Exploring Synergies between Sustainability Awareness Framework (SusAF) and Double Materiality Assessment (DMA)

Lappeenranta-Lahti University of Technology LUT
LUT School of Engineering Science
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ABSTRACT

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Master's thesis, 2025

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Software-based organizations face significant challenges in DMA due to the intangible nature of software services and rapid technological advancements. Although SusAF offers a comprehensive approach for IROs identification but its adoption remains limited because of its time-consuming process and lack of alignment with ESRS. This research adapts SusAF for ESRS-compliant DMA to enable integrated collaborative IRO identification and regulatory reporting in a single process. Using Design Science Research across seven phases, the study reviewed regulatory documents and academic literature, with validation through focus groups with 5 sustainability experts, 2 RE researchers, and 3 industry practitioners. The enhanced SusAF features a refined question set covering all ESRS topics and a conceptual methodology with pre- and post-SusAF steps. This methodology achieves 100% DMA compliance despite participant concerns about stakeholder mapping complexity and threshold analysis subjectivity. The study demonstrates that SusAF can be effectively adapted with targeted extensions to meet regulatory standards. Future research should refine the methodology through extensive case studies to enhance scalability and adoption.

"I am the master of my fate, I am the captain of my soul"
from Invictus*, by William Ernest Henley*

Vrije Universiteit Amsterdam

Universiteit van Amsterdam

Master Thesis

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DECLARATION OF AI USAGE

I hereby acknowledge that the research reported in this thesis has been carried out with the responsible and ethical utilization of artificial intelligence (AI) technologies. AI tools such as ChatGPT- 4 and Gemini were utilized to assist in specific tasks, including:

- **Language and Grammar Assistance:** AI-based writing assistants were used to enhance the clarity and coherence of the text, ensuring proper grammar and style. These tools were used to assist in refining the language while preserving the original intent and meaning of the content.
- **Conceptual Exploration and Learning:** AI-powered resources were instrumental in my learning process, helping me to clarify complex concepts, test my understanding through interactive questioning, and explore related research areas.

However, it is important to emphasize that the core ideas, research design, results, interpretations, and conclusions presented in this thesis are solely the product of my own intellectual effort. AI served as a supportive tool, not a substitute for critical thinking and independent research.

I acknowledge the limitations of AI and the potential for biases within its algorithms. Therefore, I have carefully reviewed and validated all AI-generated outputs to ensure their accuracy and alignment with the research objectives.

I accept complete accountability for the material presented in this thesis and assert that it complies with the utmost standards of academic integrity and ethical research practices.

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Glossary

CSR Corporate Social Responsiblity

CSRD Corporate Sustainability Reporting Directive

DMA Double Materiality Assessment

EFRAG European Financial Reporting Advisory Group

ESG Environmental, Social and Governance

ESRG European Sustainability Reporting Guidelines

ESRS European Sustainability Reporting Standards

EU European Union

GRI Global Reporting Initiative

NFRD Non Financial Reporting Directive

RE Requirements Engineering

SASB Sustainability Accounting Standards Board

SusAF Sustainability Awareness Framework

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1

Introduction

Our world is going through an unprecedented transformation due to climate change and resource scarcity. Societal demands for greater social and environmental responsibility are also growing. As noted by Wright *et al.* (1), corporations are now reacting to the climate crisis in various ways, which include shaping climate debates, influencing policy, and enacting organizational strategies and practices to address climate change. This shift toward greater accountability has prompted regulatory bodies worldwide to establish comprehensive frameworks for sustainability reporting. These frameworks can be utilized by companies to showcase their efforts and commitment to sustainability.

In EU, regulatory requirements for sustainability reporting have also been formalized in the form of CSRD (2). This mandates the organizations to report their impacts and future directions (3). EU has developed the reporting standards in the form of ESRS to operationalize the CSRD requirements. These standards provide detailed disclosure requirements through both general and topical guidelines. ESRS 1 (4) and ESRS 2 (5) establish the foundational principles for transparent reporting processes, while 10 topical standards (6), (7), (8), (9), (10), (11), (12), (13), (14), (15) define specific reporting requirements across environmental, social, and governance dimensions. To support implementation, EFRAG has developed a detailed implementation guide (16) for conducting DMA. EFRAG also provides a comprehensive taxonomy of data points (17) that organizations must collect and report to ensure consistent and auditable sustainability disclosure

The core aspect of CSRD is DMA, which is a comprehensive process that requires organizations to evaluate how their operations impact people and the environment and how sustainability matters affect the organization (2). This dual perspective represents a significant advancement in sustainability reporting. This approach differs from traditional

single-materiality approaches by providing stakeholders with a comprehensive understanding of organizational sustainability performance.

Parallel to these regulatory developments, the software engineering community has developed a specialized framework for sustainability assessment. SusAF (18) represents one such structured approach for evaluating sustainability impacts in IT products and services. SusAF has gained recognition as a practical tool for raising awareness of potential sustainability effects in software systems, particularly during requirements engineering and design phases. The framework guides practitioners through a series of workshops and structured questions that enable them to identify and analyze the effects of sustainability in five different dimensions. Each dimension is further explored through targeted questions that consider both positive and negative impacts. A key output of SusAF is the SusAD, which visualizes impacts across three layers corresponding to three types of order of effects: immediate, enabling, and structural. This provides stakeholders with a nuanced understanding of sustainability implications.

1.1 Problem Definition

The mandatory adoption of DMA under CSRD presents significant implementation challenges for organizations as they have to ensure authentic and comprehensive sustainability reporting. Current DMA implementations face significant hurdles, including difficulties in data collection, methodological inconsistencies, and the risk of selective disclosures that fail to present accurate representations of organizational sustainability performance (19). The criteria defining materiality are often ambiguous and subjective. This creates the opportunities for manipulation during the assessment process (20). Consequently, there is an increased risk of greenwashing, where organizations present superficial sustainability actions without addressing fundamental environmental or social issues. This undermines the legitimacy and credibility of sustainability reports and ultimately limits stakeholdersábility to make informed decisions (21).

The problem is particularly evident in IT and software development organizations. The rapid pace of technological advancement and the intangible nature of digital services complicate the measurement and reporting of sustainability impacts (22). The dynamic nature of software systems makes it challenging to assess both immediate and long-term sustainability effects across multiple dimensions. Software development companies often lack the necessary knowledge to incorporate actions related to software sustainability into their

CSR documents. The number of sustainability actions that they incorporate is often insufficient, and there is still considerable work to be done in this area (23). The complexity of evaluating digital products and services within traditional sustainability frameworks creates gaps in comprehensive impact assessment.

Although SusAF provides a structured approach to identify potential sustainability effects across different dimensions but its adoption remains limited in practice. Bambazek *et al.* (24) presented case studies where SusAF was applied in two ongoing agile development projects. SusAF helped practitioners to identify more than 20 sustainability-related impacts based on product vision and design. It was found that over half of the backlog items could be linked to at least one identified impact. However, they had some reservations about implementation due to time constraints and resource requirements. This led to the conclusion that SusAF and similar tools are often not practically used unless explicitly required by clients or regulatory demand. This situation creates a significant gap between SusAF's capabilities and its application within the regulatory landscape of DMA. This limits the potential for comprehensive sustainability integration in IT organizations.

1.2 Motivation

This study addresses the critical need to bridge the gap between regulatory requirements for DMA and the practical implementation challenges faced by IT or software-based organizations. Although CSRD has made DMA mandatory for sustainability reporting, many IT companies struggle with inconsistent methodologies that risk greenwashing and fail to capture the complex sustainability impacts of digital products and services. Although SusAF offers a structured approach to sustainability assessment, it remains underutilized due to adoption barriers and limited integration with regulatory frameworks.

The research is motivated by the potential to align the regulatory rigor of DMA with the practical methodology of SusAF to create a comprehensive solution for organizations. By exploring this alignment, the study aims to develop a practical methodology that can support the use of SusAF for their reporting processes. Such integration would not only enhance regulatory compliance but also promote more meaningful and authentic sustainability practices within the software industry.

1.3 Research Questions

Based on the identified problem and research motivation, the main research question is formulated as:

> *How can the Sustainability Awareness Framework (SusAF) be adapted to support Double Materiality Assessment requirements for software-related or IT companies?*

To further explore this question, the following sub-questions are addressed:

1. What are the conceptual alignments and gaps between SusAF and Double Materiality Assessment requirements?
2. What specific methodological extensions and process modifications are required to integrate both impact materiality and financial materiality assessment capabilities into SusAF?
3. Can the proposed methodology support the double materiality assessment in companies?

1.4 Structure of Thesis

This thesis is organized into 10 chapters that address the different aspects of this study.

1. **Chapter 1: Introduction** - This chapter provides the research context by examining the regulatory landscape of CSRD and ESRS requirements, identifying the gap between SusAF and compliance requirements, and presents the research questions that guide this study.
2. **Chapter 2: Background** - This chapter sets the foundation for the research by providing a clear analysis of the definition and evolution of double materiality. Additionally, it also covers the detailed SusAF workflow and the development of SusAF.
3. **Chapter 3: Related Work** - This chapter provides a comprehensive review of the studies that are related to this research. It covers empirical studies on DMA practices, integration approaches with broader sustainability frameworks, and the development and applications of SusAF across various organizational contexts.

4. **Chapter 4: Methodology** - This chapter outlines the methodology employed for this study by providing details of the brief literature review and iterative development process using DSR.

5. **Chapter 5: SusAF-DMA Mapping** - This chapter presents mappings between SusAF components and ESRS requirements. This identifies the gaps between SusAF and ESRS requirements in both aspects: topics and process guidelines.

6. **Chapter 6: SusAF Questions** - This chapter presents an enhanced question set designed to achieve full ESRS compliance and presents corresponding Datapoints mapped from ESRS List of data points to support comprehensive assessment processes.

7. **Chapter 7: Conceptual Methodology** - This chapter presents the adapted three-phase methodology that integrates SusAF collaborative strengths with ESRS regulatory requirements. This provides step-by-step guidance for conducting DMA in software organizations while maintaining SusAF usability intact.

8. **Chapter 8: Evaluation** - This chapter presents the comprehensive evaluation process for the developed artifacts. It provides the details of findings in focus groups with sustainability experts and interviews with RE researchers and industry practitioners

9. **Chapter 9: Discussion** - This chapter synthesizes evaluation findings with existing literature, critically analyzes the implications of SusAF-DMA alignment, and discusses threats to validity of this study and future directions

10. **Chapter 10: Conclusion** - This chapter summarizes the research contributions and outlines directions for future research in regulatory-compliant sustainability frameworks and their industrial applications.

2

Background

This chapter presents the theoretical foundation needed to understand the key concepts driving this research. It begins with a detailed definition of DMA, which forms the core requirement under the CSRD. The chapter also traces how the concept of materiality evolved from traditional financial reporting to cover up both impact and financial perspectives in sustainability reporting. Following this regulatory context, the chapter introduces the SusAF as a collaborative tool designed to identify sustainability impacts in software development. It explores SusAF's development history to show how it emerged from academic research and evolved through iterative testing with students and industry partners. It also explains the current version of the SusAF Methodology. Together, these sections provide the conceptual groundwork necessary to understand the gap between current sustainability assessment practices and regulatory compliance requirements that this research aims to address.

2.1 Double Materiality Assessment

One of the key aspects of sustainability reporting is the materiality assessment that specifies which issues are significant enough to be reported (25). The concept of materiality assessment evolved into a double materiality assessment, specifically under the CSRD. According to ESRG (26), Double Materiality is a union of impact materiality and financial materiality, covering both inside-out and outside-in perspectives. It defines the impact materiality and financial materiality as:

- **Impact Materiality**: A sustainability aspect is considered material from an impact perspective if it is connected to the impact on people and the environment through the activities, supply chain, and business operations of an organization.

- **Financial Materiality**: A sustainability aspect is considered material from a financial perspective if it is connected to triggering the financial effects (risks and opportunities) on the future cash flows and enterprise value of an organization.

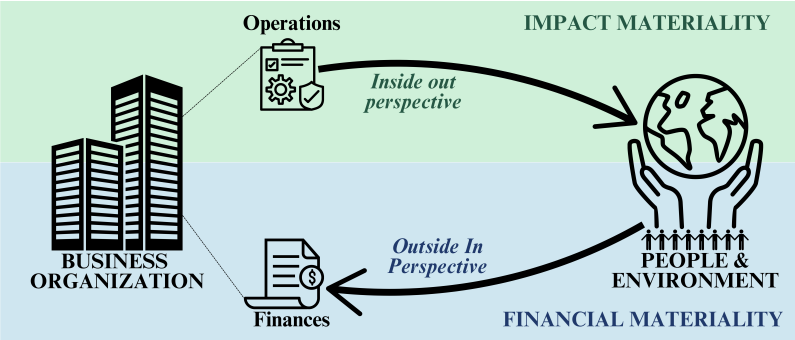

Figure 2.1: Double Materiality Assessment

This concept of double materiality is illustrated in Figure 2.1. The figure demonstrates how a business, through its operations and finances, interacts with people and the environment. The arrows indicate the two-way relationship. The downward arrow from "Business" to "People and Environment" represents impact materiality, highlighting how the business's activities can affect the environment and society. Conversely, the upward arrow from "People and Environment" to "Business" signifies financial materiality, illustrating how environmental and social factors can impact the business's financial performance. By considering both perspectives, businesses can gain a comprehensive understanding of the material issues that require attention and integrate sustainability considerations into their core business strategies.

2.2 Evolution of Materiality

In 1970, Frishkoff (27) formulated the concept of materiality in the context of financial accounting, especially to evaluate a business transaction and to dispute some controversial accounting treatment. He defined materiality as:

> "*The relative, quantitative importance of some piece of financial information, to a user, in the context of a decision to be made.*"

After his contribution, academic discussions began to formalize this idea. A key moment came when the FASB adopted this idea in its conceptual framework (28). This solidified

the concept of materiality as a fundamental element of financial reporting, establishing what is now known as financial materiality.

In 2002, CSR Europe released a communication (29) to emphasize the integration of social and environmental objectives into business operations and interactions with stakeholders. Based on these suggestions by the EU, Zadek *et al.* (30) identified that there is a challenge to disclose information on social and environmental performance that is material to business performance, whether directly or because its stakeholders care and will in the future make their caring count. They, then, took on this challenge and redefined the materiality to make it appropriate not only for sustainability reporting but also for various other aspects. They proposed a 5-stage test to determine what is material or not. These stages include direct short-term financial impacts, policy-based performance, peer-based norms, stakeholder behavior and concerns, and societal norms.

As financial reporting was focused on investor needs, a different approach was being developed, in parallel, in response to growing concerns about corporate responsibility. The GRI, founded in 1997, was a key player in this movement. Its mission was (31):

> "*To create a universal reporting framework and a language in which a discourse about sustainability performance could be carried out, and which would be used by others to form judgments about the level of performance, based on socially formulated standards.*"

GRI published its first Sustainability Reporting Guidelines in 2000 and provided the first global framework for sustainability reporting (32). GRI has continued to update its standard to incorporate the latest business trends and new challenges. The G3 guidelines (2006) directed companies to identify and report on topics that reflected their significant economic, environmental, and social impacts (31). This formalized the concept of impact materiality. In 2013, GRI published the G4 guidelines and provided a Materiality Assessment Method in their Implementation Manual (33). In 2016, they transitioned to the GRI standards in which they made impact materiality as a core principle of sustainability disclosure and formalized the concept of 'material topics' by providing 33 topic-specific standards (34).

As the GRI refined its focus on impact, other organizations developed frameworks that linked sustainability more directly to financial performance. The SASB created industry-specific standards to help companies disclose financially material sustainability information to investors. SASB published its initial conceptual framework in 2011. SASB (35)

is intended for voluntary use by public companies in making disclosures on material sustainability factors in SEC filings. SASB recognizes that each company is responsible for determining what information is material and what information should be included. In 2020, SASB issued a draft (36) of proposed changes to its standards, including those related to financial materiality, aiming to better communicate this underlying concept. These were later formalized into a standard in 2018. The definition included in their exposure draft was as follows:

> *For the purpose of SASB's standard-setting process, information is financially material if omitting, misstating, or obscuring it could reasonably be expected to influence investment or lending decisions that users make on the basis of their assessments of short-, medium-, and long-term financial performance and enterprise value.*

The EU played a decisive role in merging these two parallel streams. In 2021, EFRAG, through its report (37), proposed the mandatory inclusion of double materiality in sustainability reporting. The concept was legally established with the adoption of the CSRD in 2022. The CSRD (2) replaced the earlier directive NFRD and made a double materiality assessment a legal requirement for companies.

Building on CSRD, EU introduced ESRS (5) and provided the guidelines to conduct DMA. It provided guidelines to incorporate the dual perspective of DMA. These guidelines were developed in collaboration with GRI and ISSB to ensure interoperability within EU and global standards (38). This marks the formal establishment of double materiality as a comprehensive standard, completing its evolution from two separate reporting philosophies into an integrated and mandatory practice.

This whole evolution, starting from materiality concept to Double Materiality as a part of sustainability reporting is summarized in figure 2.2

2.3 Sustainability Awareness Framework

The SusAF (18) is a tool for sustainability design that guides the process of sustainability analysis of IT products or services. The development of SusAF followed an iterative path based on Design Science Research for almost half a decade. This step-by-step process of refinement shows how the framework grew based on real-world use. The final result is a mature and flexible tool for raising sustainability awareness in software engineering.

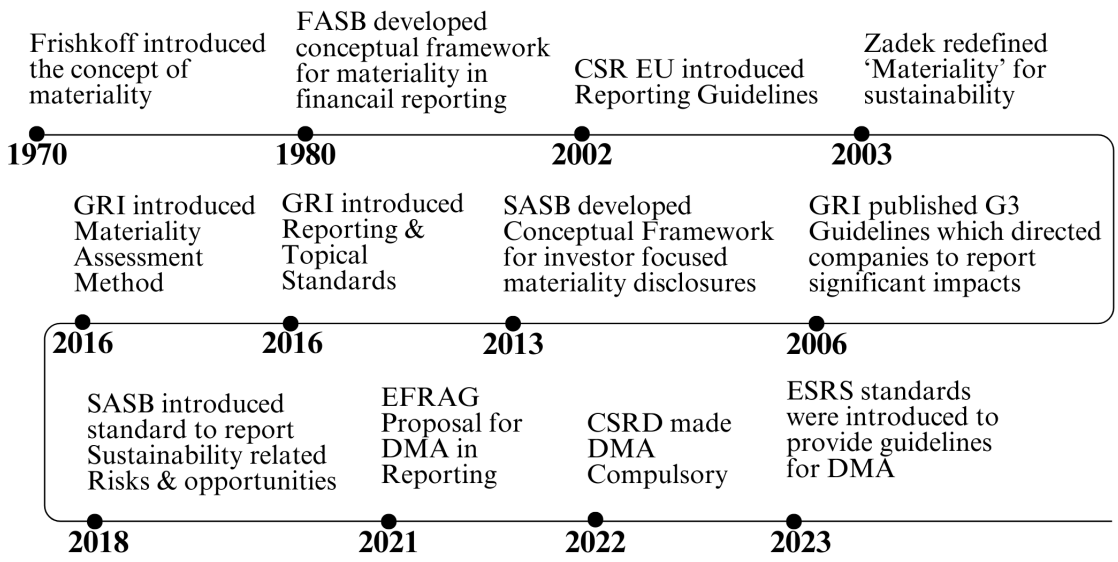

Figure 2.2: Evolution of Materiality Timeline

2.3.1 The Development of SusAF

In 2015, the *Karlskrona Manifesto* (39) laid the foundation for this framework, by providing a set of principles for sustainability design in SE. However, it did not propose any supporting tools at that time. To complement this manifesto, RE practitioners from eight countries were interviewed for their understanding of sustainability and integration of sustainability in IT product design and planning. Results revealed that they lack the specific knowledge, experience, and methodological support to integrate sustainability into their practices. (40)(41)

Based on the findings from interviews and available literature, the concept of SusAD diagram (42) was developed to support interactive collaboration among stakeholders to discover, document, and validate the potential sustainability effects of the product or service in five dimensions. Additionally, moderator slides were also developed to support teaching. The SusAD is applied and evaluated in different university courses in the United States, Finland, and Germany (43). Students found the abstract nature of sustainability difficult to link with specific IT products and struggled to initiate sustainability requirements elicitation (44).

To address the abstraction challenge, a question set was designed for SusAF. This was created with the help of an expert panel (members of the Karlskrona Alliance on Sustainability Design) using an adaptation of the Delphi method (45). This resulted in five topics

per sustainability dimension with guiding questions. An "extreme scenario" technique was also introduced to analyze potential future effects. The newer version was again evaluated with students in Germany and Finland. This time, students found the updated SusAF easy to understand and useful, leading to a significantly higher number of elicited and better-contextualized impacts in SusADs (43)(41).

After this, SusAF was improved by developing instructions for drawing SusADs and performing detailed case studies. It was also evaluated with three industry partners (Partneur, Datamatrix, Visma) in workshops. It was observed that the list of thought-out sustainability effects was significantly increased after applying SusAF. But this process highlighted a need for better data organization and analysis support for practitioners. (44)

On the basis of challenges identified, a workbook and an industry-tailored version of the moderator slide set were developed to document the process of SusAF. This new workbook was then evaluated with two more companies: Premier Park (Finland) and Jeppesen-Boeing (Sweden). Both companies substantially broadened their understanding of potential sustainability effects and found the analysis clear and useful for planning. (44)

However, Companies noted that half- or full-day workshops were not always feasible due to time constraints, indicating a need for an "Introduction to" format (a "taster" version) to demonstrate benefits before full commitment. A compressed "taster" format of SusAF (90-120 minutes) was packaged to accommodate more restrictive time frames and provide an introductory overview of the method. The taster version was applied in master's student lectures at KTH (Sweden) and La Salle (Spain), where students found the taster useful and insightful. (44)

The SusAF taster was applied in three workshops with IT company representatives in the DigiHub Network. The Participants gained a broader understanding of sustainability and software engineering, despite limited time for detailed discussion. (44) The summarized version of this whole development process is shown in Figure 2.3.

2.3.2 Structure of SusAF

The Structure of SusAF is explained in the SusAF workbook (18). It divides the whole SusAF methodology into 4 different Phases. Each phase serves a particular aspect. The summarized version of the original SusAF Methodology is presented in the figure 2.4

1. **Warm Up**: This phase sets the foundation for the Collaborative workshop. First, participants introduce themselves and share their roles and connection to the system being assessed. The facilitator presents the SusAF framework structure, explaining

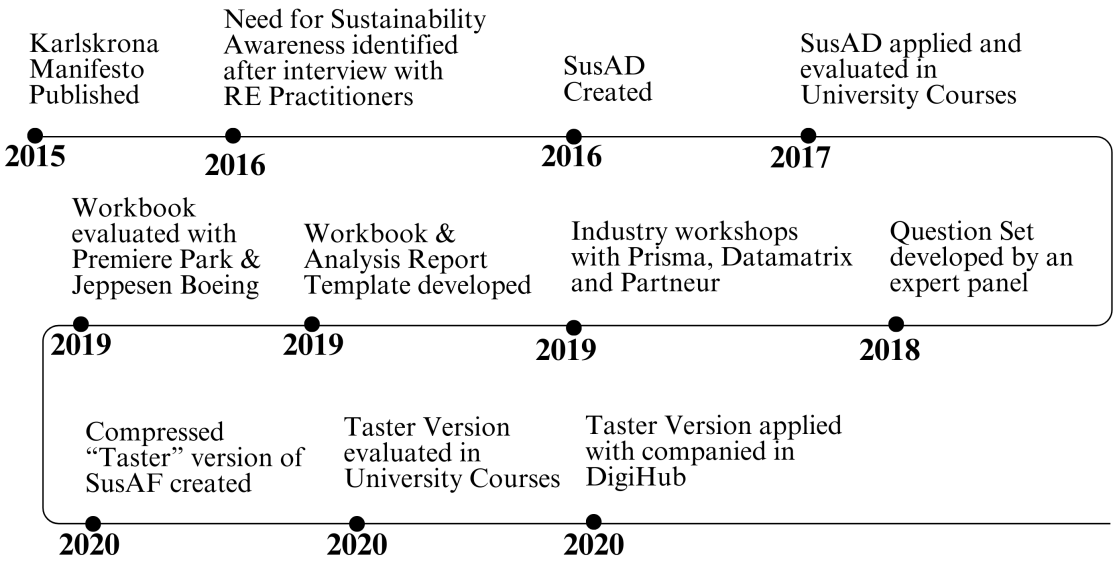

Figure 2.3: SusAF Origin Timeline

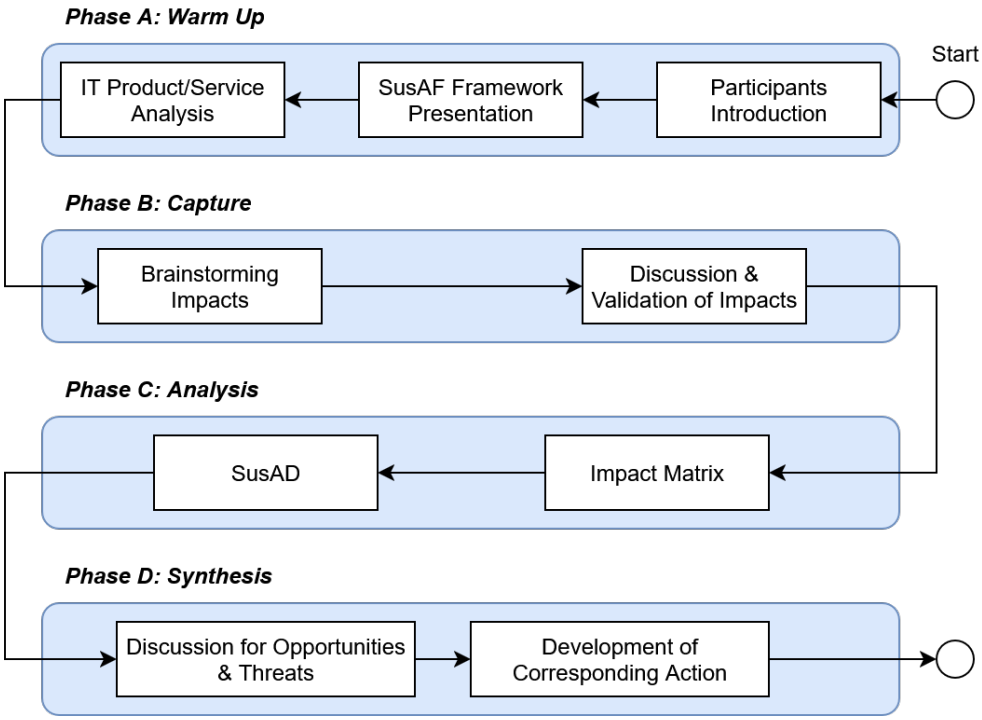

Figure 2.4: Original SusAF Methodology

the five sustainability dimensions that will guide the assessment. The team also receives a detailed presentation about the business services or IT product under evaluation to establish a shared understanding.

2. **Capture**: The phase focuses on identifying potential sustainability impacts through structured brainstorming. Participants work through a set of guiding questions across all five SusAF dimensions as explained in table 2.1. They consider impacts related to the product, services, working processes, and business model. After brainstorming, participants engage in collaborative discussion to eliminate duplicates, identify relationships between dimensions, and determine which impacts need further investigation

3. **Analysis**: This phase involves building an impact matrix to see which impacts are important or not. This also involves building chains of effects to discover causal relationships between different impacts. This chain of effect is developed in reference to three orders of effects as explained in the table 2.2. This creates a deeper understanding of how sustainability impacts propagate through the system. The analysis helps participants see the interconnected nature of sustainability effects and understand both immediate and longer-term consequences

4. **Synthesis**: The phase transforms the analysis results into actionable insights. Participants identify strategic opportunities and threats based on the material impacts discovered in previous phases. Positive impacts become opportunities that can be enhanced to create additional value. Negative impacts become threats that require mitigation or management attention. The team develops comprehensive action plans to address identified opportunities and threats, creating a bridge between assessment results and operational implementation.

Dimension	Description
Social	Focuses on Sense of Community, Trust, Inclusivity & Diversity, Equity and Participation & Communication among users
Individual	Focuses on Health, Lifelong Learning, Privacy, Safety, and Self-awareness & Free-will of users
Environmental	Focuses on Materials & Resources, Waster & Pollution, Biodiversity, Energy and Logistics
Economical	Focuses on Business Value, Customer Relationship Management, Supply Chain, Governance, Innovation
Technical	Focuses on Usability, Maintainability, Adaptability, Security, and Scalability of the system

Table 2.1: SusAF Dimensions

Order of Effects	Description
1st-Order (*Immediate)*) Effects	These refer to the direct effects of the production, operation, use and disposal of IT systems
2nd-Order (*Enabling)*) Effects	These refer to the effects that occur during usage and changed behaviour.
3rd-Order (*Structural)*) Effects	These refer to the structural changes caused by the ongoing operation and use of the system

Table 2.2: SusAF Order of Effects

3

Related Work

The literature on sustainability reporting has expanded significantly in recent years, particularly focusing on DMA challenges and methodologies. As companies work to meet CSRD and ESRS requirements, researchers and practitioners have developed various approaches to assess sustainability aspects from both impact and financial perspectives. These approaches have improved the structure and comparability of materiality assessments, especially in sectors where ESG metrics are directly measurable.

There is also a growing recognition that bridging the gap between regulatory requirements and practical frameworks like SusAF is essential for advancing sustainability assessments. Future research points toward the enhancement and integration of such frameworks, aiming to make them more adaptable to sector-specific needs and regulatory landscapes. This includes developing unified methodologies, improving the mapping of impacts and risks, and embedding sustainability considerations within the operations of organizations.

This chapter presents a targeted review of related work to directly inform and position the current study, rather than providing a broad literature survey. By focusing carefully on three different aspects, this chapter lays the groundwork for understanding the current DMA implementation landscape, the integration of sustainability frameworks in regulatory contexts, the unique strengths, and the usage and limitations of SusAF.

3.1 Empirical Studies on DMA Practice and Implementation

A number of recent empirical studies have been done to understand how organizations across Europe are interpreting, operationalizing, and disclosing DMA in their sustainability reports. These studies highlight not only the growing relevance of DM but also a range of challenges that they face in practicing it more consistently and meaningfully.

3. RELATED WORK

One of the most comprehensive and early studies in this domain is by Shami (46), who investigated the early adoption and practical implementation of the DMA concept in European corporate reporting. Shami analyzed sustainability reports from a large sample of 1,018 listed European companies for the year 2020. He applied keyword analysis and cross-referencing with ESG and credit ratings from major agencies. The study found that explicit references to "double materiality" were extremely rare (6/1018) at that early stage. Moreover, while many companies used recognized sustainability frameworks like GRI or TCFD, these were also applied inconsistently. Despite being inconsistent in the application of frameworks, they were still able to get more convergent assessments and corresponding ratings from external agencies.

The study's statistical analysis showed that the use of sustainability frameworks had improved external ratings, but the mere mention of double materiality itself does not yield a meaningful impact on the overall landscape of sustainability reporting. It argued that the lack of standardized thresholds and methodologies may lure businesses to employ Sustainability reporting only for marketing purposes. They may exploit the deficiencies and inconsistencies of the frameworks to report incomplete and deceptive information that enhances the risk of greenwashing. Due to these challenges, rating agencies also struggle to provide consistent performance evaluations. The main limitation of this research is its focus on the initial phase of DM adoption, a period when regulatory requirements and company practices were still evolving. The study does not provide a detailed methodology for how organizations can move from theoretical acknowledgment of DMA to a more comprehensive methodology of DMA. This gap underscores the need for a methodology that is capable of supporting robust and comprehensive impact identification for DMA, and my research is certainly contributing to this by developing a methodology that adapts SusAF for DMA. This would not only make the methodology regulatory compliant but also support comprehensive identification of impacts.

Several country-specific studies complement these pan-European perspectives. Dragomir (47) provided an empirical analysis of how large Romanian enterprises are adopting and disclosing double materiality assessments related to the CSRD and ESRS requirements. The authors examined the process of materiality assessment procedures of 20 listed companies through inductive content analysis of their sustainability reports. The study found that most companies focus on reporting positive environmental and social impacts but only "actual" impacts. Indirect impacts were less frequently reported. Stakeholder engagement was often limited to employees and communities through single events like interviews or

questionnaires. While all companies reported on risks, especially those related to the environment and workplace safety, their focus was more on identifying risks than on describing actions to mitigate them.

The study demonstrates that internal processes and governance structures for materiality assessments are developing; however, there remain significant gaps in the aspects of risk assessment and comprehensive stakeholder engagement. A main limitation of this research is its focus on a single year and a small sample of companies, which might not show evolving practices or differences between sectors. The authors suggest that EFRAG should issue clearer guidelines to help different sectors perform more comprehensive assessments. This call for practical guidance directly relates to this research, which proposes a methodology to help companies navigate this new regulatory landscape.

A regional contrast is provided by Szalacha (48), who explores how Polish companies have implemented the double materiality concept in sustainability reporting. The study content analysis of sustainability reports, published in 2023, of companies listed on the Warsaw Stock Exchange included in the WIG20 index that declared they had voluntarily carried out the double materiality process ("early adopters"). Their materiality determination process was analyzed according to the requirements defined in ESRS 2 in Disclosure Requirement (DR) IRO-1.

The study demonstrated that the adoption of double materiality has significantly altered both the range of reported sustainability topics and the transparency of the materiality assessment process itself. Companies reported notable changes in the number and type of material topics disclosed. Some firms focus on fewer (more relevant issues), while others expand their list to include new environmental or social topics. Szalacha attributed these shortcomings to a lack of standardized operational guidance, limited company expertise, and the novelty of the CSRD requirements. The findings underscore the need for clearer regulatory guidance and practical methodology that can support the comprehensive identification of IROs. This thesis resonates with the findings of this study by developing a methodology based on SusAF for DMA. The identification of IRO is a specialty of SusAF that is the key gap in the current implementations in corporates.

Moving to the Nordic region, Lehtinen (49) presents an in-depth qualitative case study of how eight Nordic companies interpret and implement the stakeholder engagement requirements within their double materiality assessment (DMA) processes. The study focuses on dialogic communication theory and stakeholder theory to assess the quality of engagement practices, which include the collection of data through semi-structured interviews with

employees who are directly involved in CSRD implementation. This was supplemented by an inductive thematic analysis of collected data.

The study revealed that although CSRD had prompted organizations to engage with diverse stakeholders, most companies continue to prioritize business-critical stakeholders such as major customers and suppliers over less influential or affected groups. The research also highlights that dialogic or two-way engagement methods (e.g., interviews) yield more meaningful insights than standardized surveys, but the lack of knowledge among stakeholders and the company's limited facilitation hinders the effectiveness of engagement. My research directly addresses the challenges highlighted by Lehtinen. This thesis proposes a methodology aligning the SusAF with DMA to enhance stakeholder engagement. SusAF's structured, dialogic approach is specifically designed to build knowledge and guide stakeholders to identify and articulate sustainability impacts. It therefore offers a practical solution to the engagement and facilitation gaps observed in current corporate practices.

Finally, a study by Lammert *et al.* (50) examines how the software industry is responding to the CSRD. By surveying 86 software companies across 19 EU countries, the authors found that the awareness of CSRD is growing, but most software firms still rate their sustainability efforts as moderate and feel largely unprepared for the new regulatory requirements. The study reveals that market demand for sustainable products, employee retention, and reputational concerns are the main drivers for prioritizing sustainability, while regulatory compliance is only one among several motivations.

A unique contribution of this work is its focus on the software sector's specific challenges, such as the difficulty in conceptualizing and operationalizing sustainability in a domain where impacts are often intangible and cross-cutting. The study highlights that software companies anticipate significant additional financial and personnel costs, and are concerned about the evolving nature of information and auditing standards. The authors also note that, despite recognizing the strategic value of sustainability, most firms remain in an early "discovery phase" and perceive a lack of practical guidance and sector-specific methodologies for CSRD implementation. This emphasizes the pressing need for tailored, scalable solutions. This observation reinforces the central motivation of my thesis to develop a practical methodology for DMA specifically suited to software-based companies, as SusAF's question set is more focused on SE practices.

3.2 Integration of DMA with broader sustainability frameworks

Delgado-Ceballos *et al.* (51) presented a comprehensive essay that connects the United Nations' Sustainable Development Goals (SDGs) with firm-level sustainability and ESG factors. It provides concrete examples of how firm-level ESG metrics can be mapped to SDG indicators. Authors highlight the importance of double materiality for businesses to navigate the intricate sustainability landscape and effectively contribute to SDGs. The authors utilize the ESRS guidelines on double materiality to demonstrate how businesses can embed the SDG framework into their core activities.

A key contribution of this work is the proposal of a "sustainability balance sheet" that integrates double materiality into business reporting. This approach aims to make sustainability impacts more comparable and decision-useful for both managers and stakeholders. Their research directly supports the rationale for adapting frameworks like SusAF to meet double materiality requirements, as it shows how systematic approaches to sustainability assessment can serve multiple stakeholders' needs.

Rambaud *et al.* (52) examines the concept of Double Materiality (DM) in accounting, which is defined as the simultaneous consideration of 'financial materiality' and SEM. Their research employs an analogical approach for extending the concept of materiality from financial accounting to sustainability reporting. The study examines double materiality through the lens of environmental issues, particularly biodiversity reporting, and proposes a systematic classification of different types of financial materiality and social and environmental materiality. Their framework identifies four main approaches:

1. Financial Materiality from Proprietary Theory
2. Financial Materiality from Entity Theory
3. SEM from Utilitarian Perspective
4. SEM from Ecological Perspective

The paper's main contribution is its clarification of the conceptual foundations underlying double materiality and its identification of the variations that exist in its implementation. This work provides essential theoretical grounding for understanding how different interpretations of materiality can lead to different sustainability reporting outcomes. The authors' identification of seven key points of attention for stakeholders and policymakers provides practical guidance for implementing double materiality in different types of

contexts. For research focused on adapting sustainability frameworks like SusAF to meet double materiality requirements, this paper offers crucial insights into the flexibility and adaptability of the ESRS framework to integrate with other frameworks.

Nielsen (53) explores the practical application of double materiality in ESG reporting through the development of key performance indicators, using a case study methodology focused on Port Esbjerg. The research demonstrates how organizations can create meaningful connections between their business models and ESG KPIs that document double materiality assessments. Nielsen's approach involves analyzing value chains and distribution networks to understand both scope 1, 2, and 3 emissions and broader sustainability impacts. The study utilizes the REGS model (Resilience, Emissions, Governance, and Sharing) to reconcile corporate social responsibility and ESG perspectives. It also provides a framework for identifying relevant performance metrics across different sustainability dimensions. The key contribution is the demonstration that double materiality can serve as a bridge between regulatory requirements and business strategy. By embedding double materiality into business model analysis and KPI selection, companies can create more transparent, comparable, and actionable sustainability reports. The research provides a concrete methodology for translating double materiality concepts into measurable indicators that can guide both internal decision-making and external reporting. This is particularly relevant for software development companies seeking to operationalize double materiality requirements. The study shows how organizations can move beyond regulatory compliance to use double materiality as a strategic tool for business model innovation and competitive advantage. The integration of the REGS model with double materiality matrices offers a practical approach that software companies can adapt to identify and measure their most significant sustainability impacts while addressing stakeholder expectations.

3.3 SusAF: Development, Applications, and Adaptations

Arroja (54) addresses the imperative need to integrate sustainability into software development. She argues that, although SusAF is recognized as a valuable tool to identify and reason about the impacts of Software systems across different dimensions, its practical application faces significant challenges. These challenges include the absence of dedicated tools to support its utilization, difficulties in its usability, and the considerable time it takes to complete, which intensifies the complexity of integrating sustainable concerns, especially during the initial phases of Requirements Engineering. To address these issues, the author proposes a conceptual model of a tool, GreenSusAF. The primary goal of this tool is to

support the integration of sustainability practices into all software projects by facilitating the identification and analysis of sustainability impacts during requirements elicitation and analysis.

The study employs a comprehensive methodology including a systematic mapping study of 21 papers, conceptual modeling using StarUML, and tool development using the Bubble.io Low-Code Development Platform. The research demonstrates how GreenSusAF digitizes the traditionally paper-based SusAF process through an intuitive interface that guides users through brainstorming sessions with 25 questions across five sustainability dimensions, automated effect categorization, and digital creation of SusAD. The evaluation with 41 participants revealed that 73.2% were unfamiliar with SusAF initially, but the tool successfully promoted framework adoption while reducing time consumption and complexity barriers. However, the research reveals important limitations for DMA applications as GreenSusAF remains primarily focused on software systems rather than comprehensive business operations. Notably, while it enhances impact materiality assessment by supporting structured sustainability analysis, it does not address financial materiality and provides no integration with ESRS compliance requirements, which are essential for DMA. This work directly supports our research hypothesis that SusAF requires significant extensions for DMA compatibility by demonstrating that even with optimal digital tool support, the framework's scope limitations persist. This reinforces the need for substantial adaptations in SusAF to incorporate financial materiality assessment and regulatory alignment mechanisms.

Krogstie *et al.* (55) propose a workshop methodology that applies the SusAF to analyze AI-based tools in higher education contexts, specifically focusing on tools such as ChatGPT and DALL-E. The study addresses the growing integration of artificial intelligence tools in educational settings and the need to systematically evaluate their sustainability implications across multiple dimensions. The proposed workshop employs a structured approach where participants from interdisciplinary backgrounds engage in group-based activities to identify sustainability issues using SusAF's five dimensions (economic, environmental, social, individual, and technical) and classify effects according to the framework's three orders (immediate, enabling, and structural). The methodology involves a full-day workshop format with up to 20 participants who submit reflection papers and participate in three sequential tasks: identifying sustainability issues of AI tools, classifying these issues into orders of effects, and discussing relationships across sustainability dimensions.

The primary contribution of this work lies in extending the SusAF application to the emerging domain of AI tools in higher education to demonstrate the framework's adapt-

ability to contemporary technological challenges. The workshop format encourages interdisciplinary dialogue and hands-on application of SusAF, supporting participants in recognizing and reflecting on sustainability challenges in teaching and learning contexts. However, the study is limited to impact materiality, as its analysis remains centered on identifying and discussing sustainability issues without extending to quantitative assessment or financial risk analysis. There is no exploration of double materiality or regulatory compliance aspects, which are essential for DMA. For my research, this demonstrates that even when applied to new technological domains like AI tools, the framework maintains its impact-focused orientation without naturally extending into the financial materiality assessment components. This creates a gap between the application of SusAF and regulatory requirements, which this thesis is certainly going to explore.

Lammert *et al.* (56) present a comprehensive Design Science Research study that addresses the critical gap between academic sustainability theory and industrial software engineering practice through the systematic development of a business-oriented extension to the SusAF. The research employs a six-step DSRM introduced by Peffers. The study identifies three key problem areas:

1. organizational challenges related to personnel selection
2. stakeholder involvement and structural issues concerning corporate integration and profitability requirements
3. technical limitations regarding industry-agnostic applicability

To address this, the study develops the Business-Oriented Extension of SusAF (BE-SusAF), which is an artifact designed through iterative cycles involving empirical investigations, participatory workshops, and feedback from industry practitioners. The BE-SusAF introduces new processes for stakeholder engagement, business model analysis, and the integration of sustainability into financial and organizational planning, all tailored to the realities of software industry practice.

The primary contribution of this study lies in successfully bridging the theoretical-practical divide in sustainability integration by developing BE-SusAF. This demonstrates that sustainability and profitability can be systematically aligned through structured business model integration approaches, including Value Proposition Canvas and Traffic Light Business Model Canvas methodologies. The research establishes that interface personnel, such as product managers, are more suitable for sustainability workshop orchestration than traditional software engineers, while participatory stakeholder engagement processes

enhance the comprehensiveness of sustainability analysis. The study validates the extensibility of SusAF beyond its original academic scope, which shows how sustainability frameworks can be adapted to accommodate industrial requirements, including time constraints, cost considerations, and competitive pressures. However, the research acknowledges significant limitations in its continued focus on traditional sustainability impact assessment rather than extending into regulatory compliance frameworks required for contemporary corporate reporting standards. While BE-SusAF advances SusAF's applicability in industry, it does not address the explicit requirements of DMA, such as financial risk quantification, value chain analysis, or alignment with ESRS. This underscores the need for further research to develop methodological extensions that enable SusAF and its derivatives to meet the comprehensive demands of DMA, particularly in the context of corporate sustainability reporting and regulatory obligations.

Brooks *et al.* (57) present a comprehensive study that explores the integration of SusAF with the United Nations SDGs. The research conducts a systematic mapping between SusAF's 25 topics and 95 questions against the 169 targets of the 17 SDGs through a three-stage thematic analysis. The first stage establishes general feasibility by linking SusAF topics to SDG targets, while the second stage performs detailed semantic coding using qualitative content analysis. The mapping reveals strong conceptual alignment between SusAF's 5 sustainability dimensions and the broader goals articulated in the SDGs. However, some gaps are also identified where 22% of SDG targets could not be directly mapped to SusAF questions.

The key contribution of this work is demonstrating that software systems can be systematically analyzed for their contributions to global sustainability goals through established frameworks like SusAF. This mapping is particularly relevant for this study as it provides the direction about how SusAF questions and topics can be mapped onto other sets of sustainability topics, which as ESRS standards in this case. The study also highlights important limitations, which include some technical aspects of SusAF, such as maintainability and scalability do not directly map to SDG targets, and that domain-specific expertise may be required for accurate mapping in certain contexts.

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4

Research Methodology

This chapter outlines the research methodology for the conceptualization, design, and evaluation of our proposal. It was divided into two parts—literature review and design science research—as described below.

4.1 Literature Review

This research uses a targeted literature review approach that focuses on regulatory documents and framework documentation. The approach is designed to address the specific research problem of adapting SusAF for DMA requirements under CSRD regulations.

4.1.1 Review Scope

The literature review concentrates on three main areas.

1. Regulatory Documents
    - CSRD Requirements
    - ESRS Standards
    - EFRAG Implementation Guide
2. SusAF
3. Academic Research

This focused approach is suitable for this study because the research addresses a specific regulatory compliance challenge within SusAF. The core problem is defined by the gap between SusAF capabilities and DMA requirements under CSRD, rather than theoretical

gaps in academic literature. The research aims to adapt an existing framework instead of developing completely new theoretical concepts from scratch. This targeted scope ensures the review directly supports the methodology development objectives.

4.1.2 Selection of Relevant Scientific Papers

To select relevant scientific papers, a specific search query was developed and applied to Google Scholar. The search query was:

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"SusAF" AND ("ESRS" OR "CSRD" OR "Double Materiality")
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This query returned 14 papers in total. The query was specifically designed to identify any existing work that addresses the gaps between SusAF and regulatory frameworks. All papers were in English, which simplified the review process. No specific inclusion and exclusion criteria were applied because the number of papers was already small. All 14 papers were reviewed to identify any mention of work done to explore the flexibility of SusAF and its integration with regulatory frameworks. This comprehensive review of the limited literature helped establish the novelty of the research.

4.1.3 Analysis

The regulatory documents were analyzed to extract specific requirements for DMA. This included identifying data points, disclosure requirements, and assessment procedures mandated by CSRD. The analysis focused on understanding and implementation of both impact materiality and financial materiality assessment perspectives. SusAF documentation was also examined to understand the framework's current components and processes. The review identified areas where SusAF aligns with or differs from CSRD requirements. The academic papers were also reviewed to understand existing approaches to framework adaptation and regulatory compliance. This analysis helped identify best practices and potential challenges in adapting sustainability frameworks for regulatory purposes.

4.1.4 Synthesis

The literature review synthesizes findings to identify gaps and adaptation opportunities for SusAF within CSRD requirements. The review reveals specific areas where SusAF can be adapted to meet regulatory requirements and Double Materiality Assessment guidelines. The gap analysis shows where SusAF processes can be extended or modified. It identifies new elements that need to be added to address CSRD requirements. The analysis also

highlights SusAF's existing strengths that can be leveraged for regulatory compliance. This analysis directly informs the mapping exercises and methodology development phases. The identified gaps provide clear direction for adapting SusAF to meet Double Materiality Assessment requirements while maintaining the framework's core principles and usability.

4.2 Design Science Research

This study uses DSR methodology to address the practical challenges of adapting SusAF to DMA. Among the various research methodologies available for information systems research, DSR was selected as the most appropriate paradigm for this study due to its focus on creating innovative artifacts that solve identified practical problems. As established by Henver (58), DSR is fundamentally a problem solving paradigm where:

> Knowledge and understanding of a design problem and its solution are achieved in the building and application of the designed artifact.

Unlike purely descriptive methodologies such as case studies (59), which focus on in-depth analysis of existing phenomena without necessarily working towards new and innovative artifacts. DSR (58) actively constructs and tests artifacts like frameworks and methodologies to extend organizational capabilities. Similarly, Action research (60) is more participatory and problem-oriented but lacks the structured rigor for artifact development and evaluation, as it prioritizes collaborative cycles over knowledge contribution. On the other hand, qualitative methods, such as thematic analysis or grounded theory, are more exploratory and interpretive. They focus on generating theoretical insights from data but not on designing new solutions (61). So, DSR's problem-solving paradigm fits this research by enabling the iterative building of mappings, enhanced questions, KPIs, and an adapted methodology that directly bridges the identified gap between SusAF's current capabilities and DMA needs.

The specific implementation of DSR in this study follows a three-cycle view of Design Science Research proposed by Henner (62), which provides a comprehensive framework through utilization of three cycles:

1. **Relevance Cycle** to identify practical problems from the environment;
2. **Design Cycle** for iterative building and evaluation of artifacts; and
3. **Rigor Cycle** to ground the research in the existing knowledge base.

This three-cycle approach was selected over alternative DSR models because it directly addresses this study's need to balance practical industry needs with academic knowledge and regulatory compliance. Unlike the six-step DSRM approach by Peffers *et al.* (63), which follows a linear progression from problem identification to communication. Hevner's approach enables continuous iteration between cycles that allows real-world feedback from industry practitioners (Relevance Cycle) to inform ongoing artifact refinement (Design Cycle) while maintaining theoretical grounding in CSRD and SusAF literature (Rigor Cycle). Similarly, although FEDS (64) evaluation framework guides the assessment criteria through utility, quality, and efficacy but Hevner's cycles ensure that evaluation insights continuously inform both theoretical understanding and practical adaptation. This iterative three-cycle implementation directly tackles the research gap by enabling continuous refinement of SusAF's regulatory compliance capabilities through engagement with industry practitioners (Relevance), rigorous artifact development (Design), and theoretical grounding in sustainability frameworks (Rigor).

Figure 4 shows the overview of the three-cycle design science research, adopted in this study.

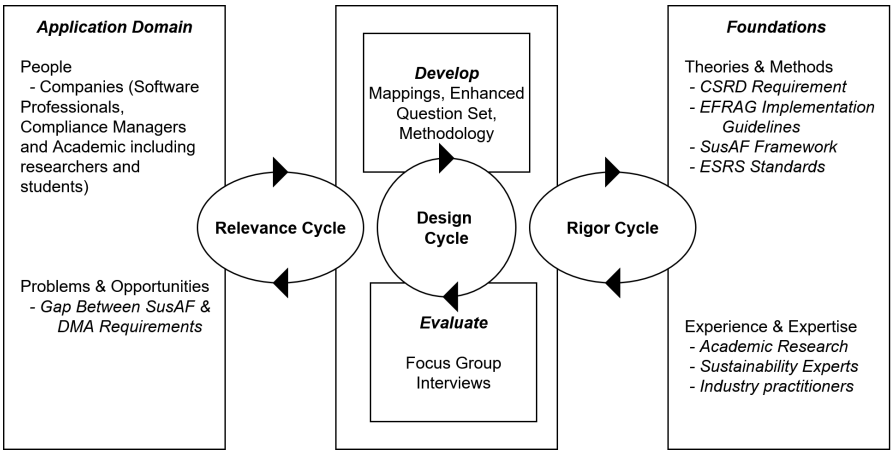

Figure 4.1: Application of DSR for this Study

4.2.1 Components

The DSR implementation comprises four interconnected components that collectively address the research questions.

- Application Domain represents the real-world environment in which the research problem exists. Key people include software professionals, sustainability officers,

and compliance managers who work in software companies. The main problem is the gap between current SusAF capabilities and DMA requirements under CSRD regulations.

- Knowledge Base provides the theoretical foundation for the research. This includes established theories and methods such as CSRD requirements, EFRAG implementation guidelines, SusAF framework, and ESRS standards. The study also incorporates the experience and expertise of academic researchers, sustainability experts, and industry practitioners. This foundation ensures the research builds on existing knowledge to create new solutions.

- Artifacts represent the actual outputs of this study that are produced through iterative development and refinement processes. These artifacts are explained in more detail in Section 4.2.2.

- Evaluation represents how the evaluation of artifacts took place throughout the research. This study was based on Focus Group Sessions with experts and interviews with RE researchers and industry practitioners. The results of evaluation are explained in more detail in Chapter 8.

4.2.2 Artifacts

Five main artifacts were developed throughout the study:

1. **Topics Mapping**: This mapping aligns SusAF topics and questions with ESRS standards. The mapping identifies how SusAF sustainability topics correspond to specific ESRS Topical Standards. The mapping process categorizes ESRS topics into three categories:

   - Fully Covered - Topics completely addressed by existing SusAF elements
   - Partially Covered - Topics that need enhancement in SusAF
   - Not Covered - Topics requiring new additions to SusAF

   The mapping was based on an initial keyword analysis. If the main keywords of a particular topic were found in SusAF questions, it was classified as fully covered. If not, the topic was further analyzed using insights from previous SusAF workshops that I attended. If the topic was addressed implicitly through the current questions, it was classified as "Partially Covered"; otherwise, it was marked as "Not Covered".

For the topics "Not Covered" or "Partially Covered", a rationale explaining the gap was also documented.

2. **Guidelines Mapping**: This mapping compares the SusAF methodology guidelines with the EFRAG implementation guidance. The EFRAG guide was preferred over ESRS 1 and 2 for this analysis. EFRAG defines the sequential flow of DMA more clearly than ESRS. The guidelines for DMA are scattered in ESRS documents, which makes cross-referencing difficult. EFRAG is based on ESRS, but it is a non-authoritative document. The mapping process identifies similarities and differences in assessment procedures. It determines which DMA guidelines are covered in the SusAF process. The guidelines are also categorized into three groups:

   - Fully Covered - Guidelines completely addressed by SusAF
   - Partially Covered - Guidelines that need more comprehensiveness in the process to fully comply with requirements
   - Not Covered - Guidelines requiring new methodology elements

   The mapping was based on a step-by-step comparison of the process. Each EFRAG guideline was reviewed against SusAF procedures to check for matches in sequence and content. If a guideline's steps were directly supported in SusAF, it was classified as fully covered. If only some steps aligned, it was marked as partially covered. If no steps matched, it was classified as not covered. This process is visible in the figure below.

3. **Enhanced Set of Questions**: This artifact provides an enhanced set of questions. It is based on gaps found in SusAF topics. For ESRS topics marked as partially covered or not covered, new questions were created. These questions were formed based on personal intuition, but they were later validated through interviews with RE researchers. The goal is to make SusAF fully matched to the ESRS standards. This set ensures complete coverage of all needed areas. It also present the relevant Datapoints in each topic as referenced from ESRS SEt of Data Points.

4. **Methodology**: This artifact provides the detailed methodology of SusAF adapted for DMA based on the gaps identified in Guidelines Mapping. The design of the methodology keeps the original SusAF structure and flow intact. Changes include only small enhancements to existing steps. New steps in SusAF were added only when it seemed necessary. Most adaptations occur in the Pre-SusAF and Post-SusAF

phases. This setup ensures smooth integration with current practices. It provides a practical guide for meeting CSRD requirements.

4.3 Research Phases

This study evolved over seven phases, as shown in Figure 4.2 and described in the next sections.

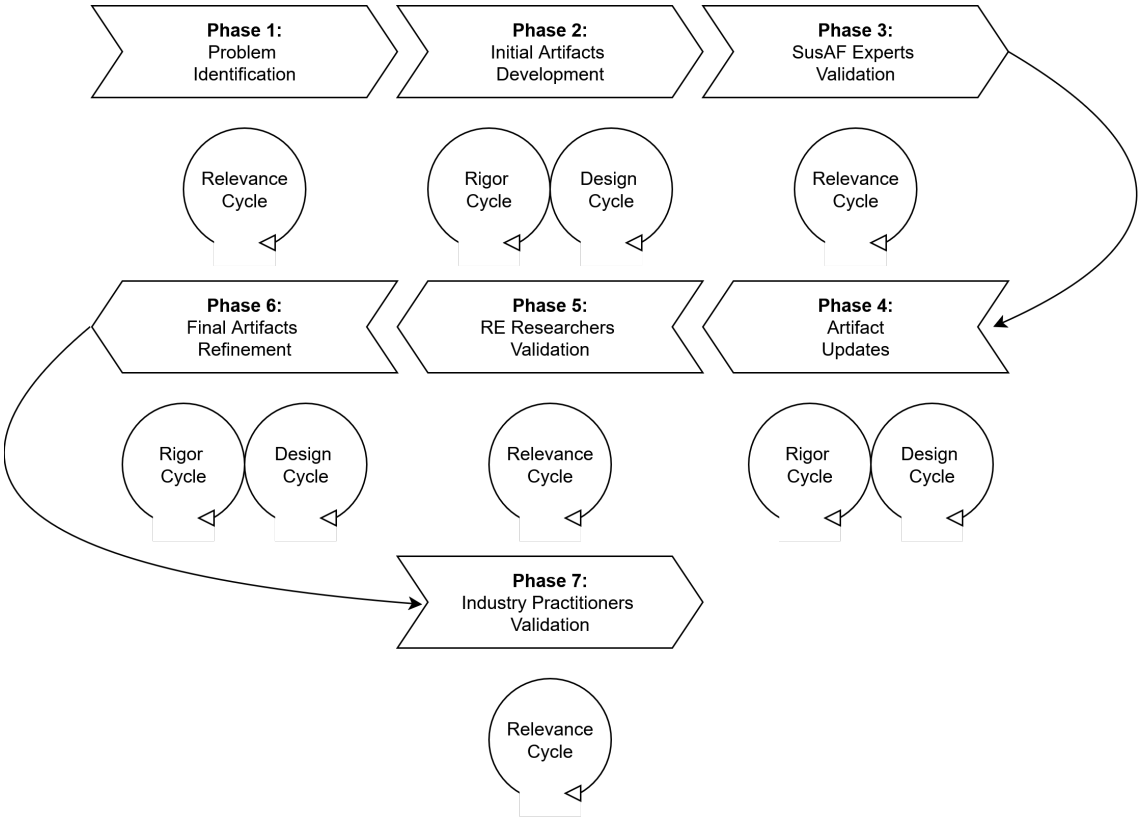

Figure 4.2: DSR Phases

4.3.1 Phase 1: Problem Identification

The research began with the relevance cycle by identifying the core issue, which shows that software companies are hesitant to use SusAF despite being a comprehensive approach to assess the companies' position on sustainability. The main reason for their hesitation was the time consumption and lack of alignment with compliance requirements, due to which they have to do DMA as a separate process. The main outcomes of this cycle were a

clearly defined research problem and questions that establish both academic contribution and practical relevance. these questions documented in the Section 1.3

4.3.2 Phase 2: Artifacts Development

In this phase, the Rigor Cycle was applied by carefully reviewing essential regulatory documents, including CSRD regulations, ESRS standards, EFRAG guidelines, and SusAF documentation. This created a solid theoretical foundation for highlighting specific gaps between SusAF and regulatory requirements.

The Design cycle was focused on creating the initial artifacts, which include topical and guideline mappings and conceptual methodology. These were built through systematic comparisons to identify alignments and gaps. Internal validity checks were also performed through cross-referencing between ESRS and SusAF documentation to ensure accurate interpretation of requirements.

The main outcomes of this phase were initial versions of topic mapping, guidelines mapping, and methodology artifacts with comprehensive documentation of the development process.

4.3.3 Phase 3: Experts Validation

After designing the mappings and methodology, they were evaluated in a focus group session of sustainability and SusAF experts. They looked at the mappings and shared their insights on the accuracy, completeness, and practical relevance of our initial findings. This session highlighted what was good and what needed improvement. The relevance cycle was applied to document the insights of experts. This was done to make sure that further refinements incorporate their feedback. The main outcomes of this phase were structured feedback on initial artifacts, identifying specific improvement areas documented in Section 8.1.

4.3.4 Phase 4: Artifact Updates

Now, again, the design cycle was applied for the refinements of Topical Mapping and Methodology with the feedback received from experts. On the basis of refined Mapping, an enhanced set of Questions was also created. The phrasing of New Questions was created with personal intuition to cover up the missed topics. At last, Datapoints mapping was also done to map the ESRS List of data points to the Enhanced set of SusAF Topics

and Questions. Rigor was maintained by cross-referencing refinements with regulatory documents. This phase produced more refined artifacts with more clarity.

4.3.5 Phase 5: RE Researchers Validation

The relevance cycle was used to test the wording of new questions included in the SusAF. They were assessed based on their relevance to Software Engineering, ease of understanding, and clarity. For this, 11 online interview sessions were conducted with RE researchers.

4.3.6 Phase 6: Final Artifact Refinement

In this phase, the design cycle was iterated to incorporate the feedback of RE researchers to make adjustments in the wording of questions. This ensured the artifacts were practical for educational and entry-level industry contexts for further evaluation.

Rigor was maintained by documenting all changes systematically and aligning them with established DSR guidelines. This resulted in a cohesive, scalable Artifacts that balances regulatory compliance with practical implementation for software companies.

4.3.7 Phase 7: Industry Evaluation

The relevance cycle tested the complete methodology through interviews with industry practitioners. Its alignment with DMA requirements, usefulness, and feasibility in real-world settings was assessed.

5

SusAF-DMA Mapping

This chapter provides an in-depth exploration of alignments and gaps between SusAF and DMA requirements by creating systematic mappings between their respective frameworks. Through detailed comparison and mapping exercises, this chapter identifies where SusAF naturally aligns with DMA principles and where significant gaps exist that require methodological adaptations. This mapping process serves as the foundation for understanding how SusAF can be modified or extended to meet regulatory compliance needs for DMA while maintaining its core strengths in comprehensive sustainability evaluation. The findings presented here directly inform the development of an adapted framework that bridges theoretical sustainability assessment tools with practical regulatory requirements for software development companies.

5.1 Topics Mapping

The mapping of ESRS Topics to SusAF Topics is shown in Table 5.3. The mapping reveals that SusAF offers a solid but incomplete foundation for a fully compliant DMA. The framework's primary strengths lie in its comprehensive coverage of direct environmental impacts and the effects on consumers and end-users. It fully addresses key topics such as Energy (E1.3), Waste (E5.3), and the full range of issues concerning Consumers & End Users (S4), including privacy, safety, and social inclusion.

However, the analysis reveals significant gaps, particularly across the Social and Governance dimensions. The original SusAF does not contain any questions that explicitly address the working conditions, rights, or equal treatment of the company's Own Workforce (S1) or Workers in the Value Chain (S2). Similarly, it lacks prompts to consider the economic, social, or cultural rights of Affected Communities (S3). In the Governance

dimension, critical topics like whistleblower protection, political engagement, and anti-corruption measures are absent. Many other topics are only partially covered, meaning SusAF's general questions touch upon the area but lack the specific detail required by ESRS, such as climate adaptation and mitigation strategies, specific types of pollutants, and key circular economy principles like repair and reuse. Table 5.1 and Figure 5.1 present the quantitative breakdown of the 37 ESRS sub-topics coverage in SusAF.

Table 5.1: Summary of ESRS-SusAF Topics Mapping

Coverage Status	No. of Sub-topics
Fully Covered	11
Partially Covered	10
Not Covered	16

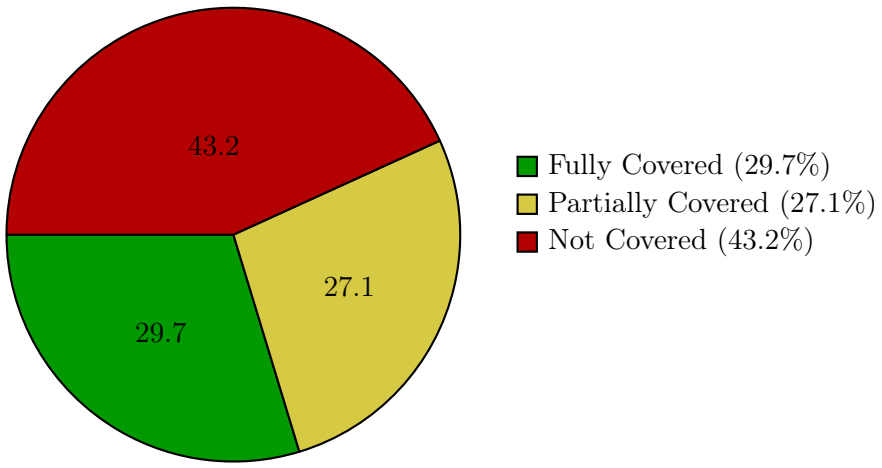

Figure 5.1: Distribution of ESRS-SusAF Topics Mapping

5.2 Process Mapping

The mapping of DMA Guidelines to SusAF process is shown in Table 5.4. This mapping is based on the major guidelines of EFRAG IG-1 that correspond to the process of DMA. Mapping reveals that SusAF provides a strong foundation for collaborative impact identification but lacks the structured depth needed for full ESRS compliance, particularly in contextual analysis, formal materiality criteria application, and reporting. The framework excels in the identification of Impacts, Risks, and Opportunities (IROs), where

its workshop-based brainstorming ensures comprehensive coverage. However, it falls short in early context-building (e.g., value chain mapping and business strategy analysis) and in applying ESRS-specific assessment criteria like scale, scope, and magnitude, often resulting in partial or no coverage. The reporting step is also underdeveloped, focusing on workshop outputs rather than the formal IRO lists and disclosure mappings required by ESRS. This highlights SusAF's value as a participatory tool but underscores the need for enhancements to meet EFRAG's systematic, evidence-based DMA process. Table 5.2 and Figure 5.2 show the quantitative breakdown of coverage of identified Guidelines for DMA in EFRAG in SusAF.

Table 5.2: Summary of DMA-SusAF Guidelines Mapping

Coverage Status	No. of Sub-topics
Fully Covered	1
Partially Covered	13
Not Covered	3

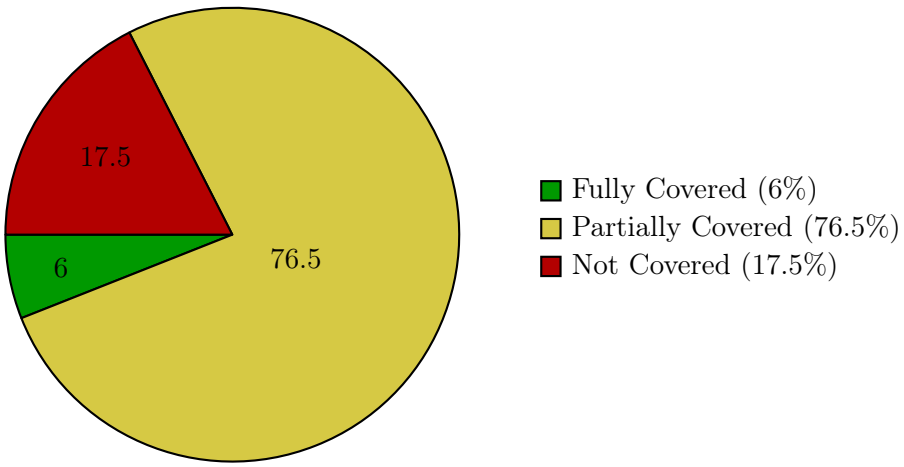

Figure 5.2: Distribution of DMA-SusAF Guidelines Mapping

Table 5.3: ESRS and SusAF Topics Mapping

Topic (ESRS code)	Sub-topics/Sub-sub-topics	Related SusAF Question	Coverage Assessment
E1: Climate Change	E1.1 - Climate change adaptation	E2: Waste & Pollution	Partially Covered (Implicitly addresses climate change through *emissions*, but does not explicitly cover climate adaptation strategies)
	E1.2 - Climate change mitigation		Partially Covered (Implicitly addresses climate change through *emissions*, but does not explicitly cover climate mitigation strategies)
	E1.3 - Energy	E4: Energy	Fully Covered (Explicitly addressed Energy production and comsumption)
E2: Pollution	E2.1 - Pollution of Air	E2: Waste & Pollution	Fully Covered (Explicitly Address Pollution of Air)
	E2.2 - Pollution of Water		Fully Covered (Explicitly Address Pollution of Water)
	E2.3 - Pollution of Soil		Fully Covered (Explicitly Address Pollution of Soil)
	E2.4 - Pollution of Living Organisms		Partially Covered (The "Biodiversity" questions cover impacts on plants and animals. However, the direct causal link from *pollution* to the health of living organisms is not explicitly mentioned.)
	E2.5 - Substances of Concern		Not Covered (Questions are too general to discuss hazardous substances)
	E2.6 - Substances of very High Concern		Not Covered (Questions are too general to discuss SVHC's)

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Topic (ESRS code)	Sub-topics/Sub-sub-topics	Related SusAF Question	Coverage Assessment
	E2.7 - Microplastics		Not Covered (Questions are too general to discuss Microplastics)
E3: Water and Marine Resources	E3.1 - Water	E2: Waste & Pollution	Partially Covered (Implicitly addressed in Water Porllution but does not explictly address consumption, withdrawls and discharges)
	E3.2 - Marine Resources		Not Covered (Does not Cover anything related to Marine Resources or Ecosystems)
E4: Biodiversity and Ecosystems	E4.1 - Direct impact drivers of biodiversity loss	E3: Biodiversity	Partially Covered (Explicitly Address most key drivers of sustainability except for 'Alien Species')
	E4.2 - Impacts on the state of Species		Fully Covered (Explictly address the impact on species of plants and animals)
	E4.3 - Impacts on the extent and condition of Ecosystems		Partially Covered (Implictly address the impact on ecosystem through plants, animals and soil but not a hollistic assessment related to Land Degradation and Desertification is Covered)
	E4.4 - Impacts on and dependencies of ecosystem services		Partially Covered (Implictly address the impact on dependencies through plants, animals and soil)
E5: Resource Use and Circular Economy	E5.1 - Resource inflows (including resource use)	E1: Materials and Resources	Fully Covered (Explicitly addressed the materials need to operate a service/product)
	E5.2 - Resource outflows related to products and services		Partially Covered (Implicitly address by Materials not specifically mention outflows)

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Topic (ESRS code)	Sub-topics/Sub-sub-topics	Related SusAF Question	Coverage Assessment
	E5.3 - Waste	E2: Waste & Pollution	Fully Covered (Explicitly addresses waste and recycling)
S1: Own Workforce	S1.1 - Working Conditions	None	Not Covered (SusAF does not explicitly cover any practices, working conditions, or human rights of the company's own workforce)
	S1.2 - Equal Treatment & Opportunities for All		
	S1.3 - Other Work Related Rights		
S2: Workers in the value chain	S2.1 - Working Conditions	None	Not Covered (SusAF does not explicitly cover any practices, working conditions, or human rights of the workers involved in the value chain)
	S2.2 - Equal Treatment & Opportunities for All		
	S2.3 - Other Work Related Rights		
S3: Affected Communities	S3.1 - Communities' Economic, Social & Cultural Rights	None	Not Covered (SusAF does not cover any aspects related social, cultural, civil and political rights of the affected communities involed in the value chain)
	S3.2 - Communities' Civil & Political Rights		
	S3.3 - Rights of Indigenous People		
S4: Consumers & End Users	S4.1 - Information related impacts for consumer / end users	I3: Privacy	Fully Covered (Explicitly address the privacy of Individuals)

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Topic (ESRS code)	**Sub-topics/Sub-sub-topics**	**Related SusAF Question**	**Coverage Assessment**
	S4.2 - Personal safety of consumers / end users	I4: Safety	Fully Covered (Explicitly address the safety of Individuals)
	S4.3 - Social inclusion of consumers / end users	S1: Sense of Belonging; S3: Inclusivity & Diversity	Fully Covered (Explicitly address the social impacts)
G1: Business Conduct	G1.1 - Corporate Culture	B4: Governance	Fully Covered (Explicitly address the governance)
	G1.2 - Protection of whistleblowers	None	Not Covered (SusAF does not address internal reporting channels, non-retaliation policies, or whistleblower protection)
	G1.3 - Animal welfare	E3: Biodiversity	Not covered (SusAF does not cover anything related to Animal Welfare)
	G1.4 - Political engagement	None	Not Covered (SusAF does not include any questions related to lobbying, political contributions,)
	G1.5 - Management of relationships with suppliers (including payment practices)	B3: Supply Chain	Partially Covered (Address the *effects* on the supply chain but not cover payment terms and grievance mechanisms)
	G1.6 - Corruption and bribery	None	Not Covered (SusAF does not cover any aspect of Corruption and Bribery)

Table 5.4: EFRAG IG-1 and SusAF Guidelines Mapping

EFRAG IG-1 Step	Relevant SusAF Step	Coverage Assessment
Cross-cutting Principles (Early Document)		
Paragraph 7: "Engagement with affected stakeholders informs the materiality assessment process, and it is consistent with the practice suggested by the international instruments of due diligence referenced in the CSRD. This entails seeking input and feedback to understand concerns and evidence about actual and potential impacts"	*All SusAF steps:* Workshop format with participant engagement throughout	Partially Covered (Stakeholder engagement is employed through workshop participants, but does not include all affected stakeholders per due diligence requirements)
Section 3.1 - Step A: Understanding the Context		
Paragraph 68: "In this step, the undertaking develops an overview of its activities and business relationships, the context in which these take place, and an understanding of its key affected stakeholders. This overview provides key inputs to identify the undertaking's IROs"	*Step 1: Warm-Up/Introduction:* Introduction of participants, SusAF framework, and IT product under analysis	*Partially Covered* (Details of Product context / Business Service and introduction of workshop participants are covered, but comprehensive business relationships and affected stakeholder mapping are not included)
Paragraph 69(a): "Analysis of the undertaking's business plan, strategy, financial statements and, when applicable, other information provided to investors"	*Step 1: Warm-Up/Introduction:* IT product analysis context	*Partially Covered* (Details of Product context / Business Service and introduction of workshop participants are covered but strategic business analysis is not included)

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EFRAG IG-1 Step	Relevant SusAF Step	Coverage Assessment
Paragraph 69(b): "The undertaking's activities, products/services and the geographic locations of these activities"	*Step 1: Warm-Up/Introduction:* IT product under analysis	*Partially Covered* (Implicitly covered in Details of Product context / Business Service but comprehensive activity mapping not included)
Paragraph 69(c): "The mapping of the undertaking's business relationships and upstream and/or downstream value chain, including type and nature of business relationships"	*Step 1: Warm-Up/Introduction:* Product context discussion	*Not Covered* (Implicitly covered in Details of Product context / Business Service but comprehensive value chain mapping not included)
Paragraph 71: "Understanding of affected stakeholders...aimed at understanding which stakeholders are or are likely to be affected by the undertaking's operations and upstream and downstream value chain"	*Step 1: Warm-Up/Introduction:* Participant introduction	*Partially Covered* (Workshop participants represent some stakeholders but formal affected stakeholder identification not included)
Section 3.2 - Step B: Identification of IROs		
Paragraph 73: "In this step, the undertaking identifies the actual and potential impacts, risks and opportunities (IROs) relating to environmental, social and governance matters across its own operations and in its upstream and downstream value chain"	*Step 2: Capture:* Collect and categorize potential effects across sustainability dimensions using silent brainstorm	*Fully Covered* (Systematic identification of actual and potential impacts/risks/opportunities across all sustainability dimensions)

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EFRAG IG-1 Step	**Relevant SusAF Step**	**Coverage Assessment**
Paragraph 74: "The undertaking should use the list of the sustainability matters in ESRS 1 paragraph AR16 to support this process and to ensure completeness"	*Step 2: Capture:* Effects categorized across Social, Individual, Environmental, Economic, Technical dimensions	*Partially Covered* (SusAF dimensions cover many ESRS topics but some gaps remain in the current set of questions)
Section 3.3 - Step C: Assessment and Determination		
Paragraph 82: "In this step, the undertaking applies criteria for assessing impact and financial materiality in order to determine the material actual and potential impacts and the material risks and opportunities"	*Step 3: Analysis:* Build chains of effects to discover causal relationships	*Partially Covered* (Causal analysis supports impact understanding but formal ESRS materiality criteria not explicitly applied)
Paragraph 84: "ESRS 1 Chapter 3.4 requires that undertakings apply objective criteria, using appropriate quantitative and/or qualitative thresholds to assess the materiality of actual and potential impacts"	*Step 3: Analysis:* Effect chain analysis	*Partially Covered* (Implicitly covered through Evidence-based chain analysis but comprehensive threshold setting for materiality not included)

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EFRAG IG-1 Step	**Relevant SusAF Step**	**Coverage Assessment**
Paragraph 85: "Therefore, the undertaking has to apply the criteria for severity to the list of impacts defined in step B above. The criteria are scale, scope and irremediable character of the impact for actual negative impacts. For potential negative impacts, the undertaking estimates also the likelihood of the impact occurring and maps it onto the relevant time horizon. For actual positive impacts, the criteria are scale and scope, and for potential positive impacts, the undertaking shall also estimate the likelihood of occurrence and map it onto the relevant time horizon."	*Step 3: Analysis:* Build chains of effects to discover causal relationships	*Partially Covered* (Effect chain analysis provides insights into impact relationships, but specific ESRS severity criteria of scale, scope, and irremediable character is not applied)
Paragraph 89: "Material risks and opportunities for the undertaking generally derive from impacts, dependencies or other factors...To assess their materiality, appropriate quantitative and/or qualitative thresholds based upon financial effects in terms of performance, financial position, cash flows, and access to and cost of capital are used"	*Step 3: Analysis*	*Partially Covered* (opportunities & risks analyzed but only from the impact perspective)

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EFRAG IG-1 Step	**Relevant SusAF Step**	**Coverage Assessment**
Paragraph 90: "Sustainability risks and opportunities are assessed based on their likelihood of occurrence and the potential magnitude of their financial effects in the short-, medium- and long-term. Therefore, the undertaking is required to go through the list of potential material risks and opportunities in step B above and apply a set of objective thresholds for likelihood and magnitude as well as consider the nature of the effects of the identified risks and opportunities."	None	*Not Covered* (Financial Opportunities and risks are not a part of SusAF process)
Section 3.4 - Step D: Reporting		
Paragraph 97: "This step consolidates the results of the previous steps and obtains the list of material IROs, which forms the basis for the preparation of the sustainability statement. Analysis performed at material topic/subtopic or sub-subtopic level is to be converted to IROs if this has not been done yet."	*Step 4: Synthesis:* Discuss opportunities and risks, develop corresponding actions + *SusAF outputs:* Final consolidation in SusAD and Report	*Partially Covered* (Results consolidated into final actions and documented in SusAD but conversion to formal IRO structure according to ESRS for sustainability statement not performed)
Paragraph 99(a): ESRS 2, IRO-1 - Document materiality assessment process	*SusAF outputs:* Sustainability Awareness Diagram (SusAD) and Report	*Partially Covered* (Process documented through SusAD and report is not structured for ESRS compliance)

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EFRAG IG-1 Step	**Relevant SusAF Step**	**Coverage Assessment**
Paragraph 99(b): ESRS 2, SBM-3 - Report material impacts, risks and opportunities	*Step 4: Synthesis:* Develop corresponding actions + Final Report	*Partially Covered* (Actions and measures identified but not structured as formal ESRS reporting)
Paragraph 99(c): ESRS 2, IRO-2 - Disclosure requirements in ESRS covered by the undertaking's sustainability statement	*SusAF Final Report:* Summary of results and measures	*Not Covered* (SusAF does not track which specific ESRS disclosure requirements are addressed or provide systematic mapping to ESRS topical standards)

6

Enhanced Set of SusAF Questions

The chapter presents an enhanced set of questions for SusAF that explicitly cover all of the ESRS Topics. New Questions were added on the basis of gaps identified in the topic mappings. It also presents the corresponding Data Points from the ESRS List of Data Points. An enhanced set of Questions as shown in table 6.1 keeps the original SusAF items and adds new ones that appear in green colored text. These new additions respond to the regulatory requirements and RE experts' feedback.

An enhanced set of Questions, as shown in table 6.1, keeps the original SusAF items and adds new ones that appear in green colored text. These new additions respond to the regulatory requirements and RE experts' feedback. This table also shows the relevant Data points mapped from the ESRS List.

Overall, a total of 22 new questions were added to the SusAF framework. These additions strengthen existing topics across all dimensions. In the Environment dimension, 10 new questions were added, including a new topic on Climate Change with two questions. Additions were made to Materials and Resources, Biodiversity, and Waste and Pollution. The Social dimension received six new questions. Additional Questions in the Social Dimension were more focused on the Workers in the value chain and Affected communities, for which they made it a separate new topic. The Individual dimension has two new questions. Each for topic of Lifelong Learning and Privacy. In the Economic dimension, one question was added to *Supply Chain* and *Governance* was enhanced with 4 questions. The Technical dimension has no changes.

These updates ensure the framework aligns with DMA needs under CSRD. They help software companies identify impacts more effectively.

Table 6.1: Enhanced set of SusAF Questions with relevant ESRS Data Points

Topic	Questions	Data Points
ENVIRONMENT		
Climate Change: Adaptation and mitigation responses to climate change impacts	• How can the product or service help people, infrastructure or ecosystems *adapt* to expected climate hazards (e.g., heat, flooding, storms)? • How does the product or service reduce adverse effects of climate change (production, use, end-of-life)?	Transition plan [E1-1_01], Adaptation Solution Types [E1-3_02], Scope 1-3 GHG Emissions [E1-6_01-13]
Materials & Resources: Use of every material and resource that is needed to produce, deploy, operate, and cease a product or service	• How are materials consumed to produce the product or service? • What about to operate the product or service? E.g., requires hardware • How can it change the way people consume material? E.g., encourage to buy more? • What resource outflows (by-products) are generated throughout the product lifecycle?	Materials and their sources [E5-4_01/02/03], Share of Recycled or Reuse Material [E5-4_04/05], Resource outflow [E5-5_07]
Biodiversity: Effects of a product or service on biodiversity in its operational environment, other affected land and marine resources	• How can it impact the plants or animals around it? Or elsewhere? • How can it change the composition of the soil around it? E.g., occupying/cropland? What about elsewhere? • Can it threaten species' population to extinction risk? • How might it contribute to the introduction or spread of invasive alien species? •Does it extract, disturb or conserve marine biomass, minerals or habitats? • Does the system impact live animals (testing, habitat, data)? How is welfare safeguarded?	Threatened Species [E4ṠBM-3_06] Number and Area of Alien Species[E4-5_15/16], Effect on Marine Resources [E3-5_03], Biodiversity Protection Policy [E4-2_17]. Impact on Land and soil [E4-5_10-13]

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Topic	Questions	Data Points
Energy: Energy use that results from producing and using a product or service	• How can the product or service affect the need for production of energy? • What about the use of energy? E.g. encourages less energy. • Does the hardware run on renewable energy? Is there a way to incentivise that?	Energy consumption from different sources [E1-5_01-19]
Waste & Pollution: Effects the product or service might have on soil, atmospheric, water and living organisms	• How can producing parts or supplies generate waste or emissions ś? • How can the use itself produce waste or emissions? • How can it influence how much waste or emissions are generated? • How can the product extend lifetime, enable reuse, repair, remanufactured or recycling of its own components or those of others? • Does the design involve the usage and release of hazardous chemicals and SVHC's? • Could the product create, release or reduce micro- or nano-plastics during use or degradation? • Could emissions affect human or animal health (toxicity, bioaccumulation)?	Measurement of waste from different sources [E2-4_01-09], Discharge of Hazardous and SVHC's [E2-5_02-13]
Water Resources: Usage and release of freshwater	• How much freshwater is withdrawn, consumed and discharged? In which catchments and stress levels?	Measurement of Water consumption and Storage [E3-4_01-08]

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Topic	Questions	Data Points
Logistics: Effect of prouct or service on moving people and/or goods	• How can it affect the need (and distance) for moving people or goods? • How can it affect the means by which people or goods move?	Fall outside of
SOCIAL		
Sense of Community: The feeling of belonging to an organization, to an area or to a group of like-minded people	• How can the product or service affect a person's sense of belonging to these groups?	Community impact process [S3-1]
Inclusivity & Diversity: Inclusion of marginalized and excluded communities	• How can the product or service impact how people perceive others? • What effects can it have on users with different backgrounds, age groups, education levels, or other differences?	Type of Consumers and their Demographics [S4.SBM-3_02-05]
Trust: Firm belief in the reliability, truth, or ability of someone or something	• How can the product or service change the trust between the users and the business that owns the system?	Feedback proccess and trust scores [S4-3_01-05]
Equity: The quality of being fair and impartial	• How can the system make people (users) be treated differently from each other? (think data analytics or decision support)	Fall outside of ESRS Scope
Participation & Communication: Imparting or interchanging thoughts, opinions or information by speech, writing, or signs	• How can the product or service change the way people create networks? participate in group work? support, criticize or argue with others?	User engagement processes [S4-5_01-03]

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Topic	Questions	Data Points
Workforce: Impact on the rights of own workforce and workers in the value chain	• How does the product or service affect the affect working conditions, wages, and job security for workers? • How has the product or service contributed to inclusivity and diversity through its own workforce and workforce in the value chain? • How does the product or service ensure equal pay and just behavior in the workforce and workforce in the value chain?	Wages Distribution of Employees [S1-10_01-04], Gender and Age Distribution of Workforce [S1-9_01-05], Collective-bargaining cover [S1-8_01-04]
Affected Communities: Impact on local and remote communities' rights	• Can local communities gain or lose access to housing, food, water or land because of the system's siting or data needs? • Is free, prior and informed consent obtained where indigenous territories or cultural heritage are involved? • How does the product support freedom of expression, assembly and human rights defenders of affected communities?	Actions taken to remediate the effects on affected communities [S3-4_01-09], MEthods available for affected communities to raise concerns [S3-3_10-13]
INDIVIDUAL		
Health: Physical and mental condition of individuals affected by product or service	• How can the product or service improve or worsen a user's physical, mental, and/or emotional health? (For example, can it make a person feel anything good or bad - e.g. (under)valued, (dis)respected, (in)dependent, or coerced?)	Actions taken to mitigate the negative impacts on health [S4-4_09-13]
Lifelong Learning: The use of learning opportunities throughout people's lives for continuous development	• How can the product or service affect people's competencies? • How does the system support or hinder professional development and skills training for workers?	Fall outisde of ESRS Scope

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Topic	Questions	Data Points
Privacy: State of being free from intrusion or disturbance in an individual's life	• How can the product or service expose (or help to hide) a person's identity, whereabouts or relations? • How can the product or service (directly or via decisions it makes) enable or prevent breaches of privacy for workers in the value chain?	Actions taken to enhance user privacy [S4-4_09-13]
Safety:Protection from danger, risk and injury	• How can the product or service expose (or protect) a person from physical harm? • How can it make a person feel more (or less) exposed to harm? What if used in an unintended way?	Actions taken to enhance user safety [S4-4_09-13]
Self Awareness & Free Will: Agency of an individual to make his/her decision on his/her own will	• How can the product or service empower (or prevent) a person from taking an action decision when necessary? Can those affected by the product or service understand its implications, express concerns or be represented by someone?	Fall outside of ESRS Scope
ECONOMICAL		
Value: Worth of principles or standards	• How can the product or service create or destroy monetary value? For whom? Are there any other related types of business value? For whom?	Fall Outside of ESRS Scope
CRM: Companyś policies to interact with current and potential customer to improve business relationships.	• How can the product or service affect the relationship between the business and its customers? • How can it enable co-creation or co-destruction of value? • How can it impact the financial situation of their customers and others?	Feedback process and trust scores [S4-3_01-05]

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Topic	Questions	Data Points
Supply Chain: Whole system of organization including resources, people and activities to support the move of a product from supplier to customer	• How can the product or service affect the supply chain of the business who owns it? • How can these changes in supply chain impact the financial situation? • How can it impact the financial situation of their customers and others? • How does the product influence payment terms, compliance audits or grievance mechanisms in the supply chain?	Payment terms with Suppliers [G1-6_01-05]
Governance: Process of interaction and decision making among the stakeholders involved in the whole system	• How can the product or service affect how and by whom such decisions are made? • How can the product or service affect the communication channels by which the relationships take place? • How can these changes impact the financial situation of the business and partners? • Does the the product or its data is used in lobbying or political activity? Is this transparent and responsible? • Are secure, anonymous channels in place for workers or users to report ethical or sustainability concerns linked to this system? • How can the product or service enable or prevent child labour or forced labour through its design or decision-making capabilities? • Could the system be mis-used for bribe payments, kickbacks or fraud detection? What controls exist (training, monitoring, sanctions)?	General Policies in Corporate Culture [G1-1_01/02], Policies for Whistleblower protection [G1-1_06-08], Statistics about anti corruption and anti-bribery controls [G1-308_01-], Political influence and lobbying [G1-5]

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Topic	Questions	Data Points
Innovation: Newness and Modifications of an existing product or service	• Do (parts of) the product or service affect the investment on research and development? • How can changes in innovation and R&D impact the financial situation? • Can it also impact the financial situation of their customers and others?	Falls outside of ESRS Scope
TECHNICAL		
Maintainability: Degree to which an application can be understood, repaired and enhanced.	• How are the operating system and runtime environment expected to change and what does that require from maintainers of this system? • How can the correctness of the system be affected by other systems or affect the correctness of others?	Falls outside ESRS scope
Usability: Ability of the users to use the products in a way it is intended to be	• What kind of knowledge or physical properties are required to use the system and how can this affect different types of users? For example, is good eyesight and small, sensitive hands required to operate a system on a small handheld device?	Falls outside ESRS scope
Adaptability: Ability of a system to adapt itself according to changes in the environment and system itself	• How could someone want to use the system in another context? • What can make that easier/more difficult? What can make that easier/more difficult for the system to adapt itself to fit new usage scenarios?	Falls outside ESRS scope
Security: Protection of a system against internal or external attacks	• Which assets controlled by this system would be desirable to an attacker? E.g. financial information, people's whereabouts or preferences, etc. • What are the risks associated with these assets? What are other likely vulnerabilities of the system?	Partially covered by consumer privacy risks [S4-1]

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Topic	**Questions**	**Data Points**
Scalability: Ability of a system to handle the growth vertically and horizontally	• How can the system support changes in workload? • What can make that easier/more difficult?	Falls outside ESRS scope

7

Conceptual Methodology

The chapter presents a Methodology that adjusts the SusAF into a comprehensive ESRS-compliant double DMA through a three-phase approach. This methodology preserves SusAF's collaborative strengths while systematically addressing ESRS regulatory requirements.

Figure 7.1 shows the general overview of Methodology.

Detailed explaination of Every step mentioned in methodology is as follows.

7.1 Phase 1: Preparation

This is a Pre-SusAF Phase that develops a foundation for conducting an effective and comprehensive SusAF Workshop. This ensures that the methodology covers the full compliance with DMA requirements that are mentioned in ESRS.

7.1.1 Business Context Analysis

The main focus of this step is to establish a comprehensive understanding of the organization's business context, strategy, and value chain relationships as required by EFRAG IG-1 Paragraphs 68-69 and ESRS 1, AR 9(a). This critical step comprises three interconnected components:

1. **Strategic Context Development**

   This involves detailed analysis of the organization's current business strategy, financial statements, and investor communications. The analysis should cover the full scope of products and services offered by the organization, along with detailed mapping of geographical, legal, and regulatory frameworks that govern operations.

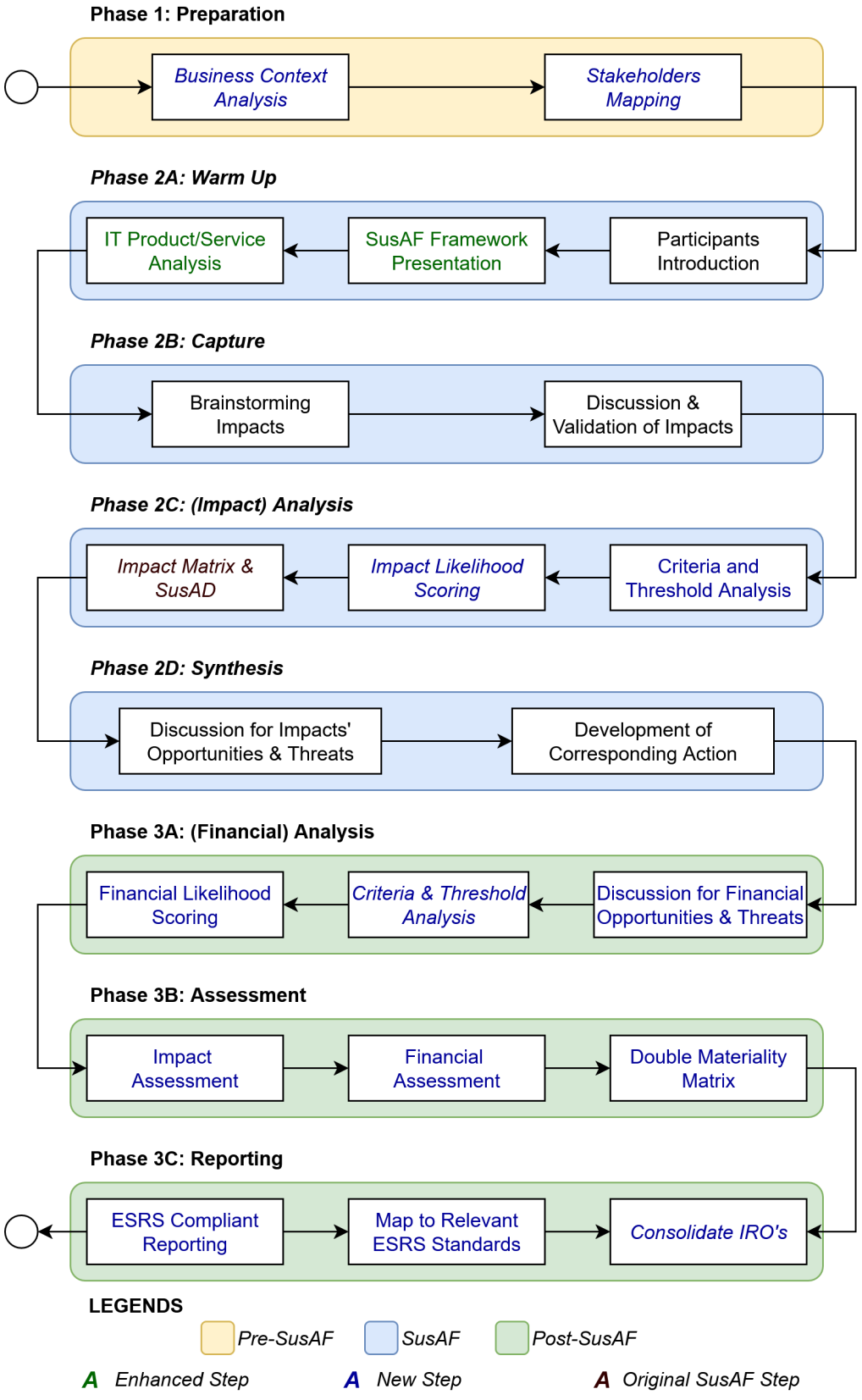

Figure 7.1: Conceptual Methodology

To have a systematic record for all things, a simple table can be created as shown in the template 7.1.

For table 7.1:

- Context represents the the domain of data recorded such *Legal Structure*, *Regulatory Compliance*, *Major Service*, *Financial Model* etc.
- Label represents the title of the Information. For example, if Context is made as "*Legal Structure*" then there can be several things that can be recorded in this domain, such as *Corporate Entity* and *Operational Base*, etc.
- Information represents the actual data for the label. Based on the example in above mentioned point, for "*Corporate entity*", it can be the details of where the organization is registered as HQ, etc.

Table 7.1: Template: Strategic Context Summary

Context	Label	Information

2. **Value Chain Mapping**

This focuses on the identification and analysis of upstream and downstream activities throughout the entire value chain. Critical business relationships are identified and assessed as potential focal points where sustainability-related IROs may originate.

This part can be done in the form of two tables, as shown in template 7.2 and 7.3.

For Table 7.2:

- Type represents the type of activities. There can be 3 main types of activities: *Upstream*, *Core*, *Downstream*.
- Activity represent the name of activity such *Platform Development*, *Customer Service* or *Identity Verification* etc.
- Description represents the details of the activity identified.

For table 7.3:

- Business Relationship represents the specific business relationship in the value chain that can have impacts in different dimensions. They would be considered as already known impacts/effects.

- Potential IRO represents the elicitation of actual IRO that can be linked with the business relationship identified in the corresponding row.

Table 7.2: Template: Value Chain Activities

Type	Activity	Description

Table 7.3: Template: Business Focal Points

Business Relationship	Potential IRO

3. **Documentation**

   The final component involves a comprehensive compilation and synthesis of all information identified and analyzed in the previous components. This documentation serves as the basis for presentations (related to Business and IT Product) and discussions in subsequent phases. It ensures that all stakeholders have access to consistent, accurate information about the organization's business context.

This step should be handled by the Sustainability Reporting Team in collaboration with the Business Strategy Analyst, to create a more comprehensive approach and give 'Business Context Dossier' as an Output, which will contain all the tables developed in this ste.p

7.1.2 Stakeholder Mapping

The main focus of this step is on the identification of relevant stakeholders. It aims to systematically identify, categorize, and map affected stakeholders onto each and every activity of the value chain according to ESRS 1, Paragraph 22, and EFRAG IG-1, Paragraph 71 requirements.

This step is executed through three sequential components.

1. **Stakeholder Groups Identification**

   The initial component involves brainstorming to identify all potential stakeholder groups associated with each activity identified in the previous step. This comprehen-

sive approach captures stakeholder groups who may be affected by or have influence over the organization's sustainability performance.

The results of this can be recorded in a template as shown by table 7.4

For table 7.4:

- Activity: Represent the name of activities. They should be from the activities identified in the previous step with template 7.2
- Stakeholder Groups represent the stakeholder groups that are associated with the corresponding activity, such as *Software Engineers*, *Product Manager*, and *DevOps Engineers* are associated with the activity of "*Platform development*"

Table 7.4: Template: Stakeholder Groups

Activity	**Stakeholder Groups**

2. **Engagement Protocol Documentation**

   This component gathers robust protocols that have been employed throughout the previous year to gather the relevant data so that appropriate and accurate data can be used to analyze the materiality. These protocols align with CSRD due diligence requirements and provide a framework for ongoing stakeholder validation.

   The results of this can be recorded in a template as shown by table 7.5

   For table 7.5

   - Group The name of the stakeholder group. They should be from the groups identified in the previous component of this step with template 7.4
   - Engagement Methods represent the engagement mechanisms that are applied throughout the previous year in order to interact with them and get the information or insights about their experience with different aspects of business related to sustainability. For example, *surveys*, *interviews* or *ratings* etc.
   - Frequency represents how often these engagements happened.
   - Key Issues represent the major issues identified through the engagements with corresponding stakeholder groups.

Table 7.5: Template: Stakeholder Engagement Protocol

Group	Engagement Methods	Frequency	Key Issue

3. **Stakeholder Organization** Following ESRS 1 requirements, stakeholders are systematically categorized into two distinct groups: "affected stakeholders" (those whose interests are affected by the organization's activities) and "users of sustainability statements" (those who rely on sustainability information for decision-making). This categorization ensures appropriate stakeholder engagement throughout the assessment process.

   The results of this can be recorded in a template as shown by table 7.6

   For table 7.6:

   - Group represents the name of the stakeholder group. They should be from the groups identified in the previous component of this step with template 7.4
   - Name represents the name of a specific stakeholder within the corresponding group. They should be the ones with whom interaction should occur for assessment and Workshop.
   - Description represents the information about the particular stakeholder, including their designation and other relevant details.
   - Expertise represents the domains in which the particular stakeholder has experience and skills.
   - Category represents the ESRS aligned classification, which can be from these two options: *Affected Stakeholders* and *Users of Sustainability Statements*
   - Type represent the type of stakeholder which can be *Internal* and *External*

Table 7.6: Template: Stakeholder Organization

Group	Name	Description	Expertise	Category	Type

7.2 Phase 2A: Warm Up

This phase is a SusAF phase, which initiates the collaborative SusAF workshop by engaging affected stakeholders in a structured introduction and context-setting process.

7.2.1 Participants Introduction

According to SusAF, this step is aimed at establishing rapport and understanding among workshop participants so that they can contribute more effectively in a harmonious way throughout the workshop. Key activities in this step include:

- Each participant introduces themselves, their organizational role, and their connection to the system under assessment
- Participants highlight specific knowledge areas and experiences they bring to the sustainability assessment
- Facilitators connect each participant's perspective to the comprehensive stakeholder mapping completed in the preparation phase

7.2.2 SusAF Framework Presentation

This step is aimed at providing participants with a comprehensive understanding of the SusAF methodology to enable productive engagement and meaningful contribution throughout the assessment process. This presentation may include the following things:

- Detailed explanation of the SusAF structure, including the Warm-Up, Capture, Analysis, and Synthesis phases
- Comprehensive overview of the Social, Individual, Environmental, Economic, and Technical dimensions that guide the assessment
- Brief overview of how SusAF Topics connects to ESRS Topical Standards.

7.2.3 Business Services Presentation

This step is aimed at providing participants with a comprehensive understanding of the system under assessment so that they can establish a shared foundation for impact identification and analysis. This presentation is based directly on the business context analysis conducted in Phase 1, Business Context Dossier prepared in Step 1 can also be shared among the participants.

7.3 Phase 2B: Capture

This is also a SusAF phase that focuses on the identification of impacts across all five SusAF dimensions using an enhanced question set with comprehensive ESRS completeness verification.

7.3.1 Brainstorming Impacts

This step is aimed at generating a comprehensive set of potential sustainability impacts through structured brainstorming using an enhanced question set that aligns with ESRS topical standards. The brainstorming process should follow a systematic approach described below:

1. Participants go through enhanced questions covering all five SusAF dimensions

2. Participants consider impacts related to products/services, working processes, and business model

3. Impacts are recorded using a color-coded system:

    - Positive Impacts on blue cards
    - Negative impacts on orange cards

This phase prioritizes quantity over quality. This mindset encourages comprehensive identification of potential effects across all sustainability dimensions.

An example followed for this process in a class activity is shown in Figure 7.2:

Figure 7.2: Example of SusAF Brainstorming Session

7.3.2 Discussion & Validation of Impacts

The main objective of this step is to facilitate collaborative discussion of identified impacts to eliminate duplicates, identify cross-dimensional relationships, and develop a comprehensive understanding of potential effects. This step may involve:

- Systematic review of impacts identified within each of the five SusAF dimensions
- Exploration of how effects in one dimension may influence or amplify effects in other dimensions
- Group discussion to determine which impacts need further investigation and analysis

7.4 Phase 2C: (Impact) Analysis

This is also a SusAF Phase, but it is specified as an Impact Analysis phase based on the nature SusAF Workshop. This phase fulfills ESRS requirements to assess the materiality of identified impacts. This also ensures a collaborative SusAF approach while incorporating rigorous regulatory requirements.

7.4.1 Criteria & Threshold Analysis

After finalization impacts, this step focuses on the creation of Criteria and thresholds to determine whether the particular impact is material or not. For Impacts, the main criteria according to EFRAG and ESRS are the following:

1. Scale (how grave the impact is),
2. Scope (how widespread it is), and
3. Irremediability (how reversible it is)
4. Likelihood (probability of occurrence of impact)

Their relevance to the types of impacts is shown in table 7.7

For each impact identified, its threshold will be developed with mutual discussion among Participants. Thresholds can be documented within the template shown in Table 7.8

7.4.2 Likelihood Scoring

For Actual Impact, the likelihood is supposed to be full 5, but for potential effects, it needs to be surveyed. So the most inclusive way is to get the score from each stakeholder and then aggregate their scores to find out the average for each impact identified

Impact Type	Assessment Criteria
Actual Negative Impact	Scale, Scope, Irremediably
Actual Positive Impact	Scale, Scope
Potential Negative Impact	Scale, Scope, Irremediably, Likelihood
Actual Positive Impact	Scale, Scope, Likelihood

Table 7.7: ESRS Criteria for Impact Materiality

Table 7.8: Template: Impact Threshold Record

Score	Scale	Scope	Irremediably
5 (Very High)			
4 (High)			
3 (Medium)			
2 (Low)			
1 (Very Low)			

7.4.3 Impact Matrix & SusAD

This step focuses on the visualization of Impacts on the basis of Analysis. There would be 2 types of Visualizations.

1. **Impact Matrix**: This Visualization will be drawn in a way that impacts identified in previous steps would be placed on a graph where the x-axis shows the Impact and the y-axis shows Likelihood. Here, the values would be based on the preliminary assumptions because the actual ESRS criteria would be applied later. Example of Impact Matrix built in SusAF workshop is in Figure 7.3

2. **SusAD**: This Visualization is the key output of SusAF as it is based on the analysis of the chain of effects between different Impacts. It gives out clear Idea of how one impact is propagating to others and so on. It is developed on a pentagon-based visualization with 3 layers. Each one corresponds to a different Order of Effect. An example of SusAD developed is shown in Figure 7.4.

7.5 Phase 2D: Synthesis

This is also a SusAF phase that transforms impact analysis results into actionable insights through the identification of opportunities and threats and the development of corresponding strategic responses

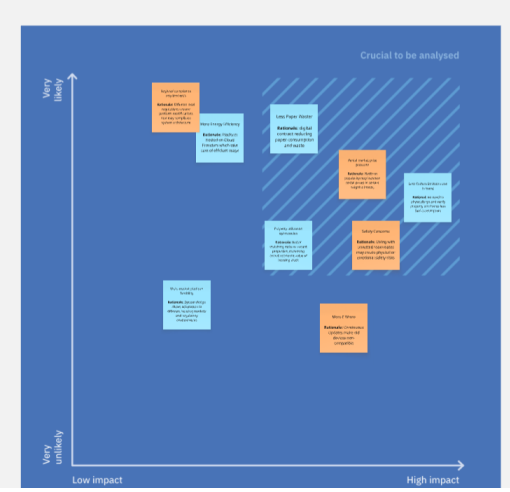

Figure 7.3: Example of Impact Matrix in SusAF

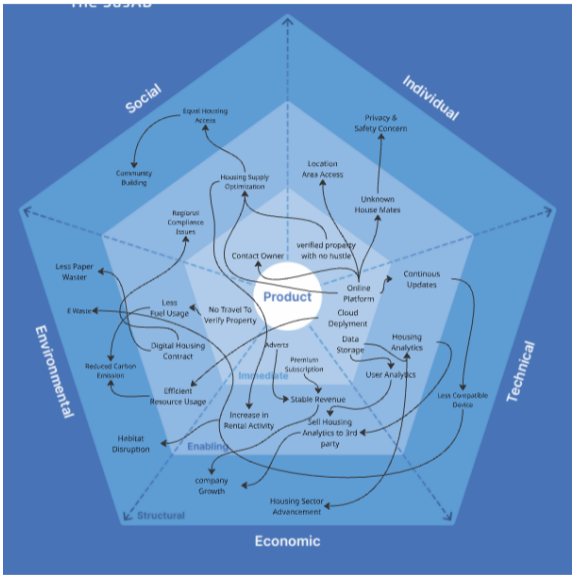

Figure 7.4: Example of SusAD in SusAF

7.5.1 Discussion for Impacts' Opportunities & Threats

This step is aimed at identifying strategic opportunities and threats based on material impacts identified in the previous phase. This provides a foundation for strategic response development. Through collaborative discussion, participants:

- Identify positive impacts as opportunities that can be enhanced or amplified to create additional value
- Recognize negative impacts as threats that require mitigation or management attention
- Connect identified opportunities and threats to the broader business strategy and stakeholder concerns

7.5.2 Developing Corresponding Actions

This step aimed to develop comprehensive action plans to address identified opportunities and threats, creating a bridge between assessment results and operational implementation.

7.6 Phase 3A: (Financial) Analysis

This is a post-SusAF phase that engages "Users of Sustainability Statements" to assess the financial materiality of impacts identified in previous phases. This completes the overall analysis required for DMA.

7.6.1 Discussion for Financial Opportunities & Risks

This step is aimed at engaging financial stakeholders in the identification and assessment of financial risks and opportunities related to impacts identified in previous phases. This step can be done in three sequential components.

1. Facilitator presents the list of positive and negative impacts from the Core SusAF workshop to the financial stakeholders.
2. For each impact, the group discusses potential financial consequences.
3. Document each identified financial risk and opportunity, linking it directly back to the specific impact from the workshop.

This systematic way creates a clear audit trail from stakeholder impact to financial consequences.

7.6.2 Criteria & Threshold Analysis

This step focuses on the creation of Criteria and thresholds to determine whether the particular financial effect is material or not. The main criteria for financial risks and opportunities, according to ESRS and EFRAG, are the following:

1. Magnitude (How big is the impact for the organization)
2. Likelihood (Probability of occurrence)
3. Time Horizon (How long can the effect affect the organization)

For each financial effect, a clear qualitative/quantitative (depending on the Effect) threshold will be developed with mutual discussion among participants. Thresholds can be documented in the template shown in table 7.9

Table 7.9: Template: Financial Threshold Record

Score	Magnitude	Time Horizon
5 (Very High)		
4 (High)		
3 (Medium)		
2 (Low)		
1 (Very Low)		

7.6.3 Likelihood Scoring

Similarly to Likelihood scoring in Phase 2C, for Actual effect, the likelihood is supposed to be full 5, but for potential effects, it needs to be surveyed. So the most inclusive way is to get the score from each stakeholder and then aggregate their scores to find out the average for each effect identified.

7.7 Phase 3B: Assessment

This is also a post-SusAF phase that involves systematically applying the pre-defined thresholds from both the Impact Analysis (Phase 2C) and the Financial Analysis (Phase 3A) to make a final, evidence-based determination of which sustainability matters are material or not.

7.7.1 Impact Assessment

This step is aimed at systematically applying the impact materiality thresholds (which were co-created with affected stakeholders in Phase 2C) to every impact identified in the workshop to assess whether the impact is material from an impact perspective or not. This step can also be done in sequential components:

1. Compare the thresholds with the actual data points corresponding to the impact on to link score in each criteria of impact
2. Apply the the formulas in table 7.10 to calculate the impact materiality score.

Table 7.10: Impact Materiality Formulas

Impact Type	Formula
Actual Positive Impact	$\frac{\text{scale} + \text{scope}}{2}$
Potential Positive Impact	$\frac{(\text{scale} + \text{scope} + \text{likelihood})}{3}$
Actual Negative Impact	$\frac{\text{scale} + \text{scope} + \text{irremediably}}{3}$
Potential Positive Impact	$\frac{(\text{scale} + \text{scope} + \text{irremediably} + \text{likelihood})}{4}$

3. Assign the final status (Material, not Material) to impacts based on the impact materiality score
4. Record the final status and the supporting calculation for the audit trail. Where data for KPIs is missing, document the limitation.

7.7.2 Financial Assessment

This step is aimed at systematically applying the financial materiality thresholds (which were co-created with Users of Sustainability Statement in Phase 3A) to every financial effect identified in the workshop to assess whether the effect is material from a financial perspective or not. This step can also be done in sequential components:

1. Compare the thresholds with the actual data points corresponding to the financial effect to link score in each criteria of impact
2. Apply the following formula to calculate the financial materiality score. Financial Materiality Score $= \frac{(\text{magnitude} + \text{TimeHorizon} + \text{likelihood})}{3}$

3. Assign the final status (Material, not Material) to impacts based on the financial materiality score

4. Record the final status and the supporting calculation for the audit trail. Where data for KPIs is missing, document the limitation.

7.7.3 Double Materiality Matrix

This step is aimed at visualizing the results of the two separate assessments and determining the final list of material sustainability matters for reporting.

This visualization would be in the form of a graph as shown in figure 7.5, with two axes where Impact Materiality Score is on the X-axis and Financial Materiality Score is on the Y-axis. All impacts would be plotted on this graph concerning their scores. Impacts that are in the top right corner of the Matrix are considered material from both perspectives.

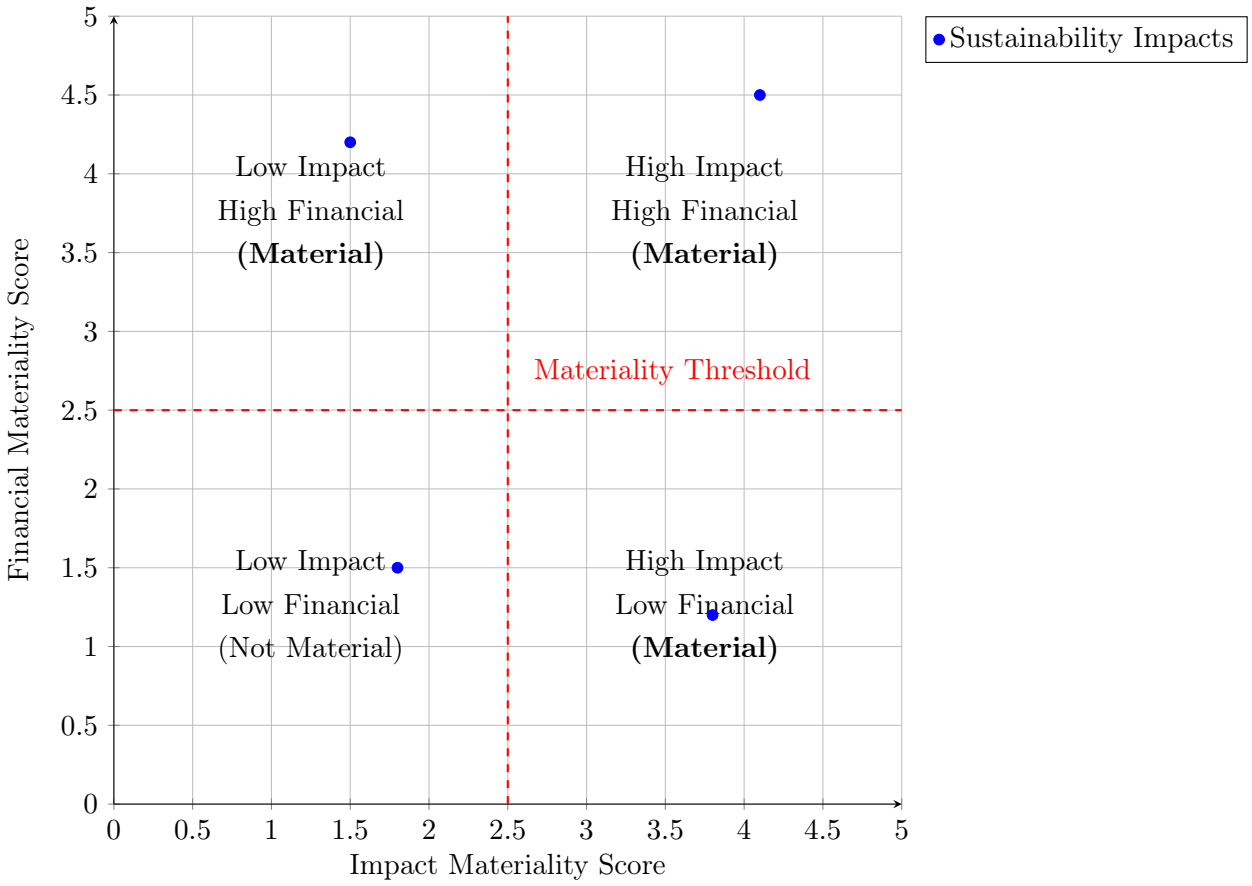

Figure 7.5: Example of a Double Materiality Matrix

7.8 Phase 3C: Reporting

This is also the post-SusAF phase that synthesizes all assessment activities and data into comprehensive, ESRS-compliant reporting to support both regulatory compliance and strategic decision-making.

7.8.1 Consolidate IRO's

This step aimed to systematically consolidate all IROs identified throughout the assessment process, with a clear distinction between impact materiality and financial materiality. This step can also be broken down into sequential components:

1. Gather all scored impacts and financial Risks, and opportunities, including their final materiality status
2. For each IRO, reference supporting data from the workshop (e.g., SusAD node IDs, stakeholder scores) and any Data Point values used in calculations.
3. f KPI data was unavailable for certain IROs, document the limitation and any assumptions made,

7.8.2 Mapping to ESRS Standards

This step aimed to systematically link all IROs to the relevant ESRS topical standards based on the mapping table **??**

7.8.3 ESRS Compliant Reporting

This step aimed to produce the final sustainability statement that communicates the DMA results, meets all ESRS disclosure requirements, and integrates sustainability into business strategy. The report should include

- Materiality process description (IRO-1), with methodology, stakeholder involvement, and SusAF details.
- List of material topics, related IROs, and business model links
- Rationale for inclusion/exclusion of disclosure

The process ensures that sustainability is embedded not only in reporting, but also in core decision-making, risk management, innovation, and long-term value creation.

Outcome of this DMA and its implications are summarized in Table 7.11

Materiality Category	Description	Action Required
High Impact + High Financial	Strategic priority for immediate action	Full ESRS disclosure + Strategic integration
High Impact + Low Financial	Important for stakeholders and compliance	Optional ESRS disclosure + Stakeholder management
Low Impact + High Financial	Financial risk management focus	Financial risk management + Investor communication
Low Impact + Low Financial	Monitor and explain non-materiality	Brief rationale in IRO-2 disclosure

Table 7.11: DMA Outcome

8

Evaluation

This chapter provides the details of evaluations done for the artifacts of this research, which include the mappings, enhanced question set, and the conceptual methodology. The goal of these evaluations is to assess the validity and practical value of the artifacts in software companies. There were three evaluations done throughout the research. The details of these evaluations are described in further detail below.

8.1 Focus Group with Sustainability Experts

The main purpose of this focus group was to validate the developed SusAF-ESRS mappings and assess the proposed methodology for DMA in software companies. The objective was to gather expert feedback on the accuracy, completeness, and practical applicability of the artifacts developed in this research.

8.1.1 Methodology

The focus group was conducted with 5 sustainability experts recruited based on their availability during the SE4GD summer school. The experts possessed diverse backgrounds in sustainability reporting, software engineering, and CSRD implementation. Anonymous introductions to the participants are in the table 8.1

The session was held in a round sitting at a table as shown in figure 8.1 The session lasted one hour. It followed a structured format where slides were presented to guide discussion topics. Handouts containing the mappings and methodology design were also distributed for detailed review.

Participant 1	He is a Software engineering student from SE4GD. He also did his Master thesis in DMA and ESRS. He has limited direct experience with sustainability reporting but understands the general principles of SusAF and DMA.
Participant 2	She is a professor of software engineering and sustainability at a University in the Netherlands. She knows SusAF relatively well but does not know much about DMA.
Participant 3	He is a professor of software engineering at a University in Germany. He knew about SusAF and had seen SusAF workshops. He knew a little about DMA, particularly, but has discussed with companies a lot about sustainability reporting.
Participant 4	He is a professor of software engineering and Sustainability at a University in Finland. He is a part of a group that created SusAF. He has seen companies using DMA through their dedicated platforms.
Participant 5	He is a researcher of software engineering and Sustainability at a University in Finland. He is also a part of a group that treated SusAF. His research experiences lie in Requirements Engineering and measurement for sustainability metrics for software.

Table 8.1: Introductions to Participants of Focus Group

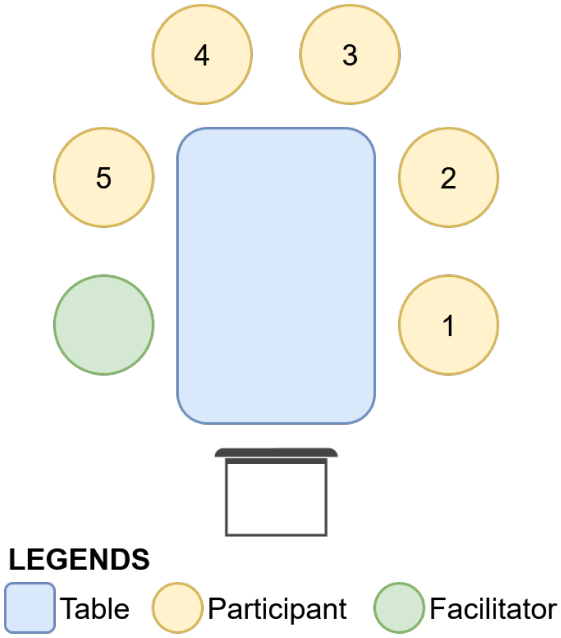

Figure 8.1: Focus Group Sitting structure

8.1.2 Key Findings

The experts identified several concerns regarding the mapping. They found the guidelines mapping very unclear and vague. They were confused, based on the initial structure of the table, which is shown in table 8.2, about whether the mappings are from SusAF to ESRS or ESRS to SusAF. They also noted that different terms were used for similar concepts across the mappings and methodology, making it difficult to trace connections between components. One expert emphasized:

> *"Same terms, same meaning, different terms, different meanings"*

The experts also questioned the practical value of topic mapping, particularly the addition of workplace dimensions to SusAF (which was the initial draft). They noted that "*Workplace*" cannot be a separate dimension. Instead, they suggested incorporating its related questions into *Social* and *Individual* dimensions.

Step	SusAF Mention	ESRS Mention	Integration Potential

Table 8.2: Initial structure of Guidelines Mapping Table

In the initial draft of the methodology, some components, external to ESRS and SusAF, were also incorporated to enhance the process, such as Stakeholder Assessment using HRIA Map (65). This approach received mixed feedback. They acknowledged the value of this assessment, but they also emphasized that the influence and impact assessment process is not explicitly defined in ESRS, making it an additional complexity to the DMA process, which won't be helpful for companies as they are more concerned about simplifying the process rather than complicating it.

8.2 Interviews with RE Researchers

The main purpose of these interviews was to evaluate the topic mapping and enhanced questions from the perspective of Software Engineering-based researchers. Evaluation was focused on the following aspects:

- Accuracy of mappings
- Organization, Quality, and Clarity of Questions
- Soundness of idea of Enhancing SusAF Questions with ESRS Standards

8.2.1 Methodology

A total of two interviews were conducted with RE researchers from diverse organizational backgrounds. Potential participants were identified through the authors of research papers related to SusAF and Requirements Engineering. Invitations for collaboration were sent to approximately 7, and 2 practitioners agreed to participate. Introductions of the interview participants are presented in Table 8.3. The interviews were conducted online via Microsoft Teams. A Document consisting of Topical Mapping and an enhanced set of SusAF Questions was sent one day before the meeting so that they could deeply review the current state of the work and then discuss their insights. At the start of each interview, consent was obtained for participation and for recording the session for documentation purposes.

8.2.2 Key Findings

The interviews with RE researchers provided valuable insights into the technical accuracy and academic soundness of the enhanced SusAF framework. The findings reveal both strengths in the mapping approach and areas requiring refinement in question placement and categorization. The details of findings in these 3 specified aspects are as follows.

Interviewee 1	He is a researcher at one of the famous research Universities in Germany. He works on business process management and sustainability. His background includes experience with life cycle assessment and teaching requirements engineering and software engineering at the university. He knows about SusAF and worked in collaboration with the SusAF Team. He is not deeply familiar with ESRS standards, but his knowledge connects sustainability topics to lifecycle assessment and impact categories.
Interviewee 2	She is a researcher with extensive experience in requirements engineering and sustainability frameworks. She completed her PhD in Brazil and has been working in Germany since 2006. She has been working as a researcher in the requirements engineering field and the variation management field for many years. She has detailed knowledge of SusAF. She also examined the Digital Market Act and Digital Sales Act to create a different set of questions.

Table 8.3: Introductions for RE Researchers

8.2.2.1 Accuracy of Topical Mapping

Both experts found the general mapping approach to be reasonable and "*logical*" to move forward.

Interviewee 2 provided more critical feedback on certain mappings. She found the climate change mapping of waste and pollution to be "*very weak*" and considered it "*too far extrapolation*". She could not find a clear reference to climate change in the waste and pollution text. Based on her feedback, I added the specific keyword in the rationale of that mapping to make it clearer.

8.2.2.2 Organization, Quality, and Clarity of Questions

The evaluation of the enhanced set of questions received mixed feedback. Generally, both of the experts find the questions clear and easy to follow to guide the conversations and brainstorming process. But they also highlighted some of the inconsistencies and concerns about the organization of questions.

One of the main issues that was brought up in both of these interviews was the placement of questions for Workforce. One of them finds the questions about the workforce good but

wrongly placed. He insisted on having a separate topic for 'Workforce' instead of embedding it in the already available topics. The other one also was of the view that it should have a separate topic, but the difference of opinion came when asked about the placement of this topic. One of them agreed to just have it in the Social Dimension, but the other one wanted to have it in the Economic dimension. She argued that the Workforce is more related to the Business Aspect of the product, which is covered under the Economic dimension.

One of them also initially struggled with the idea of having 'Climate Change' as a separate topic. He argued that it might overlap with the Waste & Pollution topic, but after discussing the intent and wording of the question, he agreed it had a separate topic. He also questioned the placement of questions related to Resource Outflow in the Materials & Resources dimension and instead suggested having a new category for it.

On the other hand, an expert noted that some of the topics had more than 6 questions to which she referred to as "*too many*". She suggested that some of the related concepts can be joined into one question, such as Hazardous Substances and SVHCs (I had separate questions for them). I also initially put the question for Animal Welfare in the Governance topic, but she argued it's more related to the Biodiversity aspect. However, the other one was confused about its placement as he thought it was either Biodiversity or Governance.

8.2.2.3 Idea of Enhancing SusAF Questions

Both experts expressed cautious support for the enhancement idea while emphasizing implementation challenges. One of them stated "*I don't disagree*" and "*probably makes sense*" when asked about enhancing SusAF with ESRS questions. However, he identified that the approach works best for "*product-based companies*" with single products, while multi-product companies would need to conduct SusAF for each product and then "*aggregate them, combine them in the end.*"

The other one found the enhancement idea "*good*" for creating synergies between SusAF and DMA processes. She understood the practical value of avoiding duplication of effort where companies currently have to conduct SusAF and DMA as separate processes. However, she emphasized that successful implementation requires that the enhancement "*should be done in a way that does not add complexity to SusAF and the workshop flow.*"

8.3 Interviews with Industry Practitioners

The main purpose of these interviews was to evaluate the refined methodology from the perspective of industry practitioners. Evaluations were focused on the following aspects:

- Compliance of methodology with DMA Requirements
- Usefulness of SusAF for DMA
- Strengths and Weaknesses of Methodology
- Feasibility for adoption of proposed methodology in a real-world corporate setting

8.3.1 Methodology

A total of three interviews were conducted with industry practitioners from diverse organizational backgrounds. Potential participants were identified through LinkedIn, and their profiles were reviewed for relevance to DMA and ESRS. Invitations for collaboration were sent to approximately 10, and 3 practitioners agreed to participate. Introductions of the interview participants are presented in Table 8.4. The interviews were conducted online via Microsoft Teams. The SusAF workbook link was also sent when the meeting time was finalized, so that they have a clear idea of SusAF, also (if not known). At the start of each interview, consent was obtained for participation and for recording the session for documentation purposes.

The interviews followed a semi-structured format where participants were presented with the complete methodology through screen share. After the screen share, general questions were asked related to the focus of evaluation as defined above. Each session lasted approximately one hour.

8.3.2 Key Findings

The industry practitioners evaluated the methodology across four key aspects, as defined above. The findings demonstrate strong alignment with regulatory requirements while identifying specific implementation challenges that require attention for successful corporate deployment. The details of the findings are as follows.

8.3.2.1 Compliance with DMA Requirements

Almost all of the 3 practitioners identified an issue with the current regulations. They all emphasized that guidelines in ESRS are very unclear and "*interpretive*" in their implementation approach. One participant commented on EFRAG:

> "*EFRAG are very smart in the sense that they give you implementation guidance, but they don't tell you exactly what they want you to do*"

Interviewee 1	He is a recent Master's graduate in Environmental Governance with three years of experience in sustainability consulting. He worked with one of the Big 4 Accounting Firms to develop double materiality tools for CSRD and ESRS compliance. He currently works with a specialized environmental consultancy. He has conducted three DMAs since joining his current company. His experience spans small and medium companies in Germany and the US. He knew about SusAF before, but only a brief idea, and hadn't participated in or seen any SusAF workshop.
Interviewee 2	He is an ESG Policies and Control Analyst at a company listed in Fortune 500 companies. His company has 86,000 employees and operates in 135 countries. He has 4.5 years of experience in sustainability reporting and has conducted 2 DMAs. His background includes a diploma in business sustainability and an ongoing master's in sustainability management. A his current company, he is responsible for compliance with CSRD, SEC filings, California Climate Disclosures, and EU taxonomy requirements. He did not know about SusAF before, but got a good idea of it after going through the SusAF Workbook.
Interviewee 3	He is an ESG reporting director at an offshore construction company in France. He has more than two years of experience in CSRD Reporting and has conducted two DMAs during his tenure. His experience includes working with various ESG ratings agencies, as well as dealing with regulators and external auditors. He also has a significant background in financial reporting, which provides him with a broader perspective on reporting frameworks. He did not know about SusAF before and tried to go through the SusAF Workbook before the interview, but did not understand it very well.

Table 8.4: Introductions for Industry practitioners

Based on these insights about regulatory guidance, all of them agreed that the proposed methodology complies with the ESRS requirements for DMA. One specified this in a way that is compliant with the requirements in "*generic terms*" as he would require more time to assess fully. It was also noted that ESRS gives companies significant freedom in how they conduct their scoring and assessment processes, which enables this methodology to withstand the "*audit scrutiny*".

One practitioner highlighted that the numerical scoring approach is not a strict requirement except for criteria and thresholds. He stated that "*if you're tracking all the documents and you're making sure you have those thresholds and you have set them in a way that makes sense*", the methodology would be compliant with ESRS implementation guidance for DMA.

8.3.2.2 Usefulness of SusAF in DMA

One practitioner found the SusAF framework "*really interesting*" because it approaches double materiality from an impact materiality background, which he describes as "*refreshing*". He explained that most companies typically think from a financial impact or risk assessment perspective first. SusAF guides them to consider impact materiality instead. He also acknowledged that SusAF is not fully compliant with DMA requirements and agreed to adapt it for DMA purposes. Overall, practitioners recognized clear benefits of SusAF for organizing workshops and providing a "*guiding narrative*" that "*makes sense*" for identification of impacts in DMA processes.

However, they had mixed reviews about SusAD itself. It was noted that "*SusAD gives you a clear idea on how the things are changing in the dynamic landscape*" that may help develop better actions for impacts in perspective of DMA but it can become "*complex very difficult to read and very difficult to track very quickly*" when a lot of impacts are recorded. This "*may not be suitable*" for end reports or auditor review.

8.3.2.3 Strengths and Concerns of Methodology

They highlighted some of the strengths of the methodology. One of them stated that bringing people together in the same room creates "*more consistent scale to issues than individual reporting*". It was also acknowledged that SusAF provides "*directed thinking methodology*" that helps with "*better identification of impacts, because generally the impacts are very vague, which you cannot think directly*" Almost all of them considered the progression of methodology as logical enough to lead to correct answers. One of them

also stated that, for tech companies that tend to be "*more agile, deal with complex ideas quicker, and more collaborative*", an impact-focused entry into double materiality is positive. Feedback also included that the methodology

> "*brings together stakeholders and condenses stakeholder engagement to a specific point rather than a very drawn out disjointed process*"

They also highlighted some concerns regarding the methodology. Most of these were related to the part of threshold setting. One of them points out that "*when you're talking about opinions, the assessment becomes very, very blurry*" and emphasizes that thresholds represent "*a big challenge regardless of SusAF and non SusAF* ". Due to this challenge, she suggested that it would be better if the threshold settings could be passed on to someone expert in that particular field. It can be a researcher who can consult scientific papers and online relevant databases, or an experienced professional. There was also another suggestion that there can be two separate sessions: one for impact identification as SusAF is, and another one can be for criteria analysis. And in between these two sessions, there can be a threshold-setting activity which should be performed only by the people relevant to the particular field.

Some of the concerns were related to Stakeholder Participation. It was emphasized that "*Stakeholder list is going to explode"* especially in big companies. This makes it difficult to conduct workshops where everyone is represented. A methodology must be developed to select only the most important stakeholders because this remains a current struggle for companies in DMA processes.

One practitioner identified one issue with the usage of SusAF for DMA as the lack of guidance to think from the perspective of financial risks and opportunities. His idea was that, just like similar questions for impact impact-based perspective, there can be questions from a financial perspective to make it more usable and compliant for DMA.

8.3.2.4 Feasibility for adoption of Methodology

They believe that the methodology "*can be done*" and is implementable. One of them views it as "*one approach that they could agree on*" among the many different ways to conduct DMAs.He sees particular value for "*software and those kinds of companies*" because "*the framework itself is already targeted to that*". He believes this targeted approach makes the methodology more relevant for its intended audience. One of them also stated that the methodology is "*marginally better than the current questionnaire approach*" with though "*not quite perfect*". But it's completely possible that big companies can try to adopt this

methodology if "*done in a way that covers every single topic in a way that is fully covered and with some enhancements*"

One of the participants distinguished between two potential user groups. He emphasized that consultants would find it easier to adopt because they "*fairly easy to adopt different frameworks and different methodologies because they've been doing it for a long time*". For companies, adoption would be "*a bit more difficult*".He suggested that for successful adoption, the methodology should be simplified in the form of digital tool. He stated:

> "*If you make it a very simple tool to use, which is goes and just asks simple questions and then kind of you click... the button. And it gives you your IROś. Yes, that would be super useful*"

9

Discussion

This research shows that SusAF can be adapted for DMA requirements under ESRS through strategic additions of Pre-SusAF and Post-SusAF phases. These enhancements directly address the gaps identified between SusAF's current capabilities and DMA regulations as shown in table 5.4

One of the major strengths of SusAF identified in this study is its comprehensive set of questions that can guide the thinking process to identify IROs but it also had some gaps. Specifically in the aspects of workforce and Governance. The placement of workforce-related questions received mixed responses from experts. This highlights different interpretations of SusAF dimensions and questions. But the *technical* dimension presents an interesting case. Although it is not covered by ESRS standards, the evaluation suggests it could serve as a sector-specific addition for software companies. However, this needs further research and more in-depth analysis . Concerning guidelines for DMA, SusAF methodology highlighted significant gaps as it only focused on the impact identification process, which is only 1 aspect of DMA. Critical elements like stakeholder mapping, financial analysis, and threshold development were absent from the framework. The developed methodology addresses these limitations through systematic extensions while preserving SusAF's collaborative strengths.

Practitioners provided mixed opinions on the proposed methodology. They confirmed its compliance with DMA requirements, but also highlighted some areas that need refinement. The main concerns that emerged for methodology involved:

- First, the methodology adds substantial preparation and post-processing phases that may burden smaller organizations.

- Second, systematic stakeholder selection approaches are needed, particularly for large companies where the stakeholder list can become very extensive.
- Third, opinion-based threshold assessments become very vague; instead, it's better to have expert consultation for criteria development.

Another theme also emerged during evaluations. SusAf is more product-oriented, while DMA focuses on the whole company. This creates confusion and implementation challenges that require careful consideration.

The SusAD visualization also received mixed feedback. The practitioners found it helpful for understanding impact relationships and developing targeted actions, but they also expressed concerns about complexity when dealing with a higher number of impacts. Industry participants emphasized the need for digital tools and simplified processes to enhance practical adoption.

Overall, this study also fits in the context of the current research landscape for DMA and SusAF. Unlike previous SusAF extensions such as GreenSusAF and BE-SusAF, this research specifically targets regulatory compliance rather than general business integration. The work responds to calls by Delgado-Ceballos et al. for systematic approaches that integrate DMA with existing frameworks to serve multiple stakeholder needs. Finally, it also addresses the methodological gaps as highlighted in section 3.1, by providing a structured approach to comprehensive impact identification in the DMA process.

9.1 Scientific and Practical Contributions

This research makes clear contributions to both academic knowledge and real-world practice in the field of sustainability reporting. It directly addresses the gap between regulatory standards and the SusAF framework. By identifying and bridging these gaps, this study creates a strong foundation for future research and development in the area of double materiality.

The key scientific contribution is the development of a practical, ready-to-use methodology that combines academic insights with the operational needs of industry. This method does not just serve as a technical solution but also operates as a bridge between scholarly frameworks like SusAF and formal corporate reporting mandates under regulations such as the CSRD. While many studies recognize the value of DMA and broader sustainability reporting, only a few have explored how to systematically integrate these principles with SusAF in a detailed and adaptable way.

9.2 Threats to Validity

The mappings and methodology design were performed by only one person. This creates potential bias in how ESRS requirements were interpreted and aligned with SusAF components. Personal views or misunderstandings may have shaped the mapping process. To reduce this threat, the mappings were validated through expert focus groups and interviews of RE Researchers. However, some bias may remain in the initial artifact development process.

Only three industry practitioners were interviewed to evaluate the methodology. This small sample limits the generalizability of findings about practical adoption and implementation challenges. The practitioners represented different company sizes and sectors, but broader industry perspectives are missing. Future research should include larger, more diverse practitioner groups to confirm the methodology's wider applicability across different organizational contexts and software industry segments.

Some interview participants had limited detailed knowledge of SusAF before the evaluation sessions. This created a risk that their feedback reflected surface-level understanding rather than deep comprehension of the framework's capabilities and limitations. Participants were provided with SusAF workbooks before interviews, but time constraints may have prevented a thorough review. This knowledge gap could affect the validity of their assessments about SusAF's suitability for DMA applications.

The methodology development relied on EFRAG implementation guidance rather than direct ESRS requirements for process mapping. Although EFRAG guidelines are based on ESRS standards, they represent interpretative guidance rather than authoritative regulatory text. This choice was made because EFRAG provides clearer sequential guidance for DMA processes. However, using a proxy document instead of primary regulatory sources may create potential misalignment with actual compliance requirements that companies must meet under CSRD.

9.3 Future Research Directions

Future research can build on this work by addressing the main limitations found in the methodology during evaluations. One important step is to test the method in a case study with a real company. This will help show how well the approach works outside of theory and highlight practical issues in day-to-day settings. Another area is the development of digital tools to make the process easier for companies. For example, simple algorithms

or basic AI suggestions could help companies select key stakeholders or set thresholds efficiently. These tools would be especially useful for smaller organizations that have fewer resources and contribute to making the method more widely usable. Further studies should also focus on the technical dimension in SusAF. There is potential for this part to become a sector-specific standard under ESRS, especially for software companies. To do this, researchers need to test the technical dimension in real-world cases and make sure it fits actual ESRS requirements. Finally, further work on the SusAD visualization is needed. Researchers can develop simpler ways to organize and present data when there are many impacts. This could include new types of diagrams or summaries that can help auditors and companies understand the information quickly and clearly.

10

Conclusion

This research successfully demonstrates that SusAF can be adapted to support DMA requirements for software companies through strategic methodological enhancements. The study developed mappings between SusAF and DMA to highlight the alignments and gaps. Based on findings from mappings, a comprehensive approach has been developed that preserves SusAFś collaborative strengths while addressing ESRS regulatory compliance needs. The enhanced set of questions includes 22 new questions that make the question set comply with the ESRS requirements. RE Researchers find the added questions clear and easy to follow. Industry practitioners also confirmed that the methodology meets DMA requirements under CSRD regulations, but need some refinements in the aspects of stakeholder mapping and threshold analysis. They also emphasized the need for digital tools and simplified implementation approaches to enhance practical adoption.

The research makes important scientific contributions by creating the first systematic adaptation of SusAF for regulatory compliance. This bridges academic sustainability frameworks with corporate reporting frameworks. The methodology enables software companies to conduct comprehensive impact identification while meeting ESRS disclosure requirements. This would potentially reduce the duplication of effort between sustainability assessment and regulatory reporting processes. Future research should focus on real-world case studies, the development of digital implementation tools, and further refinement of stakeholder selection processes. This work establishes a foundation for integrating participatory sustainability frameworks with formal regulatory requirements and supporting companies in their transition toward meaningful sustainability reporting and practice.

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Appendix