

From literature to practice: Understanding researcher perspectives towards social issues in digital battery passports

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ABSTRACT

The Digital Product Passport (DPP) is a cornerstone of the 2024 Ecodesign Regulation for Sustainable Products. It is an innovative tool designed to improve the transparency and sustainability of product value chains. The DPP acts as a digital identity card that promotes the circularity of products and strengthens compliance with legal standards and regulations. In response to the upcoming European battery regulation that will mandate digital battery passports (DBPs) for industrial and electric vehicle batteries (EVBs) from 2026, this study addresses the neglected integration of social aspects that are crucial for the sustainable management of the EVB value chain. DBPs are innovative tools designed to digitally document comprehensive details of EVBs, encompassing technical specifications, circularity data, and information on sustainability throughout their lifecycle. Although environmental aspects have been included in the conceptualization of DBPs, social factors have not been sufficiently analysed or incorporated, despite their importance for a holistic sustainability perspective in the transport sector. Therefore, this study uses a mixed-methods approach to investigate the integration of social issues into the value chain of EVBs in the context of DBPs. Through a systematic review of the scientific literature, coupled with insights from academic-led workshops, the present study identifies pressing social issues that are essential for a socially sustainable EVB value chain. The results highlight the most pressing social issues relevant to a DBP, e.g., health and safety issues of workers and local communities, fair wages, child labour, local

employment, and education and training of workers in the EVB value chain. In this case, the study highlights the researcher's view that social issues must be an integral part of DBP development to ensure that holistic aspects of sustainability are addressed, the overall management of EV value chains is improved, and ethical industry practices are supported.

1. INTRODUCTION

At the forefront of sustainability and circular economy initiatives, digital product passports (DPPs) have emerged as transformative tools that introduce a new era of product traceability and accountability (Berger et al., 2022). DPPs contain comprehensive product lifecycle data ranging from resource extraction to end-of-life (EoL) management. This facilitates the transition to a more sustainable, circular, and transparent global supply chain (Berger, Baumgartner, Weinzerl, Bachler, & Schöggel, 2023). As the European Union lays the groundwork for incorporating DPPs within its Ecodesign for Sustainable Products Regulation (ESPR), the Digital Battery Passport (DBP) is gathering particular attention (European Union, 2024). The DBP enhances the foundational concept of DPPs specifically within electric vehicle battery (EVB) systems. EVBs can be seen as an enabler of a low-carbon future, promising to replace combustion engines with clean, efficient electric power. In this case, the DBP can be promising to advance the EoL management of EVBs by providing essential information, for e.g., details regarding recycling processes (Ott et al., 2024). The introduction of DBPs is not only a technological novelty but an important channel for the collection and transmission of information critical to the legal, environmental, and ethical aspects of EVBs - a representation of the increasing overlap between digitalization and sustainability (Berger, Baumgartner, Weinzerl, Bachler, Preston, & Schöggel, 2023). In the DBP discourse, environmental sustainability and circularity aspects find great consideration (ibid). However, the social sustainability perspective has been neglected so far (Panza et al., 2023; Saari et al., 2022). Thus, there is a risk that the dynamic social issues associated with the EVB value chains are overlooked, resulting in DBPs that lack a holistic sustainability perspective.

In light of this discrepancy, this study seeks to extend the conceptual development of DBPs towards a holistic sustainability perspective by identifying and incorporating relevant social issues (social datapoints) into the conceptual framework of a DBP. Through a mixed-methods approach, using both primary data from targeted expert workshops and secondary data from a

comprehensive literature review, this study aims to develop a researcher-centred understanding of essential social issues relevant to DBPs (social datapoint requirements). The results are summarized based on the subcategories by UNEP (2020) or expanded to include further social issues in order to identify social datapoint requirements for DBPs. By breaking down these myriad social dimensions, the study highlights the need to develop DBPs that not only improve environmental performance but also promote social well-being and equity (Saari et al., 2022). In this regard, and considering the importance of this topic, this study answers the following research question:

Which social issues are central to the conceptual development of DBPs from the researcher's perspective to obtain a holistic sustainability perspective?

Consequently, the study describes an expanded perspective of sustainability that harmonizes with economic and environmental pillars, strengthens the integrity of DPPs and DBPs, and ultimately contributes to improving the holistic sustainability performance of global value chains of EVBs.

2. THEORETICAL BACKGROUND

The circular economy represents a system change, moving from a traditional linear framework for resource use to an innovative regenerative model that emphasizes the continuous recovery and reuse of resources to minimize waste and ensure improved sustainability performance (Moreno & Charnley, 2016; Suman & Rajak, 2025). The concept of circular value chains is crucial, especially in contexts such as the transport sector, where the life cycle of products has fundamental environmental and social impacts. EVBs are a great example of a product that can benefit from circular value chains, as they are made of different materials, and demand is growing rapidly as the world transitions to electric mobility (European Union, 2023).

Circular EVB value chains facilitate the efficient use of valuable and often scarce resources such as lithium, cobalt, and nickel, which are essential for battery production. By incorporating circular principles, value chains can minimize waste and reduce the need to extract new materials, which often leads to significant environmental damage and negative social impacts. Appropriate EoL management of EVBs ensures that these valuable materials remain in circulation for as long as possible, improving the overall sustainability performance of battery production (Rezaei et al., 2025). While a more circular EVB value chain has potential environmental benefits, it is important to note that greater circularity does not automatically equate to sustainability (Broman & Robèrt, 2025; Schögl et al., 2020).

For circular value chains to be effective, transparency and traceability are key (Berger et al., 2022; Centobelli et al., 2022; Wallat et al., 2024). This is where innovations such as DPPs come into play, potentially tracking the lifecycle impacts and facilitating the return and recycling of EVBs (Berger, Baumgartner, Weinzerl, Bachler, Preston, & Schöggl, 2023). DPPs are envisioned to create a closed-loop system, ensuring that every stage of the EVB value chain is documented, which is critical for enabling the circular economy (Zhang & Seuring, 2024). By providing accessible, reliable data on the origin, material composition, and environmental footprint of products, DPPs are set to become crucial in the tracking and optimisation of resource flows, thus fostering circularity across industries (Plociennik et al., 2022).

The DPP is a comprehensive digital identity card, analogous to a fingerprint for products, detailing the lifecycle information of products (Tabata & Tsai, 2025; Yasin et al., 2024). By integrating ethical and environmental information about a product, DPPs are structured to provide stakeholders, such as manufacturers, regulators, and consumers, with detailed data that enables informed decision-making that supports the goals of the circular economy (Berger, Baumgartner, Weinzerl, Bachler, & Schöggl, 2023; Berger et al., 2022). Not limited to ecological attributes, DPPs also have the potential to document and communicate the social impacts associated with product manufacturing, which is crucial from a holistic sustainability perspective (Berger et al., 2022; Panza et al., 2023; Saari et al., 2022). Although few, a handful of scientific studies have already investigated the integration of possible social issues in DPPs. In this regard, several studies point out that a DPP should include information on the social impact of a product. Still, no more detailed information is provided; see, e.g., the papers of Kebede et al. (2024), Langley et al. (2023), Panza et al. (2023), or Pohlmann et al. (2024). In some studies, social issues as relevant social datapoints in DPPs are already mentioned somewhat more specifically, such as in the study by King et al. (2023) and Plociennik et al. (2022), who name human welfare as one specific social topic. Other studies report more labour-related issues, such as labour conditions in general (Pohlmann et al., 2024; Stratmann et al., 2023) or position or salary information by gender, in particular for textiles and clothing (Alves et al., 2024). In their study, Panza et al. (2023) refer to five stakeholder groups and associated social topics and indicators relevant for DPPs in general, such as two social topics for the consumer stakeholder group, namely health and safety, and experienced well-being. One study focuses on batteries more specifically, namely Berger et al. (2022), who mention worker safety, fair wages, and forced labour as relevant social issues.

However, most scientific studies show that a too narrow or purely technical perspective in DPPs, or DBPs as in the present study, can obscure important data requirements. An integration of environmental and social issues is unavoidable in order to ensure sustainable product value chains. A well-structured DBP could provide critical insights into the ethical sourcing of raw materials, advance responsible production practices, and support efforts for extending battery life through an appropriate EoL management.

3. METHODS

The research adopts a mixed-methods approach in two sequential main phases (see Figure 1): 1. an exploratory literature review (secondary data) followed by 2. empirical primary data collection through workshops, leveraging the strengths of both qualitative insights and quantitative data from researcher workshops and quantitative data from the literature review. The literature review establishes a theoretical backbone, while workshops with researchers infuse the study with experiential knowledge and expert perspectives. A comprehensive systematic literature review serves as the first phase, aimed at constructing a theoretical foundation for identifying social issues associated with DPPs in general and DBPs. Therefore, relevant regulations, policy papers, and standards are being screened to identify possible relevant social issues in addition to the subcategories based on UNEP (2020) as preparation for the empirical work (workshops). Subsequently, academic databases (i.e., Scopus) are systematically searched using a combination of keywords related to social sustainability (issues), EVBs, DPPs, and DBPs. Articles, reports, and white papers are reviewed to identify social issues mentioned in research discourse. Records were excluded if they did not clearly relate to DPPs/DBPs and respective data content for Sustainable Product Management (SPM). The initial search led to 266 records identified for title and subsequent abstract screening. Based on the inclusion/exclusion criteria defined, 30 records are identified for full-text analysis. Of these 30 records, 15 relate to social sustainability information and respective data points in DPPs/DBPs. The other records predominantly discuss circularity or environmental sustainability-related data points represented via a DPP. Of those 15 records, nine ($n=9$) remain, as they explicitly specify social issues that should be represented in a DPP/DBP. The synthesis from the literature review not only identifies recurring themes but also highlights gaps in current research.

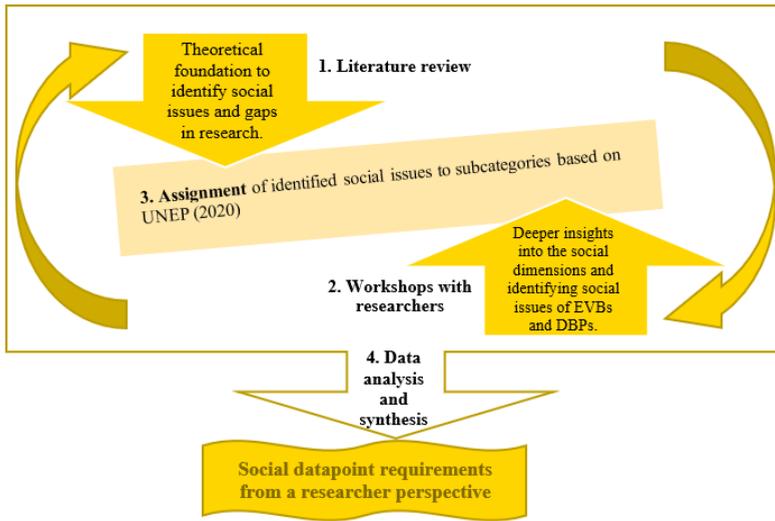


Figure 1: Methodical approach to identify social datapoint requirements from a researcher's perspective.

The literature review serves two purposes: firstly, it allows the relevance of individual social issues (social datapoint requirements) for DPP/DBPs to be identified based on secondary data. Secondly, the collection of social issues forms the basic scope for holding the workshops. Thus, the next main phase is to hold workshops with researchers ($n=64$) to gather primary data. These sessions bring together scientific experts from various fields, including sustainability, social sciences, and battery technology, to discuss and scrutinize the preliminary findings from the literature review. These workshops help to identify social issues (quantitative data) relevant as datapoints for DBPs and to gain deeper insights into the social dimensions of EVBs and DBPs, fostering an iterative dialogue that refines and enriches the themes identified in the literature. All identified social issues are assigned to the subcategories based on UNEP (2020) or have been added as additional social issues (e.g., training and education for the stakeholder group “worker”). Through an iterative process and several workshops, social datapoint requirements for DBPs from a researcher perspective are summarized, triangulated by the quantitative analysis (e.g., frequency of theme occurrence) and qualitative data, providing a conceptual basis for a holistically sustainable DBP development.

4. RESULTS

The results present social issues relevant to EVBs and the conceptual development of DBPs. The discussions draw attention to the complexity of these issues and their interconnections, emphasizing the need for their consideration in the design and implementation of DPPs.

4.1 RESULTS BASED ON SECONDARY DATA (LITERATURE REVIEW)

In total, 34 social issues were identified in the relevant literature (n=9). Based on the UNEP classification, the results show a clear preference for the "worker" stakeholder group, with a mean value of 2.50 (the sum of all mentions in the papers divided by the number of social issues per stakeholder group). Based on the mean values, the individual stakeholder groups are ranked in order: "value chain actors" (1.38), "local community" (1.09), "consumer" (1.00), "society" (0.20), and "children" (0.00). Social issues related to the stakeholder group "children" cannot be found in the respective scientific literature. When the number of social issues mentioned in the scientific papers is ranked, a focus on social issues for the stakeholder group "worker" is also evident, with the first eleven social issues related to the stakeholder group "worker" (see Table 1; Table 1 showcases only social issues with a #mentions ≥ 3).

The social issues "health and safety" (six times), as well as "child labour" and "fair salary" (five times), are mentioned most frequently. Other stakeholder groups only become apparent in 12th place, with "safe and healthy living conditions" for "local community" and "supplier relationships" and "wealth distribution" for "value chain actors". The results based on secondary data show a clear focus on the stakeholder group "worker". Overall, there is little heterogeneous discussion of social issues as a whole, with 34 social issues identified in the scientific literature, some of which are only mentioned once, such as social issues related to "local community" (e.g., cultural heritage or secure living conditions), related to "value chain actors" (e.g., fair competition or human rights due diligence), related to consumer (e.g., health and safety or feedback mechanism), and related to society (e.g., contribution to economic development or ethical treatment of animals).

Table 1: Social issues identified in scientific literature (n=9) as possible social datapoints

Rank	Stakeholder group	Social issue	Sum (#mentions)
1	Worker	Health and safety	6
2	Worker	Child labour	5
3	Worker	Fair salary	5
4	Worker	Working hours	4
5	Worker	Forced labour	4
6	Worker	Equal opportunities / discrimination	4
7	Worker	Employment relationship	4
8	Worker	Freedom of association and collective bargaining	3
9	Worker	Social benefits / social security	3
10	Worker	Sexual harassment	3
11	Worker	Smallholders including farmers	3
12	Local community	Safe and healthy living conditions	3
13	Value chain actors	Supplier relationships	3
14	Value chain actors	Wealth distribution	3

15	Consumer	Transparency	3
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4.2 RESULTS BASED ON PRIMARY DATA (WORKSHOPS)

The workshop results show that the stakeholder group “worker” is mentioned the most by the participants. Nevertheless, the distinction from the other stakeholder groups based on primary data is somewhat unclear, and the results show a heterogeneous picture of different social issues (see Table 2; Table 2 showcases only social issues with a #mentions by more than half of the participants). Based on the mean values, the individual stakeholder groups are ranked in order: “worker” (28.72), consumer (28.14), “local community” (28.00), “children” (26.50), “society” (23.80), and “value chain actors” (21.50).

The participants identified a total of 58 different social issues based on the three workshops. The social issue of health and safety is mentioned most frequently in relation to the stakeholder group “worker” (57 mentions), followed by safe and healthy living conditions for the “local community” (50 mentions). More than half of the participants mentioned a total of 27 topics relating to six different stakeholder groups. These include, for example, society-related issues (e.g., public commitments to sustainability issues or contribution to economic development), social issues related to consumers (e.g., health and safety or transparency) or social issues related to the stakeholder group “children” (e.g., education provided in the local community or health issues for children as consumers).

Table 2: Social issues identified in three workshops with sustainability researchers (n=64)

Rank	Stakeholder group	Social issue	Sum (#mentions)
1	Worker	Health and safety	57
2	Local community	Safe and healthy living conditions	50

3	Worker	Fair salary	49
4	Society	Public commitments to sustainability issues	48
5	Worker	Training and education	45
6	Worker	Child labour	44
7	Local community	Local employment	44
8	Society	Contribution to economic development	44
9	Value chain actors	Supplier relationships	43
10	Consumer	Health and safety	41
11	Consumer	Transparency	41
12	Consumer	End-of-life responsibility	41
13	Children	Education provided in the local community	41
14	Worker	Working hours	40
15	Local community	Secure living conditions	40
16	Children	Health issues for children as consumers	40
17	Worker	Forced labour	39

18	Value chain actors	Fair competition	38
19	Worker	Equal opportunities / discrimination	36
20	Local community	Community engagement	36
21	Value chain actors	Promoting social responsibility	36
22	Consumer	Feedback mechanism	36
23	Consumer	Consumer privacy	36
24	Worker	Social benefits / social security	35
25	Local community	Access to material resources	34
26	Local community	Respect of indigenous rights	33
27	Society	Technology development	33

5. DISCUSSION AND CONCLUSION

The development of DPPs and, more specifically, DBPs, represents a significant leap toward achieving transparency and accountability in the life cycle management of products, particularly in sectors such as transportation and mobility. The concept of these passports aligns closely with the goals of the CE and SPM, aiming to enhance resource efficiency, prolong product lifespans, and minimize negative sustainability impacts. While DPPs and DBPs have shown great promise in addressing the environmental and technical facets of sustainability, such as material circularity, carbon footprints, and recyclability, their contributions to social sustainability have so far been

limited. Social issues form an essential dimension of product lifecycles, particularly in globalized and resource-intensive industries like battery value chains. Failures to address these social considerations can exacerbate adverse outcomes such as unsafe labor conditions, human rights abuses, and economic inequalities. For instance, the mining of critical raw materials like cobalt and lithium, a cornerstone for lithium-ion battery production in EVs, has been associated with unethical labor practices and social displacement in different regions. Thus, the fair distribution of risks and benefits across the product life cycle is a prerequisite for a holistic, sustainable development within the context of circular economy principles. For DPPs and DBPs to contribute meaningfully to CE initiatives, they must incorporate social issues that align with not only resource management objectives but also the equitable treatment of all stakeholders. In the case of DPPs and DBPs, a more robust incorporation of social issues can provide several benefits, e.g., building trust within stakeholders through improved transparency, regulatory compliance, consumer empowerment, and supply chain accountability.

Incorporating social issues into DPPs/DBPs requires a thoughtful and systematic approach, integrating various perspectives. In this case, as a first step, a researcher's perspective can be valuable to give meaningful insights regarding relevant social issues (social datapoint requirements). It is legitimate to carry out a literature review to identify relevant topics, but this can lead to essential aspects being ignored and overlooked, especially if not much literature is available. Drawing only on scientific literature can give a too narrow picture, leading to an information asymmetry. This demands a mixed-methods approach, as used in the present study, in the form of a comprehensive literature review and gathering primary data via expert workshops with researchers.

From a researcher perspective, an information asymmetry between primary and secondary data can be observed. The amount of scientific papers related to social issues in DPPs and DBPs is rather limited, but generally, when screening social issues, previous studies show a “worker” focus, often blending out impacts on other stakeholder groups. The social issues identified via workshops in this study reveal a heterogeneous picture of possible relevant social issues, assigned to six stakeholder groups. Other than the results based on the literature review, the importance of specific topics is emphasized via a collection of 58 different social issues mentioned in total. The importance of these factors seems to vary, as several are rarely mentioned. However, a possible focus is shown by the mention of a total of 27 social issues by more than half of the participants. These 27 social issues concern topics related to “worker” (e.g., health and safety, training and education or child labor), “local community” (e.g., safe and healthy living conditions, local employment or

secure living conditions), “value chain actors” (e.g., supplier relationships, fair competition or promoting social responsibility), “consumer” (e.g., health and safety, transparency or EoL responsibility), ‘society’ (e.g., public commitments to sustainability issues, contribution to economic development or technology development), and “children” (e.g., education provided in the local community or health issues for children as consumers). Social issues relating to children are not mentioned at all in the scientific literature. Still, the primary data research shows that there are indeed relevant topics in this regard from a researcher's perspective. There is also a focus on health-related topics, such as health and safety for different stakeholder groups or in relation to safe living conditions. Overall, there are numerous social issues presented in this study that could be relevant for the conceptual development of a DPP or DBP in particular. The study thus offers a valuable contribution to support the development of DBPs from a holistic sustainability perspective. This study also serves as a call for further studies to explore the social dimension of DPPs/DBPs comprehensively. A mix of different methods and integration of various perspectives could be central to this and is highly demanded.

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