






Sustainability in product engineering – a guide to initiate targeted sustainability action

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ABSTRACT: Uncertainty in coping with sustainability demands poses a challenge to decision makers concerned with manufacturing companies' product engineering. Therefore, our paper reports on a newly developed guide to address their uncertainty and support them in initiating targeted sustainability action. The guide, based on an interview study (n = 25; 4 company cases and 1 consultancy) and a systematic literature review, addresses decision makers in product engineering and beyond. It was initially applied and evaluated in company workshops. The guide provides success criteria and reflection questions for each step toward targeted sustainability action: understanding, operationalizing, and implementing. This paper outlines the main concepts behind the guide and contributes to the literature by suggesting a novel approach to sustainability action in product engineering by addressing uncertainty.

KEYWORDS: Sustainability, Decision making, Uncertainty, New product development

1. Motivation

In approaching the topic of sustainability, companies and their decision makers face a high degree of external uncertainty, e.g., due to regulatory changes, unclear market signals, and unclear long-term consequences of sustainability action or lack thereof (Hallstedt, Isaksson, & Rönnbäck, 2020; Petersen, 2021). These sustainability specific aspects not only amplify ordinary technological, market and regulatory uncertainties emerging from the external environment, but create additional internal uncertainties or insecurities for decision makers (Shu, 2022) within and beyond product engineering (Kravchenko, Pigosso, & McAloone, 2021). Although product engineering (for conceptual clarification, see Albers & Gausemeier, 2012) is expected to play an essential role in, for example, establishing competitive advantages (Diaz, Reyes, & Baumgartner, 2022), decision makers are limited in their ability to exploit the opportunities emerging from sustainability demands due to high uncertainties and remain hesitant about sustainability action (Hallstedt et al., 2020; Kortus & Gutmann, 2023). Hence, to allow companies to successfully navigate the opportunities and risks emerging from the topic of sustainability and initiate sustainability action in a targeted manner, decision makers need support to understand and address external and internal uncertainties appropriately. What most of existing research-based recommendations on integrating sustainability action for decision makers share is a strong commitment to pre-fixed conceptualizations of sustainability and target states that are derived from these conceptualizations (e.g., Faludi et al., 2020; Wolff, Bronner, Held, & Lienkamp, 2020). However, for broader society and companies alike, challenges emerge when sustainability is understood as a conceptually fixed target state. As scientific insights progress and stakeholder perspectives on sustainability issues change, the conditions under which companies decide and act also change. Hence, if companies think about sustainability action as deriving action plans from currently existing, externally defined sustainability demands (SDGs, ESG, etc.), these actions may lead into a mismatch with updated external sustainability demands in the future. While defining fixed target states for sustainability integration may reduce complexity on a conceptual level, it does not address the uncertainty decision makers face due to changing

external sustainability demands. Even at a current point in time, multiple externally defined demands might be inconsistent with each other. Hence, decision makers need leeway to resolve tensions which emerge from uncertainties and inconsistencies in sustainability demands by addressing demands based on company-specific perspectives and priorities.

In the remaining sections of this paper, we report on the development of support for decision makers which is designed to address these challenges. The support is intended to help decision makers in establishing company-specific routines which are independent of specific sustainability demands and instead help to continuously and efficiently adjust sustainability action to changing demands. Routines which allow for flexible adjustment to moving sustainability demands enable companies to successfully deal with regulatory and other uncertainties and and exploit opportunities related to sustainability demands. The remaining sections of this paper are structured along the following lines: In [Section 2](#) we discuss existing literature against the background of the challenges described above. [Section 3](#) outlines our research approach. In [Section 4](#) we introduce key aspects of the guide we developed for decision makers based on our research. Conclusions and implications for further research are presented in [Section 5](#).

2. Existing support for sustainability action

In the following, we summarize existing literature that offers support on how to initiate sustainability action in product engineering based on a systematic literature review (following [Jäckle, Seidler, Tusch, Rapp, & Albers, 2023](#), most recent publications were added). We organize the literature along two relevant dimensions (see [Figure 1](#)): The dimension “type of support” (descriptive insights vs. prescriptive advice) and the dimension “scope of sustainability action in product engineering”. The scope of sustainability can be narrow or broad. Publications with a narrow scope focus on selected aspects of product engineering and/or selected aspects of sustainability action, e.g. one aspect of the triple bottom line, a small selection of the United Nations Sustainable Development Goals (SDGs), or otherwise narrow conceptualizations of sustainability action fields. Choosing a narrow scope comes with the advantage of complexity reduction on the conceptual level, but at the same time does not sufficiently acknowledge the uncertainty decision makers face due to highly diverse and changing external sustainability demands. Publications with a broad scope embrace a greater number of product engineering aspects and/or broader, more holistic conceptualizations of sustainability. Choosing a broad scope means that support on how to implement sustainability can acknowledge and address the uncertainty decision makers face due to highly diverse and changing external sustainability demands. As some studies summarized below show, broad scope in currently existing prescriptive advice comes with limitations as well: practitioners have difficulties in applying such support since it is not sufficiently context-specific.

		Scope		
			Narrow	
		<i>Field 1</i>		<i>Field 2</i>
		Kumar and Prabir, 2022; Mesquita and Missimer, 2021; ...		Brones et al., 2021; Xavier et al., 2020; Aguiar and Jugend, 2022; Diaz et al., 2022; Kortus and Gutmann, 2023; Villamil et al., 2022, 2023; Schulte et al., 2020; Schulte and Knuts 2022; ...
Type of support				
Descriptive insights				Prescriptive advice
	<i>Field 3</i>		<i>Field 4</i>	
	<i>Faludi et al., 2020; Mallalieu et al., 2024; Vilochni, McAloone, and Pigosso, 2024; Vilochni, Borgianni et al., 2024; Shu, 2022; ...</i>		<i>Wolff et al., 2020; Capomaccio et al., 2024; Hallstedt, 2017; Schulte and Hallstedt, 2018a, 2018b; Hallstedt et al. 2020; Maon et al. 2021; Riesener et al. 2021; Riesner et al. 2023</i>	
			Broad	

Figure 1. Overview of existing publications by scope and support

Descriptive insights with narrow scope (Field 1) Kumar and Prabir (2022) evaluate key enablers for ecodesign practices and Mesquita and Missimer (2021) conduct an empirical study on the motivation behind and implementation of social sustainability in product development. Those studies collect basic knowledge on selected fields of interest but do not offer concrete guidance on how to implement sustainability action. **Prescriptive advice with narrow scope (Field 2)** Brones, Zancul, and Carvalho (2021) and Xavier, Reyes, Aoussat, Luiz, and Souza (2020) also show a focus on ecodesign, adding recommendations for ecodesign integration. [Aguiar and Jugend \(2022\)](#) and [Diaz et al. \(2022\)](#) specify

recommendations for the integration of circular economy aspects. [Kortus and Gutmann \(2023\)](#) focus on environmental aspects of sustainability and develop a framework of dynamic capabilities an organization should develop to successfully meet environmental requirements. They suggest that companies continuously evaluate sustainability demands and define a process model ([Kortus & Gutmann, 2023](#)). [Villamil, Schulte, and Hallstedt \(2022, 2023\)](#) choose a rather broad scope of sustainability, but are narrow in that they focus on specific aspects of product engineering. They propose a method for the integration of sustainability in portfolio management and offer support for implementation. In a similar vein, [Schulte, Villamil, and Hallstedt \(2020\)](#), develop a conceptual approach to risk management and [Schulte and Knuts \(2022\)](#) derive practical support for decision makers. All those studies in field 2 offer explicit, action-oriented support for decision makers on selected issues. Since they remain narrow in scope, they do not offer comprehensive support on how to deal with great diversity and uncertainty in sustainability demands in all areas relevant to product engineering.

Descriptive insights with broad scope (Field 3) Literature in this field shares one central finding: When scope is broad, a significant theory-practice-gap exists. While research-based insights or suggestions on how sustainability integration in product engineering may be done exist, practitioners pay little to no attention to those insights because when scope becomes broader, support on how to address this scope becomes less context- and company-specific. [Faludi et al. \(2020\)](#) identify a misalignment between sustainable design and business strategies, which is supposed to explain why sustainable design methods and tools are not applied in product development. [Mallalieu, Isaksson Hallstedt, Isaksson, Watz, and Almfelt \(2024\)](#) report 53 factors that influence the adoption of sustainable design practices and identify implementation barriers. A major barrier to support adoption is a mismatch between proposed design methods and context-specific aspects which define a situation or existing practices in a company. [Vilochani, McAloone, and Pigosso \(2024\)](#) summarizes management practices for sustainable product development in a systematic literature review. In a survey on the current state of implementation of these management practices, [Vilochani, Borgianni, McAloone, and Pigosso \(2024\)](#) find low levels of implementation capability in companies. Hence, they recommend more collaboration between academia and industry to close the theory-practice gap. [Shu \(2022\)](#) highlights the uncertainty, ambiguity, and complexity of sustainable new product development that leads to paradoxical tensions, setting a focus on the framing activities of managers. Shu also finds that a holistic and integrated view of sustainable innovation is needed and that its unique challenges must be linked to management decisions. In summary, the literature in field 3 describes the central challenge for researchers who seek to develop applicable support for practitioners: The currently existing challenge to offer context-specific support which considers company-specific situations and perspectives while at the same time taking a broad scope needs to be tackled. Only when a broad scope does not come with limitations to context specificity, support becomes actionable for practitioners.

Prescriptive advice with broad scope (Field 4) Prescriptive advice with a broader scope often refers to SDGs (e.g., [Wolff et al., 2020](#)) or Corporate Social Responsibility (CSR, e.g., [Capomaccio, Reyes Carrillo, & Richet, 2024](#)) as a basis for support. [Wolff et al. \(2020\)](#) propose SDG owners (similar to product owners) to drive operational measures for sustainability implementation. [Capomaccio et al. \(2024\)](#) introduce a maturity model to assess the level of capabilities for CSR integration into the product development process. [Hallstedt \(2017\)](#), [Schulte and Hallstedt \(2018a, 2018b\)](#) and [Hallstedt et al. \(2020\)](#) offer support for sustainability integration based on the Framework for Strategic Sustainable Development (FSSD) and the conceptually related definition of sustainability by [Broman and Robèrt \(2017\)](#). All of these studies derive their support from and for fixed sustainability target states, which means that they do not account for uncertainty decision makers face due to changing external sustainability demands. Other studies take a more dynamic approach and aim to help companies react to changing demands: [Maon, Lindgreen, and Swaen \(2021\)](#) present a “conceptual framework [to] understand [...] the development of a CSR strategic agenda”. They emphasize the need for each organization to develop a company-specific understanding of CSR based on stakeholder demands and provide a descriptive dual-loop model. This model comprises, and at the same time is limited to, a continuous stakeholder dialogue loop and an integration loop with a focus on managerial perceptions. Similarly, [Riesener, Kuhn, Tittel, and Schuh \(2021\)](#) and [Riesener, Kuhn, Tittel, Singh, and Schuh \(2023\)](#) address organizational resilience. They outline five steps which are supposed to help set up product development departments in a beneficial way. In summary, literature in field 4 gives basic support on how to approach sustainability integration when a broad scope is chosen. Some even take a dynamic approach and hence provide the grounds for development of support which helps to adjust sustainability action to changing sustainability demands. However, existing support does not yet provide detailed

advice on how to implement sustainability action in all areas relevant to product engineering. Furthermore, the challenge to offer context-specific support while offering a broad scope remains to be tackled (see literature in Field 3). In the remaining sections of this paper, we report on the development of support for decision makers which is designed to overcome this currently prevailing challenge.

3. Research objective and approach

In response to the need for support from decision makers and the existing literature gap, our objective is to address the specified challenge by tackling the research question: *How can decision makers be supported in addressing their uncertainty about sustainability and initiating targeted sustainability action in product engineering?* To achieve this goal, a systematic, yet flexible research methodology is essential to gather insights from practitioners and emphasize the necessary focus on context-specific uncertainties. Thus, the research project employs the Design Research Methodology as proposed by [Blessing and Chakrabarti \(2009\)](#), complemented by inductive methods for the empirical research. In line with the research question, this publication focuses on the development of the support, highlighting the Prescriptive Study and the preliminary steps of the Descriptive Study II, while parts of the Research Clarification have been previously published in [Jäckle et al. \(2023\)](#). The development of the support is based on two studies (Descriptive Study I). A *systematic literature review* was conducted using the literature body from [Jäckle et al. \(2023\)](#). The findings provided initial insights that were used to prepare semi-structured interviews with decision makers and consultants. The *interview study* was the primary source used to inform the development of the support presented in [Section 4](#). The study includes 25 semi-structured interviews with experts, conducted across four case companies and a consultancy. All case companies are manufacturing companies. Specifically, two are in the automotive industry (6 interviews each), one in the aerospace industry (3 interviews), and one in the machinery industry (3 interviews). These companies were selected on the basis of multiple criteria: They have a significant focus on product engineering (for example, due to sufficient technological complexity of their products) and a sophisticated understanding of sustainability (for example, with multiple dimensions). This allows us to effectively capture essential complexities for developing a detailed support. They have started to initiate sustainability action in product engineering, employing various situational approaches at varying stages. This ensures the necessary insights to develop comprehensive support that covers multiple stages of targeted sustainability action. Although headquartered in Germany, they differ in size, organizational structure, and internationality to allow for the identification of generalizable aspects. In collaboration with a senior product engineering decision maker, interviewees at each company were chosen to ensure that all relevant perspectives were represented. In all cases, we explored a minimum of three distinct perspectives: A dedicated sustainability perspective (e.g., Head of Sustainability), a project-focused perspective (e.g., Head of Project Management), and a functional perspective (e.g., Head of Engineering). All interviewees were senior managers or experienced project leaders. The seven consultants are experienced experts in the fields of sustainability and product engineering that work closely with manufacturing companies. The interviews were conducted in a semi-structured manner using an interview guide. The questions covered five themes and were organized in three levels: Open-ended questions, more specific questions (informed by the literature), and probing questions. The interviews lasted between 26 and 67 minutes. The interviews were recorded and transcribed. Qualitative data in the form of interviewee statements were first paraphrased and then inductively coded (see [Gioia, Corley, & Hamilton, 2013](#)). The data was interpreted to identify problem- and solution-focused insights for targeted sustainability action. The implications of these insights defined the content and structural elements of the support. The core concepts of the support being developed were applied at an early stage in company workshops to evaluate, collect feedback and refine the support (see [Section 4.3](#)). Subsequently, expert discussions were conducted and an implementation study at a company that was not part of the DSI is currently underway. Both studies will be the subject of forthcoming publications.

4. Results and discussion

In this section, we outline the main concepts that define the content and structure of our support, which were derived from our interview study. Although these findings may highlight best practices, we cannot guarantee they will ensure a company's long-term success and sustainability due to methodological limitations. However, we consider a pragmatic best-practice approach suitable for the given situation, as decision makers are in urgent need of support and extensive quantitative, longitudinal studies which

compare the effectiveness of different, not yet existent supports on sustainability action won't be available in the near future. Our general approach to address the challenge is described in (Section 4.1), then an exemplary overview of selected core concepts used in the support is provided (Section 4.2), and results of a first evaluation are discussed (Section 4.3).

4.1. Addressing the challenge

Our data suggests what other scholars (e.g., Maon et al., 2021; Shu, 2022) indicated before, namely that companies unfold their ability to exploit opportunities from external sustainability demands if their action plans are not derived from those external demands alone but from company-specific objectives that are inspired, but not defined (in terms of fixed) by those demands. Furthermore, companies seek to develop abilities to deal with uncertainty emerging from changing external demands, e.g. because of changing regulations. Hence, in the support we offer, company-specific opportunities and risks replace pre-fixed sustainability objectives derived from externally given sustainability concepts as the starting point in initiating sustainability action. They become a lens through which external sustainability demands and related uncertainties can be examined. In effect, company-specific sustainability objectives can be derived. Furthermore, we intend to help decision makers in establishing company-specific routines which are independent of specific sustainability demands or objectives and instead help to continuously and efficiently adjust sustainability action to changing demands and objectives. Routines which allow for flexible adjustment to moving sustainability demands enable companies to successfully deal with regulatory and other uncertainties. We explicitly encourage companies to allow themselves to have leeway in dealing with external sustainability demands. Allowing for justified leeway in dealing with externally given sustainability demands is not to be mistaken as sustainability neglect or breach of conduct/rules out of ignorance. Rather, allowing for leeway acknowledges that at any given point in time, information about present and especially future conditions under which companies and decision makers act is incomplete. It accounts for the entrepreneurial character of sustainability actions decision makers pursue. Moreover, allowing for leeway can provide the flexibility companies with a short-term focus, e.g., due to limited capacities or under economic pressure, need in order to enter a path towards long-term sustainability at all, starting to resolve their uncertainty without implicit moral judgments comprised in pre-conceptualized ambitions for action. By embracing a company-specific perspective and leeway in dealing with sustainability demands, the support we offer tackles the challenge described in section 2: Our support embraces a broad and dynamic scope of sustainability and product engineering, while at the same time offering context-specific support. This approach enables companies to define company-specific sustainability objectives and efficiently adjust those objectives to changing demands when necessary. We define this approach as targeted sustainability action (TSA): Only when sustainability objectives are derived and adjusted from a company-specific perspective, companies can initiate and sustain sustainability action in a targeted manner. When TSA replaces sustainability action driven by fixed demands and sustainability concepts, companies become able to exploit opportunities emerging from sustainability demands and related uncertainties.

4.2. Overview of the guide

Our guide offers support for decision makers while considering the special role those decision makers have within companies that face the challenge of sustainability integration. The person applying the guide can be seen as a facilitator who involves the respective decision makers. He/she could be a decision maker within the company, or an internal or external facilitator who provides support to the decision makers. The guide consists of an introduction and three chapters that are structured along the following three consecutive and cyclic steps: "Understand", "Operationalize", and "Implement" targeted sustainability action in product engineering. These steps allow decision makers to continuously surface uncertainties and conflicts emerging from sustainability issues (understand), define practices to act on them (operationalize), and establish and/or execute these practices to reduce them (implement). Furthermore, this cycle itself can be implemented as a routine of continuous reflection and adjustment by transforming the practices into routines. Through these routines, the time horizon in which sustainability demands are taken into account and objectives are set can be expanded or reduced. This accounts for the evolving character of sustainability issues and allows for adjustment of product engineering practices in case objectives need to be adjusted, e.g. due to changing stakeholder demands, disruptions, or own ambitions. The application of the guide is supposed to initiate the establishment of routines, which afterwards can be sustained without further application of the guide. Thus, the cyclic steps described

above are relevant in two different stages. The first stage, the guide application, which can be regarded as the initial iteration of the three steps, where 1 “Understand”, 2 “Operationalize”, and 3 “Implement” are thought through. In the second stage, the continuous adjustment cycles, targeted sustainability action is initiated through the execution of the practices defined in Stage 1. Stage 1 (the application of the guide) acts as an initial “Prepare” practice of Stage 2, while the first cycle begins with using the Stage 1 outcomes to “Inform,” “Decide,” and “Guide.” This may lead to the execution of further “Prepare”, “Enable”, and/or “Act” practices. As these practices become routines that form continuous adjustment cycles, the guide as a support document will no longer be needed. The two stages are illustrated in Figure 2.

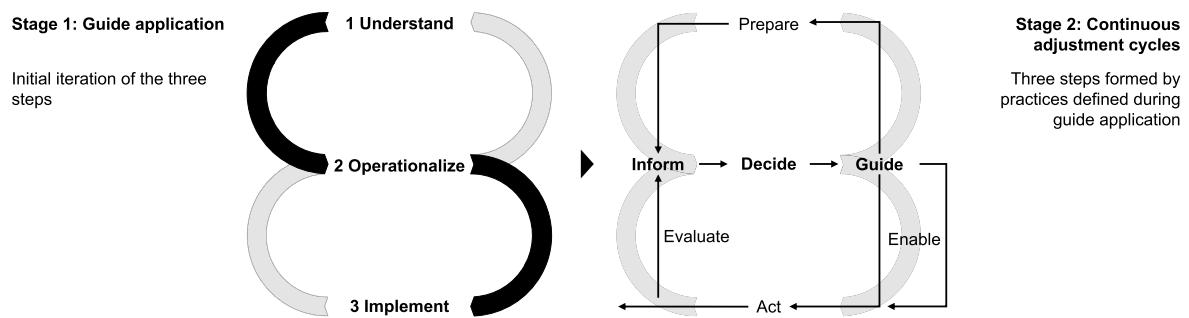


Figure 2. Two stages of initiating targeted sustainability action and structure of guide

For each of the three steps in Stage 1, the guide provides five sections to support decision makers. Their contents were inductively derived from the interview data. The level of detail of the support and therefore the presuppositions increase with each of the sections (A-E). This allows decision makers to use the guide depending on their need for support. First, to assess whether and **why** the three steps should be executed, Challenges (A) are outlined that decision makers might face. To guide decision makers on **what** should be achieved in a step, Success Criteria (B) and Guiding Questions (C) for the step are provided. Success Criteria and Guiding Questions together form the centerpiece of the support. The Guiding Questions reflect the key decisions to be made in the respective step and are detailed through subquestions. Success Criteria help decision makers ensure that their answers to the Guiding Questions lead to targeted actions. To support decision makers in **how** to execute the steps operationally, an exemplary Application (D) is described. The most detailed support is then provided by the Supporting Materials (E), which contains templates and detailed insights from our interview study (e.g., a nonexhaustive list of potential drivers for risks and opportunities) for reference. The sections are summarized in Table 1.

To illustrate key elements, we will focus on the Success Criteria and Guiding Questions of Step 1 “Understand” (Sections 1B and 1C of the Guide), as well as exemplary Supporting Materials of Step 2 “Operationalize” (Section 2E), to illustrate the level of detail of the support the guide provides. In Step 1 “Understand”, an understanding of sustainability in product engineering is to be developed. To assess an existing understanding of sustainability or develop a new one that contributes to targeted action, the Success Criteria in Section 1B of the Guide can be used. These Success Criteria and their explanations are summarized in Table 2.

Table 1. Structure of sections within each of the three steps of the guide

Section	Description	Aspect
A Challenges	Key challenges to solve in step with uncertainties	Why
B Success Criteria	Characteristics for the result of the step that fosters targeted action	What
C Guiding Questions	Major decisions to be made within step	What
D Application	Instructions on how to conduct step operationally	How
E Supporting Materials	Templates, relevant aspects to decisions with interdependencies, conditions and implications	How

Table 2. Guide Step 1 “Understand”, Section B: Success Criteria to an understanding of sustainability in product engineering that enables targeted action

Success Criteria	Description
Context-dependent	Specific to the company and its stakeholders
Consistent	Takes a company perspective, but incorporates other relevant (stakeholder) perspectives and surfaces inconsistencies
Explicit	Surfaces uncertainties and interdependencies between aspects
Reasoned	Provides reasoning for each aspect and allows reasoning to be challenged
Evolving	Takes status quo into account and allows for further refinement over time
Long-term	Includes expected future developments

These Success Criteria apply to Step 1 “Understand” and extend to all subsequent steps and iterations, while the Success Criteria for other steps apply only from those points onward. To develop such an understanding, the Guiding Questions and, if helpful, their subquestions can be answered or used as reference (Guide [Section 1C](#), [Table 3](#)).

Table 3. Guide Step 1 “Understand”, Section C: Guiding Questions and subquestions

Guiding Question	Subquestions
Why is sustainability action relevant to the company?	Which risks are to be avoided? Which opportunities are to be seized? Which drivers and conditions are implied? Which uncertainties are associated?
What can be achieved through sustainability action at the company?	Which sustainability objectives can be set based on opportunities and risks? Which interdependencies can be expected?

Those questions separate analysis from synthesis of action in order to enable conscious and reflected decision making, as opposed to derivation of objectives and actions from unreflected, external demands. To answer them, the Application section (1D) suggests workshops, interviews, and research phases. The Supporting Materials (1E) provides templates for both Guiding Questions. Moreover, they include details on potential risks, opportunities, their drivers, conditions, and uncertainties for the first Guiding Question, derived from the interview study to help answer the subquestions.

In Step 2 “Operationalize”, the practices for targeted sustainability action are defined. For example, to define the practices to “Decide” on sustainability action, a subquestion of the Guiding Question “Which practices form targeted sustainability action?” can be answered. To help detail the context-specific practices as an answer to the question, the Supporting Materials (Guide [Section 2E](#)) contain relevant insights from the interview study (as shown in [Table 4](#)).

Table 4. Guide Step 2 “Operationalize”, Section E: Supporting Materials for the Guiding Question “Which practices form targeted sustainability action?”

Aspect	Details for practices to “Decide”
What	Decide on (i) whether to act on objectives, their uncertainties, conflicts and synergies (or not) (ii) radicality of intended action (can be varied), (iii) solution space to act on remaining uncertainties and conflicts (can be limited or expandable) to define guidance (=subsequent practice “Guide”).
Who	At appropriate level and function, not in parallel. With top management commitment.
When	Now, don’t wait for the collective wisdom of stakeholders. No decision is also a decision.
How	Entrepreneurial. Opportunities are where uncertainty is. “Innovation” happens where conflicts are resolved. Transparent. Conscious.

In Step 3 “Implement”, the implementation of the defined practices is planned over time, forming the initial adjustment cycles and continuous routines if they are already known. Therefore, one-time actions (e.g., a small product change with known implications) and continuous routines (e.g., to monitor upcoming regulations) are distinguished. Completing this step concludes Stage 1. The results of all three steps provide the foundation for compiling the fact base (execute practices to “Inform”), making decisions (execute practices to “Decide”), and developing guidance (execute practices to “Guide”) for targeted sustainability action. Although this is part of Stage 2 and does not require the guide for execution, the guide provides useful information for the facilitation of this initiation of targeted sustainability action. It can serve as a reference until practices become routines.

4.3. First evaluation of the guide

The development of the support was and continues to be an iterative process. Early integration of practitioners was central. In an initial evaluation step, the core concepts of our guide were put into application in a company workshop format. This format comprised two three-hour workshops with a company that had not been involved in the interview study and was new to the topic of sustainability. The workshops involved six participants representing relevant perspectives (again identified together with a senior manager at the company, including sustainability, functional, and project perspectives, see [Section 3](#)). The discussion was facilitated by one of the guide authors and documented by an assistant. The workshops focused on the application of Step 1 “Understand”, with a discussion of implications for steps 2 and 3. The evaluation was done through a questionnaire that the participants filled out at the end of the second workshop. They evaluated several aspects of the guide application on a five-point scale: strongly disagree, disagree, neutral, agree, strongly agree, and were given the option not to answer. Four of the six participants agreed that the application of the guide reduces uncertainties regarding targeted sustainability action in product engineering, while two remained neutral. In addition, four out of six participants agreed that they expect that the application of the guide can enable targeted sustainability in product engineering, while two again remained neutral. All participants agreed that when applying the guide, it offers enough flexibility to consider the status quo of the applying company, thereof, two participants strongly agreed. Five participants agreed that the guide is free of moral judgments (thereof, four strongly agreed), while one remained neutral. Four participants agreed that the guide focuses on key decisions and balances manageability and complexity (thereof, one strongly agreed on the latter), while one remained neutral and one disagreed on both aspects. Regarding the Success Criteria of Step 1 “Understand”, five participants agreed that the application of the guide supports to develop an understanding of sustainability in product engineering that is context-dependent. Four agreed it supports to develop an understanding that is reasoned. Three agreed that support to develop an understanding that is consistent, explicit, evolving and long-term. One participant chose not to answer on the Success Criteria, while the others remained neutral. The qualitative feedback included that an early alignment with the company strategy is needed to use the results for reporting purposes. In case of application in a workshop format, a clear steering of the discussion was considered necessary to maintain focus and that an in-depth application of the guide requires additional time. Moreover, illustrating case examples for reference was expected to be helpful. This paper presents an initial version of the guide and an early evaluation. Feedback and results of the evaluations were incorporated into updated versions that were evaluated in expert discussions and are currently applied in a company project. Future publications will discuss the results.

In addition, future studies might include the standalone application of updated versions of the guide and comparative studies between decision makers who use and do not use the guide to define targeted sustainability action.

5. Conclusions

In this paper we took a novel perspective on approaching sustainability for decision makers in product engineering. The initial version of a guide that we introduced offers support for decision makers with a special focus on uncertainty in sustainability action. It includes three steps: “Understand”, “Operationalize”, and “Implement”, through which practices for targeted sustainability action are defined and continuous adjustment cycles are initiated. Although existing support suggests that uncertainty reduction can be achieved by directly deriving sustainability objectives from conceptualized and fixed external demands, we argue that such approaches do not sufficiently enable companies to define company-specific objectives that match their capacities for long- and short-term sustainability

action. Successful exploitation of opportunities that emerge from uncertainties is only possible when sustainability is understood as a moving target shaped by possibly changing external sustainability demands as well as equally changing company-specific aspects. We hope that this contribution inspires academics to embrace uncertainty as a relevant topic within sustainability research. Furthermore, we hope to encourage research on sustainability in product engineering with a pragmatic orientation towards practitioners' problems as opposed to predominantly concept- and theory-driven research.

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