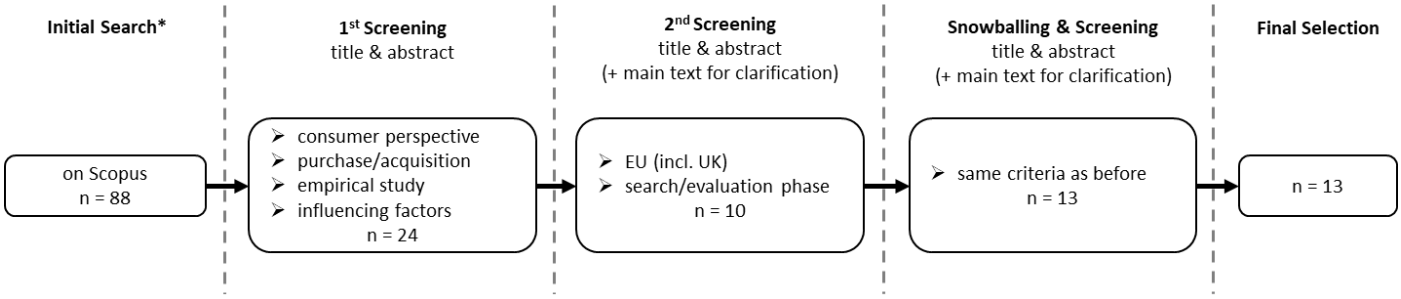
Referring back to Chapter 3, the goal of the consumer in their decision-making is defined in this research as being the choice of the mobile phone alternative that is most circular. For the information with the DPP to be relevant to the consumer in this context, it must apply according to the definition of Design Principle 1. Eppler (2006) defines the quality criteria of *applicability* as "the characteristic of information to be directly useful for a given context [or] information that is organized for action" (S. 364).

Influencing factors are considered to identify the information (characteristics) that promote the consumer's action. These factors influence the consumer's choice of a circular mobile phone alternative and thus can be decisive for their actual action.

The literature selection is presented in the following, and the identified factors are discussed afterward. Based on that, the relevance requirements can be elicited in the following sub-section.

Literature selection process

The literature review was conducted on Scopus and Web of Science. In a systematic procedure (see Figure 13), considering the before-described purpose of the literature review and screening peer-reviewed articles, review papers, and conference papers, a final set of 13 papers were selected. Table 7 provides an overview of the final selection.



* state 31.03.2023:
TITLE-ABS-KEY((consumer* OR customer*) AND ("smartphone*" OR "mobile phone*" OR "cell phone*") AND ("circular economy" OR "cradle to cradle" OR circularity OR sustainability) AND ((refus* OR avoid) OR (pss OR product-service-system*) OR (shar* OR lend* OR leas*) OR (second-hand OR secondhand OR used OR reus* OR re-us*) OR (refurbish* OR remanufactur* OR recycle* OR up-cycle*) OR (upgradeab* OR remanufacturab* OR repairab* OR reusab* OR durab* OR recyclab*) OR repurpose))
further filter: article, review papers, conference papers; English, German; final version

Figure 13: Literature selection process – Influencing factors (relevance requirements)

For the search string, it was attempted to cover all possible circular acquisition alternatives a consumer could have in theory based on CE literature. Therefore, hierarchies regarding CE (Reike et al., 2018), circular consumption in general (Maitre-Ekern & Dalhammar, 2019), circular product design (Shevchenko et al., 2023), and product-service-systems (Tukker, 2004) were consulted to get an overview of what options may exist.

In the selection process, the following selection criteria were applied according to the research context and the primary purpose of the literature review. The literature is used if it entails:

- consumer's acquisition of a circular mobile phone alternative (thus: consumer, acquisition, circular acquisition alternatives, mobile phones)
- information and/or factors influencing the consumer's choice for (more) circular mobile phone alternatives,
- empirical study methods (for practice relevance),
- a study in the EU (incl. UK, if the study was conducted before or directly after the BREXIT on 01.01.2021), and
- the consumer's search and/or evaluation phase in the acquisition process (argued to be most relevant in the DPP context; see Sub-Section 3.1.2).

Table 7: Selected literature and an indication of related CE strategy - Influencing factors (relevance requirements)

Source ID	Source	Addressed circular strategy
1	(Rousseau, 2020)	Leasing
2	(Poppelaars et al., 2018)	
3	(Wieser & Tröger, 2016)	Reuse
4	(Van Weelden et al., 2016)	Refurbish
5	(Mugge et al., 2017)	
6	(Wewer et al., 2020)	
7	(Mugge et al., 2018)	
8	(Bigliardi et al., 2022)	
9	(Agostini et al., 2021)	
10	(Boyer, Hunka, & Whalen, 2021)	Circular Products (e.g., circular design or recycled material content)
11	(Boyer, Hunka, Linder, et al., 2021)	
12	(Hunka et al., 2021)	
13	(Bigerna et al., 2021)	

Review of identified factors

By thoroughly reviewing the selected papers, a comprehensive list of influencing factors was compiled (see Table B. 1 in Appendix B), related to each source.

Compared to the CE strategies presented in the Introduction, it shows that just some of the possible strategies are covered. Nevertheless, a range of alternatives is addressed, from new but circular mobile phone designs, over reuse and refurbishment, to leasing. This is expected to match the acquisition alternatives a consumer commonly has nowadays regarding mobile phones (see also Sub-Section 1.2.4).

The authors identified a wide range of possible influencing factors which are different in nature (e.g., personal/social, marketing). At the same time, many similar factors were found by different authors, which I claim strengthens their practice relevance. Hence, I assume this comprehensive list of factors is appropriate to identify information-related factors or evaluation criteria which could be covered with the information in the DPP.

Also, Boyer et al. (2021) and Mugge et al. (2017) found different consumer groups with different evaluation criteria for refurbished mobile phones. As I view all the factors in the requirement elicitation, I assume to be able to cover the heterogenic population of EU consumers as good as possible, that should be addressed with the EU DPP.

Moreover, I do not rank the importance of the factors, as not all considered studies would allow me to do so because of different study approaches, and the ranking probably also differs per consumer type.

Identification of information-related factors

To find the influencing factors relevant in the research context, each factor is logically assessed whether it can be related to product information[12], which can be provided with the DPP. It means whether the factor directly represents product information or is influenced by it (e.g., perceived risks regarding the performance of mobile phones). The latter is also considered as they can back the choice to provide certain information (e.g., performance certificate), and they provide an understanding of the possible purpose of the information provided with the DPP (e.g., risk mitigation). In the following sub-section, this aspect is addressed again.

Also, Table B. 1 in Appendix B shows which factors I relate to product information are selected for the requirement elicitation. Since not all influencing factors directly represent product information, a brief rationale for selecting the factor is also provided. In total, 70 information-related factors (44 excl. duplicates) are selected.

[12] For this purpose, product information is seen as information that describes the product and its life cycle (see also Sub-Section 3.1.2).

5.1.2 Requirement Elicitation

The identified information-related factors are translated into requirements to elicit relevance requirements for the DPP. Table B. 2 in Appendix B provides an overview of the elicited relevance requirements related to the factors they are derived from and the respective literature source (source ID is the same as in the literature overview in Table 7). Similar factors provided by different authors are comprised to one.

The exact elicitation procedure is described as follows.

Elicitation procedure

The goal of the elicitation is, on the one hand, to elicit requirements that comprise all the factors but are as specific as possible. On the other hand, due to the number of factors, it is also intended to provide structure, for instance, by applying the mentioned breakdown structure by Dym et al., 2014 (pp. 70–72). The latter is also related to the fact that the factors differ in their specificity level.

The elicitation is conducted following three steps:

1. Structuring the selected information-related factors: Similar factors are combined, and the factors are ordered by commonality. Meaning factors that address common aspects are considered together, thus forming groups.
2. "top-down" clustering: Afterwards, the resulting groups are clustered top-down. This starts from the most generic groups (perception of benefits, perception of risks, and being able to view the product's features). This step is repeated for the following more specific groups, considering which of the higher-level groups they could belong to thematically. In this regard, the literature often provided guidance. For instance, seeing the usually more positive environmental performance of a refurbished mobile phone, as opposed to a new one, contributes to the perception of benefits. This clustering is repeated until the most specific factors (groups of factors) are assigned to a higher-level group.
3. Formulating the requirements: The first and second-level requirements are formulated to guide what functionality or kind of information the DPP should provide. The third level requirements are formulated in such a way that it is described what specific information should be included in the DPP.

Breakdown structure

As a result, the requirements are elicited in a breakdown structure with three levels of detail (see Table B. 2 in Appendix B):

The first level requirements (e.g., 1.) are the most generic and represent the functions of the information provided with the DPP, for instance, increasing the perception of benefits. These indicate which aspects play a principal role for consumers in choosing a suitable acquisition alternative (e.g., mitigating possible risks when acquiring a pre-owned mobile phone).
The second level requirements (e.g., 1.2) represent a group or category of certain information and could be further detailed by specific information items. They serve as a guide for what kind of information would be relevant to the consumer.
The third level requirements (e.g., 1.1.1) are the most specific and represent one information item that should be provided in the DPP.

Hence, while it was intended to derive a complete list of general requirements, as argued in the section's introduction, the provided breakdown structure can also inform further research (compliant with the research objective). For instance, the functions of the DPP (first-level) and the information groups (second-level) can be used to identify relevant requirements in more detail for a specific context or for other products. In contrast, the more specific third-level requirements could be used to develop and implement the DPP for the acquisition of circular mobile phone alternatives.

5.1.3 Initial Relevance Requirements

The initial list of relevance requirements is provided in Table 8.

Table 8: Initial list of relevance requirements, ordered by breakdown structure

Relevance Requirements		
compre-hensive, applicable	1.	The DPP should **increase the perception of benefits**.
	1.1	The DPP should **provide circular design information**.
	1.1.1	The information should include **durability information**.
	1.1.2	The information should include **repairability information**.
	1.2	The DPP should **provide circular composition information**.
	1.3	The DPP should **provide environmental performance information**.
	2.	The DPP should **reduce the perception of risks**.
	2.1	The DPP should **provide technical performance information**.
	2.1.1	The information should include **battery performance information**.
	2.2	The DPP should **provide proof(s) of product's reliability**.
	2.2.1	The information should include **warranty information**.
	2.2.2	The information should include **quality certification information**.
	2.2.3	The information should include **proof of data removal**.
	2.2.4	The information should include **proof of software being malware-free**.
	2.2.5	The information should include **software update information**.
	3.	The DPP should **enable the viewing of product features**.
	3.1	The DPP should **provide information about product characteristics**.
	3.1.1	The information should include **product appearance information**.

5.2 Soundness

This section elicits the information requirements regarding the *Soundness* (Design Principle 2) of the DPP information. Table 9 shows the link between Information Deficit 2 and the soundness-related requirements.

Table 9: Link between Information Deficit 2, Design Principle 2, and the Soundness Requirements
** Definition of Information Quality Criteria by Eppler (2006)*

Information Deficit 2	**Design Principle 2: Soundness** The DPP should provide information that is sound, thus based on consistent, current, and correct data.	**Soundness Requirements**
Acceptance Issues	**Information Quality Criteria***	**Incorporation in the Requirement Elicitation**
Discrepancy in comparability of information	*Consistency:* The condition of adhering together, the ability to be asserted together without contradiction.	Considering the granularity of information and data management, so that the information are consistent within the DPP and between products, and thus comparable.
	Currency: The quality or state of information of being up-to-date or not outdated.	Considering the events of when the data needs to be updated, so that the information are up-to-date and comparable amongst each other.
Discrepancy in trustworthiness of information	*Correctness:* Conforming to an approved or conventional standard, conforming to or agreeing with fact, logic, or known truth.	Considering which actors, with or without credentials have to provide the data, so that the information with the DPP are always correct, thus trustworthy, regarding the current state of the mobile phone. Additionally, considering standardization of data acquisition and information provision

For this purpose, a desk study is conducted to elicit the requirements regarding the soundness of information in the DPP. Specifically, referring to Design Principle 2, the DPP should provide sound information, thus based on consistent, current, and correct data. Here the distinction made in Sub-Section 4.1.2 between information and data needs to be taken into account when formulating the requirements.

Therefore, the information items and groups (second- and third-level requirements) identified in the previous sub-section are used as a baseline for the analysis. These information items and groups were examined in the context of Information Deficit 2 using the three pertinent quality criteria for soundness – *consistency*, *currency*, and *correctness* – respectively. Based on the established knowledge and by consulting further literature and best practices, conclusions were drawn logically to elicit the soundness-related information requirements.

In the following two sub-sections, the results of the analysis are elaborated in an argumentative way.

Finally, the elicited initial set of soundness requirements for the DPP is presented (see Sub-Section 5.2.3).

5.2.1 Concistent & Current Information

In the elaboration on Design Principle 2, the quality criteria of consistency and currency are both related to the issues consumers face regarding the comparability of information. Thus, they are both considered in this sub-section successively.

In the investigation of Information Deficit 2 (see Sub-Section 3.2.2), it was found as a central issue that the product and lifecycle information specific to one mobile phone becomes vaguer over use cycles. For instance, information about what parts have been changed in the mobile phone could get lost over use cycles but can be relevant to assess the mobile phone's durability.

Consistent Information

Eppler (2006) defines consistency of information as "the condition of adhering together [or] the ability to be asserted together without contradiction" (p. 365). In this regard, particularly the granularity of the information provided and the data managed in the DPP need to be discussed. Meaning to what level of detail the information and respective data need to be managed so that it is guaranteed that the information provided is consistent with each other, but also

concerning the actual state of the mobile phone. This is particularly important over use cycles, as the information deficit shows.
Defining requirements in that regard could thus improve the comparability of the information for consumers, as they are managed in the same way for all (pre-owned) phones, and also the information in the DPP itself are not contradictory.

Also, based on the ESPR proposal (Directorate-General for Environment of the European Commission, 2022, p. 25) and CIRPASS (Bernier et al., 2023, p. 97), the definition of the granularity level on a case-by-case basis is relevant for the DPP development. Thus, a contribution can be made here, considering specifically the consumer perspective and mobile phone case.

From my analysis, I conclude that in general the data in the DPP should be managed on different granularity levels (**Requirement 4.**) to ensure consistency. This is based on the following elaborations and aligns with the ESPR (Directorate-General for Environment of the European Commission, 2022, p. 25).

In more detail, the information should be provided on a product level to the consumer, meaning specific to the one mobile phone they acquire. Thus, also the corresponding data mainly needs to be managed on this level (**Requirement 4.1**). The requirement to have a product level instead of lower granularities (e.g., mobile phone model level) results from the need for specific information for an individual mobile phone once it enters the usage phase. This was found in the discussion of the information deficit. Also, by considering the information relevant to the consumer for their acquisition (see relevance requirements in Sub-Section 5.1.3), mainly information that describes the mobile phone as a whole was found. The only exception is the battery performance information.

In addition, while the information provided to the consumer is most relevant on a specific product level, changes in the mobile phone's components over use cycles could affect the information on a product level (e.g., material composition, product characteristics, durability). Thus, the data on a product level should also be relatable to data on a component level within the DPP (**Requirement 4.2**). That is, it needs to be ensured that the information provided to the consumer on a product level is connected to data about the components currently in the mobile phone. However, as explained, providing information on a component level to consumers is generally irrelevant, except for some specific conditional information on critical components (e.g., battery performance).

Current Information

Eppler (2006) defines currency of information as "the quality or state of information of being up-to-date or not outdated" (p. 365). Defining information requirements in that regard becomes important in light of the Information Deficit 2. The information provided by the DPP needs to be up-to-date over the mobile phone's use cycles so that the consumer can compare alternatives on a sound information base.

Generally concluding from this, the data for the provided information should be updated over the mobile phone's lifecycle (**Requirement 5.**). Thus, it should be ensured that every major event that is happening to the phone and has an influence on its relevant information is recorded, and the data is updated accordingly. This is meant to mitigate the identified risks of data losses over the usage phase, mentioned regarding Information Deficit 2 in Sub-Section 3.2.2.

To enable to verify when the information was updated last, the data updates made should be complemented by a timestamp of change (**Requirement 5.1**).

To be more specific about when the data needs to be updated, I state that the data should be updatable when the mobile phone is altered (e.g., component replacement) or processed (e.g., testing) in any way (**Requirement 5.2 & 5.6**, respectively).

Moreover, the data relevant to the product level information should also be updatable dynamically:

- depending on the age/lifetime of the mobile phone, for instance, to determine the remaining time until a warranty expires (**Requirement 5.3**),
- if components are altered (e.g., repairing), so their component data could affect product level information (e.g., material composition; **Requirement 5.4**), or
- by the mobile phone itself, for instance, through integrated sensors (e.g., battery capacity; **Requirement 5.5**).

5.2.2 Correct Information

In the elaboration on Design Principle 2, the quality criteria of correctness are related to the issues consumers face regarding the trustworthiness of the information.

In the investigation of Information Deficit 2 (see Sub-Section 3.2.2), it was found as a main issue (1) that in general information over use cycles could become trustless to the consumers, and (2) that particularly information about circularity or environmental performance is doubted.

Eppler (2006) defines the correctness of information as "conforming to an approved or conventional standard [or] conforming to or agreeing with fact, logic, or known truth." (p. 365). Comparing this definition with the outlined information deficit, the requirement elicitation can be informed so that the DPP enables trust in the provided information.

(1) It would be relevant to define the actors that have to provide the data and ensure their credibility so that the information provided with the DPP conforms with the actual state of the mobile phone over the use cycles.

(2) Moreover, for the trust in the provided information in general and in circularity or environmental information in particular, standards would be relevant to ensure correctness regarding how the data is obtained and provided.

Data provision by actors

Considering the requirements regarding when the data should be updated and the possible actors that would interact with the mobile phone in its usage phase (based on King et al., 2023, p. 5), it can be derived what actors are relevant to provide data over the use cycle.

While the manufacturer and end-of-life companies are expected to provide or alter all data items (initiation/deletion of the individual product-specific DPP), it is expected that multiple actors provide or update the different data items over the mobile phone's usage phase (e.g., owner, repairer, refurbisher, renter). Thus, in general, it can be stated that the data need to be provided by multiple actors throughout the product's lifecycle (**Requirement 6.**).

In more detail, I distinguish between private persons and businesses. Thus, it should be enabled that the data is provided by private persons/owners (**Requirement 6.1**), and on the other hand, by organizations (**Requirement 6.2**). In this way, it should be enabled to counter information loss over the mobile phone's use cycles.

Moreover, to increase the trustworthiness of the provided data, it should be complemented with the provider's credentials. While the data provision by private persons could become of particular importance with consideration the promotion of repairing (see "right to repair", European Parliament, 2022a), this can create conflicts with private person's privacy rights. Thus, there is no requirement elicited in that respect. However, I call for further research in that respect, as distrust in the information provided by private persons was mainly found problematic regarding Information Deficit 2. In contrast, the data provided by organizations – assuming their legal liability – should be complemented by their credentials (**Requirement 6.3**), so it can be traced back from which source the data comes and if it is trustful.

Application of standards

Considering the relevant information (see Sub-Section 5.1.3) and the mentioned need for standardized data acquisition and information provision, it is concluded that all information in the DPP should be based on specific standards. This is required to have the correct information with the DPP so that the consumer, above all, can trust but also compare the information without deficits.

Thus, the DPP's data should be based on applied standards (**Requirement 7**).

Nevertheless, I acknowledge that the extent of standardization can differ in the extent, depending on the difficulty of defining the information or safeguarding the information's correctness (e.g., product features vs. environmental performance information). For instance, more general terms like "durability" or "repairability" require a clear definition.

5.2.3 Initial Soundness Requirements

The initial list of soundness requirements is provided in Table 10.

Table 10: Initial list of soundness requirements, grouped per information quality criteria

Soundness Requirements		
consistent	4.	The DPP's data should be managed on **different granularity levels**.
	4.1	The data should be on **product level** granularity.
	4.2	The data should be relatable to **component level** data.
current	5.	The DPP's data should be **updated throughout the product's lifecycle**.
	5.1	The updated data should be accompanied by a **time stamp**.
	5.2	The data should be **updatable with each alteration of the product**.
	5.3	The data should be **updatable depending on the product's lifetime**.
	5.4	The data should be **updatable depending on data in the product's component inventory**.
	5.5	The data should be **updatable by the mobile phone itself**.
	5.6	The data should be **updatable when the mobile phone is processed in-between possession.**
correct	6.	The DPP's data should be **provided by multiple actors** throughout the product's lifecycle.
	6.1	The data should **be able to be provided by private persons/owner**.
	6.2	The data should **be able to be provided by organizations**.
	6.3	The data provided by organizations should be accompanied by **organization's credentials**.
	7.	The DPP's data should be **accompanied by the standards** it is based on.

5.3 Accessibility

In this section, the information requirements regarding the *Accessibility* (Design Principle 3) of the DPP information are elicited. Table 11 shows the link between Information Deficit 3 and the accessibility-related requirements.

Table 11: Link between Information Deficit 3, Design Principle 3, and the Accessibility Requirements
** Definition of Information Quality Criteria by Eppler (2006)*

Information Deficit 3	**Design Principle 3: Accessibility** The DPP should ensure that the information can be seen, reached, and used by the consumer throughout the different information contexts and the use cycles of a product.	**Accessibility Requirements**
Exposure Issues	**Information Quality Criteria***	**Incorporation in the Requirement Elicitation**
Discrepancy of accessible information in different contexts	*Accessibility:* Capable of being reached, capable of being used or seen.	Considering requirements that ensure that the DPP and its information can *be seen* in the different contexts.
		Considering requirements that ensure that the DPP and its information can *be reached* in the different contexts.
Discrepancy of accessible information over use cycles		Considering requirements that ensure that the DPP and its information can *be used* regardless of the mobile phones use cycle.

For this purpose, a desk study is conducted to elicit the requirements regarding the accessibility of information of the DPP. Specifically, referring to Design Principle 3, the DPP should ensure that the information is visible and accessible to the consumer throughout the different information contexts and the use cycles of a product. Therefore, the issues regarding Information Deficit 3 are analyzed using the three accessibility aspects of Design Principle 3 – the *capability to be seen, reached, and used* – to elicit the accessibility-related information requirements, respectively.

In the following two sub-sections, the results of the analysis are elaborated in an argumentative way.

Finally, the elicited initial set of accessibility requirements for the DPP is presented (see Sub-Section 5.3.3).

5.3.1 See & Reach the Information

In the elaboration of Design Principle 3, the accessibility aspects of the DPP's information being able to be seen and reached are related to the accessibility issues arising from the variety of acquisition contexts. Thus, they are both considered in this sub-section successively.

As mentioned regarding Information Deficit 3 (see Sub-Section 3.2.3), in general, the variety of information and acquisition channels for mobile phones could lead to information deficits. First, the consumers may not be aware of certain existing information (sources) in their specific acquisition context, but which they may need for their decision-making. In this regard, a possible mismatch between the information provided in an offline as opposed to an online setting can occur. Second, especially when acquiring a pre-owned mobile phone, the consumer becomes dependent on the information provided by the seller and may not receive all information needed.

See the information

Consequently, regarding the DPP's information to be capable of being seen by the consumer, the consumer always needs to become aware of the possibility of obtaining extended product information using the DPP (**Requirement 8.**). This aspect could also be linked to the identified lack of awareness about circular alternatives (Mugge et al., 2017; Poppelaars et al., 2018; Van Weelden et al., 2016; Wewer et al., 2020), which can be addressed by the DPP information provision as well.

To further elaborate, the different possible information channels presented regarding Information Deficit 3 are considered (see Sub-Section 3.2.3). Mainly, the common mix of offline and online information sources needs to be considered to ensure the consumer's awareness of the DPP information.

Hence, there should be at least a reference to the DPP on the product packaging in the offline setting (**Requirement 8.1**) and in online offerings/adverts (**Requirement 8.2**). Having a sign referencing to the extended information available with the DPP can also increase the awareness and usage of the DPP after the actual acquisition.

Reach the information

Regarding the capability of the DPP's information to be reached, I draw the link to how the consumer accesses the DPP. In this regard, multiple possibilities are already developed in the context of the DPP concept (e.g., QR codes, RFID; see Bernier et al., 2023, p. 89). However, an additional study would be required to determine the best technical implementation, which is beyond the scope of this research.

Based on the issues identified in Information Deficit 3, it is generally concluded that it should be taken into account that nowadays, information is obtained in different offline and online contexts during the customer's acquisition process (**Requirement 9.**). This circumstance should be addressed in the development of the DPP.

This entails that the DPP information should be made accessible in the different settings a consumer has contact with the product and its information (**Requirement 9.1**). For instance, a DPP website for online shoppers or printouts and mobile access (e.g., through a QR-code) for offline shoppers can be considered.

Concerning the issue of the consumer being dependent on the information provided by the seller of a pre-owned mobile phone, it is concluded that the DPP information should also be shareable by the mobile phone owner with other actors through different means (**Requirements 9.2**). So, if a private person wants to resell their phone to another person or a business (e.g., a refurbisher), they should be able to share the information of their personal mobile phone's DPP. This is also important to allow an open market with private reselling as an alternative to commercial offerings. Nevertheless, it needs to be ensured that sharing the information of their owned device must not come with personal harm to the private phone seller (e.g., regarding privacy).

5.3.2 Use the Information

In the elaboration of Design Principle 3, the accessibility aspect of the DPP's information being capable of being used is related to the accessibility issues occurring over the mobile phone's use cycles.

The investigation of Information Deficit 3 (see Sub-Section 3.2.2) found that possible loss and unavailability of information occurs over the mobile phone's lifecycle. Hence, the DPP and its information should be accessible throughout the multiple use cycles of the mobile phone (**Requirement 10.**).

In more detail, there could be possible information losses because of product packaging and documents being removed from the mobile phone during its lifetime. That is why the DPP information should be accessible through a unique product identifier attached to the mobile phone (**Requirement 10.1**).
Furthermore, enabling accessibility could be particularly challenging when the DPP is deployed initially. When deploying the EU DPP, not only new phones should be of the advantage of having the additional DPP and its information. Thus, it needs to be ensured that the information is accessible for new and used mobile phones alike (**Requirement 10.2**). This means that mobile phones already being used can also get a DPP registered. However, I acknowledge that complete details or up-to-datedness of information may not be given in comparison to a mobile phone that is newly introduced to the market.

5.3.3 Initial Accessibility Requirements

The initial list of accessibility requirements is provided in Table 12.

Table 12: Initial list of accessibility requirements, grouped per information quality criteria

Accessibility Requirements		
be seen	8	The availability of **extended information with the DPP should be made visible** to the customer.
	8.1	The availability of extended information with the DPP should be **indicated on the product packaging**.
	8.2	The availability of extended information with the DPP should be **indicated with product's online advert**.
be reached	9.	The information should be **accessible in different contexts.**
	9.1	The information should be **accessible through different contact points** with the product.
	9.2	The information should be **sharable with people other than the mobile phone owner/user** without harming the mobile owner/user of the phone.
be used	10.	The information should be **accessible throughout the mobile-phone's lifecycle**
	10.1	The information should be **accessible through a unique product identifier attached to the mobile phone**.
	10.2	The information should be **accessible for new and used mobile phones** alike.

5.4 Answering Sub-Question 3

To recap, this chapter approached Sub-Question 3, namely:

What initial information requirements can be elicited based on the design principles, so that the EU DPP can address the potential information deficits of EU consumers?

To answer Sub-Question 3: An initial list of information requirements is elicited (see Table 13). They comprise requirements specifying how the DPP information provision should be designed to ensure relevance, soundness, and accessibility of the information, to address the identified information deficits of EU consumers.

For the research's outcome, this initial list of requirements serves as an initial draft specifying how the DPP should be designed under consideration of the research's context.

In the next chapter, this initial list of information requirements is evaluated to revise them based on expert feedback and thus enhance their utility for the practice and research. In addition, the evaluation can also mitigate possible limitations of desk research (e.g., bounded rationality, limited view).

Table 13: Initial list of information requirements

Relevance Requirements		
compre-hensive, applicable	1.	The DPP should **increase the perception of benefits**.
	1.1	The DPP should **provide circular design information**.
	1.1.1	The information should include **durability information**.
	1.1.2	The information should include **repairability information**.
	1.2	The DPP should **provide circular composition information**.
	1.3	The DPP should **provide environmental performance information**.
	2.	The DPP should **reduce the perception of risks**.
	2.1	The DPP should **provide technical performance information**.
	2.1.1	The information should include **battery performance information**.
	2.2	The DPP should **provide proof(s) of product's reliability**.
	2.2.1	The information should include **warranty information**.
	2.2.2	The information should include **quality certification information**.
	2.2.3	The information should include **proof of data removal**.
	2.2.4	The information should include **proof of software being malware-free**.
	2.2.5	The information should include **software update information**.
	3.	The DPP should **enable the viewing of product features**.
	3.1	The DPP should **provide information about product characteristics**.
	3.1.1	The information should include **product appearance information**.
Soundness Requirements		
consistent	4.	The DPP's data should be managed on **different granularity levels**.
	4.1	The data should be on **product level** granularity.
	4.2	The data should be relatable to **component level** data.
current	5.	The DPP's data should be **updated throughout the product's lifecycle**.
	5.1	The updated data should be accompanied by a **time stamp**.
	5.2	The data should be **updatable with each alteration of the product**.
	5.3	The data should be **updatable depending on the product's lifetime**.
	5.4	The data should be **updatable depending on data in the product's component inventory**.
	5.5	The data should be **updatable by the mobile phone itself**.
	5.6	The data should be **updatable when the mobile phone is processed in-between possession**
correct	6.	The DPP's data should be **provided by multiple actors** throughout the product's lifecycle.
	6.1	The data should **be able to be provided by private persons/owner**.
	6.2	The data should **be able to be provided by organizations**.
	6.3	The data provided by organizations should be accompanied by **organization's credentials**.
	7.	The DPP's data should be **accompanied by the standards** it is based on.
Accessibility Requirements		
be seen	8	The availability of **extended information with the DPP should be made visible** to the customer.
	8.1	The availability of extended information with the DPP should be **indicated on the product packaging**.
	8.2	The availability of extended information with the DPP should be **indicated with product's online advert**.
be reached	9.	The information should be **accessible in different contexts.**
	9.1	The information should be **accessible through different contact points** with the product.
	9.2	The information should be **sharable with people other than the mobile phone owner/user** without harming the mobile owner/user of the phone.
be used	10.	The information should be **accessible throughout the mobile-phone's lifecycle**
	10.1	The information should be **accessible through a unique product identifier attached to the mobile phone**.
	10.2	The information should be **accessible for new and used mobile phones** alike.

6. Evaluation & Revision

In this chapter, the elicited initial list of information requirements is revised after evaluation. Therefore, it is determined to what extent the initial information requirements can be used for practice and research or need to be revised to enhance their practice relevance.

The outcome of this chapter is a list of revised information requirements.

Thus, Sub-Question 4 is answered:

SQ4:	What revised information requirements result from the requirements' evaluation regarding their utility for the practice and research?

For the evaluation, expert interviews are conducted, and the expert's input is used to validate and revise the initial list of information requirements if needed.

In the first section, the applied method of expert interviews is elaborated. The second section presents the revision based on the expert's feedback. Finally, the answer to Sub-Question 4 is provided (see Section 6.3).

6.1 Method – Expert Interviews & Evaluation

In this section, the applied method of expert interviews is detailed. The interview inputs were used to evaluate and revise the initial information requirements and to gain a further understanding of potential implementation issues (see Chapter 7).

Regarding Sub-Question 4, the purpose of the evaluation is to evaluate the initial information requirements regarding their utility for the practice and research. This is whether the requirements address the consumer needs regarding the relevance, soundness, and accessibility of the information provided with the DPP. Thus, the information requirements can be used to develop an EU DPP (compliant with Knowledge Gap 1) that addresses consumers' identified information deficits.
For this purpose, the experts also evaluated the design principles as they are meant to transfer the information deficits into the information requirements. So, it could be proved whether the connection is properly made or relevant aspects for the information requirements are missing.

As a result of the interviews, the initial list of information requirements can be revised (see next section) to provide the outcome of this research.

Selection of experts

The required diverse and multinational consumer perspective is approached by interviewing consumer experts from different EU member states in the context of an EU-wide DPP deployment. In addition, interviewing multidisciplinary experts involved in the DPP development allows me to consider the results of this research in the context of the ongoing DPP research.

12 interviews were conducted with experts from EU consumer associations (n = 5) and research institutes (n = 7). The experts are selected based on their longtime expertise regarding the DPP or related policies, consumer needs (in the context of mobile phones), and familiarity with circular economy principles. The experts were approached via publicly available information. The overview of the interviewed experts is presented in Table D. 1 in Appendix D.

Furthermore, my selection of experts allowed a critical discussion of implementation issues from different perspectives. The experts have experience in assessing consumer-related policies and issues and/or researching the challenges and further development of the EU DPP in their profession.

I also acknowledge that the expert comments could be limited to their specific background, which is a drawback of the method (Johannesson & Perjons, 2021, pp. 148–149). I do not see this circumstance as a major drawback for the research findings because, on the one hand, the societal experts' specific consumer perspective is intended. Also, do

they work in different consumer-related areas. On the other hand, the DPP researchers provide a relatively diverse background. Thus, I consider the interviewees to represent an appropriate variety of relevant perspectives.

Interview procedure

The interviews were conducted in the period of 11/04 – 21/04/2023.

Before the interview, the experts were asked for their consent to participate in this thesis research and they received the interview material, incl. the background of the interview, the procedure, and the design principles and information requirements to be discussed. Moreover, if their time allowed, they could provide an initial evaluation (similar to the interview evaluation) and comments on the design principles and information requirements before the interview. This was meant to facilitate the interview procedure.

The interviews were conducted online, were recorded, and lasted around 30 - 60min. Because of the limited interview time, requirements are occasionally discussed per group instead of individually. However, experts had to state their opinion taking all single requirements into account. Some interviews were conducted in German instead of English to ensure informed consent and understanding of the material and questions (see experts overview in Table D. 1 in Appendix D).

During the interview, the requirements' appropriateness to address the consumers' information deficits were evaluated by asking the experts whether they approve the requirements and if they cover all essential aspects regarding relevance, soundness, and accessibility from their perspective. Also, the comprehensiveness of the requirements was asked to ensure that the requirements can be used for further DPP development.
The detailed interview protocol can be found in Appendix D.

The identified information deficits were not presented to the experts so that the experts' views would not be influenced. Thus, they could think about appropriate design principles that address information deficits they have in mind from their experience. In this way, possible limitations of the problem explication based on desk research could be addressed.

Based on the expert feedback, the design principles and information requirements could be revised if necessary.

6.2 Requirement Revision

This section elaborates on the revision of the design principles and information requirements. As a result, the final set of information requirements, and thus the answer to Sub-Question 4 can be provided in the following sub-section.

Revision Process

By conducting expert interviews, each design principle and information requirement is evaluated regarding:

- the comprehensiveness (Are the design principles and requirements clear and understandable?),
- completeness (Are there design principles or requirements missing?), and
- appropriateness (Are the design principles or requirements useful to address consumers' needs?).

The experts' evaluations and comments are systematically collected before and during the interviews. It is important to note that Expert 1 confirmed the design principles but saw themselves as not in a position to make a statement about the suitability of the information requirements for the consumer. Nevertheless, Expert 1 commented on the requirements in terms of implementation issues.

With argumentative judgment, based on this research's established knowledge and additional sources, I assessed each expert's comment on whether it should be adopted. Table 14 shows the revised list of design principles and information requirements, including an indication of what items were approves, adopted, or added compared to the initial list. Table C. 1 in Appendix C additionally provides information about by whom the design principles and information requirements were evaluated how. Also, the argumentation of how I incorporate the remarks in the revised requirement list is stated.

The revision table does not mention expert comments regarding possible challenges in implementing the requirements. These comments are discussed as part of the boundary conditions in the next chapter.

General conclusions from the evaluation

Based on the revision of the information requirements in discussion with the experts, general conclusions are drawn in the following.

First, while the information deficits were not evaluated, experts often addressed issues that I also found in the identification of information deficits. For instance, the issues of information overload or information's irrelevance (Information Deficit 1), or the necessity to consider information provision in both an online and an offline context (Information Deficit 3). Thus, the identified information deficits could be approved from the practice and research perspective.

Second, it shows that the defined design principles could cover the most essential aspects. The experts were asked whether they consider them appropriate to address consumers' information deficits. So, not explicitly regarding mobile phones (in line with their generic characteristic). Expert 6 stated that they see these principles as also applicable to other stakeholders. Consequently, I draw two conclusions in that respect. First, I assume that the defined design principles could also be applied to other products. Second, I conclude that my list of requirements is also more likely to be complete in addressing the consumer's possible information deficits because of the close link between the design principles and information requirements.

Third, the importance of clearly defined terms and requirement scope became apparent. This calls for standard definitions in the DPP development and a rigorous investigation of the consumer's behavior and needs in detail. It also links to the general finding that the principle of relevance can be essential for the requirements themselves. Based on the expert comments, assessing which requirements are most relevant is required. On the one hand, to satisfy the most crucial consumer needs and, on the other hand, to allow a proper DPP implementation.

Finally, I see that especially the requirements regarding information's relevance and soundness demand attention. The expert comments are not contradictory but call for a distinct scope and specification. For instance, Experts 3 and 7 propose further conducting consumer studies to get more detailed insights into the different information requirements. Furthermore, Expert 4 points out that the soundness requirements need to be defined for each information item. I agree on this, as my performed analysis for the requirement elicitation showed. However, in the scope of this thesis research, only a list of general information requirements is provided that are not information item-specific.

In addition, some experts, like Expert 2 regarding "warranty information", noticed that the list of relevance requirements does not only comprise commonly considered material information or circular economy indicator (e.g., the proportion of recycled material; see also product passport review by van Capelleveen et al., 2023). However, all experts from consumer associations confirmed the relevance of the considered requirements. I conclude that my approach of consulting influencing factors to elicit the relevance requirements is valid to derive the information that is relevant in the consumer acquisition process.

Table 14: Revised list of design principles and information requirements, including an indication of revision

Design Principles		**Revision** ✓ approved o adapted + added
1	**Relevance:** The DPP should provide relevant information to the consumer, that is comprehensive and applicable.	✓
2	**Soundness:** The DPP should provide information that is sound, thus based on consistent, current, and correct data.	✓
3	**Accessibility:** The DPP should ensure that the information can be seen, reached and used by the consumer throughout the different information contexts and the use cycles of a product.	✓
Relevance Requirements		
1.	The DPP should increase the **perception of circular characteristics**.	o
1.1	The DPP should **provide circular design information**.	✓
1.1.1	The information should include **durability information**.	✓
1.1.2	The information should include **repairability information**.	✓
1.1.2.1	The information should include an **indication of the difficulty of repair**.	+
1.1.2.2	The information should include **information about the availability of spare parts**.	+
1.2	The DPP should **provide circular composition information**.	✓
1.3	The DPP should **provide environmental performance information**.	✓
2.	The DPP should improve the **assessment of reliability assurance**.	o
2.1	The information should include **warranty information**.	✓
2.2	The information should include **quality certification information**.	✓
2.3	The information should include a statement about **how long software updates will be guaranteed**.	o
3.	The DPP should improve the **assessment of the product condition**.	o
3.1	The DPP should provide information about the **functionality of the product**.	o
3.1.1	The information should include **battery performance information**.	o
3.2	The DPP should provide information about the **product hardware condition**.	o
3.2.1	The information should include product **appearance information**.	o
3.3	The DPP should provide information about the **product software condition**.	+
3.3.1	The information should include a statement **whether the software is updated to the latest version**.	+
3.3.2	The information should include **proof of data removal**.	o
3.3.3	The information should include **proof of software being malware-free**.	o
4.	The DPP should ensure the **comprehensibility of provided information**.	+
5.	The DPP should ensure the **comparability of provided information**.	+
Soundness Requirements		
6.	The DPP's information should be managed on **different granularity levels**.	✓
6.1	The information should be provided on **item level**.	o
6.2	The information provided on an item level should be **relatable to data on a component level**.	o
7.	The DPP's information should be **updated throughout the product's lifecycle**.	✓
7.1	The updated information should be accompanied by a **time stamp**.	✓
7.2	The information should be **updatable with each alteration of the product**.	✓
7.3	The information should be **updatable depending on the product's lifetime**.	✓
7.4	The information should be **updatable depending on data changes on a component level**.	o
7.5	The information should be **updatable by the mobile phone itself**.	✓
7.6	The information should be **updatable when the mobile phone is processed in-between possession**	✓
8.	The DPP's data should be **provided by authorized actors throughout the product's lifecycle**.	o
8.1	The information should be **based on data provided by private persons/owner**.	o
8.2	The information should be **based on data provided by organizations**.	o
8.3	The data provided by organizations should be accompanied by **organization's credentials**.	✓
9.	The DPP's information provision should be **defined by standards.**	o
9.1	The provided **information** should be **based on standards**.	+
9.2	The **required data** for the information provision should be **defined by standards**.	+
Accessibility Requirements		
10	The availability of **extended information with the DPP should be made visible** to the customer.	✓
10.1	The availability of extended information with the DPP should be **presented saliently on the product packaging**.	o
10.2	The availability of extended information with the DPP should be **presented saliently with product's online advert**.	o
11.	The information should be **accessible in different contexts.**	✓
11.1	The information should be accessible **through consumers' most common information channels for product information.**	+
11.2	The information should be accessible **in online and offline** environments.	+
11.3	The information should be **sharable with people other than the mobile phone owner/user** without harming the mobile owner/user of the phone.	✓
12.	The information should be **accessible throughout the mobile-phone's lifecycle**	✓
12.1	The information should be **accessible through a unique product identifier attached to the mobile phone**.	✓
12.2	The information should be **accessible for new and used mobile phones** alike.	✓

6.3 Answering Sub-Question 4

To recap, this chapter approached Sub-Question 4, namely:

What revised information requirements result from the requirements' evaluation regarding their utility?

To answer Sub-Question 4: A revised list of information requirements (incl. design principles) has been created based on the expert feedback (see Table 18; in Conclusion Section 8.1).

For the research's outcome, the list of evaluated and revised information requirements represents the final outcome/artifact of my design research. Thus, the list and its design process can inform the answer to the main research question.

In the next chapter, to further generate knowledge for the DPP development, possible implementation issues are considered that could arise in implementing an EU DPP developed based on my information requirements. These implementation issues frame the boundary conditions that need to be in place so that the DPP can mitigate the consumer's information deficits.

7. Boundary Conditions

In this chapter, boundary conditions are investigated that can inform the implementation of an EU DPP developed based on my information requirements.

The outcome of this chapter is a structured overview of possible boundary conditions that should be considered in the EU DPP implementation process. This consideration also allows me to answer the main research question more nuancedly, considering the broader context besides the consumer focus.

Thus, Sub-Question 5 is answered:

SQ5:	How can boundary conditions inform the implementation of an EU DPP based on the elicited information requirements?

To identify the possible boundary conditions, additional expert comments were acquired during the requirements evaluation interviews. Finally, the expert comments are synthesized to provide structure and meaning for the research and development of the DPP implementation. To facilitate the understanding and usage of my findings, a framework is created that can inform research and development regarding the DPP implementation.

In the first section of this chapter, the Boundary Condition Framework is established as a tool to provide the conceptual overview of the identified boundary conditions. The boundary conditions are described by possible implementation issues addressed by the experts that could arise when implementing the information requirements.

In the second section, the experts' stated implementation issues associated with the identified boundary conditions are presented.

Finally, the answer to Sub-Question 5 is provided (see Section 7.3).

7.1 Boundary Condition Framework

This section establishes the Boundary Condition Framework, which helps structure the expert comments. Thus, it serves as a tool to provide an overview and inform the DPP implementation process.

First, the method used to obtain an additional understanding of boundary conditions and the procedure for creating the framework are presented. Next, the Boundary Condition Framework is described.

7.1.1 Method

As argued in the method section of the evaluation (see Sub-Section 2.2.4), it is necessary to obtain additional understanding about implementing the DPP in the research context to reduce potential uncertainties and risks.

Defining the term "boundary conditions"

I define boundary conditions as the conditions that determine whether the EU DPP developed based on my identified information requirements can actually mitigate consumers' information deficits. The DPP implementation needs to address the boundary conditions so that the elicited information requirements can establish an EU DPP with the desired value for consumers.

The boundary conditions can be identified by considering possible issues that can arise when implementing the elicited information requirements. Thus, implementation issues can describe what aspect need to be taken into account regarding the boundary conditions and outline how these aspects could affect the degree to which the EU DPP can contribute to the mitigation of the consumer's information deficits. Thus, these specific issues need to be considered before or during the implementation of the DPP to reduce unintended negative consequences of the DPP and increase its potential to mitigate consumers' information deficits.

Expert interviews

To this end, during the semi-structured evaluation interviews, the experts sometimes commented critically on the design principles' and information requirements' implementation. They were also asked at the end of the interview to consider potential implementation issues, challenges, or important aspects for implementing the requirements and the DPP in general (see also interview protocol in Appendix D).

Using the initial list of information requirements was done because of the practicality of doing both the evaluation and the discussion of implementation issues simultaneously. However, I do not see a major drawback because of this approach, as it can be noticed in the evaluation that primarily minor changes were made between the initial and the revised list of information requirements.

Clustering of implementation issues & boundary conditions

By reviewing the interview recordings, making comprehensive notes, and analyzing the notes, I logically clustered the expert comments into common themes: comments discussing the same aspect were grouped, and an appropriate name was assigned. As a result, 11 groups of implementation issues were found. The groups of implementation issues are elaborated in the following Section 7.2.

By further analyzing the expert comments, the grouped implementation issues that can describe a similar determining boundary condition were considered together. An appropriate name for the respective boundary condition was assigned afterward. As a result, four boundary conditions are defined:

Suitability of the DPP	The development process and the resulting DPP is suitable to serve the objectives (e.g., material consumption reduction) and address the consumer needs in the research's context.
Information Efficiency	The information and its provision to the consumer are most effective in serving the DPP objectives and addressing the consumer needs while using the least possible data.
Data Governance	The data for the DPP is governed in a way that supports the intended information provision (including, for instance, roles and rights or trust mechanisms), also considering the lifecycle of the DPP's data and the implementation of third-party applications.
Data Provision	The data and its governance required to serve the consumer needs are in accordance with the interests and capabilities of the data provider (including private persons if necessary) and incorporate standards ensuring information validity.

Table 15 provides an overview of the implementation issue groups, ordered by the boundary condition they belong. Moreover, which expert contributed to which group of implementation issues is presented.

As can be noticed, one group of implementation issues was not assigned to a particular boundary condition. Based on the expert feedback, the *Heterogeneity of Consumer Needs* can influence different boundary conditions and thus is a decisive factor, particularly for the first two boundary conditions (*Suitability of the DPP*, *Information Efficiency*).

Table 15: Overview of boundary conditions, related implementation issue groups, and the experts' contribution

Boundary Conditions	Implementation Issue Groups	Expert Contribution
	Heterogeneity of consumer needs	E3, E5, E8-E10, E12 (n = 6)
Suitability of DPP	Suitability of DPP as a solution	E1, E5, E8-E10 (n = 5)
	Process of DPP development	E1, E11, E12
Information Efficiency	Data efficiency	E2, E3, E5, E7, E8, E10, E12 (n = 7)
	Processing of data	E7, E8, E11, E12
Data Governance	Data governance in general	E1-E3
	Lifecycle of the DPP	E5, E10
	Third-party applications	E3
Data Provision	Consumer needs VS data provider interests/capabilities	E1-E3, E6, E7, E12 (n = 6)
	Data provision by private consumers	E1-E4, E6-E8, E10 (n = 8)
	Standardization & validity of information	E2-E5, E7-E12 (n = 10)

7.1.2 The Boundary Condition Framework

The groups of implementation issues are composed into a Boundary Condition Framework create structure and meaning from the experts' considered implementation issues. This framework also structures the elaboration of the experts' addressed implementation issues (see the following section), and it can facilitate further practical and scientific discussions regarding the DPP implementation.

Creating the framework

The created groups of implementation issues and their allocation to boundary conditions (see previous sub-section) build the basis for the framework.

In addition to this thematic clustering and providing structure, the boundary conditions are set in relation to create meaning for the DPP implementation. This is, suggesting how to approach the boundary condition procedurally in the DPP implementation. Therefore, it is determined which boundary condition one should consider before examining the other. The developed sequence is based on possible dependencies that can be found in the experts' implementation issues. For instance, the degree to which data privacy (data provision) is a concern would depend on which data or information is actually of the highest relevance (information efficiency).

Hence, one can first consider the definition of the actor's and society's needs (*Definition of Needs*). This implies, on the one hand, the establishment of the suitability of the DPP to address these needs. On the other hand, it also includes the assurance that the needs are satisfied with the provision of information most efficiently. An influencing factor to be dealt with is the heterogeneity of consumers and their needs.
Second, based on the knowledge about how the DPP can satisfy the needs by providing information efficiently, one could further develop the socio-technical DPP system (*Socio-technical System Development*). In particular, to enable the provision of information with the DPP, it is necessary to define the required data's governance and how it can be made available. As actors and institutions play a paramount role in that respect, besides the technical aspects, I highlight here the socio-technical perspective.

This process is also in line with principal systems design practices in which stakeholder needs are clarified first before system requirements are elicited (e.g., Dym et al., 2014).

Furthermore, the resulting framework also partly represents the chosen approach for this thesis research. It is so, starting from the actor's perspective to derive needs and then elicit the system requirements based on that. This contradicts the more technical approach of the EU DPP project "CIRPASS" (see Sub-Section 1.2.2), which was also noticed by Expert 3 during the interview.

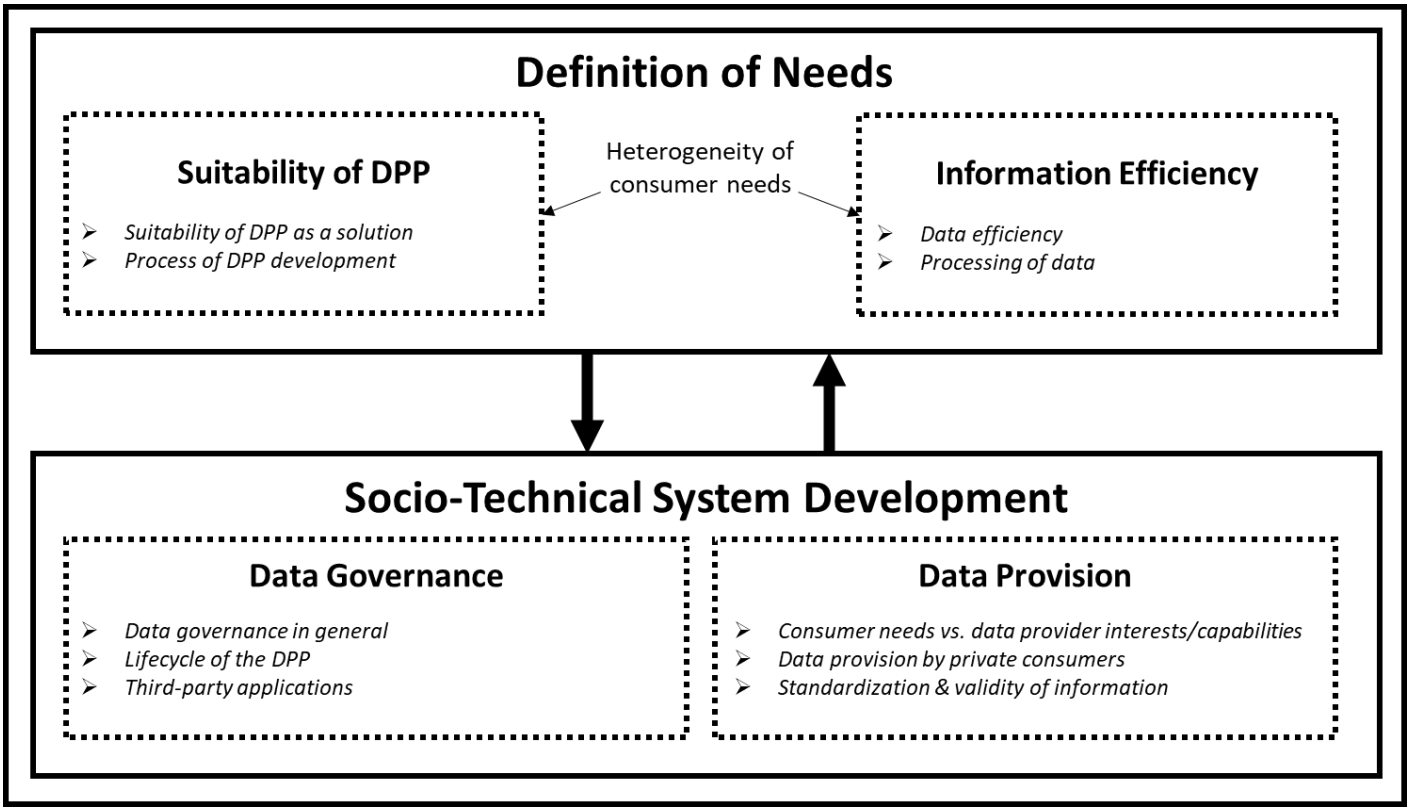


Figure 14: Boundary Condition Framework

Framework Description

The Boundary Condition Framework is presented in Figure 14.

The dashed line boxes show the identified boundary conditions. The Heterogeneity of Consumer Needs is stated as an influencing factor regarding the suitability of the DPP and the efficiency of its information.

The grouped themes of implementation issues, which the experts anticipated, are added for each boundary condition. These describe the boundary conditions in more detail.

Moreover, the process-oriented view is incorporated by mentioning the *Definition of Needs* at the top before the *Socio-Technical System Development*.

Although I illustrate the boundary conditions as individual aspects and in a procedural manner for the DPP development, I emphasize that the boundary conditions are highly interrelated and need to be considered iteratively. This can also be noticed when reviewing the expert comments in the following section. This is why, for instance, another arrow goes from the *Socio-technical System Development* back to the *Definition of Needs*. For instance, if the consumers require to have use phase information about the phone, but it cannot be implemented because of challenges in the data provision, the needs should be reassessed (e.g., Is the DPP suitable to serve this need?).

In the following section, the implementation issues stated by the experts are described in more detail.

7.2 Implementation Issues

In this section, the experts' specific comments on the implementation issues are summarized. The established Boundary Condition Framework structures these elaborations.

Thus, first, the influencing factor of the consumer's heterogeneity is addressed before each boundary condition is successfully discussed in the subsequent sub-sections.

To clarify once again, the boundary conditions are the basic conditions that should be created so that the elicited information requirements can realize their purpose in leading to an EU DPP that can mitigate consumers' information deficits in acquiring most circular mobile phones.

7.2.1 Influencing factor: Heterogeneity of consumer needs

One factor identified as determining the DPP's suitability as a solution and the definition of the required information is, in general, the heterogeneity of the consumers and their needs. In particular, as the DPP should be deployed across the EU.

Diversity of consumers and their needs

Experts 3 and 9 highlight that consumers are diverse (e.g., age, interest), which presents a challenge in providing information that suits the different consumer segments. Expert 3 suggests that segmentation research could be useful in understanding what drives different consumer segments. Lastly, Expert 10 suggested that while the circular composition and environmental performance may not be relevant to all consumers, it is probably important to pro-environmental consumers. In this respect, also Expert 8 assumes that the DPP will probably most benefit consumers that are already environmentally conscious.

Digital exclusion

Furthermore, concerning the consumers' heterogeneity, Experts 5, 8, 9, and 12 highlight that implementing DPP as a digital solution could exclude certain groups of people, such as those with low income or who are digitally excluded and have no access to digital tools or being handicapped in using them. So, Expert 5 sees the risk of the DPP impeding social justice. Expert 8 suggests that existing accessibility design standards should be considered so that the solution can be designed to be inclusive and accessible to everyone. In addition, Experts 9 and 12 also emphasize the importance of providing access to online and offline information, as offline options may better suit the needs of the digitally excluded. In this regard, Expert 8 points out that the DPP should not substitute existing offline information sources.

7.2.2 Suitability of DPP

Experts claim that, based on the detailed knowledge of what the particular actor needs (in this case: the consumer) and what is required from a societal point of view, the fundamental question of the DPP's suitability as a solution must be clarified.

Suitability of DPP as a solution

According to Expert 1, one has to ask whether the anticipated **added value of the DPP** is also what the consumer needs. Expert 1 saw the main benefit of the DPP in centralizing data given the multiplicity of actors involved in a product's life cycle. However, from Expert 1's point of view, the consumer only has direct contact with the seller at the moment of acquisition and is therefore not directly confronted with the mentioned multiplicity of actors. From the consumer's point of view, only the direct seller is responsible for delivering a reliable, trustworthy product. In contrast, Expert 1 stated that the DPP is thus likely to be of primary use to the sellers or business actors in the supply chain.

Furthermore, Expert 1 questioned whether the DPP is the **best solution to address the information deficits** of consumers and promote transparency. They pointed out that other information-related requirements are already defined in legislation, for instance, regarding software updates or product-specific information sharing in the health or automotive sector. Expert 1 said that the overall goal should be to help or nudge consumers toward the "right"

behavior, which is not necessarily achieved using a DPP. In this respect, Expert 8 raised the question of whether the DPP is how consumers want to receive or acquire their information.

Experts 5, 9, and 10 discussed, for instance, possible **industry standards** for eco-design or **policies regarding marketing** as an alternative or necessary supplement to providing (more) information. While Expert 5 assumed that consumers mainly care about the functioning of pre-owned products instead of comparing all information, Expert 9 also found using industry standards necessary, as not all responsibility can be placed on consumers and their actions. In addition, Expert 5 also argued in favor of promoting eco-design and other industry standards because of the challenges they see regarding information efficiency (see the following boundary condition). Finally, Expert 10 argued that even if the DPP is used, it must be ensured that the phones are repairable anyways, for example. Here, I also draw the link to the next sub-section of "Information Efficiency", as some of my information requirements could become obsolete with changes in industry standards.

Expert 1 identified the **broad definition** of the circular economy concept as one possible reason that leads to the general assumption that the DPP can add value to the transition. In that regard, Expert 5 emphasized the need for the DPP to promote the highest CE strategies to create the anticipated benefits.

Process of DPP development

With reference to Experts 1 and 11, an essential factor that influences the suitability is the governance of the DPP development. Expert 1 required to discuss boundary conditions from different viewpoints (e.g., law, business) instead of only from the dominant technical perspective in the DPP development.

In particular, from a consumer perspective, Expert 11 raised concerns about the current definition of DPP, which they see primarily being done with the involvement of industry consortia and not NGOs, which may lead to the interests of the industry being prioritized over those of the consumers. They feared the risk that information may be withheld (also seen by Expert 12) or even the DPP infrastructure will be managed by the private sector instead of EU institutions, leading to one-sided interests.

Following this, Expert 1 noted that due to the diversity of products and actors involved, the current approach is to examine each product's requirements. However, they see a risk of bureaucratic overload and the creation of silos, which contradicts the ambition of a cross-sectoral DPP. Thus, Expert 1 questioned the extent to which regulations should regulate the DPP and suggested that more flexible governance may be necessary.

7.2.3 Information Efficiency

To ensure that the needs of consumers and society are addressed and that adverse effects are limited, Expert 5 saw the implementation of the principle of "data efficiency" as an essential boundary condition for developing the DPP. Also, Expert 7 saw the consideration of this principle as a prerequisite for the development and implementation of the DPP. Due to the consumer perspective and focus on information rather than data, I use the term "information efficiency" here. However, I assume that these two terms are closely related. Furthermore, I note that many other experts mention implementation issues that fall under the principle mentioned by Expert 5.

Data efficiency

Expert 5 described data efficiency from a data science perspective with the aim of **having the most beneficial information with the usage of the least data**. Applied to this research's context, that would mean providing consumers just the information they need to make their choice towards a most circular mobile phone consumption while minimizing the data obtained, processed, and stored for that purpose.

Expert 5 introduced this principle because they disagreed with the assumption they often note in (scientific) reports and legislation that is having more data or information would always result in benefits. They found that there are at least two counterarguments:

1. More data can lead to an information overload for consumers, making it challenging to make use of the information (also mentioned by Experts 3, 7, 8, and 12), and
2. The environmental and climate impact of all the data collection, e.g., through energy consumption, is not considered so far.

Experts 5 and 10 brought the **example** of providing "use history" information that they doubted to be of actual value to the consumer, who, in their view, rather have an interest in the current condition of the phone at the point of sale. However, providing a "use history" would require collecting and storing many multiplying pieces of information, and also Expert 12 saw many challenges in that respect (e.g., privacy concerns). Expert 12, moreover, saw the presentation of basic product features in the DPP (referring to requirement 3., initial requirement list), which are generally not changed, as unnecessary, since consumers already obtain these from other sources when they decide in principle on a specific mobile phone model. Finally, the expert mentioned the fundamental discussion on whether the DPP should be a tool for centralizing data/information.

Hence, Experts 2, 3, 5, 7, and 8 emphasized the need to prioritize or rank and **focus on the most relevant information**. In particular, Expert 3 expected that more data than the consumer needs would be collected anyways, for instance, for other actors in the product's value chain.

Expert 7 required to rigorously assess my elicited information requirements regarding whether they are actually most relevant. In particular, because they feared that every extra piece of information and associated data could create a so-called "data graveyard"[13] with overbearing administrative efforts, particularly for small and medium-sized enterprises (SME) and upcoming circular business models. In the worst case, as Expert 7 imagined, this could even make circular business models economically less attractive and result, for instance, in increased repair costs (due to the additional administrative efforts). They also thought that any additional information would reduce consumer comprehension. Thus, Expert 7 proposed to combine some information that I now stated individually in my information requirements, for instance, the ones that could be combined in a quality certificate (e.g., requirements under Requirement 3. of my final requirement list).

Expert 10 concluded that information efficiency generally requires the discussion of the possible conflict between promoting transparency and avoiding information overload. Expert 12 suggested that labels could help as a tool to promote information efficiency, also regarding how to make the presentation of information most efficient.

In addition, the aspect pointed out by Expert 4 is interesting in this discussion. They posed the question of whether the relevance of the information is context-dependent; for instance, there may be different requirements regarding a new phone as opposed to a used phone. I also found this aspect regarding Information Deficit 1.

Processing of data

Concerning the last statement by Expert 12, I found the determination of how the data should be processed as closely related to information efficiency. For instance, Experts 7 and 11 demanded the definition of how the data is prepared and presented to the consumer, emphasizing accessibility and comprehensibility, thus, user-friendliness. Furthermore, based on Experts 8 and 12's comments, everyone should easily understand the information, regardless of their knowledge. It should be standardized to allow for comparison between mobile phones. In this respect, Expert 12 stated that using best practices, like the already introduced EU Energy Labels, could be an example of DPP development.

Hence, besides the type of information, it needs to be defined how the information should be presented to the consumer to be of use and inform the necessary data processing.

[13] "Data Graveyards are places where well-intentioned and meticulously collected information "go to die". They serve as large repositories of unused data." (stated in Open Data Watch, 2022; based on Cluster & Sethi, 2017)

7.2.4 Data Governance

Data governance in general

Often experts made comments closely related to data governance as they see its relevance in developing the DPP. In particular, Expert 1 raised the issue of determining who should carry out the data processing, if it should be within the EU DPP itself and for whom, as different users may require different information. On the other hand, Expert 2, in general, emphasized the importance of ensuring the soundness of information, which is closely related to data governance, including the management of data, rights, and access. In addition, Expert 3 discussed the need to ensure that the "right" actors provide the information and highlighted the importance of roles and authorizations for data entry, as well as the trustworthiness, traceability, and accountability of data sources. Thus, the experts identified the relevance of also considering rather social aspects of the DPP development, encompassing the actors' management regarding the required data and information and setting associated rules.

Lifecycle of the DPP

Besides the mainly discussed required governance of setting up and maintaining the DPP, Expert 10 also highlighted that one needs to consider the "end-of-life" aspect of the DPP, which means the definition of what happens with the item-related DPP if the phone is not used anymore, because of end-of-life or special occasions (e.g., the phone gets crushed). Expert 5 also saw the link to data efficiency concerning this discussion, as storing information about mobile phones that are just lying in the drawer would cause a lot of unnecessary resource consumption.

Third-party applications

In the context of data governance, Expert 3 addressed the implementation of third-party applications/services built upon the basic DPP, which was not the focus of this thesis research but could become relevant as the EU Eco-design Directive anticipates it and if the consumer needs require them. Expert 3 identified the issue that data governance could become increasingly complex as more and more actors would seek access to data over time. As the ecosystem expands with more actors, the governance challenge will increase if the third-party service providers demand access that may not be mandated in the DPP agreements/regulations from the beginning. This could lead to issues with getting permission to access data and other information or with actors wanting access beyond what is defined in initial legislative directives. Regarding this issue, I draw the link to the comment by Expert 1 in the context of the DPP's suitability, calling for a flexible governance arrangement.

7.2.5 Data Provision

Closely related to data governance is the boundary condition of data provision. Based on the experts' comments, the issue in this context is not so much who can provide the data that meets consumers' information needs but whether the data providers are actually able to provide the data in the required quality. Thus, the experts saw three implementation issues, the solution of which is a boundary condition for the implementation of the DPP, namely:

1. consumer needs conflicting with the data provider's interests/capabilities,
2. challenges regarding the information provision by consumers themselves during the usage phase, and
3. challenges in the standardization and validity assurance of the data and information.

Consumer needs VS data provider interests/capabilities

For instance, Experts 1 and 3 stressed the need to **balance consumers' interests and data providers' rights** (e.g., manufacturers and vendors). According to Expert 1, this balancing exercise could be based on case law, but the reasoning for interference with actors' rights needs to be elaborated first. However, Expert 1 expected the information that consumers need to be less problematic as it is already processed and aggregated. However, data providers' legal situation, rights, and freedoms need to be assessed against property rights such as intellectual property rights and trade secrets. Expert 12, for instance, already recognized manufacturers' resistance in DPP-related discussions regarding data provision.

From a business perspective, Experts 2, 6, and 7 highlighted the difficulty of **obtaining data from various companies of different sizes** (e.g., SMEs). According to Expert 6, this is particularly challenging in the electronics industry, where

many companies may not have an overview of their suppliers. Expert 2 worried about possible extra costs and bureaucratic effort that may arise from implementing DPP and could make circular business models economically unattractive. They mentioned this aspect in particular in the context of verifying that the mobile phone is software-clean and malware-free, which they say is difficult to do in practice and likely requires third-party verification. Thus, Expert 2 stated that consumer benefits need to be weighed against the costs for businesses.

For Expert 2, this also raised the question of whether the DPP should be implemented for mobile phones already in circulation when the DPP is first introduced or only for mobile phones that will be newly put on the European market from then on. Expert 6, on the other hand, suggested the usage of existing data first, starting with the voluntary provision and stepwise extending the scope of data provision and mandatory obligations.

Data provision by private consumers

One more specific challenge regarding data provision that the experts identified is the provision of data and information by consumers themselves during the usage phase or if they want to share information with the (potential) subsequent mobile phone owner. These comments are, for example, linked to the information requirements 8.1 and 11.3 (final requirement list) and the necessity of consumers, for instance, to provide information about what parts they have repaired or replaced. This aspect is particularly relevant when introducing the EU's "right to repair" for consumers (see European Parliament, 2022a).

Expert 7 pointed out that the entity putting the product on the market usually has **legal responsibility and accountability** regarding the quality of the product and related information. However, there are differences between commercial and private sellers. In contrast to commercial sellers, for instance, private sellers are not obliged to give a legal warranty, and private sales are a less regulated grey area in law. Hence, Expert 7 concluded and suggested that only legally accountable actors should have access to change master data, which would limit consumers changing rights to just providing additional voluntary information.

In this respect, Expert 1 thought that requiring information provided by the consumer could actually create an additional role for the consumer within the product's value chain, the **role of a data gatekeeper**. On the one hand, consumers are information demanders at the point of sale. On the other hand, they can influence the information flow in the after-use market by granting access to their products' information, for instance, to the refurbisher. As a result, Expert 1 assumed that the consumer would get an active role in transmitting information from one actor to the other within the market, contributing to one of the DPP's functions, namely, opening up the data economy. Expert 1 stated that manufacturers currently have the most data about the products and thus can decide with whom, like dependent repair shops, they want to share the information for the after-market. Moreover, they mention the close link to competition law. Nevertheless, they see the necessity to discuss whether the consumer should be put into this active role with responsibilities or at least that the different roles of the consumers need a clear framework.

What Experts 2, 3, 4, 6, 8, and 10 saw in general as critical regarding information provision and sharing by private consumers are possible **privacy concerns**. Experts 2, 3, and 6 required that the data provision should comply with existing law and be voluntary. In this respect, Expert 3 mentioned online second-hand marketplaces or reviewing sites in which voluntary information provision by private persons is already standard. Expert 6 also emphasized that the voluntary provision of information in this context should not affect the private person's ability to participate in the market. In addition, Expert 6 warned that the DPP must not become a digital consumer passport but that the focus must be solely on information about the product. Thus, the sharing of personal data must be limited. Experts 4 and 10 referred to information requirement 7.5 (final requirement list), regarding data provision by the mobile phone itself, in this discussion about privacy concerns. They required to consider data privacy in that respect as well.

Standardization & validity of information

Finally, experts see the challenge in standardization and validity assurance of the provided data and information. Based on the experts, these aspects are crucial to ensure the trustworthiness, reliability, and comparability of the information provided to the consumer. Experts 3, 8, and 11 also mentioned this aspect to be closely linked to the issue of data/information provision by private persons. They saw the **challenge of ensuring the data's reliability** if private consumers have the (voluntary) responsibility to provide data. Expert 11 suggested that the consumer should be supported as much as possible by technical means (e.g., the data collection by the phone itself) to improve reliability.

Furthermore, Expert 3 saws it difficult to ensure that the data can be trusted and is not tampered with, and consequently imagines that, in theory, one would also require private persons to be authorized and authenticated when providing information to the DPP. However, they acknowledge that this would be very difficult in practice regarding limited accountability of private persons and personal information sharing.

Experts 2, 5, 7, 8, and 10 called for the **standardization** of data collection, verification, and reporting. However, Experts 2 and 5 assumed data processing and information provision standardization to be complicated. In particular, in a manner that comparability between products can be guaranteed. However, Expert 8 claimed that defining how the information is processed and presented to the consumer is essential so that this decision is not left to commercial parties, which can have conflicting interests. Expert 10 even saw standardization as a prerequisite before the further development of DPP is possible. Expert 7, moreover, called for standardization on an EU level but also stated that this will already be the case for the information technology infrastructure and the DPP's information content. They highlighted, in addition, that how the data is entered is essential to be standardized.

Regarding **comparability**, Expert 5 brought the example of the challenge to provide reliable and comparable environmental performance data and information and also prove compliance with "anti-greenwashing regulations" (see, for instance, European Commission & Directorate-General for Justice and Consumers, 2022). They mentioned that the lifecycle assessment (LCA) methodology is commonly used nowadays. However, it provides much freedom in making assumptions and contextual choices, even though it is officially standardized. Thus, they demanded to have appropriate methods first, if actually possible. Furthermore, Expert 9 brought the example of providing reliable and legally binding durability information as particularly difficult. Nevertheless, Expert 8 emphasized that the comparability of the information is of high importance for the consumer, and Expert 11 stressed the importance of standardization to avoid greenwashing and false labelling.

Concerning **validity**, the experts saw different challenges. On the one hand, experts 4 and 7 raised concerns about the possibility of provided data being manipulated, for instance, in the case where mobile phones would transfer data themselves. On the other hand, Experts 9 and 10 required that the objectivity of the data is safeguarded. Expert 9 emphasized the need for data from independent sources as much as possible. Expert 10 saw this challenge also closely linked to the difficulty of ensuring product comparability. They mentioned as an example the complexity of obtaining objective and comparable battery performance information, as there are multiple possibilities to describe and manage the battery's performance. Nevertheless, Expert 10 argued that the data needs to be as objective as possible to make the data or resulting information (e.g., label) applicable. Experts 11 and 12 identified in that respect the need to make the classification of the mobile phone's outer appearance (information requirement 3.2.1, final requirement list) as objective and standardized as possible.

7.3 Answering Sub-Question 5

To recap, this chapter approached Sub-Question 5, namely:

How can boundary conditions inform the implementation of an EU DPP based on the elicited information requirements?

To answer Sub-Question 5: Four boundary conditions (*Suitability of DPP*, *Information Efficiency*, *Data Governance*, and *Data Provision*) could be identified based on the experts' comments on possible implementation issues regarding an EU DPP developed based on my elicited information requirements. In addition, it is found that the heterogeneity of consumer needs can generally influence the definition of needs. A Boundary Condition Framework is created to provide structure and a procedure for the implementation. Consequently, the framework can be used for further research or practice to develop and implement the EU DPP.

For the research's outcome, the identified boundary conditions can serve to consider the information requirements, which are elicited from a consumer perspective only, from a more contextual view. This is, when answering the main research question, one has to take these boundary conditions into account. Moreover, the framework can inform the implementation of an EU DPP based on my information requirements.

In the next chapter, the final conclusion regarding the main research question is provided.

8. Conclusion

In this chapter, the answer to the main research question is presented based on the findings made through the research process.

Furthermore, the contribution of my research is pointed out, the limitations of the research are addressed, and avenues for further research are provided. Finally, recommendations for the DPP implementation are given.

8.1 Answer to the Main Research Question

The main objective of this research is to elicit information requirements for an EU Digital Product Passport (DPP) that addresses the information deficits of EU consumers, hindering them from acquiring the most circular mobile phone alternative. Furthermore, these information requirements are meant to inform the emerging research and ongoing development regarding the novel concept of the EU DPP.

Therefore, being the first research to investigate EU DPP information requirements from a consumer perspective and in the electronics sector, the aspiration is to lay the foundation for further research and development.

In order to elicit the information requirements, a rigorous Design Science Research (DSR) approach was applied, including five main research steps:

1. Identification of Information Deficits
2. Definition of Design Principles
3. Elicitation of Information Requirements
4. Evaluation & Revision of the Information Requirements
5. Informing the implementation of an EU DPP

The five guiding sub-questions, associated with each one of the research steps respectively, are discussed in the following. Answering these sub-questions is meant to draw a general conclusion to the main research question.

Sub-Question 1

SQ1:	What are potential information deficits in the EU consumer's acquisition process of most circular mobile phone alternatives, that could be addressed by the EU DPP?

To better understand how the EU DPP could support the consumer in their decision-making process towards acquiring a (most) circular mobile phone alternative, their problem of information deficits is explicated. For this purpose, a systematic decision analysis based on Davis (1982, p. 17) is applied to determine how information is used in the consumer's acquisition process and analyze how potential information deficits could arise in this context. The analysis was based on scientific literature and related legislative texts.

First, the consumer acquisition process is conceptualized with the *Engel-Kollat-Blackwell (EKB) Model* by Engel et al. (1990), and it is found that product information provided with the DPP is most relevant in their **search and evaluation** of acquisition alternatives. In particular, the consumer's information processing was found to be decisive in whether the consumer uses the information for their decision-making, and the DPP could thereby assist regarding the **exposure and acceptance of information**.

Regarding this outlined process of consumer information usage in the acquisition process, information deficits were defined as *the mismatch between the product information a consumer needs to identify and evaluate mobile phone alternatives for choosing the most circular one and the information the consumer actually gets provided.*

Second, considering the DPP's anticipated use for the exposure and acceptance of product information, **three potential information deficits** from the consumer perspective were elaborated (the first two regarding acceptance, the third regarding exposure). Finally, the information deficits to be resolved by the EU DPP, and thus addressed by the information requirements, are presented with the main findings in Table 16.

Table 16: Overview of identified information deficits

Information Deficits		
Information Deficit 1: The amount and/or type of information provided may not match the consumers' needs regarding evaluation criteria for their choice of the (most) circular mobile phone alternatives.	**Information Deficit 2:** The information provided may not be reliable (e.g., comparable, trustworthy) over the mobile phone's lifecycle to be considered in the consumer's evaluation of acquisition alternatives.	**Information Deficit 3:** The information provided in different contexts and over the mobile phone's lifecycle may not be accessible for consumer's identification of acquisition alternatives and product information.
Affects the consumer's **acceptance** of information due to • *A discrepancy regarding the amount of information* • *A discrepancy in information's utility*	Affects the consumer's **acceptance** of information due to • *A discrepancy in comparability of information* • *A discrepancy in trustworthiness of information*	Affects the consumer's **exposure to** information due to • *A discrepancy of accessible information in different contexts* • *A discrepancy of accessible information over use cycles*

In conclusion, three information deficits are identified regarding the exposure and acceptance of product information in the consumer's acquisition of most circular mobile phone alternatives. These information deficits should be addressed with the EU DPP, based on its added value expected by the European Commission (2022c, pp. 584–588).

Sub-Question 2

SQ2:	What are the design principles ensuring that the elicited information requirements address the potential information deficits of EU consumers?

Design principles are established to elicit information requirements defining an EU DPP that addresses the identified information deficits. For this purpose, scientific literature was systematically reviewed for their rigorous identification and definition.

I see design principles as the means to link the needs from practice (mitigation of the information deficits) with the requirement. In order to identify and define design principles that can make this link, I established the information deficits as **information quality problems**. This is, the DPP's information provision needs to be of quality – or fulfilling consumers' needs and expectations – to effectively mitigate the information deficits.

Moreover, to ensure that the design principles, and thus the information requirements, incorporate the consumer perspective, the notion of ***information* is differentiated from *data***. This is, while *data* is a formalized object being meaningless in its "raw" nature, *information* is the meaning a person attaches to it.

Hence, the usage of the Information Quality Framework by Eppler (2006) (incl. information quality criteria) was argued to be appropriate for defining the design principles, taking the elaborated foundations into account.

To define the design principles, this framework's **information quality categories and criteria** that best reflect the identified information deficits were chosen respectively. As a result, **three design principles, namely relevance, soundness, and accessibility**, were established. Each one represents one information deficit. Table 17 presents the design principle and their definition(s). Moreover, it shows how they create the link between the information deficits and the requirement elicitation.

Table 17: Link between Information Deficits, Design Principles, and the Requirement Elicitation

Information Deficits	**Design Principles** (incl. definition of related quality criteria by Eppler (2006))	**Incorporation in Information Requirement Elicitation**
Information Deficit 1	**Design Principle 1: Relevance** The DPP should provide relevant information to the consumer that is comprehensive and applicable.	**Relevance Requirements**
Discrepancy regarding the amount of information	*Comprehensiveness:* The quality of information to cover a topic to a degree or scope that is satisfactory to the information user.	Consideration of the right scope of information in the DPP.
Discrepancy in information's utility	*Applicability:* The characteristic of information to be directly useful for a given context, information that is organized for action.	Consideration of information that is actionable. This is, acquiring factors that influence consumers in their decision-making for circular alternatives and derive the information requirements from there.
Information Deficit 2	**Design Principle 2: Soundness** The DPP should provide information that is sound, thus based on consistent, current, and correct data.	**Soundness Requirements**
Discrepancy in comparability of information	*Consistency:* The condition of adhering together, the ability to be asserted together without contradiction.	Considering the granularity of information and data management, so that the information is consistent within the DPP and between products, and thus comparable.
	Currency: The quality or state of information of being up-to-date or not outdated.	Considering the events of when the data needs to be updated, so that the information are up-to-date and comparable amongst each other.
Discrepancy in trustworthiness of information	*Correctness:* Conforming to an approved or conventional standard, conforming to or agreeing with fact, logic, or known truth.	Considering which actors, with or without credentials have to provide the data, so that the information with the DPP are always correct, thus trustworthy, regarding the current state of the mobile phone. Additionally, considering standardization of data acquisition and information provision
Information Deficit 3	**Design Principle 3: Accessibility** The DPP should ensure that the information can be seen, reached, and used by the consumer throughout the different information contexts and the use cycles of a product.	**Accessibility Requirements**
Discrepancy of accessible information in different contexts	*Accessibility:* Capable of being reached, capable of being used or seen.	Considering requirements that ensure that the DPP and its information can *be seen* in the different contexts.
		Considering requirements that ensure that the DPP and its information can *be reached* in the different contexts.
Discrepancy of accessible information over use cycles		Considering requirements that ensure that the DPP and its information can *be used* regardless of the mobile phones use cycle.

In conclusion, three design principles (*relevance*, *soundness*, *accessibility*), representing each information deficit respectively, guide the information requirement elicitation process by incorporating information quality categories/criteria from a consumer perspective. In this way, it is promoted that the information and its provision with the DPP are of quality and thus address the information deficits.

Sub-Question 3

SQ3:	What initial information requirements can be elicited based on the design principles, so that the EU DPP can address the potential information deficits of EU consumers?

The defined design principles are applied to structure and guide the requirement elicitation process. Hence, requirements regarding *relevance* (Design Principle 1), *soundness* (Design Principle 2), and *accessibility* (Design Principle 3) of information are elicited.

The **initial list of information requirements** can be found in Section 5.4.

According to Design Principle 1, the information provided with the DPP should be **relevant, meaning comprehensive and applicable,** so that the consumer has the needed amount and type of information to evaluate alternatives. Consequently, a systematic literature review of empirical scientific studies was performed to identify factors influencing consumers' decision-making regarding circular mobile phone alternatives (applicability). **Product information-related influencing factors** were selected from a complete list of factors different in nature (e.g., marketing), which could be addressed with the EU DPP (comprehensiveness). From these factors, relevant information requirements were elicited and organized in a **three-level breakdown structure**. Hence, the breakdown structure can inform further research with different purposes. For instance, while the highest-level requirements could be used for other products, the lowest-level requirements could inform the EU DPP development for this research's context.

According to Design Principle 2, the information and data provided with the DPP should be **sound, meaning consistent, current, and correct,** so that the consumer can compare and trust the product information in their evaluation of alternatives. The requirements regarding sound information were elicited by analyzing the identified information items and groups from the relevance requirements. Defining the granularity level of information and data management (consistency) and the updating of the data in the DPP (currency), the elicited requirements ensure that the consumer has comparable information. Moreover, analyzing which actors need to provide data and the standardization of data acquisition and information provision (correctness), requirements are elicited that can contribute to building trust in the provided product information.

According to Design Principle 3, the information provided with the DPP should be **accessible, meaning being capable of being seen, reached, and used,** so that the consumer is aware of and can access the needed information no matter their information or acquisition channel used (be seen, be reached), or of the use cycle of the mobile phone (be used). Therefore, considering the three accessibility aspects, the circumstances described for Information Deficit 3 were examined, and appropriate information requirements were elicited.

In conclusion, 42 initial information requirements are elicited, using the design principles and related information quality criteria as a guideline in the process. Thus, an EU DPP developed with these requirements could address the potential information deficit of consumers by promoting the relevance, soundness, and accessibility of product information in the acquisition process of (circular) mobile phones.

Sub-Question 4

SQ4:	What revised information requirements result from the requirements' evaluation regarding their utility for the practice and research?

Interviews with experts from consumer policy/advocacy and DPP research were performed to evaluate and revise the initial list of information requirements. First, experts evaluating the requirements' **comprehensiveness, completeness, and appropriateness** assessed their utility for practice and research. This is whether the requirements cover all the essential aspects relevant to consumers and are understandable to inform further DPP development. In addition, the design principles were evaluated in the same procedure to examine the foundations of the requirement elicitation and see if the link to the information deficits was adequately made. Based on the expert evaluation and feedback, the initial list of information requirements was revised according to argumentative judgment. The **revised list of information requirements** is presented in Table 18 (incl. the design principles).

Most remarks regarding the requirements formulation, specificity, and structure were made. Especially regarding the relevance and soundness requirements, the expert pointed out that precise specifications are required. This further specification could be made based on the expert feedback for some initial requirements.

In addition, the experts also **stressed issues similar to my identified information deficits** and approved the **design principles to be complete and appropriate for general purposes**. Consequently, the foundations of the elicited requirements are valid, based on expert feedback.
In conclusion, 50 evaluated and revised information requirements are provided for further EU DPP research and development. In addition, the experts confirmed the utility of the requirements for practice and research, as they saw issues for the consumer similar to my identified information deficits and approved the design principles to be appropriate to translate these issues into the information requirements.

Sub-Question 5

SQ5:	How can boundary conditions inform the implementation of an EU DPP based on the elicited information requirements?

In addition to eliciting the information requirements, I identified the **boundary conditions** that determine the implementation of an EU DPP developed based on my identified information requirements that should mitigate consumers' information deficits. These boundary conditions are described by **implementation issues** regarding the information requirements.

Additional expert comments on implementation issues were gathered while evaluating the initial design principles and information requirements. To better inform the implementation of the EU DPP, the expert comments are analysed, clustered, and composed into a **Boundary Condition Framework**.

The framework comprises **four boundary conditions**: **Suitability of the DPP, Information Efficiency, Data Governance, and Data Provision**. In addition, the **Heterogeneity of Consumer Needs** is a decisive factor, particularly for determining the DPP's suitability and defining information efficiency. Based on the expert's feedback, these aspects should be considered in the research and development regarding the implementation of the EU DPP.

In conclusion, to what extent an EU DPP developed based on the revised information requirements can actually mitigate consumer's information deficits is determined by the four identified boundary conditions, which are partly dependent on the heterogeneity of consumer needs.

Table 18: Revised list of design principles and information requirements

Design Principles	
1	**Relevance:** The DPP should provide relevant information to the consumer, that is comprehensive and applicable.
2	**Soundness:** The DPP should provide information that is sound, thus based on consistent, current, and correct data.
3	**Accessibility:** The DPP should ensure that the information can be seen, reached and used by the consumer throughout the different information contexts and the use cycles of a product.
Relevance Requirements	
1.	The DPP should increase the **perception of circular characteristics**.
1.1	The DPP should **provide circular design information**.
1.1.1	The information should include **durability information**.
1.1.2	The information should include **repairability information**.
1.1.2.1	The information should include an **indication of the difficulty of repair**.
1.1.2.2	The information should include **information about the availability of spare parts**.
1.2	The DPP should **provide circular composition information**.
1.3	The DPP should **provide environmental performance information**.
2.	The DPP should improve the **assessment of reliability assurance**.
2.1	The information should include **warranty information**.
2.2	The information should include **quality certification information**.
2.3	The information should include a statement about **how long software updates will be guaranteed**.
3.	The DPP should improve the **assessment of the product condition**.
3.1	The DPP should provide information about the **functionality of the product**.
3.1.1	The information should include **battery performance information**.
3.2	The DPP should provide information about the **product hardware condition**.
3.2.1	The information should include product **appearance information**.
3.3	The DPP should provide information about the **product software condition**.
3.3.1	The information should include a statement **whether the software is updated to the latest version**.
3.3.2	The information should include **proof of data removal**.
3.3.3	The information should include **proof of software being malware-free**.
4.	The DPP should ensure the **comprehensibility of provided information**.
5.	The DPP should ensure the **comparability of provided information**.
Soundness Requirements	
6.	The DPP's information should be managed on **different granularity levels**.
6.1	The information should be provided on **item level**.
6.2	The information provided on an item level should be **relatable to data on a component level**.
7.	The DPP's information should be **updated throughout the product's lifecycle**.
7.1	The updated information should be accompanied by a **time stamp**.
7.2	The information should be **updatable with each alteration of the product**.
7.3	The information should be **updatable depending on the product's lifetime**.
7.4	The information should be **updatable depending on data changes on a component level**.
7.5	The information should be **updatable by the mobile phone itself**.
7.6	The information should be **updatable when the mobile phone is processed in-between possession**
8.	The DPP's data should be **provided by authorized actors throughout the product's lifecycle**.
8.1	The information should be **based on data provided by private persons/owner**.
8.2	The information should be **based on data provided by organizations**.
8.3	The data provided by organizations should be accompanied by **organization's credentials**.
9.	The DPP's information provision should be **defined by standards.**
9.1	The provided **information** should be **based on standards**.
9.2	The **required data** for the information provision should be **defined by standards**.
Accessibility Requirements	
10	The availability of **extended information with the DPP should be made visible** to the customer.
10.1	The availability of extended information with the DPP should be **presented saliently on the product packaging**.
10.2	The availability of extended information with the DPP should be **presented saliently with product's online advert**.
11.	The information should be **accessible in different contexts.**
11.1	The information should be accessible **through consumers' most common information channels for product information.**
11.2	The information should be accessible **in online and offline** environments.
11.3	The information should be **sharable with people other than the mobile phone owner/user** without harming the mobile owner/user of the phone.
12.	The information should be **accessible throughout the mobile-phone's lifecycle**
12.1	The information should be **accessible through a unique product identifier attached to the mobile phone**.
12.2	The information should be **accessible for new and used mobile phones** alike.

Main Research Question

Main Research Question

What information requirements can be elicited for an EU DPP that addresses the information deficits of EU consumers hindering them from the acquisition of the most circular mobile phone alternative?

The answer to the main research question builds upon the answers to each sub-question.

Based on decision analysis, three information deficits that hinder EU consumers from acquiring the most circular mobile phone alternative are identified. These deficits pertain to the exposure and acceptance of product information during the consumer's acquisition process. To address the deficits with an EU Digital Product Passport (DPP), three design principles are applied to elicit the DPP's information requirements: relevance, soundness, and accessibility.

The relevance design principle emphasizes the need for comprehensive and applicable information that enables consumers to evaluate (circular) mobile phone alternatives. The soundness design principle focuses on providing consistent, current, and correct information, fostering comparability and trust of provided product information for the consumer. Finally, the accessibility design principle aims to ensure that consumers can identify and access the necessary information through various channels and at different stages of the mobile phone's use cycle.

Based on these design principles, 42 initial information requirements were elicited to guide the development of an EU DPP that addresses the identified information deficits. These requirements are elicited so that they consider the applicability, comprehensiveness, consistency, currency, correctness, and accessibility of information provided with the DPP. In addition, the initial list of requirements was revised through expert evaluation, resulting in a final set of 50 information requirements that can inform the DPP's further development.

Furthermore, boundary conditions for implementing an EU DPP are identified based on my information requirements. A Boundary Condition Framework is created that structures the boundary conditions and related potential implementation issues and thus can inform further research and development.

In this research's context, four boundary conditions determine to what extent an EU DPP, developed with the elicited information requirements, can mitigate consumers' information deficits. These conditions include the suitability of the DPP in the given context, the efficiency of the DPP information, the governance of its data, and the provision of its data. The heterogeneity of consumer needs in the EU context determines the DPP's suitability and defining efficient information.

In conclusion, the research provides valuable insights into the information requirements and boundary conditions necessary for developing and implementing an EU DPP to address the information deficits consumers face when attempting to choose the most circular mobile phone alternative. Furthermore, by using the design principles based on information quality criteria, the EU DPP developed with the elicited information requirements could promote the relevance, soundness, and accessibility of product information provided to the consumer, ultimately assisting consumers in making informed decisions and fostering a more circular economy in the mobile phone industry.

Hence, I contribute to accelerating the circular economy transition in the EU to tackle the societal challenge of continuous material consumption growth.

8.2 Scientific Contribution

In order to demonstrate the scientific contribution of this research to the scientific knowledge base, it is reflected about the two main knowledge gaps identified at the beginning.

Knowledge Gap 1 (KG1): The EU DPP, related to the ESPR proposal and CIRPASS project, is intended to address the societal challenge of continuous material consumption growth. However, further research is required to explicate the novel concept and prepare its near-term implementation.

This thesis research contributes to the general research and development of the EU DPP (KG1) by (1) gaining essential insights during the research's DSR process and (2) initiating a different discussion and perspective regarding the DPP's development.

In particular, the following five results from the design process can make a contribution:

- The DPP could address consumers' information deficits, particularly regarding the exposure and acceptance of information.
- Information quality frameworks are a valuable tool to ensure that the DPP's information provision can be of value to the information receiver/user (clearly distinguishing between information and data).
- My defined design principles can be used to elicit information requirements from a consumer perspective for the DPP regarding circular products (as evaluated by the experts)
- Revised information requirements, evaluated with expert feedback, can inform the development of an EU DPP for mobile phones used by consumers.
- Boundary conditions can be considered in the DPP development to mitigate possible implementation issues.

More specifically, from a scientific perspective, these contributions show

- the complexity of the consumer perspective (e.g., multiplicity and heterogeneity of consumers' information deficits and needs),
- the value of applying established theories (e.g., consumer behavior, information quality),
- possible starting points for the further definition and development of the DPP (e.g., actor-/product-perspective, design principles, and information requirements, Boundary Condition Framework), and
- bases for critically discussing the DPP concept and its implementation in general (e.g., implementation issues and boundary conditions).

In addition, I argue that the applied research approach facilitates replication, and my findings are generalizable. This is important, as I identified in the initial literature review that researches around the EU DPP concept is still emerging (see Sub-Section 1.2.2). To be more specific, the rigorous DSR process and its documentation in this report allow the scientific replication and extension of my research. Furthermore, the establishment of design principles, the elicitation of higher-level information requirements, and the consideration of boundary conditions allow the application of my findings, for instance, for different products (in the consumer context) or domains (e.g., research and development of accompanying policies in the ESPR proposal).

Knowledge Gap 2 (KG2): Information requirements from an actor- and product-specific perspective are hardly investigated yet but are required in the near term to inform the overall DPP development and set up context-specific pilots.

I can contribute to developing the EU DPP in the near term (KG2) with my elicited actor- and product-specific information requirements. Specifically, they guide the development of an EU DPP that can address consumers' information deficits in acquiring most circular mobile phone alternatives. Moreover, considering the arguments for this research's contextual focus, I can provide the DPP's usage by consumers for acquiring mobile phones as a relevant use case for piloting the EU DPP.

In conclusion, while providing context-specific insights (KG2) and thus addressing the required near-term development of the EU DPP, I also highly contribute to the general EU DPP research and development in light of the novelty of the concept. This is achieved by opening up the scientific discussion around the EU DPP, among others, through the consideration of primarily socio-technical boundary conditions and the establishment of valuable tools that can be used by other researchers in the DPP context as well (e.g., the defined design principles and the usage of information quality frameworks).

8.3 Societal Contribution

This thesis research faces the current and severe societal challenge of human material consumption growth, which poses pressures on the earth's ecosystem and, thus, on humans.

The urgency of this situation makes it necessary to transition to a circular economy as soon as possible, for example, by introducing new technologies such as the EU Digital Product Passport. However, introducing new technology in a societal context can come with uncertainties.

With the contribution of this master thesis, I claim to contribute to both

(1) the development of the EU DPP, which effectively contributes to the acceleration of the circular economy transition, and

(2) the mitigation of potential risks to society due to introducing the novel DPP technology.

On the one hand, by focusing on the circular acquisition of mobile phones by consumers, I can demonstrate a relevant use case of the EU DPP. On the other hand, by defining design principles and eliciting information requirements that address the specific issue of information deficits of consumers hindering them from making a "pro-circular" acquisition choice, I can further inform the purposeful development of the EU DPP within the circular economy transition.

On the other hand, by identifying possible boundary conditions for the implementation of the EU DPP in this research's context based on expert interviews, aspects can be identified that determine to what extent the EU DPP can actually fulfill its purpose and thus contribute to the societal challenge. In this research's case, they determine to what extent an EU DPP developed based on the information requirements can actually mitigate the consumer's information deficits. Thus, a consideration of boundary conditions can serve to determine which conditions must prevail in order for uncertainties in implementation to be reduced.

In conclusion, this master thesis makes an essential contribution to society by aiding the development of the EU Digital Product Passport so that it can effectively accelerate the transition to a circular economy while considering potential challenges associated with its implementation.

8.4 Limitations

While an essential contribution to science and society could be achieved with my research, the results are also subject to limitations that need to be considered. These limitations result mainly from the research methods and information sources used. Although I already attempted to consider possible limitations in the research methodology design (see Chapter 2), limitations can still affect the research outcomes.

Relevance of Product Information

The research conducted here is based on the assumption of the European Commission that consumers need additional or the right information to decide to acquire a circular product alternative (European Commission, 2022b, pp. 14, 65). This assumption was adopted for the research to shed more light on the resulting introduction of an EU DPP.

However, as I found during the literature review for influencing factors on consumers' acquisition choice that multiple factors can have an influence, which is also backed by other literature (Eurostat, 2022a; Gomes et al., 2022; Mostaghel & Chirumalla, 2021), thus, the question arises, if the provision of product information can lead to the actual behavior of the consumer. Furthermore, as mentioned by the European Commission 2022a (p. 63), this potential gap between the declared willingness and the actual behavior was also found in an EU study investigating consumer engagement in the circular economy (LE Europe et al., 2018).

Consequently, even if the EU DPP based on my information requirements would mitigate the consumer's information deficits and provide relevant information, it does not necessarily mean that the application of the DPP also leads to the actual acquisition choice for a more circular product. Also, Engel et al. (1990, pp. 517–519) state that the actual set of evaluation criteria depends on multiple factors, and thus product information can dynamically change in their relevance to one consumer. This is also important to consider in terms of expectations regarding the information requirements.

Desk Research

The choice of desk research to answer Sub-questions 1, 2, and 3 can reflect the practical perspective critical in design research, only to a limited extent (Johannesson & Perjons, 2021, p. 102). Thus, research depends on how other scholars collected empirical data and under what conditions. This is also reflected in the number and scope of studies that could be considered in eliciting relevance requirements.

Even if a rigorous and transparent process in desk research analyses was strived for as far as possible, bounded rationality and bias of the researcher could not be excluded (see also Section 2.2). Moreover, although experts evaluated the results, this is also subject to limitations (see next paragraph). Therefore, this must be considered when concluding the process results.

Expert Interviews

The methodology of expert interviews is subject to limitations, which I tried to take into account in the research approach by selecting a variety of different experts.

However, on the one hand, the selection of experts can only represent a specific set of perspectives or backgrounds. Especially for the boundary conditions, this means that they cannot be based on an all-encompassing list of possible implementation issues. Thus, the boundary conditions primarily reflect the expertise or background of the experts.
On the other hand, the experts' statements may be influenced by their interaction with the researcher. This has to be considered concerning the research results, especially for the evaluation and boundary condition results.

8.5 Further Research

This research with its findings throughout the DSR process offers many possible starting points worth exploring further for the still-emerging knowledge base around the EU DPP. However, in the following sub-section, some most interesting research directions are provided.

Segmentation Studies

In general, by conducting this research, I noticed the complexity that is already inherent if one only considers the use of the EU DPP for one specific actor (activity) and product. Even though there could be similarities regarding the requirements with other products or contexts, rigorously eliciting them would require high effort, as this research shows. Moreover, experts addressed this issue when discussing the DPP implementation (see Sub-Section 7.2.2). Thus, I share their doubts about whether the currently called-for approach of actor- and product-specific requirement elicitations is feasible in light of the EU DPP's addressed scope. Nevertheless, taking an actor- and product-specific perspective is essential to define specific use cases of the EU DPP. Hence, further research could investigate how to balance this trade-off. One possibility in this respect could be the conduction of segmentation studies and consequential prioritization for the EU DPP implementations.

Segmentation studies for both the consumer and the product could be interesting. This is, it would be researched how the consumers can be grouped based on their needs. Moreover, it could be investigated whether the DPP should focus on specific ones of these consumer groups. For example, the studies by Boyer et al. (2021) and Mugge et al. (2017) give examples of possible segmentations into consumer groups based on the consumers' importance of specific evaluation criteria for their acquisition choice-making.

On the other hand, the segmentation of products could further facilitate context-specific requirement elicitation and reduce efforts in the DPP development. Further research could investigate which characteristics of products could use the same information set. For instance, utilitarian products versus products with emotional value. However, this classification might depend on the individual viewpoint of the individual consumer (group).

Consumer Studies

As mentioned in the limitations section, to support my findings and the underlying assumption of the DPP's added value for consumers, the actual relevance of product information compared to other factors should be further investigated. Also, by reviewing the papers on influencing factors, it was found that many factors are interrelated and different in their impact on the consumer. Hence, researchers could perform choice experiments to study the relevance of product information in the context of other factors.

In addition, consumer studies can also be conducted to develop further and specify the final list of information requirements. To address the gap between the stated willingness of consumers to consider certain information or circular alternatives and their actual acquisition behavior, evolutionary requirement elicitation with experimentation could be of value. Thus, the DPP could be further developed while being tested by consumers Davis (1982, pp. 12–19).

DPP's Promotion of highest CE *Strategies*

As introduced in this research, my motivation is to accelerate the circular economy transition by promoting the highest CE strategies. However, during the review of influencing factors for consumers' acquisition choice (see Section 5.1), I noticed that the factors regarding leasing were less concerned with product information compared to CE strategies, where the consumer owns the mobile phone. While this finding is limited to the scope of the reviewed literature, I assume that consumers might give more responsibility to the product-service provider from whom, for instance, they lease their mobile phones. Consequently, I wonder if the DPP can be of value if society is transitioning towards higher CE strategies and how it can promote them.

These aspects need to be studied in further research, as I identified the need for the highest CE strategies to reduce overall material consumption. Thus, consumer studies identifying the specific consumer needs and barriers regarding higher-level CE strategies could be conducted to analyze which factors could be provided or addressed with the EU DPP. One question regarding this study would be whether the DPP should include service information.

In conclusion, further research is needed to facilitate future DPP development, strengthen my findings, and investigate the DPP's value in the CE transition.

8.6 Recommendations for the DPP Implementation

From the implementation issues presented in Section 7.2, I draw the main recommendations to be considered when developing and implementing the EU DPP.

As can be seen regarding the implementation issues mentioned by the experts, many factors can be considered essential to further research, address, and resolve. For the DPP development and implementation, in general, and the further usage of my elicited information requirements, in specific, I highlight the three most addressed groups of implementation issues as recommendations in the following.

They are ordered according to the sequence of consideration, referring to my established processual view in the Boundary Condition Framework. Hence, one should first incorporate the principles of efficiency in the DPP implementation process. Afterward, the necessary standards or rules should be developed and implemented to enable the validity and comparability of the information. Finally, it should be investigated whether the established set of information also requires the provision of data by private consumers and how it can be implemented, considering the necessary data/information standards and a socio-technical perspective.

1. Recommendation:
Introduction of *efficiency* as a guiding principle for the DPP development in general.

As can be concluded from the experts' comments, considering the principle of efficiency is decisive for many possible implementation issues and the DPP development as a whole.

According to their statements, ensuring the efficiency of information could mitigate, for example, the irrelevance of information or information overload for consumers, unbearable burdens for (smaller or early stage) businesses, "data graveyards", and negative environmental impacts (e.g., through energy consumption). Thus, it could support the adoption of the DPP and whether it can address the information deficits, the mitigation of market barriers, and transitional ambitions of the EU other than the CET (e.g., environmental sustainability, energy transition[14]).

In this case, implementing this principle requires determining which information needs to be provided with the DPP, that most influences the consumer's choice of the most circular acquisition alternative. Here I also see the connection to the question regarding the added value of the DPP for consumers (see Sub-Section 7.2.2). Based on the determined information, it is necessary to investigate how this information can create added value for consumers with the least possible use of data (flow). According to Expert 12, labels like the EU Energy Label can be a best practice example.

Important to point out is that I also see the other policies that will be introduced along the DPP (e.g., regarding product design and product labeling) as a decisive factor for the DPP's efficiency. As the experts stated, setting product design standards as an alternative or accompanying measure to enhanced information provision, one needs to consider how this could affect the DPP. For instance, providing information can become obsolete if products have a certain repairability or minimum time for software updates by law. Thus, one has also to consider efficiency in a dynamically changing environment. This also comprises the heterogeneity of consumers, for instance.

Hence, it should be considered which specific purpose the DPP can have within the policy mix beyond information provision. This is, what effect should the DPP have (e.g., nudge towards higher level CE strategies) to achieve a specific objective (e.g., material consumption reduction)?

Moreover, the principle is also relevant to specify, for instance, my soundness-related information requirements (see Sub-Section 7.2.3) and efficiently determine the necessary data governance (see Sub-Section 7.2.4).

Concerning Experts 2, 3, 5, 7, and 8, one can further develop my elicited information requirements regarding this principle by applying prioritization or combining information into a quality certification. In this context, for example, I also see the view of information as a product, as discussed by Wang et al. (2005, Chapter 7), as a helpful concept. Thus

[14] On environmental sustainability, see for instance: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/protecting-environment-and-oceans-green-deal_en
On the energy transition, see for instance: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/energy-and-green-deal_en

methods can be applied which are established for the efficiency improvement of products, e.g., continuous quality improvement (e.g., Lee & Haider, 2014) or economic value evaluation (e.g., Viscusi & Batini, 2014).

2. Recommendation:
Development of information and data standards as a prerequisite for the provision of valid and comparable information to consumers.

Implementation issues regarding the second recommendation were addressed most often by the experts. They see standardization of the data and/or information as a prerequisite to ensure comparability and validity of the information and thus make them sound to support and protect the consumer

All experts agreed on the necessity to standardize how the data for the information is generated (Experts 2, 5, 7, 8, 10) and it needs to be defined to what extent the information provision can also be standardized. Regarding the latter, accessibility design standards can be interesting (see Sub-Section 7.2.1).

In addition, next to the scope and the specifics of the standards, one also already has to consider their implementation during the development. This comprises the roll-out on an EU-level (Expert 7) but also the cost-benefit analysis from a business point of view (Experts 2, 6, 7; regarding "consumer needs VS data provider interests/capabilities" in Sub-Section 7.2.5). This is also in line with the finding by Gåvertsson et al. (2020), investigating with stakeholder consultation possibilities of quality labeling for re-used ICT equipment in Sweden. I also identify a close relation to the information's efficiency (1. Recommendation), as it helps to scope what data and information are really relevant and thus need to be considered for the standardization.

3. Recommendation:
Investigation of the extent to which the provision of data by private consumers is necessary and how it can be implemented from a socio-technical perspective.

I mentioned that information from the usage phase can be relevant (e.g., about which parts were replaced), in particular, when acquiring pre-owned mobile phones. This is especially the case, if one considers the possibly increasing consumer engagement in circular economy practices, like repairing. However, if the provision of data or information by private consumers becomes absolutely necessary and is expected to be of the same quality as can be required of business actors, experts saw several challenges related to: legal responsibility/accountability, the role of the consumer in the data economy, privacy protection, and the validity of the information (see Sub-Section 7.2.5).

Hence, after it is clarified what information and data is needed and to what extent (see the first two recommendations), I see it as a priority to further investigate the specific issue of data provision by private consumers. Not only because of the addressed challenges but also because the information can be required by other actors in the value chain. The provision of usage phase data/information is yet not existing and addressed sufficiently (see Section 3.2). For instance, by investigating boundary conditions of quality labeling for re-used ICT equipment in Sweden, Gåvertsson et al. (2020, p. 369) found that one main issue for businesses to provide such labeling is the uncertainty about what happened with the product throughout its former use cycles.

On the one hand, technical means could be considered to facilitate the data provision and improve validity, like data provision by the mobile phone itself (Expert 11). On the other hand, experts highlighted the importance of safeguarding individuals' privacy rights and proposed data and information provision on a voluntary basis with consent by the consumer (Experts 2, 3, 6, 7). Consequently, I emphasize that a socio-technical perspective is required to not only develop technical possibilities of data sharing, but to also particularly define the institutional framework involving the consumer perspective.
In that respect, online marketplaces (Expert 3) or review websites, where private consumers already share information voluntarily, can be taken as an example. Another best practice mentioned by Expert 9 is the consumer reporting website by the Belgian consumer & testing association[15]. On their website, consumers can report their issues and experience with products. By analyzing the information, insights about the usage phase are generated, for instance, regarding the product's average durability in practice. Nevertheless, one has to define how this information can be added to the DPP (if necessary) in a standardized and valid way.

[15] see (state 15.05.2023): https://www.test-aankoop.be/te-rap-kapot?updateBeanConsent=true

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Appendix A: Initial Literature Review

Table A. 1: DPP literature review - Overview and analysis of selected documents

No.	Source	Sector	Main stakeholder perspective	Outcome of document			
				Definition of concept	High-level requirements	Sector-/product-specific requirements	Use-case / system design
Legislative Documents							
1	ESPR Proposal (Directorate-General for Environment of the European Commission, 2022)	General	all	✓	✓		
Scientific Papers							
2	(van Capelleveen et al., 2023)	General	none specific	✓			
3	(Ducuing & Reich, 2023)	General	none specific		✓		
4	(King et al., 2023)	General	all	✓			
5	(Koppelaar et al., 2023)	Critical raw materials	business				✓
6	(Shanker et al., 2023); multiple	General	none specific		✓		
7	(Van Engelenburg et al., 2022)	Critical raw materials	government			✓	
8	(Berger et al., 2022)	Electrical vehicle batteries (EVB)	business, consumer			✓	
9	(Clark et al., 2022)	Batteries	all			✓	
10	(Plociennik, Pourjafarian, Saleh, et al., 2022)	General	business		✓		
11	(Plociennik, Pourjafarian, Nazeri, et al., 2022)	End-of-life treatment	business				✓
12	(Walden et al., 2021)	General	all	✓			
13	(Adisorn et al., 2021)	General	all	✓			
Research Institute Publications							
14	(Berg et al., 2022); multiple institutes	Plastics	business				✓
15	(Durand et al., 2022); Wuppertal Institute & Fraunhofer Institute	Energy-related products	government				✓
16	(Saari et al., 2022)	Manufacturing	business				✓

17	(University of Cambridge Institute for Sustainability Leadership (CISL) & Wuppertal Institute, 2022)	General	business				✓
18	(Götz et al., 2021); Wuppertal Institute	General	all	✓			
19	(Jansen et al., 2022); Wuppertal Institute	General	none specific	✓			
20	(Bernier et al., 2023); CIRPASS project	General	none specific	✓			

Table A. 2: Analysis of DPP initiatives
(B = Batteries, T = Textile, E = Electronics); first 14 initiatives by (Jansen et al., 2022), last 3 initiatives by (Bernier et al., 2023)

No	Name	Organization(s)	Addressed key sectors				Source
			all	B	T	E	
1	KEEP (Keep Electrical and Electronic Products)	Chalmers Industriteknik				✓	https://keepelectronics.com/#/
2	DIBICHAIN	DIBICHAIN (Capgemini/Altran)	✓				https://dibichain.com/ https://innovative-produktkreislaeufe.de/Projekte/DIBICHAIN.html
3	Battery Passport	Global Battery Alliance		✓			https://www.globalbattery.org/battery-passport/
4	Product Circularity Data Sheet (PCDS)	Luxembourg Ministry of the Economy	✓				https://pcds.lu/
5	myEcoCost	TriaGnoSys	✓				https://www.myecocost.eu/index.php/aboutmyecocost/objectives
6	Produkt-information 4.0	TU Berlin, Circular Fashion UG, BSB Quack Gutterer			✓	✓	https://www.tne.tu-berlin.de/menue/forschung/projekte/pi/
7	DigInform	Fraunhofer IWKS	✓				https://www.diginform.de/ https://www.iwks.fraunhofer.de/de/presse-und-medien/pressemeldungen-2021/projektstart-diginform.html
8	TrueTwins (Digital Passport for products)	TrueTwins			✓		https://www.truetwins.com/
9	Digital Product Passport	Spherity GmbH		✓			https://spherity.com/spherity-product-pass/
10	circularity.ID® Open Data Standard	circular.fashion UG			✓		https://circularity.id/static/circular.fashion_circularityID_white_paper_2021.pdf
11	Threadcounts	Threadcounts			✓		https://www.threadcounts.io/ https://uploads-ssl.webflow.com/5e1c147e4b6c087a2680db97/5e26a1ad16b6d1c966fc5933_Minespider_Whitepaper.pdf
12	Minespider	Minespider AG		✓			https://www.minespider.com/upstream-producers https://www.minespider.com/battery-passports https://uploads-ssl.webflow.com/6098de8910ab20fb71ac62b9/60cb022e84f17b18e4a46575_Minespider%20v0.4%20-%20Light%20Paper.pdf https://www.crunchbase.com/organization/minespider

13	Cradle to Cradle Passport	Cradle to Cradle Products Innovation Institute (C2CPII)	✓				https://www.c2ccertified.org/get-certified/product-certification
14	Circular Product Data Protocol	EON Group Holdings, Inc.			✓		https://www.eongroup.co/circular-product-data-protocol
15	Digital Product Passport	atma.io	✓				https://www.atma.io/
16	B-TraaS (Blockchain Traceability as a Servic)	Bureau Veritas	✓				https://www.bureauveritas.fr/besoin/origin-la-solution-blockchain
17	CircThread	Consortium of research institutes and businesses (funded by the European Union under the H2020 programme)		✓			https://circthread.com/
18	Tings	/			✓		(Bernier et al., 2023)

Appendix B: Relevance Requirements

Table B. 1: Extensive list of influencing factors, including the selection of product information-related factors relevant to the requirement elicitation

ID	Source	Circular Strategy	Influencing Factors	Included in Requirement Elicitation	Rationale for being related to product information
1	(Rousseau, 2020)	Leasing	personally preferred duration of use		
			lack of control		
			perceived risks	✓	e.g., product's current condition
			seeing phone as extended self		
			lack of clarity (e.g., insurance, follow-up of defects/accidents, overall costs, final ownership)		
			preference for own ownership		
			privacy/security risks		
			environmental benefits	✓	e.g., life cycle performance
			desire for newest model		
			predictable limited monthly cost		
			price		
			flexibility and convenience		
			variety of phones		
			desire to stay with the status quo		
2	(Poppelaars et al., 2018)		awareness & familiarity		
			understanding		
			reliability & trust in the service	✓	e.g., quality certification
			relationship with service provider		
			positive image of service provider		
			financial aspects of the service		
			ease & convenience of the service		
			low commitment with the service		
			product characteristics	✓	= product information
			necessity to get new phone		
			environmental benefits	✓	e.g., life cycle performance
3	(Wieser & Tröger, 2016)	Reuse	uncertainty about phone's life expectancy	✓	e.g., durability information
			perceived risks	✓	e.g., product's current condition
			warranty	✓	= indication about minimum durability
4	(Van Weelden et al., 2016)	Refurbish	awareness		
			understanding		
			availability		
			thrill of newness		
			perceived benefits *(used to aggregate other factors)*	✓	e.g., life cycle performance
			financial benefits		

			environmental benefits	✓	e.g., life cycle performance
			absence of undesirable innovative features	✓	based on product information
			unique product features	✓	based on product information
			higher performance than second-hand products	✓	e.g., quality certification
			perceived risks *(used to aggregate other factors)*	✓	e.g., product's current condition
			perceived performance (risk)	✓	e.g., product's current condition
			financial risk		
			time risk	✓	e.g., quality certification
			obsolescence risk		
			product appearance, signs of prior use (wear and tear)	✓	= product information
			familiarity		
			confidence in own ability to judge		
			warranty and service	✓	= indication about minimum durability
			price		
			information provision (e.g., battery condition, and results of performance tests)	✓	= product information
			seller image		
			brand image		
			retail experience		
			performance characteristic	✓	= product information
			use history	✓	= product information
			characteristics of electronic device	✓	= product information
5	(Mugge et al., 2017)		awareness		
			perceived benefits *(used to aggregate other factors)*	✓	e.g., life cycle performance
			environmental benefits	✓	e.g., life cycle performance
			perceived risks *(used to aggregate other factors)*	✓	e.g., product's current condition
			perceived performance (risk)	✓	e.g., product's current condition
			personal innovativeness		
			environmental consciousness		
			involvement in smartphones		
			knowledge about smartphones		
			value (price) consciousness		
			social-adjustive function		
			value-expressive function		
			upgraded battery	✓	= product information
			guaranteed software updates	✓	e.g., software update info
			upgraded performance	✓	= product information
			classification system (conditions of system)	✓	= product information
			information about the refurbishing process	✓	e.g., quality certification
			quality certification	✓	= product information
			upgraded internal storage	✓	= product information
			upgraded screen	✓	= product information
			unbiased testimonials		

			upgraded camera	✓	= product information
			extendable protection period		
			more innovative features	✓	= product information
			extended trial period		
			extendable protection coverage		
			updated appearance	✓	= product information
			leasing option		
			age		
			gender		
6	(Wewer et al., 2020)		awareness		
			understanding		
			perceived risks *(used to aggregate other factors)*	✓	e.g., product's current condition
			perceived performance (risk)	✓	e.g., product's current condition
			perceived durability	✓	e.g., durability information
			perceived quality	✓	e.g., quality certification
			perceived reliability	✓	e.g., quality certification
7	(Mugge et al., 2018)		perceived risks *(used to aggregate other factors)*	✓	e.g., product's current condition
			product appearance, signs of prior use (wear and tear)	✓	= product information
			concerns about availability of software updates	✓	e.g., software update info
			concerns about software contagion (e.g., remaining data from previous owner, malware)	✓	e.g., quality certification
			warranty and service	✓	= indication about minimum durability
			information about the refurbishing process	✓	e.g., quality certification
			verbal information about prior use	✓	e.g., product's current condition
			trust in the refurbishment process & company (e.g., certification)	✓	e.g., quality certification
8	(Bigliardi et al., 2022)		perceived benefits *(used to aggregate other factors)*	✓	e.g., life cycle performance
			perceived risks *(used to aggregate other factors)*	✓	e.g., product's current condition
			green perceived value	✓	e.g., life cycle performance
			environmental knowledge		
9	(Agostini et al., 2021)		importance paid to distribution		
			importance paid to seller reputation		
			attitude		
10	(Boyer, Hunka, & Whalen, 2021)	Circular Product in general (e.g., used, circular design)	desire for newest model		
			CE score (recycled/reused material or component content)	✓	= product information
			price		
			appearance	✓	= product's current condition
			reseller type		
			repairability (easy to fix, fixability)	✓	= product information
			customer service		
11	(Boyer, Hunka, Linder, et al., 2021)		CE score (recycled/reused material or component content)	✓	= life cycle performance
			appearance	✓	= product's current condition

			battery life	✓	= product information
			warranty length	✓	= indication about minimum durability
			reseller type		
			repairability (easy to fix, fixability)	✓	= indication about minimum durability
			customer service		
12	(Hunka et al., 2021)		CE score (recycled/reused material or component content)	✓	= life cycle performance
			appearance	✓	= product's current condition
			battery life	✓	= product's current condition
			warranty length	✓	= indication about minimum durability
			reseller type		
			repairability (easy to fix, fixability)	✓	= indication about minimum durability
13	(Bigerna et al., 2021)	Circular Design (durable, repairable)	durability	✓	= indication about minimum durability
			repairability	✓	= indication about minimum durability
			price		
			income		
			trust in certification		
			education		
			age		
			environmental engagement		
			intensity of use		
			ecolabeling	✓	= product information
			quality certification	✓	= indication about minimum durability

Table B. 2: Overview of information-related influencing factors and their link to the elicited initial relevance requirements (incl. breakdown structure; the level of detail is increasing from left to right)

Source ID	information-related Influencing Factors	Relevance Requirements		
		3rd level: specific Informaiton Item	2nd level: Information Group	1st level: Function of DPP
4, 5, 8	perceived benefits			1. The DPP should increase the **perception of benefits.**
3	uncertainty about phone's life expectancy	1.1.1 The information should include **durability information.**	1.1 The DPP should provide **circular design information**	
6	perceived durability			
13	durability			
10 - 13	repairability (easy to fix, fixability)	1.1.2 The information should include **repairability information**		
10 - 12	CE score (recycled/reused material or component content)		1.2 The DPP should provide **circular composition information.**	
1, 2, 4, 5	environmental benefits		1.3 The DPP should provide **environmental performance information.**	
8	green perceived value			
13	ecolabeling			
1, 3 - 8	perceived risks			2. The DPP should reduce the **perception of risks.**
4	higher performance than second-hand products		2.1 The DPP should provide **technical performance information.**	
4 - 6	perceived performance (risk)			
4	performance characteristic			
5	upgraded performance			
5	classification system (conditions of system)			
7	information provision about the technical performance			
4	information provision (e.g., battery condition)	2.1.1 The information should include **battery performance information**		
11, 12	battery life			
2	reliability & trust in the service		2.2 The DPP should provide **proof(s) of product's reliability.**	
4	time risk			
6	perceived reliability			
3, 4, 7	warranty	2.2.1 The information should include **warranty information.**		
11, 12	warranty length			
5	information about the refurbishing process	2.2.2 The information should include **quality certification information**		
5	quality certification			
6	perceived quality			
7	trust in the refurbishment process & company (e.g., certification)			
13	trust in certification			
7	concerns about software contagion (e.g., remaining data from previous owner, malware)	2.2.3 The information should include **proof of data removal.** 2.2.4 The information should include **proof of software being malware-free.**		
5	guaranteed software updates	2.2.5 The information should include **software update information**		
7	concerns about availability of software updates			
2	product characteristics			3. The DPP should enable the **viewing of product features.**
4	absence of undesirable innovative features			
4	characteristics of electronic device			
4	unique product features		3.1 The DPP should provide information about **product characteristics**	
4	use history			
5	upgraded battery			
5	upgraded internal storage			
5	upgraded screen			
5	upgraded camera			
5	more innovative features			
7	verbal information about prior use			
4, 7, 10 - 12	product appearance, signs of prior use (wear and tear)	3.1.1 The information should include **product appearance information**		
5	updated appearance			

Appendix C: Revision of Information Requirements

See next page for the extensive revision table.

Table C. 1: Extensive revision table, including comments on how the expert remarks are incorporated or not

		Expert Evaluation ✓ approved o adapt/specify x refused	Revisions
Design Principles			
1	**Relevance** The DPP should provide relevant information to the consumer, that is comprehensive and applicable.	✓ (all)	Requirements to be added: *x. The DPP should ensure the comprehensibility of provided information.* *x. The DPP should ensure the comparability of provided information.*
2	**Soundness** The DPP should provide information that is sound, thus based on consistent, current, and correct data.	✓ (E1-E10, E12) o (E11)	/ not adopted; proposed rephrasing did not match definitions from literature
3	**Accessibility** The DPP should ensure that the information can be seen, reached and used by the consumer throughout the different information contexts and the use cycles of a product.	✓ (E1, E2, E5, E9) o (E3, E4, E6-E8, E10-E12)	/ not adopted; proposed rephrasing did not match definitions from literature
Relevance Requirements			
1.	The DPP should **increase the perception of benefits**.	✓ (E2-E10, E12) o (E11)	*1. The DPP should increase the perception of circular characteristics.*
1.1	The DPP should **provide circular design information**.	✓ (all)	
1.1.1	The information should include **durability information**.	✓ (all) o (E9)	/ not adopted; further research required
1.1.2	The information should include **repairability information**.	✓ (E2-E5, E7, E11, E12) o (E6, E8-E10)	*1.1.2.1 The information should include an indication of the difficulty of repair.* *1.1.2.2 The information should include information about the availability of spare parts.*
1.2	The DPP should **provide circular composition information**.	✓ (E3-E12) o (E2)	/ further research required
1.3	The DPP should **provide environmental performance information**.	✓ (all)	
2.	The DPP should **reduce the perception of risks**.	✓ (E2-E5, E8-E12) o (E6, E7)	*2. The DPP should improve the assessment of reliability assurance.* This requirement will be merged with the former requirement 2.2, as a result of the adjustments made to the 3. requirements.
2.1	The DPP should **provide technical performance information**.	✓ (E3-E12) o (E2)	*3.1 The DPP should provide information about the functionality of the product.* This requirement will be added to the requirements of 3. as explained below.
2.1.1	The information should include **battery performance information**.	✓ (all)	This requirement will be added to the requirements of 3. as explained below.
2.2	The DPP should **provide proof(s) of product's reliability**.	✓ (E2, E3, E6-E12) o (E4, E5)	/ not adopted; our definition of "reliability" based on literature is appropriate
2.2.1	The information should include **warranty information**.	✓ (E2-E10) o (E11, E12)	/ not adopted; word "warranty" is sufficient for this level of detail
2.2.2	The information should include **quality certification information**.	✓ (all)	
2.2.3	The information should include **proof of data removal**.	✓ (E2-E6, E8-E12) x (E7)	This requirement will be added to the requirements of 3. as explained below.
2.2.4	The information should include **proof of software being malware-free**.	✓ (E2-E6, E8-E12) x (E7)	This requirement will be added to the requirements of 3. as explained below.
2.2.5	The information should include **software update information**.	✓ (E2-E6, E10, E11) o (E7-E9, E12)	*2.3 The information should include a statement about how long software updates will be guaranteed.* (the numbering already takes the changes made regarding 3. into account) Information regarding the current software version installed are added to the requirements of 3. as explained below.
3.	The DPP should **enable the viewing of product features**.	✓ (E3-E11) o (E2) x (E12)	*3. The DPP should improve the assessment of the product condition. (former requirement 3.)* *3.1 The DPP should provide information about the functionality of the product. (former requirement 2.1)* *3.1.1 The information should include battery performance information. (former requirement 2.1.1)* *3.2 The DPP should provide information about the product hardware condition. (former requirement 3.1)* *3.2.1 The information should include product appearance information. (former requirement 3.1.1)* *3.3 The DPP should provide information about the product software condition.* *3.3.1 The information should include a statement whether the software is updated to the latest version. (part of former requirement 2.2.5)* *3.3.2 The information should include proof of data removal. (former requirement 2.2.3)* *3.3.3 The information should include proof of software being malware-free. (former requirement 2.2.4)*
3.1	The DPP should **provide information about product characteristics**.	✓ (E3-E9, E11, E12) o (E2, E10)	
3.1.1	The information should include **product appearance information**.	✓ (E3-E6, E9-E12) o (E2, E7, E8)	
Soundness Requirements			
4.	The DPP's data should be managed on **different granularity levels**.	✓ (all)	
4.1	The data should be on **product level** granularity.	✓ (E2-E6, E8-E12) o (E7)	*6.1 The information should be provided on item level.*
4.2	The data should be relatable to **component level** data.	✓ (E3, E6, E9, E12) o (E2, E4, E5, E7, E8, E10, E11)	*6.2 The information provided on an item level should be relatable to data on a component level.*
5.	The DPP's data should be **updated throughout the product's lifecycle**.	✓ (all)	
5.1	The updated data should be accompanied by a **time stamp**.	✓ (all)	
5.2	The data should be **updatable with each alteration of the product**.	✓ (E2-E12)	
5.3	The data should be **updatable depending on the product's lifetime**.	✓ (E3-E12) x (E2)	/ not adopted; as appropriate to our definition
5.4	The data should be **updatable depending on data in the product's component inventory**.	✓ (E2, E4-E12) o (E3)	*7.4 The information should be updatable depending on data changes on a component level.*
5.5	The data should be **updatable by the mobile phone itself**.	✓ (all)	
5.6	The data should be **updatable when the mobile phone is processed in-between possession**	✓ (E3-E12) x (E2)	/ not adopted; requirement not obsolete from our point of view as it not only comprises changes made to the phone but also tests made with the phone
6.	The DPP's data should be **provided by multiple actors** throughout the product's lifecycle.	✓ (E2, E4-E12) o (E3)	*8. The DPP's data should be provided by authorized actors throughout the product's lifecycle.*
6.1	The data should **be able to be provided by private persons/owner**.	✓ (E2, E4-E6, E8-E12) o (E3, E7, E12)	*8.1 The information should be based on data provided by private persons/owner.*
6.2	The data should **be able to be provided by organizations**.	✓ (E4-E6, E8-E12) o (E3, E7)	*8.2 The information should be based on data provided by organizations.*
6.3	The data provided by organizations should be accompanied by **organization's credentials**.	✓ (E2, E4-E12) o (E3)	/ not adopted; further research required
7.	The DPP's data should be **accompanied by the standards** it is based on.	✓ (E3, E4, E6, E8-E12) o (E2, E5) x (E7)	*9. The DPP's information provision should be defined by standards.* *9.1 The provided information should be based on standards.* *9.2 The required data for the information provision should be defined by standards.*
Accessibility Requirements			
8	The availability of **extended information with the DPP should be made visible** to the customer.	✓ (all)	
8.1	The availability of extended information with the DPP should be **indicated on the product packaging**.	✓ (all)	*10.1 The availability of extended information with the DPP should be presented saliently on the product packaging.*
8.2	The availability of extended information with the DPP should be **indicated with product's online advert**.	✓ (E2-E10, E12) o (E11)	*10.2 The availability of extended information with the DPP should be presented saliently with product's online advert.*
9.	The information should be **accessible in different contexts.**	✓ (all)	
9.1	The information should be **accessible through different contact points** with the product.	✓ (E3, E5-E8, E12) o (E2, E4, E9-E11)	*11.1 The information should be accessible through consumers' most common information channels for product information.* *11.2 The information should be accessible in online and offline environments.*
9.2	The information should be **sharable with people other than the mobile phone owner/user** without harming the mobile owner/user of the phone.	✓ (all)	becomes requirement 9.3
10.	The information should be **accessible throughout the mobile-phone's lifecycle**	✓ (all)	
10.1	The information should be **accessible through a unique product identifier attached to the mobile phone**.	✓ (all)	
10.2	The information should be **accessible for new and used mobile phones** alike.	✓ (all)	

Appendix D: Expert Interviews

Table D. 1: Overview of interviewed experts

	Organization Type	Role	Expertise
E1	Scientific/Educational Institute	Researcher - ICT & IP Law	+10 years experience in ICT related (EU) law. +5 years of research in data protection, property law in the digital environment, and data regulation and governance in the EU context. Thereby also investigating the EU DPP concept.
E2	Scientific/Educational Institute	Researcher - Environmental Informatics	+8 years of research in business analytics and data mining with special focus on circular economy and sustainability. Among others, studying (digital) passports in the CE context.
E3	Scientific/Educational Institute	Researcher - Digital Infrastructures for CE Monitoring	+ 12 years of research in B2B and B2G ICT systems. Special expertise in digital infrastructure initiation, standardization, and upscaling for circular economy monitoring. Participant in the CIRPASS project, contributing to the task on inventory of existing DPP pilots and initiatives.
E4	Scientific/Educational Institute	Researcher - Complex ICT Systems	+ 10 years of ICT engineering and research in systems of systems, digitalization and information-intensive ecosystems. Investigating the implementation of complex socio-technical integrated systems, like the EU DPP.
E5	Scientific/Educational Institute	Researcher - ICT for CE	3 years of research in information systems, like the DPP, and how they can address needs and gaps within the circular economy's data and information flows. This includes particularly CE monitoring and data governance.
E6	Scientific/Educational Institute	Researcher - Human-Machine-Systems	Research in applying artificial intelligence for CE. In particular, it is investigating how a DPP can create a standardized data basis for using Artificial Intelligence to conserve resources. > interview in German
E7	Research Institute	Researcher - Energy and Resource Efficiency	15 years of research in national, European, and international projects in the fields of energy and resource efficiency. Among others, research regarding the EU Ecodesign Directive, energy and product labels, and the EU DPP in this context. > interview in German
E8	Supranational Consumer Association	Expert - Consumer Policy	+5 years expertise in legal and policy analyses, particularly regarding EU product policy, the EU Ecodesign Directive and Energy Labelling legislation. Advocating the EU consumer perspective in EU policy making.
E9	National Consumer Association	Expert - Consumer Policy	Many years of expertise in consumer rights and consumer policy. Advocating the national consumer's perspective in policy making
E10	National Consumer Association	Researcher - Digital Consumer Products	+15 years of expertise in national and international projects with focus on digital consumer products (e.g., smartphones) from a technical and consumer perspective. Special expertise regarding product's circular design characteristics (e.g., repairability, durability)
E11	National Consumer Association	Expert - Consumer Policy	Focus on consumer policy regarding resource conservation (e.g., Ecodesign Directive). Advocating the national consumer's perspective in policy making and product passport development. > interview in German
E12	National Consumer Association	Expert - Consumer Policy & Research	Research on consumer interests with regard to the sustainability and circularity of consumer products. Among others, in the context of the EU Ecodesign Directive. Advocating the national consumer's perspective in policy making. > interview in German

Semi-Structured Evaluation Protocol

Before the interview, the experts signed the informed consent form. They received the presentation slides of the interview (incl. an introduction slide about the research's background) and the evaluation table as used by the researcher (to be pre-filled if possible to facilitate the interviewing process). The evaluation table comprised a list of the design principles and initial information requirements, plus columns to mark whether the design principles or information requirements are approved, refused, or should be adapted respectively. Additionally, the experts (or the researcher during the interview) could leave comments, e.g., if they see a particular information requirement missing.

Pre-Interview - *before recording*

1. Personal introduction
2. Validating Expertise
    a. For how many years have you been working/researching in your field?
    b. What knowledge do you have about the DPP/circular economy/consumer perspective?
3. Asking to what extent they have prepared on the basis of the material sent

Introduction – *start of recording*

1. Short introduction to the procedure of the interview/evaluation
2. Short introduction to the research's background and the main research question

Design Principles

3. Introduction to the design principles (incl. their purpose and definition)
4. Asking for each design principle if it is comprehensive, appropriate, and complete
    a. Do you understand the design principle?
    b. Do you approve the design principle to be useful to address consumers information deficits?
    c. Do you see any design principle missing?

Taking notes of the expert's comments during the discussion of the design principles.

Relevance/Soundness/Accessibility Requirements

Presentation of the information requirements per design principle, respectively. Evaluation procedure is the same.

6. Introduction to the information requirements (incl. their purpose)
7. Asking for each (group of) information requirement if it is comprehensive, appropriate, and complete
    a. Do you understand the information requirements?
    b. Do you approve the information requirement to be relevant regarding the relevance/soundness/accessibility of information/data?
    c. Do you see any information requirements missing?

Taking notes of the expert's comments during the discussion of the information requirements.

Implementation Issues

7. Asking if they see any implementation issues
    a. Do you see any barriers, problems, or aspects to consider in implementing the information requirements discussed?

Taking notes of the expert's comments during the discussion of implementation issues.

Besides these standard questions, I asked for clarification if any comments by the experts were not clear enough.