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Sharing and Managing Sustainability Information and Data in Collaborative Ecosystems—Insights From Testing a Novel Assessment Method With the Automotive Industry

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ABSTRACT

The manufacturing industry is under pressure from upcoming legislation and societal expectations to design sustainable solutions, requiring improved intraorganizational and interorganizational collaboration to ensure sustainability is integrated throughout the product's lifecycle. However, one limitation is the current inability to share and manage sustainability information and data effectively among value chain actors. To address this, we make three key contributions in this study: (i) 14 key sustainability-contextualized assessment criteria to guide the assessment of a collaborative ecosystem's current ability to share and manage sustainability information and data; (ii) an interactive and cross-functional method that integrates these 14 assessment criteria promoting ownership, awareness, and a shared understanding of key issues and ways forward; (iii) situation-specific knowledge on how to assess the ability to share and manage sustainability information and data in collaborative ecosystems, by applying the assessment method across six industrial case studies with the automotive industry.

1 | Introduction

There is a growing consensus that the manufacturing industry must improve its contribution to more sustainable solutions to support an sustainability transition (Bengtsson et al. 2018). Several upcoming legislative initiatives, such as the Digital Product Passport, the Corporate Sustainability Reporting Directive, the Right to Repair Directive, and the EU Taxonomy (European Union 2024), also impose greater lifecycle responsibility on value chain actors in the manufacturing industry. It is therefore crucial that such actors adopt sustainable design (Mallalieu et al. 2024), with the early design phases highlighted as critical for making key decisions (Bhander et al. 2003; Hallstedt et al. 2023). However, the industrial implementation of sustainable design remains limited in manufacturing, which struggles to adequately integrate socio-ecological considerations into the design process (Mallalieu et al. 2024; Vilochani et al. 2024). A recent study (Mallalieu et al. 2024) across several manufacturing companies in Sweden found that the appropriate management of sustainability information and data is one critical barrier. There is, more specifically,

i. A lack of access to sustainability information and data early in the design process
ii. A lack of understanding of what sustainability information and data are required
iii. A lack of shared understanding and interpretation of sustainability information and data among collaborating actors

iv. A lack of time and resources to collect sustainability information and data

Since a significant part of the necessary sustainability information and data is typically scattered across internal functions, and across several actors in the value chain. For example, information and data related to the social conditions of workers in raw-material extraction and on downstream activities. Moreover, it is also typically challenging to appropriately integrate some sustainability criteria into the evaluation of concepts such as “repairability” and “minimizing safety risks” (Mallalieu et al. 2023). In turn, this highlights a limited ability to manage sustainability information and data within manufacturing companies, and between collaborating value chain actors. At the same time, Mallalieu et al. (2024) also found that there are discrepancies and misaligned expectations between different actors and functions inside organizations, for example, designers, sustainability experts, material experts, and IT/PLM[1] departments, and similar findings were found by Schöggl et al. (2023) and Trevisan et al. (2023). The management of sustainability information and data has remained a challenge for some time (e.g., Bhander et al. 2003; Gmelin and Seuring 2014; Chebaeva et al. 2021).

At the same time, effective and efficient management of resource flows is also expected to require closer involvement and collaboration with external actors across the value chain and product lifecycle (Geissdoerfer et al. 2026; Jugend et al. 2024; Mallalieu et al. 2024). In turn, this adds interorganizational related challenges concerning the management of information and data, while also amplifying the issues raised above (i–iv), which significantly raise the expectations on value chain actors' collective ability to share and manage sustainability information and data across a product's lifecycle appropriately (Dokter et al. 2025; Isaksson et al. 2025; Rashid et al. 2013). Moreover, Geissdoerfer et al. (2026) found a lack of guidance on how to design such collaborative setups in a recent review of circular ecosystems. There is thus a risk of scattered and misaligned efforts, both internally and externally, in designing, setting up, and managing the flows of resources, information, and data between collaborating value chain actors, that is, the *collaborative ecosystem*.[2] The aim of this study is, therefore, to develop and propose prescriptive support that, early in the design process, can facilitate and guide the identification of key challenges in managing sustainability information and data within a collaborative ecosystem. In turn, this can improve the collaborative ecosystem's long-term ability to make informed decisions, enabling more sustainable choices in, for example, materials, suppliers, and end-of-life strategies throughout the solution's full lifecycle, and adequately integrate sustainability, that is, social, ecological, and economic, throughout the solution's full lifecycle (Mallalieu et al. 2024; Isaksson et al. 2025). The following research question guided this study:

- How can the assessment of a collaborative ecosystem's ability to appropriately share and manage sustainability information and data be facilitated?

By addressing the research question, this study makes three novel contributions: (i) 14 key sustainability-contextualized assessment criteria to guide the assessment of a collaborative ecosystem's current ability to share and manage sustainability information and data; (ii) an interactive and cross-functional method that integrates these 14 assessment criteria to promote ownership, awareness, and a shared understanding of key issues and ways forward; (iii) the generation of situation-specific knowledge on how to assess the ability to share and manage sustainability information and data in collaborative ecosystems, by applying the assessment across six industrial case studies with the automotive industry. Moreover, the *Design Research Methodology* (Blessing and Chakrabarti 2009) was used to structure this research, engaging several value chain actors from the automotive industry throughout the process.

The remainder of this paper is structured as follows. First, a background is presented to clarify the need for this research. Second, the research approach used to develop, adapt, and evaluate the proposed assessment method is presented. Third, the proposed assessment method is presented, along with key insights from its application across six case studies. Fourth, the key contributions of this research are discussed and highlighted, followed by key limitations and future work. Last, the conclusions are presented.

2 | Background

First, background on information and data in the context of sustainable design, where common challenges, approaches, and views on information and data quality are presented (Section 2.1). Second, this is expanded upon in the context of collaborative ecosystems, which give rise to new challenges that call for prescriptive guidance and support (Section 2.2).

2.1 | Information and Data in Sustainable Design

High-quality, mature information and data are important for the design of any product, enabling informed decision-making and helping avoid, for example, cognitive biases. The early phases of design are typically considered to have high potential to improve the sustainability performance of a solution throughout its lifecycle (Bhander et al. 2003; Hallstedt et al. 2023). Here, design freedom is high, and we make key decisions about materials, core technologies, product functionalities, manufacturing methods, and end-of-life strategies. In turn, such decisions rely on high-quality and mature information and data to ensure sustainability, that is, social, ecological, and economic, is appropriately integrated throughout the product's full lifecycle. Moreover, manufacturing companies need to move away from designing physical artifacts in isolation and instead design the product's complete lifecycle as part of a larger socio-technical system (Ceschin and Gaziulusoy 2016; Isaksson et al. 2022).

At the same time, it is generally known that there typically is less known and higher uncertainty in the early phases of design, that is, less availability of high-quality and mature information and data, and it is commonly referred to as the *design process paradox* (Ullman 1992; Chebaeva et al. 2021). For context, Eder (1998) divides the design process into the four generic phases of (i) understanding the problem, (ii) conceptualizing, (iii) embodiment, and (iv) detailing and refers to (i) and (ii) as the "early stages of designing." Despite this dilemma, key decisions are still made early in the design process in practice (Ulrich and Eppinger 2016), and it is therefore important to ensure that high-quality, mature sustainability information and data are available to the greatest extent possible. *Front-loading* is a common approach to counter the *design process paradox*, aiming to generate as much relevant knowledge about the *design problem* and its potential solutions as possible early in the design process (Thomke and Fujimoto 2000; Dorst and Cross 2001). Interestingly, some approaches acknowledge the lack of high-quality, mature sustainability information and data and propose alternative methods to support sustainability decision-making when such data are unavailable. Hallstedt et al. (2023), for example, systematically derive qualitative and quantitative metrics to guide development, whereas Parolin et al. (2025) use narratives. Despite efforts and progress, the topic of sustainability information and data remains a contemporary issue in the sustainability literature and continues to require attention (e.g., Bhander et al. 2003; Gmelin and Seuring 2014; Chebaeva et al. 2021; Mallalieu et al. 2024).

Furthermore, providing high-quality, mature sustainability information and data on alternative solutions and their lifecycle-wide sustainability impacts is challenging to define and, once defined, to acquire. For example, which information and data to collect to capture total energy consumption across the product's full lifecycle for different materials is both difficult to define and to acquire. It depends on several factors that are not set during the early phases, including the final geometry, the material supplier, the manufacturing process, and the source's geographical location. In turn, this requires extensive intraorganizational collaboration, because such lifecycle information, data, and knowledge are typically scattered, or "siloed," across functions and disciplines within an organization (Mallalieu et al. 2024; Rashid et al. 2013). Borsato (2014) delves into a common issue associated with such "data siloing": data incompatibility, which can arise when information and data are represented differently internally, and offers a more technical solution. Mallalieu et al. (2023) identified another technical issue related to data incompatibility: Lifecycle-focused sustainability criteria are difficult to incorporate into conventional product design assessments, which currently tend to focus, for example, on in-use product functionality, but offer no clear way to address this. A common approach to addressing these issues is the use of interactive, cross-functional work formats that promote knowledge and information sharing among multidisciplinary teams (Ritzén and Lindahl 2001; Mallalieu et al. 2024).

This study similarly posits that it is necessary to promote the sharing of high-quality, mature sustainability information and data among relevant stakeholders across the value chain. Moreover, numerous research efforts have clarified what constitutes data quality and maturity, as well as how to manage data. For example, Wang and Strong (1996) outline several factors that clarify what is meant by "good data," and later Wang (1998) proposes the Total Data Quality Management methodology to provide further guidance on how organizations can manage data quality. There are also established standards related to data quality management, such as ISO 8000. Blanco et al. (2007) also propose a framework for managing information maturity in the design process. Yassine et al. (1999) instead propose a method for modeling information flows to identify information dependencies in the design process, thereby enabling their effective management. Later, Hajali et al. (2023) similarly model the existing information and data flow at a company to understand how a new manufacturing technology can be appropriately integrated into the internal value chain. Brinkmann and Wynn (2025a), like Wang and Strong (1996), outline a large set of factors or aspects that clarify what is "good information," and later propose an approach to assess, or "clarify," information maturity (Brinkmann and Wynn 2025b). However, many of the proposed frameworks include an extensive set of considerations (e.g., Wang and Strong 1996; Brinkmann and Wynn 2025a), and it is unclear which of these are relevant in an already time-pressured environment (Mallalieu et al. 2024; Isaksson et al. 2025). Furthermore, these aspects are neither sustainability-specific nor examined in the context of sustainable design and collaborative ecosystems, leaving a conceptual gap.

2.2 | Sharing and Managing Sustainability Information and Data in Collaborative Ecosystems

Moving toward more sustainable solutions will require more effective and efficient management of resource flows, which calls for closer, improved interorganizational and intraorganizational collaboration in the design process as organizations become increasingly dependent on one another (Geissdoerfer et al. 2026; Dokter et al. 2025; Schöggl, Baumgartner, et al. 2024). In this paper, we refer to this collaborative setup as a collaborative ecosystem of value chain actors that together need to ensure that sustainability, that is, social, ecological, and economic, is appropriately considered throughout the product's complete lifecycle (Dokter et al. 2025). Such a collaborative ecosystem is illustrated in Figure 1 to highlight the complexity of designing and managing it, which comprises several layers of value chain actors with their own value chains.

Furthermore, appropriate management of sustainability information and data in such collaborative ecosystems extends beyond data quality and maturity, introducing new challenges. For example, this adds complexity and thus requirements on the information and data management capabilities of actors in the value chain (Schöggl, Stumpf, and Baumgartner 2024; Mallalieu et al. 2024; Rashid et al. 2013), introducing challenges such as trust, ownership of data, and agreement on what sustainability information and data is needed and can be shared (Mallalieu et al. 2024; Dokter et al. 2025; Isaksson et al. 2025; Aryee et al. 2025).

On the one hand, such a collaborative and integrated setup is expected to create new opportunities to improve the management of sustainability information and data (Trevisan et al. 2022; Schöggl et al. 2023; Isaksson et al. 2025). For example, information and data sharing among actors can improve as interorganizational relations strengthen as trust increases and/or terminology is streamlined. Emerging digital technologies and tools can enhance the ability to collaborate, design, and manage solutions that integrate sustainability throughout their lifecycles

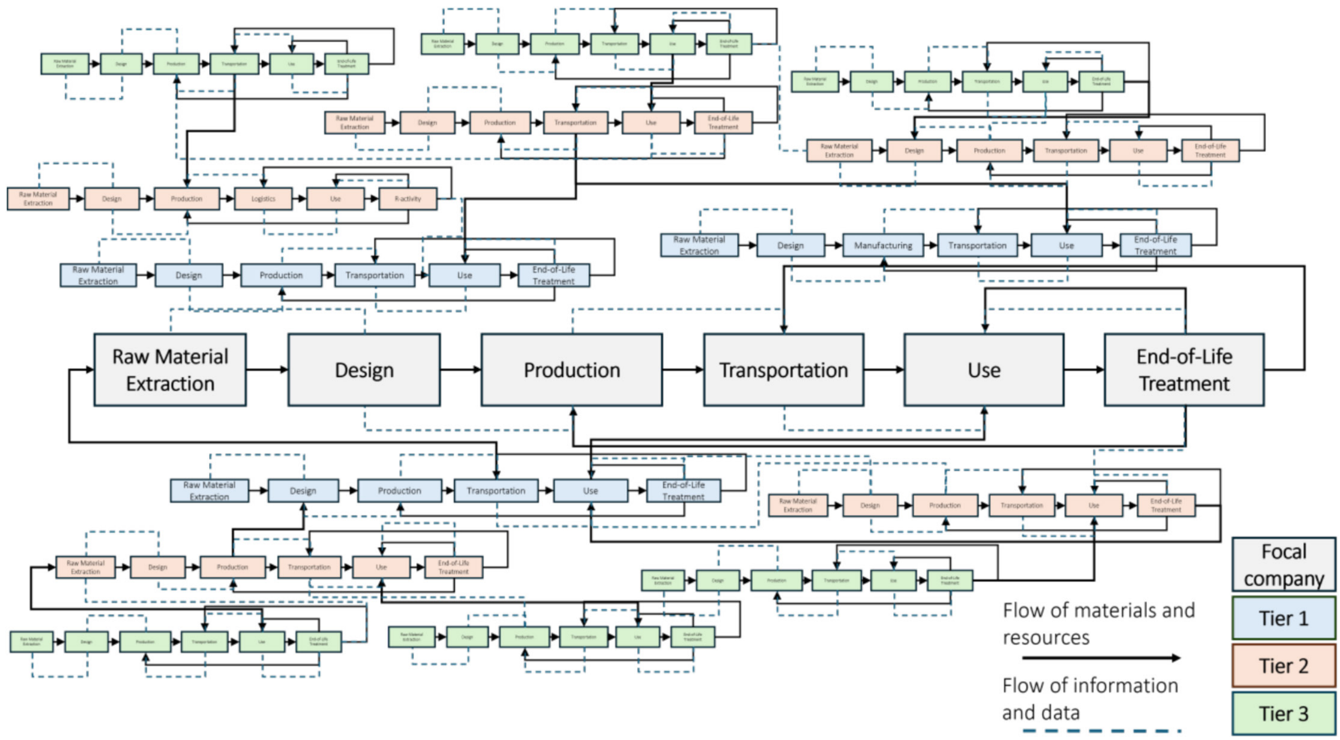

FIGURE 1 | Stylistic illustration highlighting the complexity of designing and managing a collaborative ecosystem (adapted to ISO 14001:2015).

(Han et al. 2023; Rusch et al. 2023; Neri et al. 2023). On the other hand, this can, in turn, add new information and data management challenges (Schöggl, Stumpf, and Baumgartner 2024; Mallalieu et al. 2022, 2023, 2024), such as a lack of interoperability between internal and external data standards, software, and tools. Again, this further underscores the need for closer interorganizational and intraorganizational collaboration, preferably in interactive and cross-functional formats that promote ownership, shared understanding, and awareness of key issues to be resolved together (Ritzén and Lindahl 2001; Burnes 2015; Schöggl, Baumgartner, et al. 2024; Mallalieu et al. 2024).

Last, although such collaborative setups have received considerable conceptual attention in the literature, empirical studies remain scarce (Schöggl, Baumgartner, et al. 2024). At the same time, the literature highlights a lack of clear guidance and practical support for designing or setting up such collaborative ecosystems (Aryee et al. 2025; Geissdoerfer et al. 2026). To summarize, there is sufficient justification for developing practical support to guide and promote the sharing and management of sustainability information and data in collaborative ecosystems. More specifically, guidance and facilitation in:

i. Assessing and understanding the current ability to appropriately share and manage sustainability information and data in the collaborative ecosystem
ii. Streamlining requirements and expectations among key stakeholders concerning the collaborative ecosystem's ability to share and manage sustainability information and data
iii. Identifying hotspots and proposing strategic actions to overcome critical issues concerning the sharing and management of sustainability information and data
iv. Promoting both intraorganizational and interorganizational collaboration among stakeholders across the value chain

In turn, addressing this (i.e., i–iv) can improve the collaborative ecosystem's long-term ability to make informed decisions, enabling more sustainable choices in, for example, materials, suppliers, and end-of-life strategies throughout the solution's full lifecycle, and adequately integrate sustainability, that is, social, ecological, and economic, throughout the solution's full lifecycle (Mallalieu et al. 2024; Isaksson et al. 2025).

3 | Research Approach

The overarching research approach used to develop, adapt, and evaluate the method followed the *Design Research Methodology* (Blessing and Chakrabarti 2009) because it is useful for structuring and guiding the development of prescriptive support. The research was conducted in three main phases using a combination of methods between March 2023 and February 2026, as illustrated in Figure 2.

The first phase used two workshops and 13 semi-structured interviews with several value chain actors to collect qualitative data (Säfsten and Gustavsson 2020). The first phase (Research Clarification and Descriptive Study I) aimed to identify key challenges of information and data management in the context of sustainable design and collaborative ecosystems, serving as the baseline for the proposed assessment method.

The second and third phases focused on a multiple-case study (Säfsten and Gustavsson 2020) conducted as part of an ongoing action research study at an automotive OEM to adapt

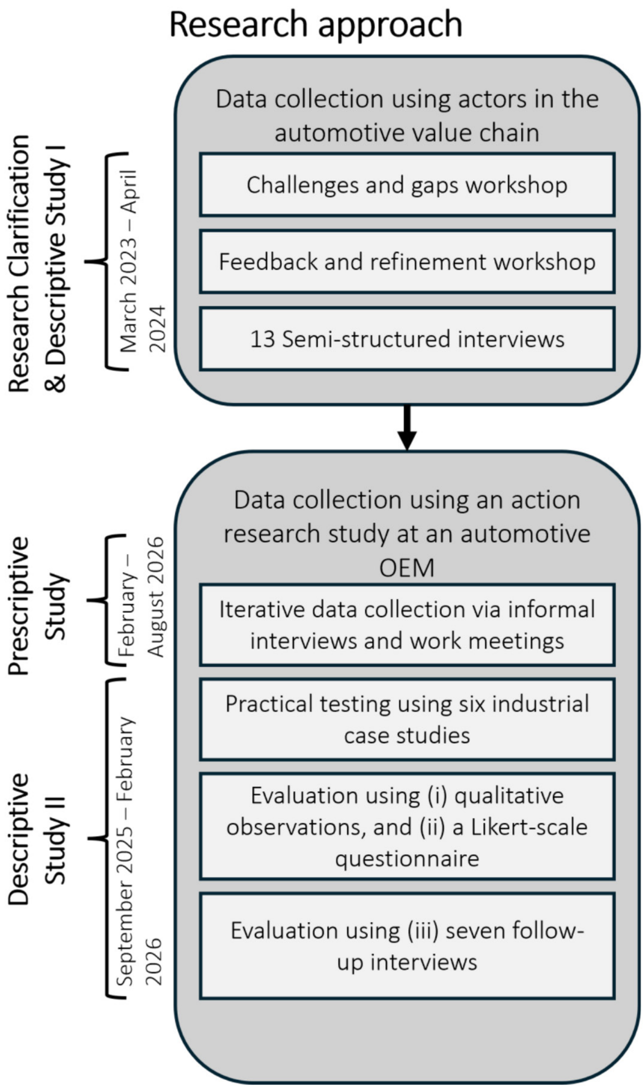

FIGURE 2 | The research approach used to develop, adapt, test, and evaluate the proposed method for assessing sustainability information and data management capabilities.

and test an assessment method (Lewin 1946; Ottosson 2003; Säfsten and Gustavsson 2020). The second phase (Prescriptive Study), more specifically, aimed to gain a deep understanding of the existing processes, practices, and challenges in the sharing and management of sustainability information and data within a single automotive OEM, that is, focusing on theory elaboration by incorporating contextual idiosyncrasies (Ketokivi and Choi 2014). Moreover, such practices are generally highly complex and unique within any organization, and much unspoken information is available but difficult to uncover without close interaction (Ottosson 2003; Brahma et al. 2026). *Action research* is therefore a suitable approach for obtaining the deep understanding necessary to contextualize and adapt the assessment method to the desired context and environment, ensuring it remains relevant to the case companies (Ottosson 2003; Mallalieu et al. 2024).

The third phase (Descriptive Study II) aimed to test and evaluate the proposed assessment method in as realistic a context as possible, using six parallel case studies to structure this phase (Eisenhardt 1989; Säfsten and Gustavsson 2020). Here, three different methods were used to triangulate and collect qualitative data used to evaluate the proposed assessment method's effectiveness and applicability (Eisenhardt 1989; Säfsten and Gustavsson 2020), including (i) a Likert scale questionnaire, (ii) qualitative observations from the practical test, and (iii) follow-up interviews. Altogether, this also enables the generation of situation-specific knowledge for how the assessment method guides and facilitates the assessment of a collaborative ecosystem's ability to share and manage sustainability information and data appropriately (Eisenhardt 1989; Ketokivi and Choi 2014). These three phases will be described in detail below, followed by an explanation of how the evaluation data were collected.

3.1 | Data Collection With Actors in the Automotive Value Chain

The first phase (Research clarification and Descriptive Study I) focused on collecting data and framing the core industrial problem to be addressed, as well as the underlying questions and challenges to be incorporated into the proposed assessment method. Six supplementary studies have contributed to this study (Mallalieu et al. 2022, 2023, 2024; Brahma et al. 2026; Isaksson et al. 2025; Dokter et al. 2025), which together framed the core and overarching industrial problem of sharing and managing sustainability information and data across the value chain. Across these studies, several industrial actors from the Swedish manufacturing industry have been involved, and together they indicated the need to study this problem in greater detail and in the context of sustainable design and collaborative ecosystems. Moreover, as mentioned in Section 2.1, several established frameworks for data quality and maturity exist, raising numerous challenges, but it is unclear which of these are most relevant to address. Additionally, these frameworks are neither sustainability-specific nor examined in the context of sustainable design and collaborative ecosystems, leaving a conceptual gap. Therefore, to address this, two interactive workshops and 13 semi-structured interviews were conducted between March 2023 and April 2024 with industrial actors in the automotive value chain to better understand the underlying issues and the challenges companies face in managing sustainability information and data. All participants involved in the activities are listed in Appendix A, and seven different companies representing different parts of the automotive value chain were involved to improve generalizability and ensure that these challenges are relevant beyond the automotive OEM that serves as the focal company in this study.

The first workshop (4 h) focused on identifying key challenges and current gaps in managing sustainability information and data within the automotive value chain and was conducted as a guided brainstorming exercise. The second workshop (2 h) focused on refining, streamlining, and validating the outcomes from the first workshop. The 13 semi-structured interviews were used to identify concrete examples and to generate a more nuanced understanding of the issues stakeholders face in their daily work, how they address these issues today, and how a potential method could be useful in practice. The scope of the interviews was not limited to sustainability information and data management, and the themes and questions covered are also listed in Appendix A. A total of five researchers, who are the authors of this paper and active in this topic, participated in the data collection and analysis to improve rigor (Creswell 2014; Säfsten and Gustavsson 2020), resulting in 14 key assessment criteria. The criteria can be used to assess an ecosystem's ability to share and manage sustainability information and data appropriately and are presented in detail in Section 4.1.1. Moreover, these criteria have also been further developed to suit the context of sustainable design and collaborative ecosystems, which require further theory elaboration (Ketokivi and Choi 2014). Lastly, literature assisted this process in parallel by streamlining terminology and strengthening external validity (Creswell 2014; Säfsten and Gustavsson 2020).

3.2 | Action Research Study at an Automotive OEM

The second and third phases of this study were part of an ongoing action research study (Lewin 1946; Ottosson 2003; Säfsten and Gustavsson 2020) at a market-leading automotive OEM (Company A). Company A's real business scenario stems from its ambition to integrate new, more sustainable materials into its products and is currently exploring how to achieve this in collaboration with six first-tier material suppliers. Furthermore, to enable this and support early decision-making, Company A needs to request and collect new sustainability information and data on these materials. Company A, therefore, initiated a research project, referred to as a *sustainable material data ecosystem*, to explore how access to high quality, mature sustainability information and data can be improved. One researcher was invited to support the initiative on-site at Company A as part of an action research study starting in February 2025 and expected to end in June 2026. As mentioned, *action research* was considered a suitable approach for obtaining the deep understanding necessary to contextualize and adapt the assessment method, ensuring its relevance to the case companies and bridging the gap between academic research and practical application (Ottosson 2003; Mallalieu et al. 2024). Several means, or "tools," were used to support the action research study at Company A:

- Acquiring an internal company email, key badge with access to the site, and access to Teams channels, which significantly increased access to key stakeholders inside the organization and complementary information about their roles and responsibilities.
- Access to internal databases with documentation of, for example, organizational structure, templates for internal methods and tools, terminology, and development process charts.
- A template that Company A uses for both internal and external communication was used with the intention of making presentation material appear as "made here".
- Physically located at the company during meetings and key activities, for 2 to 3 days a week, for the initial 3 months of the study.

From February 2025 to August 2025, more than 30 informal work meetings and interviews were conducted to understand this organizational context. For example, getting acquainted with the company's internal language, daily challenges and priorities, formal roles, existing methods and tools, and design processes. These informal meetings involved different internal stakeholders, including:

- Product designers and component owners to better understand how they work with product development and integrate sustainability, along with the challenges they face concerning sustainability information and data.
- Managers and other "gatekeepers" who are responsible for internal resources, and might have input about what challenges to prioritize.
- Material specialists to better understand what sustainability data are available, but also what data could be relevant for Company A and how it could improve and support the decision-making process concerning material selection.
- Representatives from the information and data management/PLM function, to better understand what internal data structures and rules are important to consider, what other tools exist, and the internal data flows.
- Database governance representatives, as data are scattered across the organization, where several databases are used to store and manage it. It is also important to find synergies and overlaps with the *sustainable material data ecosystem*.
- Representatives from the purchasing function who are negotiating with material suppliers, and have ongoing sustainability initiatives related to the sourcing of materials. They also need sustainability information and data to improve and support decision-making regarding material procurement.
- Sustainability experts and "champions," to better understand what challenges they experience in integrating sustainability into the design process, what priorities they see, and how the sustainability information and data could improve and support the decision-making on material selection.

Several similar meetings were also held with representatives from the material suppliers for the same purpose. Learnings and insights from the action research study were continuously captured and used to iteratively develop the final assessment method, which is presented as the Prescriptive Study and can best be described as an abductive process (Säfsten and Gustavsson 2020; Dorst 2011), which also aligns with Ketokivi and Choi's (2014) view on theory elaboration. As mentioned, the 14 key assessment criteria from the first phase served as the core of the assessment method. In contrast, this second phase instead focused on understanding how these can be integrated into an interactive, cross-functional method that simultaneously promotes ownership, shared understanding, aligned expectations, and awareness of key issues to be resolved together (Ritzén and Lindahl 2001; Schöggl, Baumgartner, et al. 2024; Mallalieu et al. 2024). In turn, this resulted in a proposed procedural logic and intended use, presented in Section 4.1.2. For example, which roles to involve, the overall steps to take, and the order in which to take them. Moreover, a template was created to provide a step-by-step, practical guide to the assessment and to capture the outcomes, as presented in Section 4.1.3. The final assessment method was subsequently applied and tested across six parallel case studies involving Company A and six of its first-tier suppliers and is described in more detail below.

TABLE 1 | The case companies involved in the six case studies.

Company	Type	Size	Case
Company A	OEM in the automotive value chain	90,000+ employees	1, 2, 3, 4, 5, and 6
Company B	First-tier steel supplier in the automotive value chain	15,000+ employees	1
Company C	First-tier aluminum supplier in the automotive value chain	3500+ employees	2
Company D	First-tier polymer supplier in the automotive value chain	1100+ employees	3
Company E	First-tier polymer supplier in the automotive value chain	300+ employees	4
Company F	First-tier polymer supplier in the automotive value chain	6900+ employees	5
Company G	First-tier biomaterial supplier in the automotive value chain	2–10 employees	6

3.3 | Practical Test of the Assessment Method Using Six Parallel Case Studies

A multiple-case study design was employed in the action research study (Eisenhardt 1989; Säfsten and Gustavsson 2020) to structure testing in as realistic a context as possible, serving primarily as Descriptive Study II. A total of six real industrial cases were carried out, and the case companies are listed in Table 1. It is difficult to claim what is a suitable number of cases; however, six is generally considered sufficient for this type of study (e.g., Eisenhardt 1989).

The six case studies, one per material supplier, were identical in terms of scope and revolved around Company A, acting as the focal company in the collaborative ecosystem seeking to incorporate new sustainable materials into its parts and components, which require closer collaboration and involvement of these suppliers to share and manage sustainability information and data. Moreover, this set of six cases was purposefully sampled and designed (Flick 2007; Cash et al. 2022) to generate situation-specific knowledge about how the assessment of a collaborative ecosystem's ability to appropriately share and manage sustainability information and data can be guided and facilitated (Eisenhardt 1989; Ketokivi and Choi 2014).

Following this, the proposed assessment method was applied in line with its intended use across six carefully selected multidisciplinary teams from the automotive OEM, together with representatives from the first-tier suppliers, who engaged in a facilitated dialogue on the 14 key assessment criteria during a 3-h workshop. This was done in September 2025, and the purpose of this workshop was to address the issues (i–iv) raised in Section 2.2, but specifically among the companies involved in the *sustainable material data ecosystem*. This setup is illustrated in Figure 3, in which 24 people from the seven companies took part. Additionally, six researchers, including four of the authors

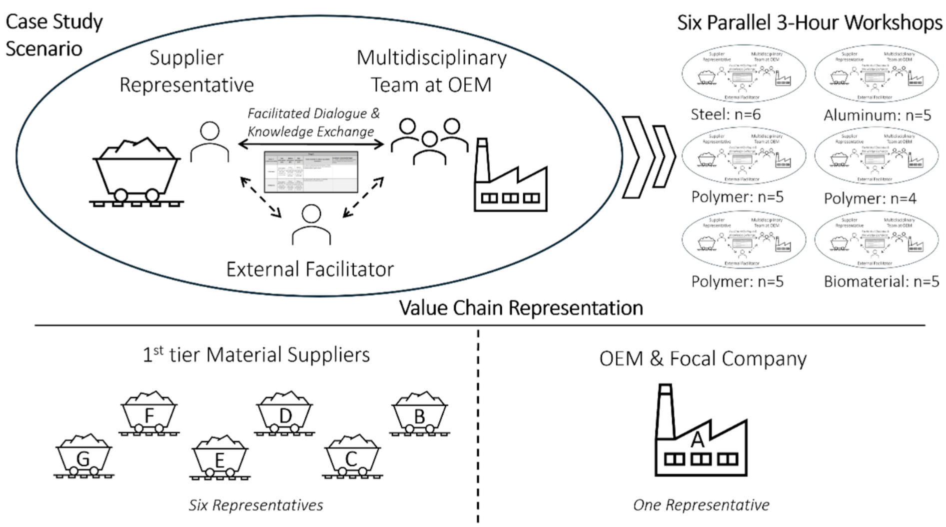

FIGURE 3 | Case study design and setup.

of this paper, participated to support the dialogue and made qualitative observations within these groups (Creswell 2014). Moreover, the researcher active in the action research study supported the workshop by describing the method, clarifying its intended use and purpose, answering general questions and concerns, tracking time and progress within each team, while also making qualitative observations across all six groups.

Before the workshop, between May 2025 and August 2025, an Excel list with 40+ sustainability data points was defined and created to serve as input, that is, the sustainability information and data to be assessed. Examples of sustainability information and data that were requested include "energy use [MJ/kg produced material]," "water deprivation potential [m3-world eq./kg produced material]," "recycled content [%]," "repairability potential of material [low/medium/high]," and "labor conditions [compliance to standard]." The data points varied in complexity and characteristics; some were purely quantitative, while others were qualitative. Moreover, all data points were strictly material-oriented, given the scope of the research project, and the suppliers were tasked with populating this list as fully as possible before the workshop. To clarify, there was thus no information or data on, for example, how much CO_2 a mobility solution emits per kilometer. However, this sustainability information and data can nevertheless guide decisions on materials that, in turn, contribute to a mobility solution with lower CO_2 emissions, for example, during raw material extraction and production.

3.4 | Collecting Data to Evaluate the Proposed Assessment Method

Three different methods were used to triangulate and collect qualitative data used to evaluate the proposed assessment method's effectiveness and applicability (Eisenhardt 1989; Säfsten and Gustavsson 2020). First, outcomes were captured during the workshop through qualitative observations by the academic participants (Creswell 2014) and through visual recordings captured using the guiding template. These observations and recordings were later digitized for recordkeeping purposes and later analyzed by the involved researchers. These results are presented in Section 4.2 and can be used to evaluate if and how the assessment method was effective in guiding and facilitating the assessment of a collaborative ecosystem's ability to share and manage sustainability information and data appropriately.

Second, at the end of the 3-h workshop, the participants were asked to evaluate the method using a Likert-scale questionnaire ($n = 22$), as it is also relevant to understand how method users perceived it (Mallalieu et al. 2024). The questionnaire was inspired by Rossi et al. (2016) and Almefelt (2005), who propose several criteria for evaluating methods. The questionnaire structure and questions used are in Appendix B, and the detailed results and analyses of the responses are available in Appendix D.

Last, six follow-up interviews were conducted between October 2025 and February 2026 to evaluate whether and how the assessment method effectively guided and facilitated the assessment of a collaborative ecosystem's ability to share and manage sustainability information and data appropriately. These interviews more specifically focused on following up (a) what, and if any, key insights and new knowledge were gained among the six teams; (b) if these resulted in any key actions within the *sustainable material data ecosystem*; and (c) the anticipated impact of acting on these outcomes. In total, seven interviews were conducted: one per team (between October 2025 and November 2025) and one with the project manager from Company A (in February 2026), as this person has a holistic view of (a–b) from a project perspective. The results from these follow-up interviews were synthesized and analyzed by the researcher participating in the action research study, but were later assessed by the remaining researchers to improve rigor (Creswell 2014; Säfsten and Gustavsson 2020) and are presented in Section 4.3.

4 | Results and Discussion

First, the assessment method is presented along with how it was used in practice by the case companies. Second, generalized outcomes from applying the assessment method in practice are presented and discussed. Third, a summary of the follow-up interviews is presented and discussed.

4.1 | Proposed Method to Assess the Ability to Manage Sustainability Information and Data Management in a Collaborative Ecosystem

The proposed assessment method comprises several well-thought-out facets, which will be presented in further detail below. This includes (i) the 14 key sustainability-contextualized assessment criteria guiding the assessment, (ii) the procedural logic and intended use, and (iii) a guiding template that was used during the 3-h workshop, with extracts from the case studies to provide clarity on how it can be used in practice. The results from the questionnaire are also summarized and presented.

4.1.1 | Proposed Key Criteria to Appropriately Assess and Guide a Collaborative Ecosystem's Ability to Share and Manage Sustainability Information and Data

Several aspects or criteria can be used to assess the maturity and quality of information in the design process. Additionally, as emphasized in Section 2.2, the appropriate sharing and management of sustainability information and data in a collaborative ecosystem require consideration of aspects beyond quality and maturity. In this study, we propose 14 key assessment criteria to guide the appropriate sharing and management of sustainability information and data sharing in a collaborative ecosystem. The 14 key criteria are presented in Table 2, along with explanations in the context of sustainable design and collaborative ecosystems, questions to trigger dialogue, and their rationale.

4.1.2 | Proposed Procedural Logic and Intended Use of the Assessment Method

The intended users of the proposed assessment method are a multidisciplinary team[3] with sufficient competence and experience to provide a qualitative assessment in an interactive format.

TABLE 2 | The 14 key sustainability-contextualized assessment criteria that can be used to assess and guide a collaborative ecosystem's ability to share and manage sustainability information and data.

Assessment criteria	Explanation and questions	Rationale
Actuality	Assess whether the managed sustainability information and data in the collaborative ecosystem are up to date. When was it collected? Is it still valid today? Have any changes not been updated? Is it continuously updated using live sensors? Are there any data points that are typically subject to fluctuations or frequent changes?	Sustainability information and data can be subject to fluctuations or changes that affect their actuality, for example, the type of energy that supplies the factory, which in turn influences the CO_2 footprint, or technological advancements that improve recycling performance over time. In turn, this calls for data points that are repeatedly updated. Whereas other types of data, for example, the density of a material, remain the same. There are also legislative demands regarding data veracity, which make certain data points more critical.
Accuracy	Assess the accuracy of the managed sustainability information and data in the collaborative ecosystem. How well does the data correspond to the real value? Was it objectively measured, by for example, testing or sensors, or collected by a subjective measure? Is it a precise scalar value, or a rough scale/range of values?	Certain sustainability information and data are qualitative and require scales or ranges that are precise and sufficiently accurate to provide appropriate guidance. Some data points are also provided based on expert opinion and are thus subjective, where, for example, experience can influence accuracy. Some data points result from complex calculations involving multiple causal relations and are occasionally based on assumptions that, in turn, affect accuracy.
Reliability	Assess whether the managed sustainability information and data within the collaborative ecosystem are reliable and trustworthy. Is the actor providing the data trustworthy? Have inexperienced personnel provided the data? Has the data been validated by a neutral/third-party actor, or collected via standard procedures?	Some actors might be prone to exaggerating their sustainability performance, for example, by overstating the material's durability or by relying heavily on secondary data rather than testing. Some data points stem from complex calculations with many causal relations, are occasionally based on assumptions, and, when followed, calculation standards can increase reliability.
Accessibility	Assess whether the sustainability information and data managed in the collaborative ecosystem are accessible. Can the data be easily accessed by all stakeholders? Can relevant stakeholders access the data? Is it provided in a time-efficient digital format? Do all stakeholders in the organization hold clearance to access the data? Can the data easily be retrieved from the source and used as input to other tools/software?	The data points are seldom provided in a format that makes them accessible and useful for internal development activities, for example, simulations or copy-and-paste across different sustainability assessments. Certain data points are sensitive and therefore seldom shared with a wide range of actors inside the focal company, but only with a limited set of stakeholders.
Completeness	Assess whether the managed sustainability information and data in the collaborative ecosystem are complete. Does the information and data cover a systemic perspective on sustainability? Does it cover the full lifecycle phases (cradle-to-cradle) and all three pillars of sustainability, that is, social, ecological, and economic? Are perspectives from multiple actors included, for example, raw material extractors, material providers, logistics providers, manufacturers, users, and downstream actors?	Sustainability information and data need to cover a full systemic perspective, and there is seldom a single actor who can provide the full sustainability impact of a product across its lifecycle. A limited perspective can lead to sub-optimal decisions, for example, reducing CO_2 in the use phase, but to an overall increase due to CO_2 emissions from manufacturing and downstream activities.

(Continues)

TABLE 2 | (Continued)

Assessment criteria	Explanation and questions	Rationale
Scalability	Assess whether the management of sustainability information and data in the collaborative ecosystem is scalable. Do we utilize unique data formats, classifications, and structures, or do we align with standards that can be used outside of this ecosystem? Can all actors inside the ecosystem efficiently utilize the data? Can other actors outside the ecosystem also utilize the data? Is it possible to manage this sustainability information and data across several products and projects within the organization?	Sustainability information and data management is a maturing field, and several actors are working in parallel, leading to unique formats and approaches for consolidating data. Formats and approaches must align with standards to not "reinvent the wheel." There is also a risk that, depending on the scope, managing sustainability information and data will become too complex and time-consuming to handle at scale. For example, if a company expects to log and manage unique lifecycle data for all unique products currently in use.
Flow security	Assess whether the sustainability information and data are managed securely when transferred among actors in the collaborative ecosystem. Can we ensure that there are no breaches and that data are not compromised? Do we use a sophisticated system/software, or email, to manage the flow of data among stakeholders and actors?	Certain sustainability information and data can be sensitive or constitute intellectual property, and the flows and sharing of data must therefore be secure. It can be either that external actors gain access to sensitive data or that internal actors, by mistake, compromise critical data.
Storage security	Assess whether sustainability information and data are managed securely when stored across different stakeholders and actors within the collaborative ecosystem. Can we ensure that there are no breaches and that data is not compromised? Do we use a sophisticated system/software or local folders to manage data storage? Can anyone make changes to the data, or only a select group?	Certain sustainability information and data can be sensitive or constitute intellectual property, and therefore, their storage must be secure. It can be either that external actors gain access to sensitive data or that internal actors, by mistake, compromise critical data.
Communicability	Assess whether actors in the collaborative ecosystem appropriately understand and interpret sustainability information and data. Is the data point using a relevant unit? Is the name of the data point unambiguous? Is experience or competence required to understand and interpret the data? Will the data be understood and interpreted the same by different actors in the ecosystem? Does it mean different things to different stakeholders? Is it possible to understand and interpret when it is explained?	Certain sustainability information and data may be considered novel to some stakeholders and, therefore, difficult to understand and interpret. For example, what does "water deprivation potential measured in [m3-world eq./kg produced material]" mean, and what is considered low/high in relative terms? Certain data points are also expected to be used by several different types of stakeholders. For example, "water deprivation potential measured in [m3-world eq./kg produced material]" might easily be understood by a sustainability specialist, but not by a consumer who wants to make a sustainable choice when deciding between two different types of lawn mowers.

(Continues)

The method depends on engaging relevant stakeholders across the value chain, and the following roles are recommended for involvement in the assessment.

- Designers or design teams,[4] because they know what type of sustainability information and data are required to support decision-making in their daily operations
- A *method expert*[5] who has experience in using this assessment method and can support facilitating the use, by for example, clarifying the required inputs and appropriate use, and potentially make minor modifications and adaptations to fit the current situation
- Representatives from IT/PLM departments, because they have the technical depth to provide input on requirements,

TABLE 2 | (Continued)

Assessment criteria	Explanation and questions	Rationale
Transparency	Assess whether there is full transparency of sustainability information and data in the collaborative ecosystem. Is there complete transparency of sustainability information and data across the lifecycle to all stakeholders? Is there complete transparency of sustainability information and data across the lifecycle to a set of stakeholders? Is there transparency in sustainability information and data across the lifecycle for all stakeholders? Is there some transparency of sustainability information and data across the lifecycle, and only to some stakeholders? Are all data points fully disclosed? Are there sensitive data points that are not disclosed?	To comply with upcoming legislation, there is a need for improved transparency regarding a product's sustainability impact. This can be seen as two-dimensional, that is, vertical through all supplier tiers, and horizontal across the product lifecycle. There may occasionally be conflicts of interest regarding transparency, because certain information can be sensitive, such as material composition, but at the same time, information of high value to a downstream actor seeking to optimize the resource recovery process. Actors in the ecosystem need to be transparent enough to enable more sustainable decisions by different stakeholders, but without harming their own company.
Traceability	Assess whether there is full traceability of sustainability information and data in the collaborative ecosystem. Is there full traceability regarding the origin and evolution of data in the ecosystem? Do we know where the data come from and who collected it? Do we know how the data were collected? Do we know when the data were collected? Is there sufficient traceability and coverage of product-related data? For example, data about where the raw material comes from, the substances added in the process, and the conditions of employees who extracted the material, or what happens to the product downstream?	To comply with upcoming legislation, there is a need for improved traceability, which covers two different aspects: (i) product-related traceability, that is, the scope of what product-related data should be available, for example, the materials' origin, substances/alloys added to improve resource recovery activities, or information about physical repair activities made to prolong the product's life; (ii) traceability of the data points as such, that is, where the provided data come from, ensuring its origin and evolution can be traced.
Ownership	Assess whether there is clear ownership of sustainability information and data managed in the collaborative ecosystem. Are the roles and responsibilities among the management and governance of data clear and understood? Are the roles and responsibilities for management and governance of data agreed among the actors involved? Who is responsible for updating the data? Who is responsible for deciding who can gain access to the data? Who owns the data? Is it clear who is held accountable for the data?	It is not fully clear who has, or should have, ownership of sustainability information and data, or of the activities related to their management and governance. It is important to discuss and agree on these issues, which are sometimes seen as "soft issues" with no clear or present answer, mainly because a seemingly new setting requires increased, closer collaboration among actors in the ecosystem.
Value of information and data	Assess whether the managed sustainability information and data provide value to the collaborative ecosystem. Does the data provide value to all actors in the ecosystem? Does the data provide value to any actor in the ecosystem? Can the data support decision-making? Is the data necessary for compliance with legislation? Can we agree that the sustainability information and data are relevant to the ecosystem?	Certain sustainability information and data have different values to different actors and stakeholders. It is not always clear whether the requested data add value or merely consumes time and resources; therefore, it is important to ensure that the data provided are valuable. This can also cause disharmony in the ecosystem if, for example, some actors feel they need to provide data for the sake of providing it, without receiving any value in return.

(Continues)

TABLE 2 | (Continued)

Assessment criteria	Explanation and questions	Rationale
Labor intensity	Assess whether the managed sustainability information and data are labor-intensive to collect across the collaborative ecosystem actors. Does managing data require extensive time and resources? Does data consolidation require extensive time and resources? Is it time-consuming to ensure that data is up to date?	The management of sustainability information and data is considered to require extensive time and resources. It must therefore be managed efficiently and effectively. Many small actors are expected to provide data, but consider themselves unable to meet these requirements. This can also cause disharmony in the ecosystem if, for example, some actors feel they need to provide data for the sake of providing it, without receiving any value in return.

technical feasibility, and expectations related to the management of data, along with relevant data standards

- Sustainability experts, because they can provide a nuanced view of what sustainability information and data are of interest, ensure that there is a clear link to different legislations and directives and that relevant standards for collecting data are followed
- Managers, or project leaders, because it is important to achieve buy-in to the issues that require attention
- Engineering specialists, because sustainability information and data need a systemic perspective, which may require the involvement of, for example, specialists/representatives from supply chain, materials development, and manufacturing operations
- Representatives from "process, method, and tools development functions," because they have a good understanding of the overall internal processes and tools used internally, and thus how sustainability information and data can be integrated into this ecosystem, while also complying with the design logic and terminology

The assessment is preferably carried out at the product or component level, because the relevance and complexity of managing different sustainability information and data can vary significantly across products or components. The assessment method is also recommended to be carried out in three sequential steps. There is also a preceding step that defines which sustainability information and data should be collected and provided, a prerequisite for using the proposed assessment method as intended. The overall procedure is visualized in Figure 4, and each sub-step will be described below, using the six case studies as examples, in which a physical A0 template was used to guide, structure, and capture the results. The template is in Appendix C, and snapshots will be provided to clarify how the method can be used in practice.

It is important to emphasize that the preceding step is critical and a prerequisite to the proposed assessment method, which can be conducted systematically to ensure a comprehensive systemic sustainability perspective (e.g., Hallstedt et al. 2023; Watz and Hallstedt 2023). Moreover, the preceding step can also be carried out using a predefined set of product criteria typically used internally at the focal company to assess sustainability performance, or an upcoming regulation that introduces requirements for new types of sustainability information and data. The preliminary set of sustainability information and data may be fully, partially, or sparsely populated, but this will influence the assessment. The assessment method should thus be used iteratively early in the design process to improve sustainability information and data management capabilities over time.

4.1.3 | Adaptation and Practical Testing of the Proposed Assessment Method With the Case Companies

In this study, the preceding step was carried out in May 2025 using the *Sustainable Product Development Workshop* (Schulte and Hallstedt 2018), combined with input collected during the action research study related to product criteria used internally to assess sustainability performance at Company A. Furthermore, given the scope and focus of the *sustainable material data ecosystem* initiative, the Sustainable Product Development Workshop was modified, and the product criteria were rephrased as material-oriented data points rather than product-oriented ones. For example, a product criterion related to repair was rephrased to "repairability potential of material [low/medium/high]" to make it a material-oriented data point. As mentioned in Section 3.4, this resulted in an Excel list with 40+ data points. Following this, each material supplier was asked to collect and consolidate sustainable material data and populate the Excel list for their material.

During the interactive workshop, Step 1 was conducted straightforwardly by asking the involved stakeholders to review the Excel list individually for 10–15 min. The time spent on this will vary by case, depending on factors such as the scope and coverage of the data (i.e., the number of data points). Step 2 was completed within the smaller teams during the 3-h workshop by jointly discussing the 40+ data points for each assessment criterion in a structured manner, spending approximately 5 min per criterion. Figure 5 illustrates the template used to structure this discussion; the same structure was applied to all 14 assessment criteria.

The participants were encouraged to assign a grade from 1 to 9 and to provide qualitative answers or arguments for their choice. Additionally, because they assessed all 40+ data points simultaneously, they could identify potential individual data hotspots that require attention. As mentioned, this assessment is preferably conducted in smaller multidisciplinary teams rather than individually. Step 3 was conducted in the same setup during the 3-h workshop and focused on jointly discussing and elaborating on the implications and risks, as well as on what actions to take. Again, this is ideally done one data point at a time per

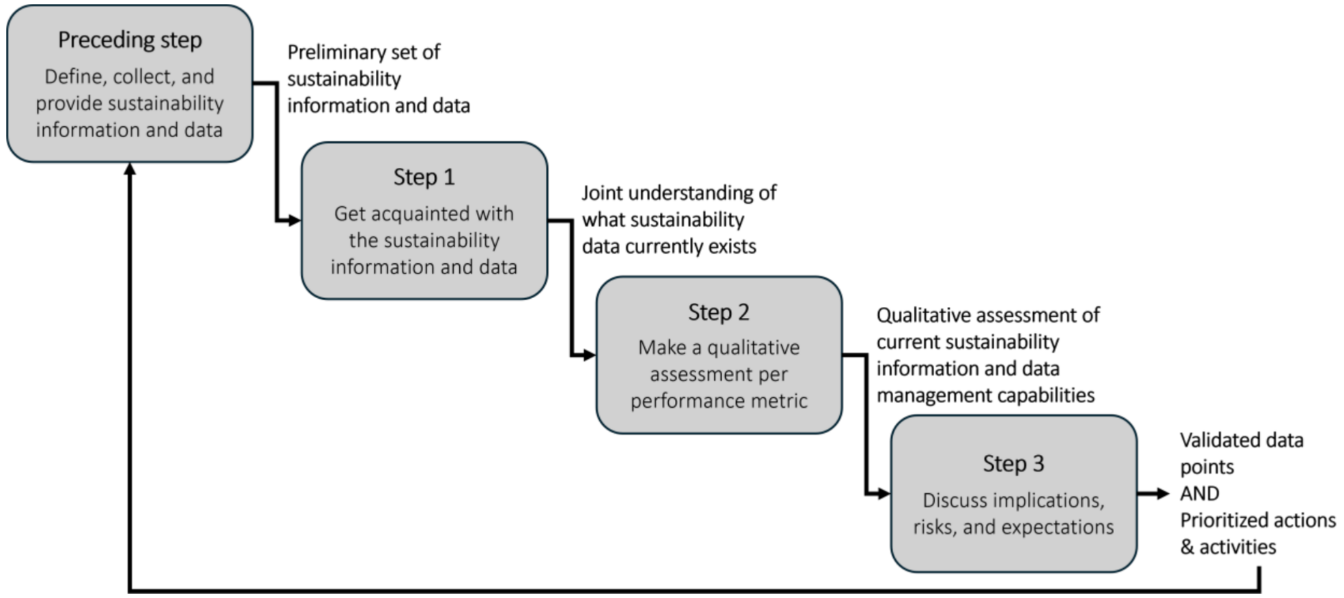

FIGURE 4 | The procedure of applying the proposed assessment method, along with expected inputs and outputs.

assessment criterion. However, due to time constraints, Step 3 was performed simultaneously for all 40+ data points. A total of 45 min was spent on Step 3 during the 3-h workshop. Figure 6 illustrates the template used to structure this discussion; the same structure was applied to all 14 key criteria. This part of the template is placed slightly to the right of Step 2.

The individual responses for each group are not presented; instead, a synthesis of the main outcomes is provided in Section 4.2. Furthermore, to illustrate how the results were captured during the workshop, two snapshots are shown in Figure 7.

Furthermore, the types of answers, that is, outcomes from using the proposed assessment method, can vary substantially; three hypothetical examples are provided to illustrate what could be discussed in theory.

1. Assuming there are large parts of obsolete data, this will result in a low score on, for example, *actuality*. In turn, if these data are used to comply with legislation, it can result in fines. This can be addressed, for example, by ensuring that internal activities keep data continuously up to date. However, this can result in extensive manual labor, making it beneficial to invest in a digital system to manage data more efficiently.
2. Assuming there are plans to roll out an aggressive circular design strategy, which includes the reuse, repair, and remanufacturing of a set of components to prolong the average life of a fleet of vehicles. In turn, this can require the company to track unique product data to ensure efficient resource use and to pursue the appropriate circular design strategy. However, this goes beyond what the ecosystem can manage, because there were low scores in, for example, *scalability*, *transparency*, or *traceability*. Instead, the stakeholders agree that it is more beneficial to roll out a stepwise introduction of circular strategies to ensure the circular design strategy can be realized in practice.
3. Assuming there are large volumes of relevant sustainability data but scattered across several different internal functions and external actors, this will result in a low score on, for example, *accessibility*. Such an issue can be addressed, for example, through consolidation efforts that ensure sustainability data are stored and accessible in a central database. However, this can instead result in issues related to *communicability* or *scalability* if different formats and terminology are used across the actors in the ecosystem. In turn, this highlights that the collaborative ecosystem needs to consider several issues simultaneously in such an effort.

4.2 | Empirical Outcomes From Applying the Proposed Assessment Method in Practice

The empirical outcomes obtained from applying the proposed assessment method in practice with the case companies are presented below. These outcomes were captured visually during the workshops and through qualitative observations by the facilitators.

4.2.1 | Clarifying the Value of Sustainable Material Information and Data

One key issue raised during the assessment was the time and effort the material suppliers spent collecting the requested sustainable material information and data, that is, populating the Excel list with 40+ data points. Several participants raised this issue during the 3-h workshop, stating that 40+ data points are "too much" and that it is "better to focus on the most critical ones." According to the material suppliers, two main factors made this a tedious and time-consuming activity: (a) Some of the requested sustainability information and data were argued as too vague and ambiguous, making it cumbersome to collect and consolidate; (b) some of the requested sustainability information

Step 2					
Assessment criteria	**Low performance (1-3)**	**Medium performance (4-6)**	**High performance (7-9)**	**Grade between 1-9, and add a qualitative assessment**	**Sustainable material data hotspot** E.g., if there is any particular data that is considered critical to address, or of interest, or should be removed.
1. Actuality	*Sustainability information and data in the ecosystem are not up to date*	*Critical sustainability information and data in the ecosystem are up to date*	*Relevant sustainability information and data in the ecosystem are up do date*	*E.g., Data are continuously checked and updated (<10 days), or collected using sensors with real-time data, or data are not considered subject to large fluctuations.*	
2. Accuracy	*Sustainability information and data in the ecosystem are inaccurate*	*Critical sustainability information and data in the ecostem are accurate*	*Relevant sustainability information and data in the ecosystem are accurate*	*E.g., data correspond to the real value, or use precise quantitative values, or collected via standard.*	

FIGURE 5 | Snapshot of the template design and structure for Step 2, highlighting the guiding questions for Criteria 1 and 2. The same design and structure were used for all criteria.

Step 3		
a) What are the implications and potential consequences of this? E.g., increased cost, reduced sustainability performance, affects our ability to realize the solution, or to meet reporting legislations.	**b) How does it affect us, and is this an implication we need to address?** E.g., do the potential consequences have a negative or significant impact, or are the consequences uncertain and instead pose a risk.	**c) What strategic actions should be taken to address this?** E.g., develop or utilize existing standards, develop or implement software, streamline data formats, invest in internal competence, or change the design.

FIGURE 6 | Snapshot of the template design and structure for Step 3, highlighting the guiding questions and empty spaces to capture input. The same design and structure were used for all 14 assessment criteria.

and data do not currently exist, and/or are difficult to retrieve, either internally or from their suppliers.

The dialogue concerning the *value of information and data*, therefore, received significant attention, and Company A was asked to rework the Excel list and to more clearly define which sustainability information and data were most critical to them. This included clarifying some of the requested sustainable material information and data that were deemed too vague or ambiguous, and removing less relevant information and data. Altogether, this emphasized the overarching need within the collaborative ecosystem to clearly define, understand, and agree on which data are relevant to provide. Within the *sustainable material data ecosystem*, this reduced the number of data points to 20, down from the 40+ initially requested. The importance of establishing shared understanding and interpretation of the requested sustainability information and data was also highlighted, as it enables efficient and effective data collection and sharing among the value chain actors.

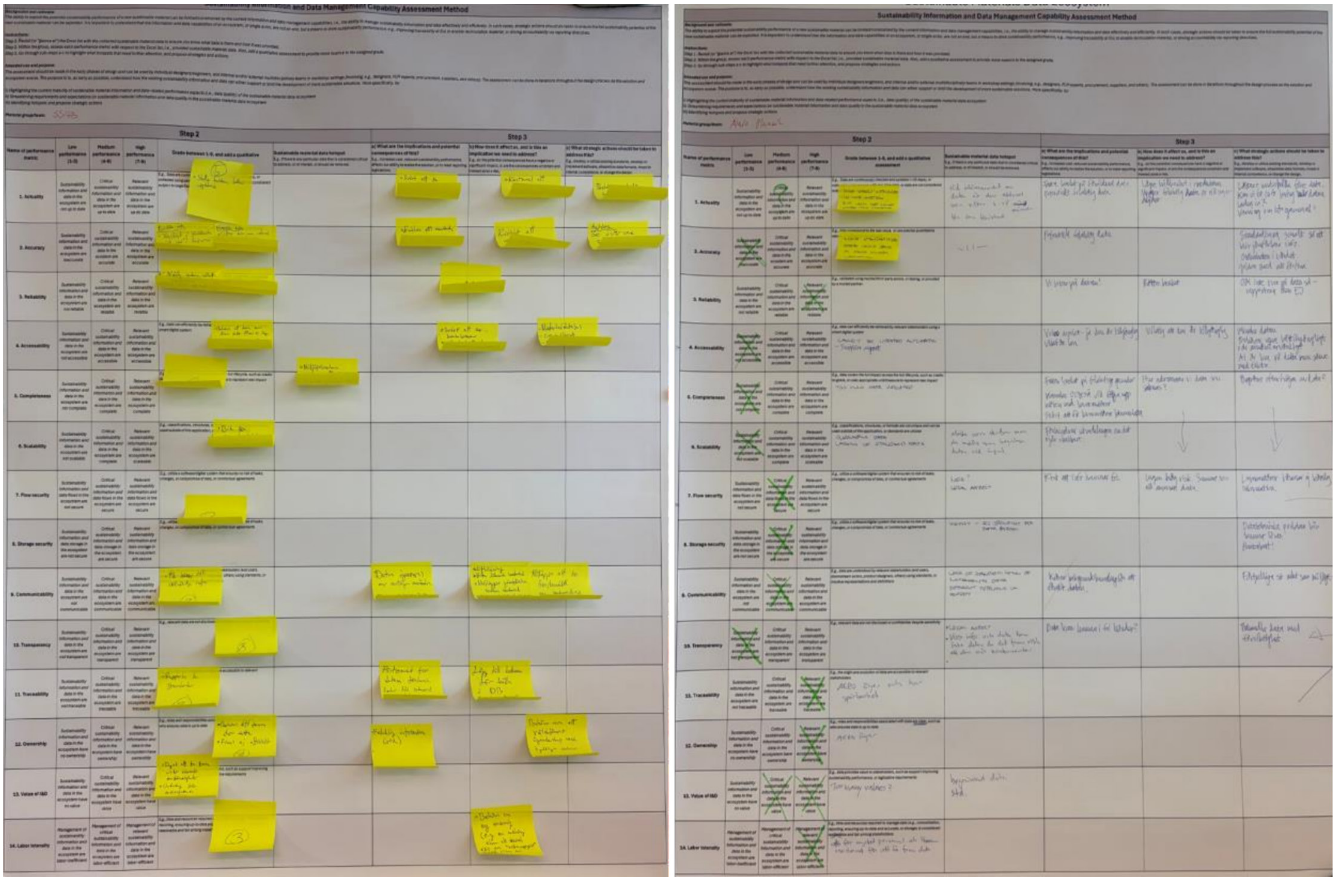

FIGURE 7 | Illustrative examples of how results were captured during the 3-h workshop.

4.2.2 | Means for Collecting and Sharing Sustainable Material Information and Data

The time and resources required to collect the sustainable material information and data requested by Company A varied between the material suppliers. Some of the material suppliers stated that they used standards and software related to *Life Cycle Assessments* (LCA) and *Environmental Product Declarations* (EPD) (e.g., European Commission 2022), which saved them considerable time and effort in collecting and providing data. This supplier has recently made a strategic decision to make all sustainability information and data non-sensitive. In turn, data collected using such standards showed a positive impact on several criteria, including *accuracy*, *reliability*, *accessibility*, *scalability*, *communicability*, *traceability*, and *labor intensity*. However, these standards are limited to environmental aspects and do not include social sustainability, which was explicitly raised as a limitation. Moreover, environmental information and data from LCAs and EPDs are typically consolidated and provided in reports or PDF format, which is considered less favorable for a product designer with limited time and less experience working with sustainability data. In contrast, another supplier could not share all the requested sustainability information and data because it was considered highly sensitive. Instead, certain data points were manually selected and added, which influenced the scores for *scalability*, *transparency*, and *labor intensity*.

As a result, the case companies will explore different strategic actions within the *sustainable material data ecosystem*, including using new AI technologies to extract specific sustainability-related material information from such PDFs and present it in a more user-friendly way, making it more *accessible* and *communicable* to product designers. Furthermore, it became clear that many different standards are used in LCAs and EPDs, because, for example, CO_2 allocation differs by standard, and some actors might prefer the one that is most beneficial to them. This was deemed to result in issues related to *accuracy*, *reliability*, and *communicability*. Altogether, this emphasized the need within the collaborative ecosystem to clearly define and agree on the accepted means for collecting the data.

4.2.3 | Ambiguous and Vague Sustainable Material Information and Data

As mentioned, some of the requested sustainability information and data were considered too vague and ambiguous. For example, quantifying aspects such as "labor used in material acquisition is done in a rightful way that is not in conflict with the needs of the local community," and therefore utilized simple qualitative and semantic metrics, or scales. Moreover, some data points were difficult to quantify accurately because they were product-oriented criteria rephrased as material-oriented criteria, for example, "repairability potential of material." Several dialogues across the six groups focused on developing a shared understanding and interpretation of sustainability information and data. For example, within one group, there was also some scrutiny of the assigned values/scores for "supply chain risk," where the team from Company A argued that the score should be "worse" because the material is sourced in a region relatively prone to floods, which can influence the supply of this material, and discussed for quite some time.

Nevertheless, it was difficult for the suppliers to provide such ambiguous data effectively before the workshop, and there were several explicit requests to exclude sustainability information and data considered too ambiguous. Altogether, this negatively influenced the scores on *availability*, *accuracy*, *reliability*, *communicability*, and *completeness*. To address this issue, activities related to improving the qualitative and semantic metrics, or scales, for some ambiguous data points were proposed and initiated within the *sustainable material data ecosystem*. For example, define and use clear semantic scales of what characterizes a material with high "repairability potential," instead of "low/medium/high," which were considered too vague.

4.2.4 | Lack of Systemic Perspective in Sustainable Material Information and Data

It became evident during the assessment that a limited involvement of value chain actors reduced the *completeness*, *transparency*, and *traceability* of the data. The material suppliers could not, as anticipated, provide the full coverage of a product's lifecycle, and therefore scored low on *completeness*, *transparency*, and *traceability*. For example, data on "Global Warming Potential" included only emissions from a limited set of lifecycle phases, leaving gaps in the sustainability information and data provided. Despite being anticipated, the assessment method successfully raised awareness among the stakeholders involved. Furthermore, the limited set of value chain actors made it difficult to provide sustainability information and data on social sustainability, as many social sustainability data points were argued to pertain to upstream activities.

Altogether, this contributed to lower scores in *completeness*, *transparency*, and *traceability*. Even though the stakeholders involved were predominantly positive about the inclusion of such sustainability information and data, it was also considered to require closer involvement from additional upstream and downstream value chain actors across supplier tiers. In turn, this highlighted the need to involve a broader set of value chain actors to cover the product's lifecycle fully.

4.2.5 | Improving the Interorganizational and Intraorganizational Collaboration

The assessment involved both stakeholders from the focal company, and several material suppliers and effectively raised several key issues, providing a platform for stakeholders to discuss critical issues related to sustainable material information and data management. The material suppliers seemed to benefit from being able to discuss the *value of information and data* with the focal company, because providing the data required significant time and effort. The dialogue around that helped agree on which data to prioritize short-term and which data could be of interest long-term, and, as mentioned, this reduced the number of data points to 20, compared with the 40+ initially requested. Furthermore, many internal stakeholders at the focal company also viewed it as beneficial to involve a cross-functional team in the assessment. For example, it became evident that several parallel related initiatives are ongoing and need to be synchronized.

4.3 | Results From Follow-Up Interviews

Seven interviews were conducted to follow up on the workshop, and extracts from these are presented here to verify the outcomes and key insights presented in Sections 4.2.1–4.2.5. During the interviews, one supplier representative raised the apparent issue of variation in the sustainability information and data suppliers can provide, stating that

> There is a huge discrepancy in what suppliers can and will provide, and this will limit the ambition substantially.

Ambition here refers to the scope of data available in the *sustainable material data ecosystem*, arguing that the demands or expectations for what sustainability information and data should be available there need to be streamlined. The same interviewee also stated that across all suppliers, there is a general lack of social and economic sustainability information and data for specific materials and that this must be addressed over the long term. In turn, one idea discussed was that social sustainability is not something you can be better at; you are either in or out. Social sustainability data can be governed at a more organizational level, that is, baseline requirements that the *sustainable materials data ecosystem* imposes on suppliers, such as those related to working conditions. Again, the argument was that the ambition for social sustainability should not differ between materials, whereas, for example, CO_2 emissions or energy use can.

The supplier, which had many IP issues in providing the requested sustainability information data, stated during the interview that these issues became evident during this research initiative, that is, when it was first requested. Apparently, parts of the data come from upstream actors, which, in theory, could be shared with the focal company alone, but as the supplier representative stated,

> It might require complex contract work.

Another supplier representative stressed that although EPDs provide a solid basis for standardizing data collection, multiple standards are still in use. Moreover, despite these thorough standards providing some guidance, there are still a lot of:

> It depends.

In line with this, another supplier representative elaborated on different standards that could serve as a potential basis, and that there is generally a lot of discussion regarding how to allocate emissions, for example, preconsumer and postconsumer scrap. Following this, he explicitly stated,

> You do not want to contribute to greenwashing, but some companies make weird calculations when you include your own spill and scrap.

As a result, Company A raised the need to make an internal decision on how to proceed. Moreover, another supplier representative elaborated on the complexity of data collection, stating that their data depends on many lower-tier suppliers, and they do not always know exactly how those suppliers collect it.

Last, below is an extract in which the project manager was asked to summarize the main benefit of applying the assessment method in this interactive format:

> The obvious feeling is that we have been able to build a better connection among the people involved in this initiative. The assessment method forced people within company A to discuss. For example, the guy from the lab, the people from sustainability, and the people from functions Y and Z were discussing for the first time, all together in the same place. Also, they were aligning, and that was not easy to do outside the predefined context provided by the assessment method. Secondly, it has initiated reflection, especially on the people driving sustainability within the company.

This quote captures the essence of why interactive, cross-functional work formats that promote knowledge and information sharing among multidisciplinary teams are beneficial in this context.

5 | Implications

First, the key contributions of this research are presented. Second, the main limitations and need for future work are presented.

5.1 | Key Contributions

Based on the empirical findings from this study, as presented and discussed in Section 4, this research makes three key contributions, which are elaborated in the subsections below, focusing on novelty and validity.

5.1.1 | 14 Key Sustainability-Contextualized Assessment Criteria

In this study, we have highlighted a key barrier to implementing sustainable design in the manufacturing industry. More specifically, value chain actors' current inability to sufficiently share and manage sustainability information and data in collaborative ecosystems. This is a challenging and multifaceted issue, and various frameworks have been proposed to guide the management of high-quality and mature data (e.g., Wang and Strong 1996; Brinkmann and Wynn 2025a; ISO 8000). However, these are extensive, and it is unclear which of these are relevant to address in an already time-pressured environment (Mallalieu et al. 2024; Isaksson et al. 2025). Furthermore, these aspects are not sustainability-specific nor studied in the context of sustainable design and collaborative ecosystems, which pose additional challenges beyond quality and maturity (Mallalieu et al. 2024; Dokter et al. 2025; Isaksson et al. 2025), thereby leaving a conceptual gap for theory elaboration (Ketokivi and Choi 2014). In response to this, we provide:

Key Contribution 1: Fourteen key sustainability-contextualized assessment criteria that frame generalized and key issues in sustainability information and data management within collaborative ecosystems, presented in Section 4.1.1. These can be used to guide the assessment of a collaborative ecosystem's ability to appropriately share and manage sustainability information and data.

Contribution 1 is based on qualitative data collected through two workshops and 13 semi-structured interviews conducted with seven companies representing different parts of the automotive value chain. In turn, this is argued to improve generalizability and ensure that these challenges are relevant beyond the automotive OEM that serves as the focal company in this study. Moreover, a questionnaire with 22 respondents from the same automotive OEM and six first-tier material suppliers found these 14 assessment criteria relevant, capturing key aspects. This also supports generalizing these challenges beyond the automotive OEM, thereby strengthening the external validity of the 14 key assessment criteria (Säfsten and Gustavsson 2020).

5.1.2 | Interactive and Cross-Functional Assessment Method

In this study, we have also highlighted that many of these challenges need to be understood, shared, and addressed collaboratively by value chain actors, requiring interactive, cross-functional methods that promote knowledge and information sharing among multidisciplinary teams (Ritzén and Lindahl 2001; Burnes 2015; Mallalieu et al. 2024). However, there is generally a lack of clear guidance and practical support for designing or establishing such collaborative ecosystems (Aryee et al. 2025; Geissdoerfer et al. 2026), leaving a practical gap. In response to this, we provide:

Key Contribution 2: An assessment method that integrates the 14 key assessment criteria into an interactive and cross-functional method promoting ownership, awareness, and a shared understanding of key issues and ways forward. The method includes procedural logic and intended use, the roles to involve, the overall steps to take and their order, and a template that serves as a practical guide to the assessment and captures the outcomes, presented in Sections 4.1.2 and 4.1.3.

Contribution 2 is based on an action research study within an automotive OEM that seeks to improve the sharing and management of sustainability information and data with six first-tier material suppliers through a *sustainable material data ecosystem*. Data collection was conducted through more than 30 informal interviews and work meetings with internal and external stakeholders to ensure the assessment method was relevant within this context and to bridge the gap between academic research and practical application (Ottosson 2003; Mallalieu et al. 2024). This involved six parallel case studies with different first-tier material suppliers, thereby supporting the generalizability of the proposed assessment method (Säfsten and Gustavsson 2020).

5.1.3 | Assessing a Collaborative Ecosystem's Ability to Share and Manage Sustainability Information and Data

As mentioned, collaborative setups have generally received considerable conceptual attention in the literature, whereas empirical studies on this topic remain scarce (Schöggl, Baumgartner, et al. 2024), leaving a gap in the elaboration of theory (Ketokivi and Choi 2014). Moreover, case studies were identified as suitable for generating situation-specific knowledge about how the assessment of a collaborative ecosystem's ability to appropriately share and manage sustainability information and data can be guided and facilitated, and accommodating contextual idiosyncrasies (Eisenhardt 1989; Ketokivi and Choi 2014; Säfsten and Gustavsson 2020). In response to this, we provide:

Key Contribution 3: Situation-specific knowledge on assessing the ability to share and manage sustainability information and data in collaborative ecosystems, presented in Sections 4.2 and 4.3. This was done by applying the assessment method across six industrial case studies in the automotive industry. More specifically, the assessment method was used to facilitate dialogue between six carefully selected multidisciplinary teams from the automotive OEM and representatives from the first-tier suppliers during a 3-h workshop.

Contribution 3 is based on qualitative data that were collected using (a) qualitative observations during the workshop and (b) follow-up interviews 2 to 4 months after the workshop. In addition, (a) a Likert scale questionnaire at the end of the workshop, which indicated that the assessment method was perceived as useful, applicable, and relevant among the involved participants. Together, these three sources triangulate the empirical findings (Eisenhardt 1989; Säfsten and Gustavsson 2020), which strengthen the internal validity that the proposed assessment method was effective in guiding these six teams in:

i. Assessing and understanding the current ability to appropriately share and manage sustainability information and data in the collaborative ecosystem
ii. Streamlining requirements and expectations concerning the collaborative ecosystem's ability to share and manage sustainability information and data
iii. Identifying hotspots and proposing strategic actions to overcome critical issues concerning the sharing and management of sustainability information and data
iv. Promoting both intraorganizational and interorganizational collaboration

Again, it needs to be emphasized that the assessment method itself does not provide answers to key challenges and issues; instead, it facilitates systematic discussion, enabling the stakeholders involved to jointly identify and agree on ways forward. This also aligns with research findings on similar assessment approaches (e.g., Bogers and Horst 2014; Schöggl et al. 2017) and supports strengthening the external validity (Ketokivi and Choi 2014; Creswell 2014; Säfsten and Gustavsson 2020). However, there are some limitations regarding generalizability that will be discussed below.

5.2 | Limitations and Future Work

There were two limitations in the design of the six industrial case studies that affect the generalizability and validity of the latter two phases of this study (Prescriptive Study and Descriptive Study II): (i) The actors were representatives of the automotive industry, whereas other sectors were underrepresented, which can limit generalizability (Säfsten and Gustavsson 2020). Therefore, the assessment method needs to be tested in additional industrial settings before its generalizability and external validity can be assessed appropriately beyond the situational context of this study. (ii) The case studies included a set of automotive value chain actors, that is, one OEM acting as the focal company and six first-tier material suppliers. In turn, it focused on materials and lacked perspectives from, for example, downstream actors, which can influence collaborative dynamics and methoduse, and thus the outcomes. Therefore, there is potential for further theory elaboration by including a more comprehensive representation of the full product lifecycle and value chain.

Furthermore, two limitations of the assessment method were identified through its application in practice: (i) The need for a dedicated person with expertise in the method to facilitate the discussion, as some elements were difficult to understand without explanation. This was both observed during the workshop and evident in the questionnaire. That said, the importance of an experienced facilitator in this context has been highlighted in previous research (e.g., Mallalieu et al. 2024; Schöggl et al. 2017). This would, for example, positively impact the assessment criteria that were difficult to understand, as they could be explained on an ad hoc basis during the method's use. Such an individual would also bring relevant experience with common issues and ways forward to enhance the discussion. Moreover, it is possible to develop better instructions and include real examples, as some participants propose and as noted in previous literature (e.g., Gericke et al. 2022). (ii) The time required to carry out the assessment was explicitly raised as insufficient during the workshop and was evident in the questionnaire. To address this, some of the 14 key criteria may be modified or removed, depending on the situation. However, this would potentially reduce the method's effectiveness (Mallalieu et al. 2024). Another aspect that significantly influences time is the scope and coverage of the sustainability information and data assessed, which further highlight and underscores the importance of appropriately defining which sustainability information and data are of interest. Therefore, also argued to be a critical prerequisite to the assessment method, as noted in previous literature (e.g., Watz and Hallstedt 2023; Schöggl et al. 2017).

6 | Conclusions

Altogether, the three key contributions of this study: (i) 14 key sustainability-contextualized assessment criteria; (ii) an interactive and cross-functional method that integrates these 14 assessment criteria; (iii) situation-specific knowledge on how to assess the ability to share and manage sustainability information and data in collaborative ecosystems, support to answer the formulated research question: "How can the assessment of a collaborative ecosystem's ability to appropriately share and manage sustainability information and data be facilitated?" and fulfilling the stated aim of this study, which was to develop and propose prescriptive support that, early in the design process, can facilitate and guide the identification of key challenges in managing sustainability information and data within a collaborative ecosystem. Moreover, the three empirical sources collectively indicate that the assessment method effectively guided key stakeholders in discussing critical, complex issues regarding the current ability to manage sustainability-related material information and data within the collaborative ecosystem. In turn, this led to actions that can improve the collaborative ecosystem's long-term ability to make informed decisions, enabling more sustainable choices in, for example, materials, suppliers, and end-of-life strategies throughout the solution's full lifecycle, and adequately integrating sustainability, that is, social, ecological, and economic, throughout the solution's full lifecycle.

However, it should be emphasized that the assessment method does not, by itself, improve an ecosystem's sustainability information and data management capabilities; rather, it highlights key issues and gaps, creating a shared understanding of pressing needs. Furthermore, the assessment method depends on the involvement of key stakeholders, an experienced facilitator, and sufficient time to conduct the assessment. Lastly, given the limitations identified in this study, future work should focus on testing the assessment method with a larger set of value chain actors across industries and with a stronger product-oriented focus. In turn, this can improve its generalizability beyond the context studied, enhancing its external validity and alignment with its intended use and purpose.

Author Contributions

Adam Mallalieu: project administration, conceptualization, methodology, investigation, data curation, formal analysis, visualization, writing original draft, reviewing, and editing. Ola Isaksson: project administration, resources, conceptualization, supervision, methodology, investigation, formal analysis, reviewing and editing. Sophie Isaksson Hallstedt: funding acquisition, project administration, conceptualization, supervision, methodology, investigation, formal analysis, reviewing and editing. Matilda Sandgren Watz: project administration, conceptualization, methodology, investigation, data curation, formal analysis, reviewing and editing. Giliam Dokter: project administration, conceptualization, methodology, investigation, data curation, formal analysis, reviewing and editing. Lars Almefelt: conceptualization and supervision.

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Conflicts of Interest

The authors declare no conflicts of interest.

Endnotes

[1] Product Lifecycle Management (PLM) is occasionally used when referring to information and data management.

[2] There are several different terms used in literature for this type of collaborative set-up, including, for example, *circular ecosystem* (Geissdoerfer et al. 2026). However, we instead use the notion of a collaborative ecosystem, since we do not impose the circular economy as the sole end goal but rather treat it as a means to achieve the ultimate goal of appropriately integrating socio-ecological sustainability throughout a product's entire lifecycle and value chain (Broman and Robèrt 2017).

[3] The assessment can be done individually using the 14 key criteria, but it will negatively influence the intended use and outcomes, as it removes the collaborative aspect of the method.

[4] Many manufacturing companies outsource several design tasks and instead use *product* or *component owners* for some parts or components, and it is appropriate to involve them in such cases.

[5] See Mallalieu et al. (2024) for an explanation of a *method expert*.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Appendix A:** Interviewees and interview template. **Appendix B:** Evaluation format and structure. **Appendix C:** Assessment method template. **Appendix D:** Results and analysis of questionnaire.