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Navigating the Complex ESG Accounting Landscape: Engineering a Method Selection Framework

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Abstract. Environmental, social, and governance accounting (ESGA) aids organizations in achieving their sustainability goals through continuous improvement. Suitable method selection is crucial to prevent rework, additional expenses, trivial outcomes, and reduced confidence in sustainability practices. The current ESGA method selection process lacks comprehensive consideration of alternatives and criteria, occasionally resulting in suboptimal choices. This work aims to achieve optimal ESGA by engineering a method selection framework. The research approach is based on the design cycle, where engineering decisions are informed by empirical evidence. The main findings are that the framework, which includes a decision model and a supporting information system, can reduce the chances of organizations selecting an unsuitable method, whilst sparing decision-making managers time and effort. Firstly, the reusable elements of the framework can help managers of any organization select a suitable method more efficiently since they do not have to produce these elements themselves. Secondly, the results demonstrate how selection frameworks and tools can aid organizations in navigating the complex ESG accounting landscape. Lastly, this study lowers the barrier for organizational impact management; in particular, for measuring and reporting ESG impact, which is a rigorous assessment of the organization's progress towards sustainable development goals.

Keywords: Organizational Sustainability, Environmental Social and Governance Accounting, Sustainability Reporting, Decision Model, Information Systems Engineering.

1 Introduction

Business Informatics plays a crucial role in realizing sustainability goals [1]. In this research, we demonstrate how business informatics can alleviate sustainability issues [2], by engineering and

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validating a method selection framework. As part of the framework we also build a decision model and operationalize it in a decision support system (DSS). The framework assists organizations in selecting a method for assessing the environmental, social, and governance (ESG) effects of business operations. Assessing ESG performance entails measuring and reporting on indicators such as the consumption of drinking water, duration of parental leave, and disclosure of lobbying activities. We refer to the process of assessing and reporting these effects as ESG accounting (ESGA) [3]. During the accounting, data are extracted from enterprise resource planning systems, documentation, and stakeholders. These data are collected in a tool. The ESGA domain abounds with ESGA methods, frameworks, and standards (for brevity, we refer to all these by methods) that define how to perform ESGA practices. Examples of such methods are the ISO 14001 standard [4], the GRI Standards [5], the United Nations Global Compact [6], and the B Impact Assessment [7] of the B Corp network. The existence of such a large number of methods in combination with the absence of a comprehensive overview of these methods, causes great complexity in navigating the ESG landscape.

Several countries have initiated mandatory sustainability disclosure regulations and the International Financial Reporting Standards (IFRS) Foundation is working on an international standard and mandate for sustainability reporting [8]. With ESGA gradually becoming an obligatory practice, all organizations will eventually have to select an ESGA method. We found that during this selection, managers in the organization typically do not consider all ESGA methods and sometimes select a method that is unsuitable for their organization. Choosing an ESGA method that fits the organization's characteristics and needs is critical since it forms the foundation for a journey toward becoming a more responsible entity. Selecting an unsuitable method can result in rework, resource waste, trivial results, or loss of confidence in sustainability practices [9]. Considering all decision-making criteria and alternatives (i.e., ESGA methods) currently requires a lot of manual work. Given the importance of selecting the right ESGA method, the potential relevance for all organizations, and the vast amount of data that should be considered in the selection process, we deduce that the ESGA method selection process can benefit from a structured approach, in the form of a method selection framework [10]. We engineer the framework by investigating the multi-criteria-decision-making (MCDM) method selection problems for the ESGA domain. As part of this investigation, we conceptualize and formalize the MCDM problem. Next, we engineer a decision model that operationalizes the method selection framework. Lastly, we engineer a DSS that implements the decision model. Therefore, the main goal of this research is: **To ensure well-informed ESGA method selection by engineering a selection framework that evaluates alternatives and returns a shortlist of methods that fit the requirements of managers to mitigate the threat of rework and ineffective ESGA.**

The contributions of our work include (i) a validated method selection framework, including the decision model for ESGA method selection that can be used by managers of any organization to improve their sustainability assessments and reporting, (ii) insights into an unconventional decision-making process, given that subjective aspects hold considerable weight in the ESGA method selection process, and (iii) our results are valuable to the business informatics community and beyond given that they show how the competencies of this community can help organizations improve their impact.

The structure of this article is the following. Section 2 discusses background information and related work. The research method is explained in Section 3. Section 4 presents the proposed framework for ESGA method selection and explains the results related to contribution (i) and (ii). We report on the validation case studies and reflect on contribution (iii) in Section 5. Section 6 discusses the results and Section 7 presents our conclusions.

2 Background

2.1 Diversity in Ethical, Social, and Environmental Accounting Methods

Though the IFRS is working on a standard for sustainability disclosures, some level of diversity in ESGA methods remains preferable considering the heterogeneity of organizations [11]. Moreover, each method has its focuses and strengths. For instance, some methods are tailored to a specific industry sector, such as STARS [12], which is developed to assess the sustainability performance of educational institutions. Some methods are developed to assess the performance of organizations in a specific region or country, e.g., the Social Balance method [13], which is tailored to the context of the Spanish Social and Solidarity Economy. Moreover, the degree of freedom with which the methods define the disclosure topics and indicators can differ (i.e., whether they leave room for interpretation or customization). Another difference is that some methods grant certifications or labels when the application reveals a high ESE performance (e.g., B Impact Assessment), while others do not (e.g., GRI Standards). Lastly, ESGA methods can focus on either environmental topics, social topics, topics related to business ethics and governance, or any combination of the three. All these differences are motivations for organizations to select more than one ESGA method, and at the same time increase the risk of choosing an unsuitable method.

2.2 Factors Influencing Ethical, Social, and Environmental Accounting

Individual commitment, idealism; competitive advantage; manipulation of public perception; forestalling of legislation; keeping up with competitors; inducing change; public image; pressure from ethical investors; communication of risk management; and legitimation are motivations for organizations to assess and report on their ESE performance [14]. Factors that influence which ESGA method is eventually selected by organizations include the commitment and vision of individual leaders within the organizations [15] and costs. Progressive leaders call for reprioritizing ethical, social, environmental, and economic performance. With their change of stance, they can take the ESE performance of their organizations to a new level. To reach economic goals, costs play an essential role. Organizations do not only consider the initial costs of selecting and adopting the ESGA method but also the later costs of maintaining certification. Mosgaard and Kristensen [16] found that companies discontinued their ISO14001 certification because the resources needed to maintain the certification were too high compared to the experienced benefits. In our earlier work, we have identified 79 factors that influence which ESGA method is selected [9].

Various attempts have been made to compare ESGA methods, such as the model created by [17] to analyze and compare ESGA methods based on the method's context, content, and process. However, none of these attempts have been as rigorous as the solution we propose. We deem such a rigorous approach necessary because there are many factors that organizations should take into account when selecting an ESGA method. For instance, to avoid accusations of greenwashing it is best if ESGA methods prescribe a set of ESG disclosure topics (e.g., gender equity, energy consumption, and greenhouse gas emission) since selective disclosure presents a potential bias [18].

2.3 Complexity in the ESGA Landscape

The ESGA landscape is inherently complex due to the multitude of available methods, and their sheer diversity. Organizations aiming to align their practices with sustainability goals find themselves grappling with an intricate web of considerations. Navigating this complexity requires organizations to understand the structure, content, and political impact of individual methods.

Utilizing decision models is a common approach to managing complexity in a domain where multiple attributes are to be considered [19]. The integration of decision support systems can be beneficial in enhancing ESG performance [20]. Our DSS has a specific focus on selecting methods that serve as the foundation for measuring performance before initiating improvement efforts.

Choosing an appropriate ESGA method is essential in ensuring that ESG reports do not merely spotlight areas where the company excels but also confront and address ethical trade-offs that might otherwise be overlooked or concealed [21]. We tackle complexity in ESGA method selection by understanding the variability, deriving selection criteria, and proposing a generalized approach for selecting methods. Several other works have investigated how to manage the complexity of ESG accounting and reporting using novel techniques, such as generative AI and other industry 4.0 technologies [22], [23].

2.4 Multi-Criteria-Decision-Making

Decision analysis, the study of decision-making for problems with multiple objectives, has been developed and widely employed in solving complex decision-making problems. In literature, decision-making is typically defined as a process or a set of ordered activities concerning stages of problem identification, data collection, defining alternatives, selecting a shortlist of alternatives as feasible solutions with the ranked preferences, and eventually selecting one or more methods to be applied in the organization. The authors of [24] define decision-making as a process that consolidates critical assessment of evidence and a structured process that requires time and conscious effort. Moreover, the decision-making process encourages managers to establish relevant decision criteria, recognize a comprehensive collection of alternatives, and assess the alternatives accurately [25]. A variety of decision-making tools and approaches, such as MCDM, have been introduced within the last three decades [26], [27], [28], [29], [30], [31]. The tools and techniques based on MCDM are mathematical decision models aggregating criteria, points of view, or features [32]. An iterative process is applied to analyze managers' priorities and describe them consistently in a suitable decision model. This iterative and interactive modeling procedure forms the underlying principle of the decision support tendency of MCDM, and it is one of the main distinguishing characteristics of the MCDM as opposed to statistical and optimization decision-making approaches [27].

Earlier research used decision models for decision-making problems in the software engineering domain, such as software architecture pattern selection [26]. Several case studies were conducted to evaluate the effectiveness and usefulness of the decision models to address these MCDM problems. The results showed that the decision models could reduce decision-making time and support decision-making. Decision support systems have been used to increase the sustainability of organizations for decades [33], [34], however, we have not come across any work that uses a decision model for recommending ESGA methods.

3 Problem and Research Method

Problem statement

The *context* of this research is organizations selecting an ESGA method to measure and report on their impacts. There are multiple motivations for companies to select ESGA methods and a good match between the ESGA method and the company's values is crucial to yield maximum benefits. The main *stakeholders* are workers, typically on the managerial level, who select ESGA methods for their organization. Other important stakeholders are the ESG accountant, who will conduct the accounting; recipients or consumers of the ESG report, such as shareholders, customers, and governments; and employees who will use the ESGA insights, such as department managers, the company board, and marketing personnel. The *goal* of the manager who selects the ESGA method is to select a method that fulfills the ESG reporting needs of the company. Section 6 presents metrics that retrospectively assess whether a suitable ESGA method was selected. The *problems* in ESGA method selection are (i) that there is no comprehensive overview of which ESGA methods exist, (ii) there is no exhaustive list of decision-making criteria in the domain, (iii) determining the values of the decision-making criteria for each ESGA method is a time-consuming task, and (iv) there is no structured approach for selecting an ESGA method after considering a set of alternatives.

Research questions

To achieve the research goal, we formulate 3 research questions. Let us briefly explain each of them.

RQ1: Does the ESGA method selection process conform to a conventional decision-making process?

A typical decision-making process comprises the following 6 activities: (1) identifying the goal of the decision-making process, (2) selecting the criteria/parameters/factors, (3) selecting the alternatives, (4) selecting the weighing methods to represent the importance of criteria, (5) applying an aggregation method, and (6) making a decision based on the aggregation results [35]. As part of this research question, we investigate whether the ESGA selection process consists of these 6 activities.

RQ2: How to engineer a decision model for ESGA method selection?

To reduce the complexity of the ESGA method selection process we engineer a decision model for ESGA method selection. We manage the complexity by lowering variability and proposing a generalized approach in the form of a method selection framework. Engineering the decision model involves designing the decision model, populating it with data, and implementing the DSS.

RQ3: How to validate whether the framework can support managers in making well-informed decisions regarding ESGA method selection?

To discover whether the framework can effectively support managers in formulating decision-making criteria and evaluating alternatives based on requirements, the framework has to be validated. We do this by applying the framework to case study organizations.

Research method

We apply a research method in line with the Design Cycle of the Design Science paradigm [36]. The selection framework was subjected to several iterations where we designed the decision model and validated it with experts. Each iteration led us to include more details in the decision model. In this research, we report on the third iteration. For the fourth iteration, we plan to integrate the decision model and DSS into a meta-method for developing ESGA information systems, enriched with ethical value elicitation [37]. Let us briefly explain each of the iterations.

In the first iteration of this design science research, we performed activities 1, 2, and 3 from the method selection framework (Figure 1). We first conceptualized the ESGA domain to capture its complexity. Then, we verified whether the ESGA method selection process conformed with a conventional decision-making process by conducting 4 interviews with organizations that perform ESGA. The organizations were (1) Ghent University, a university located in Ghent, Belgium, (2) Equinox, an organic kombucha brewer located in the United Kingdom (UK), (3) Standing on Giants, a UK-based agency for businesses that want to build a brand-owned, online community, and (4) Stanford University, a university located in Stanford, United States of America (USA). We asked the professionals involved in selecting the ESGA method for their organization to narrate their selection processes. Then we reviewed whether these companies had executed the 6 conventional activities. Based on these insights, we concluded that the ESGA method selection process is an MCDM and can be supported by a selection framework. We then created a formal specification of the MCDM to understand what artifacts had to be created [38]. Next, we created the first version of the decision model by conducting interviews with 15 experts, surveying 50 practitioners and consultants, and performing a literature study [9]. We selected 22 ESGA methods to be part of the initial version of the decision model. The ESGA methods were selected from our ESGA method repository [39]. We chose a diverse set of ESGA methods in terms of focus (i.e., environmental, social, or governance dimension), intended audience (i.e., industry-specific or general), and region (i.e., globally applied or specific to one region).

In the second iteration, we determined which decision-making criteria can be supported by a DSS and validated this subset of decision-making criteria with 5 experts. For some criteria, we defined proxy variables, given that these criteria cannot be operationalized directly. We also validated the proxy variables and formulas with the 5 experts. Moreover, we collected values of the decision-making criteria for each ESGA method. The values were determined by conducting a literature study and 15 semi-structured domain expert interviews. We refer to the collection of values as mapping (full explanation in Section 4.6).

The third iteration focuses on activities 4, 5, and 6. We implement the decision model in the DSS. After careful consideration, we have chosen a pre-existing model-driven decision support technology [40], under the rationale that (i) its model-driven engineering nature fits well with the approach we follow of creating a decision model of the ESGA method selection problem, (ii) it has been validated thoroughly in multiple iterations, and (ii) it is free and open source. Moreover, this was the most cost-effective approach to implementing the DSS. From a model-driven engineering perspective, our decision model becomes the input for the runtime interpreter that provides support to the decision-making process. After engineering the supporting DSS, we conducted 4 case studies in which we simulated the decision-making process with the managers who selected the ESGA methods of the previously mentioned organizations. During the simulation, managers are presented with a list of criteria. For each of the criteria, they specify their requirement (i.e., context definition). The requirements are fed to the decision model. Based on the requirements, the DSS presents a shortlist of suitable methods. We then ask the manager to reflect on the items on the shortlist and select an ESGA method. Finally, we consolidate the knowledge of all 3 iterations into a method selection framework.

4 A Framework for ESGA Method Selection

4.1 ESGA Method Selection vs. Typical Decision-Making Processes

Based on 4 interviews, we conclude that the ESGA method selection process conforms to a typical decision-making process. All managers mentioned that they started by searching for a set of ESGA methods. Then, they defined criteria and requirements that a method should adhere to. For each of the criteria, they collected the values per alternative, after which they checked which method met their requirements. Three out of four managers created a shortlist of candidate methods, which they then presented to internal stakeholders to gather opinions on each shortlisted item. Finally, the 3 managers selected 1 method. One manager did not create a shortlist because after taking into account all requirements, only 1 alternative remained, so they immediately selected that method. Based on these interviews we deduce that the ESGA method selection process conforms to a typical decision-making process. Since the activities described by the managers were performed manually, not all possible alternatives were evaluated and all data had to be collected manually. Supporting the process with a decision model can be more cost-effective and allows for systematically evaluating each alternative, thus limiting the risk of selecting an unsuitable method.

4.2 The Proposed Framework

In this section, we propose a generalized framework for selecting a suitable ESGA method, as shown in Figure 1. The framework consists of a domain, which in our case is *ESGA practices in industry*. The first step in the framework is the *conceptualization* of the domain, done by researchers and engineers (activity 1), which results in a *conceptual model*. The conceptual model for the ESGA domain is further explained in the next section and depicted in Figure 2. After conceptualization, the *formalization* of the domain follows (activity 2), resulting in a *formal specification*. For the sake of brevity, we only include part of the formal specification below; the full formalization for the ESGA domain is available in a technical report [38]. These artifacts provide the basis for *decision modeling* (activity 3), which entails creating a *decision model*. The decision model consists of the domain, criteria, and alternatives. The following sections discuss these elements in detail. Next, the researchers and engineers, *engineer a model-driven inference engine* (activity 4), which yields a *decision support system*. The decision model is then uploaded to the DSS. ESGA accountants and managers perform the *context definition* (activity 5) by inputting their requirements and priorities in the DSS. Given this input, the DSS recommends a set of suitable methods, which we refer to as the *recommendation results*. The manager eventually performs the *method selection* by selecting an ESGA method from the recommendation results (activity 6) and *adapts said method* in their organization (activity 7). Since the domain is likely to change over the years, the decision model needs to be evolved through a *model evolution* (activity 8), to keep it updated and relevant to practitioners. The diagram in Figure 1 can be read as an overview of the framework infrastructure (e.g., the decision model and decision support system are elements that can be reused throughout many organizations, while the requirements and priorities are organization-specific. While the article discusses all elements, we place the focus on those with green backgrounds. The ordering of the activities takes into account the natural flow of the research method activities, the practitioners' use of our framework, and also any other constraint that defines precedences (e.g., that the model-driven DSS tool needs to be implemented before its use).

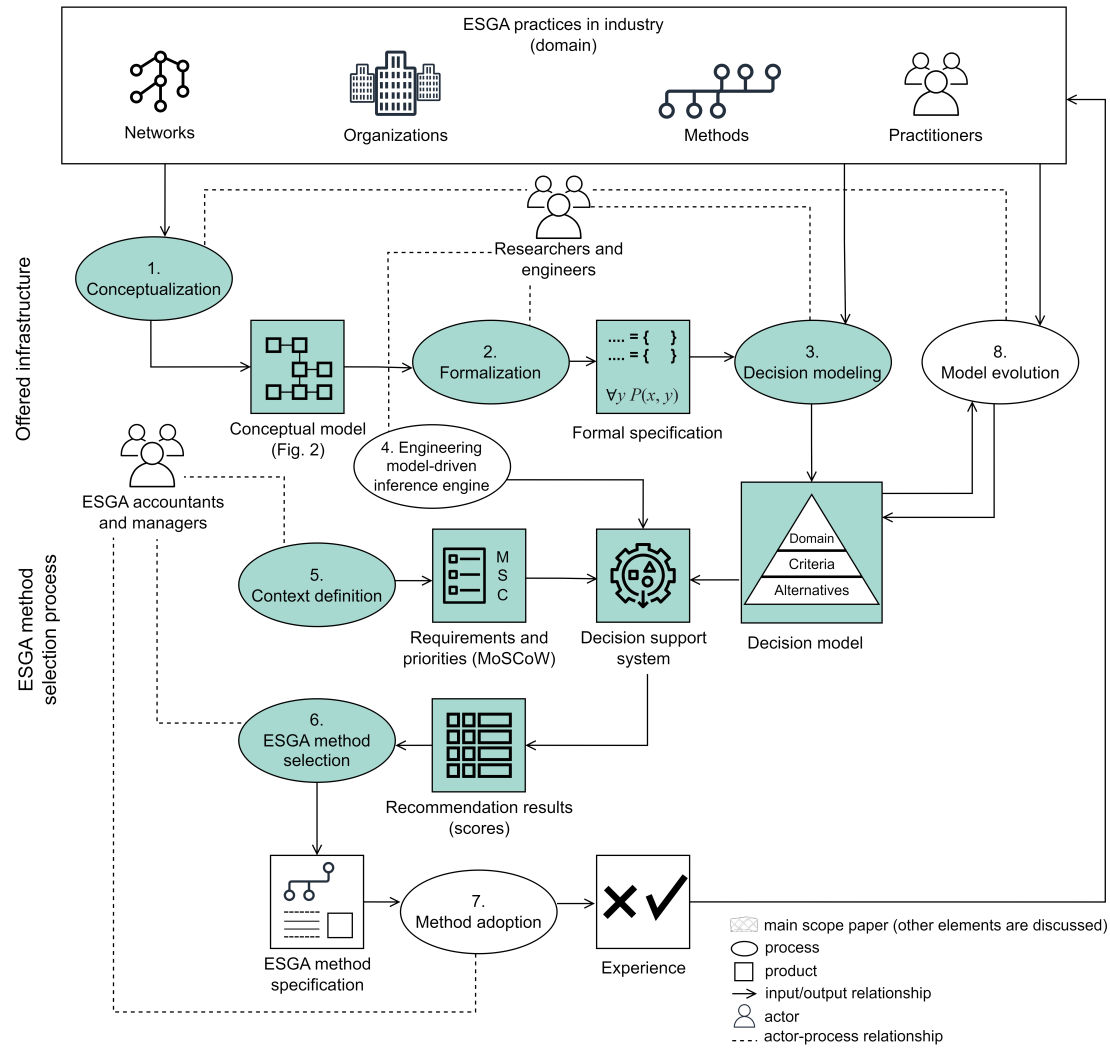

Figure 1. The proposed ESGA method selection framework

4.3 Conceptual Model of the ESGA Method Selection Process

To provide an overview of the concepts involved in selecting a method, our framework dictates creating a conceptual model using the Class Diagram notation [41]. The design of the conceptual model is informed by expert interviews and a literature review. The model for our domain is depicted in Figure 2. It illustrates how an *ESGA method*, which consists of a *process* and *accounting tool*, can be recommended by the *decision support system*. The DSS and accounting tools are two types of *information systems*. The DSS bases the recommendations on a *decision model*, that comprises *reusable elements* and *specific elements*. The reusable elements can be used in any ESGA method selection process, and include the set of ESGA methods, the *decision-making criteria* relevant to the domain of ESGA, and *values* for each decision-making criterion per ESGA method. The specific elements are specific to an instance of the selection process and contain *priorities* and *requirements* of the selection criteria. The *decision-making manager* determines the priorities and requirements based on their experience and the characteristics of the organization they work for. The following sections briefly explain all of the decision model elements and show instances of the elements.

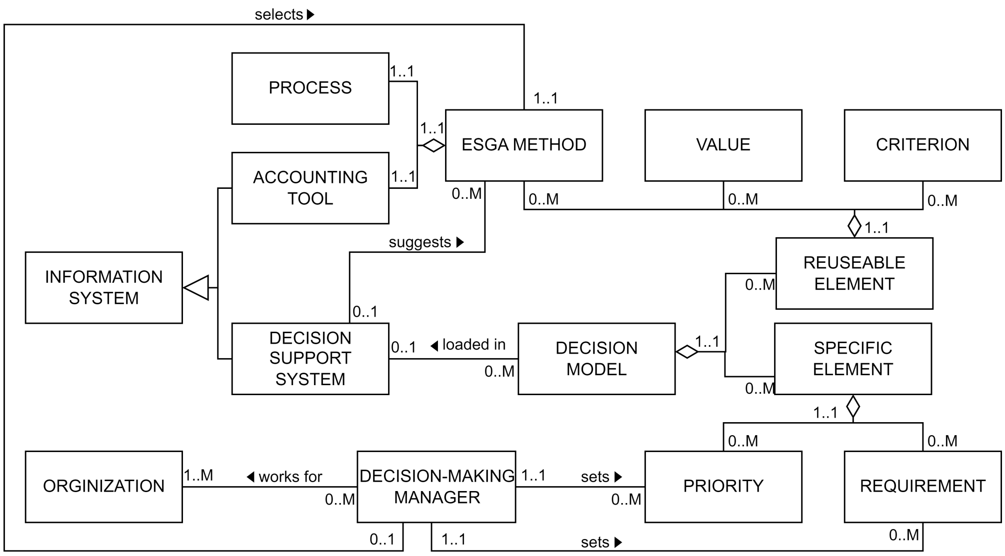

Figure 2. A conceptual model of the ESGA method selection process supported with a decision model. The notation is UML Class Diagram, except for the use of **M** instead of * to represent *many* maximum cardinalities. Cardinalities are look-across.

4.4 ESGA Methods Included in the Decision Model

To define the set of ESGA methods included in the decision model, we have first collected 66 ESGA methods by employing a multivocal-literature review. We have only included a subset of 22 methods in the decision model to limit the scope. When compiling the subset, we have considered that the subset should represent all facets of ESGA methods. Meaning that the methods in the subset differ in scope, industry applicability, geographical adoption, focus, and flexibility. The 22 methods can be observed in the first row of Table A1 (see Appendix).

4.5 ESGA Decision-Making Criteria

$Criteria = c_1, c_2, ...t_{Criteria}$ are the characteristics and facts that distinguish the domain alternatives, based on which it is possible to judge the extent to which the alternatives suit the needs of the decision-maker, and therefore determine which one is the best candidate. Each criterion is defined by an identifier i, a name n, its data type dt, the type of mapping that will provide values mt

(which can be either direct or indirect), and a formula f that is used to define the value of the criteria in case of indirect mappings. $Criteria = \{(i,n,dt,mt,f) : (i \in \mathscr{S}) \wedge (n \in \mathscr{S}) \wedge (dt \in \{Boolean, level, numeric\}) \wedge (mt \in \{direct, indirect\}) \wedge (f \in \mathscr{F}) \wedge ((t = direct) \rightarrow (f = \emptyset))\}$ where $\mathscr{F}$ is the set of all possible formulas.

In earlier research, we elicited and validated a list of relevant criteria when selecting an ESGA method by performing a literature study, interviewing 19 experts, and surveying 50 practitioners and consultants [9]. The criteria and their definitions can be found in the above-cited paper or in the technical report [38]. We found 79 criteria, of which 61 criteria are objective, and 18 are subjective. The values are very personal for subjective criteria and differ per decision-maker. Examples of subjective criteria are familiarity of the manager with the ESGA method, ease of use, and simplicity of the accompanying ICT tool support. For objective criteria, the values are the same for all decision-makers. Examples are whether the method issues an official label or certification after the method is successfully applied, whether the method is supported by an online ICT tool, and whether the method prescribes that the accounting data should be externally audited. Only objective criteria can be implemented in our decision model. In the decision model, we distinguish 3 types of objective criteria, namely:

- Boolean criteria which refer to facts that can either be true or false, or characteristics that are either part of a given domain alternative or not. $Criteria^{Boolean} = \{(i,n,dt,mt,f) \in Criteria : (dt = Boolean)\}$. For instance, whether an ESGA method offers certification or not, which is defined as follows: $C3 = (C3, Certification, Boolean, direct, \emptyset)$
- Levels criteria which refer to facts or characteristics that can be coded with an enumeration. $Criteria^{Level} = \{(i,n,dt,mt,f) \in Criteria : (dt = level)\}$. For instance, the maturity of an ESGA method network (which can be coded with the values high, average, and low): $(C53, Network\ maturity, level, indirect, f_{C53})$. In this article, we have considered the same list of levels for all level criteria, having 3 possible values. $Levels = \{low, average, high\}$ and $\forall 1 \leq i \leq |Criteria^{Level}|(LevelList_i = \{low, average, high\})$
- Numeric criteria refer to facts or characteristics that can be coded with a real number. An example of a numeric criterion is the price of a certification related to an ESGA method. $Criteria^{Numeric} = \{(i,n,dt,mt,f) \in Criteria : (dt = numeric)\}$.

There are 49 Boolean criteria, two-level criteria, and no numeric criteria in our decision model. Ten objective criteria could not be operationalized due to a limitation in the technology. These criteria require input from the user. For instance, the criterion "industry sector" indicates to which industry sectors the ESGA method is applicable. The decision-maker would have to input the industry sector their organization operates in to find a suitable ESGA method. The DSS does not allow user inputs at the time of this research. We aim to solve this issue for future versions of the DSS.

4.6 Mapping between ESGA Methods and Criteria

To characterize each of the domain alternatives based on the criteria, there needs to be a mapping between both sets. Direct mapping occurs when an expert determines the values themselves, typically by inspecting method documentation, asking other experts, interviewing the method engineers, etc. An indirect mapping takes place when the value is calculated using a formula, based on the values of proxy variables. Indirect mappings are used when the valuation of a given criterion is not possible or it is deemed too subjective, but the formula based on proxy variables constitutes a good approximation. In our research, the mapping of values related to Boolean criteria is always direct, through which an expert finds out or determines the values. In contrast, mapping values related to level criteria are always indirect, in which a formula calculates the values. The mapping defines the value of each criterion for each of the methods. The level criteria and the proxy variables that the criteria values are based on are presented in Table A2 (see Appendix).

4.7 Defining Requirements Based on Criteria

When confronted with selecting an ESGA method, the manager needs to define requirements based on the criteria and prioritize each requirement. After that, the inference engine of the DSS will process the information and return a ranked list of ESGA methods. For Boolean criteria, the requirements can be considered implicit (as in "the criteria must hold true"), but for level criteria, the requirements must be explicitly formulated by the user. In our case studies, we have exclusively used the average and high levels, but other options should be possible when decision-makers request them. The decision-maker prioritizes requirements with one of the MoSCoW [42] priority levels: must, should, could, won't.

4.8 Adding a Method to the Shortlist

After this, the inference engine determines a score for each method and adds the methods with the highest score to the shortlist. The scores are computed through a systematic evaluation of each method (also called alternative) against the criteria. The process begins with assigning weights to each criterion, reflecting its importance in the decision model. These weights are derived based on the predefined mappings and the decision-maker's preferences. Following this, the impact factor of each criterion is calculated, using a predefined formula. The formula takes into account the weight of the criterion and its relationships with other criteria. A key feature of this approach is its flexibility in prioritizing specific criteria over others, as indicated by the decision-maker's preferences (e.g., using the MoSCoW method). This ensures that the relative importance of criteria is maintained throughout the decision-making process.

To determine the feasibility of each alternative, the inference engine evaluates whether it meets the essential criteria (must-have) and does not violate any prohibitive criteria (won't-have). This hard constraint check is critical in filtering out inadmissible alternatives before the final scoring phase. Finally, the score of each alternative is calculated by aggregating the impact factors of criteria, with adjustments made based on their priority levels. This results in a set of scored alternatives, from which feasible solutions are identified. These solutions are then ranked to identify the most suitable options for the decision-making scenario.

In summary, the inference engine in an MCDM context facilitates a structured and systematic approach to decision-making, enabling the evaluation of alternatives against a comprehensive set of criteria. By leveraging logical rules and facts, it ensures that the decision process is both transparent and aligned with the decision-maker's objectives and preferences. The full details of the process followed by the inference engine are discussed and formalized in [40]. The DSS uses a hybrid strategy by applying additive compensatory and elimination models [43]. The result is a partial order of methods. The methods with a higher score are presented in the initial positions of the list.

Let us exemplify the work of the inference engine with a simplified, illustrative example in Listings 1, 2, and 3. The dummy input consists of 4 ESGA methods, 5 criteria, criteria mappings, and priorities (Listing 1). The full decision model contains 22 methods and 55 criteria. In a real scenario, the priorities are set by the decision-maker. Next in the example in Listing 2, the inference engine computes a weight for each criterion, based on the priorities, and checks whether the methods adhere to the hard constraints (must-haves and won't-haves). The methods with the highest scores are added to the shortlist and the shortlist is ordered by descending scores. The example output is shown in Listing 3.

```
# Methods
methods = ["CGBS", "BIA", "XES SB", "GRI"]

# Criteria
criteria = ["Online Tool", "Certification", "External Audit", "Scientific Coverage",
"Training Material"]

# Criteria priorities
priorities = {"Online Tool": "Must", "Certification": "Must", "External Audit": "Should",
"Scientific Coverage": "Should", "Training Material": "Must"}

# Criteria mappings
criteria_satisfaction = {
    "CGBS": [False, True, True, True, True],
    "BIA": [True, True, True, True, True],
    "XES SB": [True, False, True, True, True],
    "GRI": [True, False, False, True, True]
}
```

Listing 1. Dummy input

```
Function GetWeightFromMappingsAndPreferences(criterion):
    if priorities[criterion] == "Must": return 3
    elif priorities[criterion] == "Should": return 2
    else: return 1

Function CalculateImpactFactor(criterion, weight):
    # Dummy calculation for illustration
    return weight * 0.5


Function HardConstraintCheck(method):
    For each criterion in criteria:
       If criterion is Must-Have and method does not meet it:
        Return False
       If criterion is Won't-Have and method violates it:
        Return False
    Return True

Function AddMethodToShortlist(method):
    shortlist.append(method)

For each method in methods:
    If HardConstraintCheck(method):
        method.score = CalculateMethodScore(method)
        AddMethodToShortlist(method)

Sort shortlist by descending scores
Print("Shortlist of methods:")
```

Listing 2. Simplified calculations in the inference engine

```
Shortlist of methods:
BIA - Score: 6.0
GRI - Score: 4.5
XES SB - Score: 4.2
```

Listing 3. Example output

5 Validating the Decision Model

The proposed framework led to the production of several tangible artifacts (i.e., conceptual model, formalization, decision model, and decision support system). Given that the conceptual model and formalism serve as tools to engineer the decision model we opt to validate the decision model. For this, we have simulated the ESGA selection process in responsible organizations by conducting 4 case studies. The four organizations (mentioned in Section 3) have already selected an ESGA method, thus we consider the case studies as a simulation that intends to replay the decision-making with a new process and technology. During the case studies, the managers are asked why they chose the ESGA method that their organization currently applies. After speaking freely, we explain each criterion and requirement, after which we ask the managers to prioritize every requirement using the MoSCoW prioritization technique. Once the list of prioritized requirements is entered in the DSS, a shortlist of suitable methods is returned.

The managers' initial priorities contained many must-have hard constraints. When we entered these priorities in the DSS, the DSS could not find any ESGA methods that satisfy all hard constraints. To generate meaningful results, some hard constraints had to be relaxed. We have relaxed the constraints in consultation with the case study participants. Relaxing the constraints was done by changing must-haves to should-haves or won't have to could-haves. For Ghent University, Equinox, Standing on Giants, and Stanford University 14, 13, 12, and 4 hard constraints were relaxed, respectively. The initial priorities and the priorities after the adjustments can be found in Table 1. The following subsections describe each case study by (i) briefly describing the current ESGA practices of the organization, (ii) discussing some of the decision-making criteria that the manager deems essential, and (iii) explaining the decision model results.

Table 1. The initial case study prioritizations and the adjusted prioritizations after the relaxations. If a must-have is changed to a should-have, the priority becomes a "→ S". The relaxation of a won't have to a could-have is denoted with a "→ C".

Criteria	ID	Ghent University Initial	Ghent University Adjusted	Equinox Initial	Equinox Adjusted	Standing on Giants Initial	Standing on Giants Adjusted	Stanford University Initial	Stanford University Adjusted
Self-assessment option	C2	M	M	M	M	M	M	M	M
Certification	C3	S	S	S	S	M	→ **S**	S	S
Scoring	C4	M	→ **S**	M	M	S	S	S	S
Publishability of results	C5	M	→ **S**	S	S	S	S	C	C
Predefined indicators	C6	M	M	M	M	S	S	S	S
Extendable with indicators	C7	M	→ **S**	M	→ **S**	C	C	C	C
Indicator explanation	C8	M	M	M	M	M	M	S	S
Official tool support	C9	S	S	M	M	C	C	S	S
Offline tool	C10	C	C	W	→ **C**	S	S	C	C
Online tool	C11	S	S	M	M	M	M	S	S
Whistleblowing mechanism	C12	M	→ **S**	M	→ **S**	S	S	S	S
Built-in survey tool	C13	M	→ **S**	M	→ **S**	C	C	C	C
Infographic generation	C14	S	S	M	→ **S**	S	S	S	S
Networking tool	C15	S	S	S	S	C	C	C	C
Multiple users per account	C16	M	→ **S**	M	M	S	S	W	→ **C**
Continuous improvement of tool	C17	M	→ **S**	M	→ **S**	M	→ **S**	S	S
Internal validation	C18	M	→ **S**	S	S	C	C	S	S
Peer review	C19	S	S	S	S	W	W	S	S
External audit	C20	S	S	M	M	C	C	C	C
Existence of network	C21	S	S	M	M	M	M	C	C
Democratic method development	C22	S	S	S	S	S	S	S	S
Evolvability of the method	C23	M	M	M	M	M	M	C	C
Input from the community	C24	M	→ **S**	M	→ **S**	M	→ **S**	C	C
Local network groups	C25	S	S	M	→ **S**	M	→ **S**	C	C
Network specific events	C26	C	C	S	S	S	S	C	C
Help desk	C27	S	S	M	M	S	S	S	S

Criteria	ID	Ghent University Initial	Ghent University Adjusted	Equinox Initial	Equinox Adjusted	Standing on Giants Initial	Standing on Giants Adjusted	Stanford University Initial	Stanford University Adjusted
Training material	C28	S	S	M	→ **S**	S	S	C	C
Online directory	C29	C	C	M	M	M	M	M	→ **S**
Map visualization	C30	C	C	M	→ **S**	S	S	C	C
Official trademark for members	C31	S	S	M	M	M	→ **S**	M	→ **S**
Newsletter	C32	C	C	S	S	S	S	C	C
Social topics	C33	M	M	M	M	M	M	S	S
Environmental topics	C34	M	M	M	M	M	M	M	M
Support improvement planning	C35	M	→ **S**	M	→ **S**	M	→ **S**	S	S
Goal suggestion	C36	M	→ **S**	S	S	M	→ **S**	S	S
Improvement action suggestion	C37	M	→ **S**	S	S	S	S	S	S
Existence of social market	C38	C	C	M	→ **S**	C	C	C	C
Discount for members	C39	C	C	S	S	C	C	C	C
Mapping to SDGs	C40	S	S	S	S	C	C	C	C
Workshop on SDGs	C41	C	C	S	S	C	C	C	C
Existence of aggregated report	C42	C	C	S	S	M	→ **S**	S	S
Benchmarking/comparing results	C43	C	C	M	→ **S**	M	→ **S**	M	M
Serious blogs	C44	C	C	S	S	M	M	C	C
Newspaper coverage	C45	C	C	S	S	C	C	C	C
Expelling members	C46	C	C	M	M	M	→ **S**	S	S
Commitment statement	C47	M	→ **S**	C	C	M	→ **S**	C	C
Public manuals	C48	M	M	S	S	S	S	S	S
Scientific coverage	C49	C	C	C	C	C	C	C	C
organizational fit	C54	M	M	M	M	S	S	S	S
Principle-based	C55	M	→ **S**	S	S	M	→ **S**	S	S
Popularity, {average, high}	C52	M	M	C	C	S	S	S	S
Network maturity, {average, high}	C53	M	M	S	S	C	C	M	→ **S**

5.1 Case Study 1: Ghent University

Current status. Seven years ago, Ghent University performed a materiality assessment. An external company advised them to report on their material topics according to the GRI Standards. Since then, they have performed an ESGA annually. The accounts are not externally audited since the GRI Standards do not require auditing the accounts. Ghent University's manager expressed that the GRI Standards enable effective stakeholder communication and are internationally recognized. Before deciding on the GRI Standards, Ghent University also considered the STARS method. Nowadays, Ghent University deviates more and more from the GRI Standards and tailors the method to suit their specific needs and wishes.

Requirements. The manager initially prioritized 24 requirements as must-haves, 14 as should-haves, 14 as could-haves, and zero as won't-haves. After relaxing some problematic hard constraints, ten must-haves, 28 should-haves, 14 could-haves, and zero won't-haves remained. In terms of requirements, the manager indicated that an ESGA method must be complete; so the method should cover both environmental (C34) and social topics (C33). Moreover, it should be possible to use the method without purchasing a license and without having to involve third parties. Thus, the manager prioritized the requirements corresponding to the criteria "Free self-assessment option" (C2) and "Public manuals" (C48) as must-haves. Other requirements that were prioritized as must-haves are those that correspond to flexibility, guidance, and support, such as "organizational fit" (C54), "Indicator explanation" (C8), and "Evolvability of the method" (C23). Other hard constraints are: "Whistleblowing mechanism" (C12), "Improvement action suggestion" (C37), "Internal validation" (C18), and "Commitment statement" (C47). In Ghent University's prioritization, there are no won't-haves. This means that all requirements are either important, desired, or tolerable.

Results. The shortlist produced by the decision model contains the B Impact Assessment, SMETA, and the Common Good Balance Sheet. Surprisingly, the GRI Standards are not recommended because some of the must-haves are not met by the GRI Standards. For instance, the manager indicated that it is essential that the assessment results are quantified with a numeric score to compare accounting results with other organizations. GRI has not included a scoring mechanism in its method; as a result, the requirement is not met by the GRI Standards, and the decision model deems it an infeasible alternative. Other hard constraints that are not met by the GRI Standards are C12, C18, C37, and C47. For the full list of criteria and priorities, see Table 1.

A possible explanation as to why Ghent University's ESGA deviates increasingly every year from the guidelines posed by the GRI Standards could be that the GRI Standards are insufficient and do not meet the university's requirements. Therefore, there is a mismatch between the requirements and the selected method. The B Impact Assessment covers 71% of the criteria that the manager deems important, SMETA covers 51%, and the Common Good Balance Sheet covers 48%. The B Impact Assessment and the Common Good Balance Sheet are feasible results. SMETA, on the other hand, is a method that enables businesses to assess their sites and suppliers to understand working conditions in the supply chain. This method is not tailored to educational institutions. We reflect on this issue in the discussion.

5.2 Case Study 2: Equinox

Current status. Equinox performs its ESGA according to the B Impact Assessment. They became a certified B Corporation in September 2020 [44]. To obtain the B Corporation certification, the account needs to be externally audited by B Lab, and the organization should score at least 80 of 200 points. Equinox was looking for a robust method and a tool with a good infrastructure. They chose the B Impact Assessment because of its large and active community, multi-layered support, and configurable costs. According to the manager, the B Impact Assessment would ensure high accountability and integrate operational and social challenges. Moreover, internal stakeholders were most excited about this method. Alternatives considered by Equinox are methods in the ISO 14000 family, The Planet Mark, and engineering their own method based on the Sustainable Development Goals.

Requirements. Equinox's manager initially identified 29 must-haves, 19 should-haves, 3 could-haves, and 1 won't-have. 12 must-haves had to be changed to should-haves, and the won't-have was changed to a could-have. When presented with the decision-making criteria, the manager stated that a suitable ESGA method needs to assess both environmental (C34) and social topics (C33), has to have a free self-assessment option (C2), and must be adaptable to organizational characteristics (C54). The manager expressed that a method with predefined indicators (C6) is a must since this increases accountability and the indicators must have elaborate explanations (C8) to ensure they are correctly interpreted. The method must also be continuously improved (C23) to keep up with societal changes. Equinox's manager mentioned that there must be an online directory (C29) in which stakeholders can look up organizations that apply a particular method to increase visibility and promote ethical consumption. Apart from the requirements mentioned above, the manager indicated that specific requirements could not be relaxed, despite their low coverage. These requirements state that it must be possible to have multiple users per account (C16) since it provides traceability of the accounting; there must be an official trademark (C31) for members to use because the trademark can help organizations communicate their values to important stakeholders; a method must have a scoring mechanism (C4) to quantify the accounting results; the accounting results must be externally audited (C20) as externally auditing the results ensures that the ESE account is correct and truthful; networks must be able to expel members (C46) to make sure that everyone in the network adheres to the same values and norms; the accounting must be supported with an online tool because without an online tool (C11), performing the assessment is too inefficient for Equinox; there must be a help desk (C27) because it is crucial that support, where needed, is provided during the assessment.

Results. After adjusting the initial prioritization, the decision model returned only 1 suitable ESGA method, the B Impact Assessment, which matches Equinox's decision. This method covers 73% of the requirements expressed by the manager. The B Impact Assessment does not cover all should-have requirements hence the coverage is only 73%. For instance, the B Impact Assessment cannot be extended with additional indicators (C7), nor does it have a whistleblowing mechanism (C12), built-in survey tool (C13), or networking tool (C15).

5.3 Case Study 3: Standing on Giants

Current status. Standing on Giants applies the B Impact Assessment and has been a certified B Corporation since August 2020. Similar to Equinox, Standing on Giants passed the threshold of 80 out of 200 points, and B Lab audited their account. When choosing an ESGA method, Standing on Giants did not consider any alternatives. They selected the B Impact Assessment because their peers use this method, therefore, "Commonly used by peers" (C73) was the only requirement for Standing on Giants; other selection criteria and requirements were not considered. This makes the company an interesting case to explore the usefulness of our decision model.

Requirements. Even though Standing on Giants only considered 1 requirement when they selected the B Impact Assessment, during the case study, the manager prioritized 21 requirements as must-haves, 17 as should-haves, 13 as could-haves, and 1 as won't-have when presented with our list of criteria. To generate meaningful results, 12 must-haves were changed to should-haves. The requirement that specifies that a method is supported by an online tool (C11) and has a low coverage (45%), but the manager stated that a suitable method must be supported by an online tool, otherwise, they would not use the method. Therefore, that hard constraint requirement can under no circumstances be relaxed. Other important decision-making criteria for Standing on Giants are the fact that the method must be able to evolve (C23) to stay up-to-date; there must be an official trademark (C31) that responsible organizations can use; there must be an online publicly available repository (C29) to which all responsible organizations are added once they successfully apply the method; there must be blogs (C44) related to the method where the ESE performance of the organization is discussed; the indicators are well explained (C8) to avoid confusion, and the assessment contains both social (C33) and environmental topics (C34).

Results. According to the decision model, the B Impact Assessment and STARS are the most suitable methods for Standing on Giants. STARS is a method developed for educational institutions only, so Standing on Giants cannot use this method to evaluate their performance. We present a solution for this issue in the discussion. The other method on the shortlist, the B Impact Assessment, perfectly aligns with the manager's choice. The manager stated that they felt reassured that they had made the right decision. The B Impact assessment covers 78% of the requirements indicated by the manager. Some requirements that are not covered by the B Impact Assessment but are desired by Standing on Giants are the existence of aggregate reports (C42) where the performance of the whole network is analyzed, the presence of a whistleblowing mechanism (C12), a functionality of the ESGA tool that allows automatic creation of infographics (C14) based on the account data, and an offline tool (C10).

5.4 Case Study 4: Stanford University

Current status. Stanford University has been measuring and monitoring its ESE performance using STARS since 2012. The reports are externally audited and have received the highest rating defined by the method, i.e., Platinum. Before selecting STARS, Stanford University considered 4 alternatives, namely the GRI Standards, CDP, The International Sustainable Campus Network, and the SDG Action Manager. They based their ESGA method selection on the industry sector, expected required effort, data availability, feasibility of gathering the required data, costs, potential benefits, benchmarking capabilities, reputation, and recognition. Eventually, Stanford University chose STARS since the method is tailored to higher education, they were involved in the creation of STARS, and they have a close relationship with Aashe (the organization that developed STARS).

Requirements. Initially, Stanford University's manager categorized 6 criteria as must-haves, 23 as should-haves, 22 as could-haves, and 1 as a won't-have. During a second interview, the manager indicated that the requirement that states that the method network must have an online directory (C29) of responsible organizations might be relaxed to a should-have. The same applies to the requirement that states that the network maturity (C53) must at least be average. Per request of the manager, these requirements were relaxed because after having thought about these requirements, the manager concluded that these are not hard constraints, since not fulfilling them is not an insurmountable obstacle. Anyhow, the relaxations were not necessary to generate a meaningful result. Additionally, two hard constraint requirements had to be relaxed due to low coverage (C16, C31).

Compared to the other case studies, Stanford University has few hard constraints. After the changes, only 3 hard constraints remained. Like the other case studies, Stanford University deems it essential to include environmental topics (C34) in the assessment. In contrast to the other case studies, Stanford University deems social topics (C33) necessary, but these topics are not an absolute must, therefore they are rated as a should-have. The manager expressed that it is essential to compare ESE performance (C43) to identify improvement areas and discover in which aspects they can learn from their peers.

Results. The top 3 most suitable ESGA methods on the shortlist are the B Impact Assessment, STARS, and CDP. The B Impact Assessment meets 75% of the requirements, STARS has coverage of 66%, and CDP has 60% coverage. The manager pointed out that Stanford University has considered all 3 methods and that the DSS recommendations can help select additional ESGA methods and tools. They also mentioned that they are willing to apply multiple methods because, within the STARS network, Stanford University's results are only compared with other educational institutions. The manager expressed that they want to compare their performance with businesses in other industry sectors and wish to exchange knowledge between academia and industry.

5.5 Case Study Results into Perspective

In 75% of the case studies, the DSS shortlist contains one of the ESGA methods that the organization currently applies. This means, that 3 out of 4 managers selected an ESGA method that is deemed suitable according to the decision model. In the case of Ghent University, their current ESGA method was not on the shortlist. This does not mean that the decision model's shortlist is invalid. The Ghent University manager attested that their current ESGA method does not fulfill their needs and requires a high number of changes to adapt to their needs. In 50% of the cases, the DSS put the current ESGA method on the number one spot of the shortlist. However, in decision-making, the automatically computed shortlist only provides suggestions of the most suitable alternatives. Therefore, the decision-maker should always use domain knowledge to make the final decision. Hence, the DSS does not need to return the most suitable method in the number one spot, necessarily. All alternatives on the shortlist should be considered.

Our objective was to help decision-makers make more well-informed decisions by engineering a selection framework that evaluates alternatives and returns a shortlist of methods that fit the requirements of managers to mitigate the threat of rework and ineffective ESGA. By introducing a selection framework we reduce the complexity in the ESGA method landscape. The case study managers perceived that our proposal can assist them, and other decision-makers, with better-informed method selection. Their opinions can best be summarised with a telling quote.

> "I love it. This is so helpful. I am literally writing them (the recommended ESGA methods) down. [...] I think it is perfect. We have really been confronted with this problem of like which reporting standard should we follow and it is really nice to see these in a clear recommendation format."

6 Discussion

6.1 Has a Suitable Method Been Selected?

Assessing whether a successful ESGA method has been selected can only be done retrospectively, after several years. To perform this assessment the following metrics should be taken into account.

- Continued use of the method: whether the organization has continued to use the method over time or has decided to switch to a different method. Switching to another method is a clear indication that the initial method was unsuitable or that the organizational context has changed drastically.
- Number of changes: the number of changes made to the ESGA method definition to ensure a better fit with the organizational needs. A high number of required changes shows that the ESGA method was not the most suitable. Examples of changes are adding or removing indicators to be measured, or including additional ESG topics in the assessment.
- Satisfaction related to the ESGA report: if stakeholders and consumers of the ESG report are unsatisfied with the report, the underlying ESGA method did not meet the requirements. Dissatisfaction may arise when the stakeholders cannot use the ESG report to make decisions.
- Topic materiality match: whether the topics in the ESG report match the topics resulting from the materiality assessment. If the topics in the report and topics identified in the materiality assessment do not match, the method is unsuitable.

6.2 Results in the Context of Earlier Work

All managers expressed that they trusted the results and would recommend using the decision model because it is more cost-effective than selecting an ESGA method without a decision model. Moreover, helps navigate the vast and complex landscape of ESGA methods. The manager from Stanford University stated that they will use the recommendations to select an additional ESGA method. The managers from Ghent University, Standing on Giants, and Equinox stated that they are currently satisfied with their way of assessing and reporting ESG disclosures and do not plan to change or extend their set of ESGA methods. Standing on Giants' manager expressed to be satisfied with the DSS results because the most suitable method turned out to be the B Impact Assessment, which is the method that they currently apply. The managers from Ghent University, Stanford University, and Equinox indicated that the decision model will help them and other managers in the ESGA method selection process. All in all, the managers agreed that the decision model is a useful tool, which contains more knowledge than they could have collected manually.

The decision model contains several reusable elements that prevent managers from having to create these elements themselves, thus eliminating tedious, time-consuming activities. Moreover, the decision model can provide a more systematic approach to evaluating and comparing ESGA methods. Even in the extreme case when a manager knows beforehand that a certain requirement is the only truly important requirement for their organization, the decision model can still provide inspiration for expanding the set of requirements that is taken into account during the selection process. Even if the set is eventually not extended, the manager can be assured that their final conclusion was well-informed. Standing on Giants' manager, highlighted the importance of a DSS as they stated that the decision model is useful as long as it is operationalized in a DSS.

Related recent work, presents a DSS architecture for the development and ESG strategies [45]. The authors propose an architecture that assesses the ESG maturity of companies, aligns business activities with ESG criteria, and formulates ESG strategies, including the planning and execution of ESG-related activities. Our work has the same aim: improving companies' sustainability performance by introducing decision support systems. Where the related work [45] focuses on one specific ESGA method, namely the ESG-index, we believe that there is not one ESGA method that fits with the needs and characteristics of all organizations. Hence, our decision model contains 22 ESGA methods. On the other hand, the proposed DSS architecture helps companies formulate a sustainability strategy and implement that strategy. It would be valuable to integrate our approaches, given that both have their strengths and limitations. Moreover, the usage of our DSS in combination with the DSS proposed by [46] may be beneficial for managers, given that our DSS recommends a suitable accounting method and their DSS recommends solutions for sustainability issues (e.g., waste management).

The consequence of selecting an ESGA method is that a new information system (i.e., the ESGA tool) is embedded in the organization. According to the experiences reported by the managers participating in the case studies, to make this decision it was not sufficient to only think about conventional information system selection criteria. Managers had to take into account criteria that are outside the boundary of the information systems. For instance, the community around the ESGA method; the reputation of the organization developing the method; the extent of a method's contribution to transforming the traditional economic system; the priorities of the leaders of the organizations; and the actions of competitors. The decision model can recommend a set of the most suitable ESGA methods along with their corresponding information systems. However, there is a chance that organizations may deem another method or system more suitable because they take other factors into account. This does not detract value from our proposal since the final decisions would always be better informed if the decision model is used. Nonetheless, we acknowledge that MCDM problems do not yield an optimal solution, therefore, decision-makers' input is required to select the most suitable solution, which is in line with earlier findings [47].

6.3 Validity

To mitigate the threats to construct validity, we followed the MCDM theory and the 6 steps of a decision-making process [35] to build the decision model for ESGA method selection. We also analyzed ESGA method documentation and conducted expert surveys and interviews. The decision model has been evaluated through 4 case studies with ESGA-performing organizations in the USA, UK, and Belgium. A remaining threat is that managers misinterpreted the meaning of some criteria; we have done our best to mitigate it by offering explanations whenever it felt necessary, but it cannot be discarded entirely.

To mitigate the threats to the internal validity of the framework, we define success when the ESGA method that the organization is currently applying is contained in the shortlist yielded by the decision model or when this list provides new suggestions that the case study participants find interesting. Emphasis on the case study participants' opinion as a measurement instrument is risky, as they may not have sufficient knowledge to make a valid judgment. We counter this risk by conducting more than one case study, assuming that the case study participants handle in their interest. Also, the DSS itself has been validated on several occasions [40], [48], [49] which builds trust in the technology.

We evaluated the decision model with organizations in 3 different countries in 3 industry sectors to mitigate external validity threats. Moreover, the criteria are established using knowledge sources concerning ESGA methods with different focuses, degrees of freedom, and application domains. Although this research has taken into account 22 ESGA methods, we assume that the decision model can be generalized to all ESGA methods and even to all impact measurement methods.

Through direct mapping, domain experts provide values for criteria and proxy variables. The mapping is analogous to a measurement process and, thus, is subject to potential measurement errors. Such errors would then be propagated to the criteria that use indirect mapping. Boolean criteria and proxy variables are subject to type I and type 2 errors, that is, potential false positives and false negatives, respectively. Proxy variables are subject to inaccuracy. To further increase the validity of the decision model, an uncertainty analysis could be performed by estimating the probability distributions for errors made during the mappings (i.e., measurement errors made while providing values to Boolean and numeric criteria and proxy variables) and applying Monte-Carlo or analytic techniques to propagate the uncertainty through the decision model and the algorithm applied by the inference engine. To inform the estimation of the probability distributions, more experience with the decision model is convenient, which is why we have not yet performed such an analysis.

Furthermore, Boolean and numeric criteria are subject to missing values; that is, the fact that perhaps the domain expert cannot find evidence to determine a value. In the case of Boolean criteria and proxy variables, missing values will likely be confounded with false values; that is, the expert will easily confuse missing information about the mechanisms used to gather input from the community with the nonexistence of such mechanisms.

As can be observed in our case studies, the priorities defined by the managers significantly affect the results yielded by the inference engine. Defining many hard constraints (i.e., must-have and won't-have requirements) can drastically reduce the length of the resulting list of candidate ESGA methods, eventually even producing an empty list. The decision model and its implementation are thus sensitive to unreasonable prioritization. However, when the managers realize that they have been overly rigid with their priorities they have the option to adjust them and obtain a new shortlist.

6.4 Limitations and Future Work

In some cases, the decision model's recommendations did not fit the organizational characteristics of the case study organizations. This can be avoided by operationalizing the criteria that the DSS could not support. For instance, in the case of Ghent University, the decision model suggested

SMETA as a suitable method because SMETA meets the manager's requirements. However, if the criterion "Associated industry sector" was operationalized the manager could have indicated that they are only interested in methods specifically developed for educational institutions or methods that can be applied by organizations in any industry sector. Then the DSS would not have returned SMETA as a suitable method.

Material topics determine which indicators are assessed and can therefore influence which ESGA method should be selected. The set of material topics differs per company. In this research, we chose to disregard the materiality of ESG topics because this information cannot easily be added to the decision model. It could be operationalized in the DSS by adding all ESG topics as Boolean criteria. However, the list of topics is so extensive that this would result in adding many additional criteria. Managers would then have to prioritize an extensive list of criteria, which might be too cumbersome. We made a trade-off analysis between the ease of use of the decision model and the accuracy of the method recommendation. To improve the quality of the decision model we can add the criterion "governance topic". Along with the already included criteria "social topics" and "environmental topics", they would cover the taxonomy that is common in ESG reporting.

To create the decision model, the mappings had to be created manually. This means that all values of Boolean mappings, level mappings, and numeric values had to be determined by analyzing the method documentation and interviewing method engineers and experts. Making the decision model available saves future managers much time since they can reuse our mapping. However, ESGA methods and information systems evolve as the focus on environmental and societal challenges shifts over time. Therefore, the mapping values may change as the methods evolve. In that case, the mappings need to be updated manually and the decision model has to be generated and uploaded to the DSS again. Therefore, the DSS can easily be outdated if it is not constantly maintained. Future work could research how the decision model should be evolved so it does not become obsolete and retains its value over the years. We plan to develop features that allow scraping information from websites to produce the mappings.

7 Conclusion

Based on this research, we conclude that our framework, which proposes an approach for engineering decision support can alleviate problems associated with ESGA method selection. The process of selecting an ESGA method contains all the activities of a typical decision-making process. Contrary to a conventional decision-making process, this selection process also considers unconventional subjective criteria, which have considerable weight. Hence, human input will be required to achieve an optimal solution. Furthermore, we have engineered a decision model and implemented it in a DSS. The decision model contains reusable elements. Collecting data on these elements is a tedious, time-consuming task. Our decision model ensures that managers do not have to spend resources to produce the reusable elements themselves. We have validated the decision model with managers of four case study organizations. The managers attest that the decision model can support them in making well-informed decisions and help manage the complexity of ESGA method selection.

All in all, we hope that our work mitigates the risk of organizations selecting an unsuitable method. By providing the knowledge and technology to spend fewer resources on the selection process, we offer organizations a chance to focus more on improving their environmental, social, and governance performance, achieving sustainable development, and addressing the grand challenges of our time.

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Appendix

Table A1. The Boolean criteria mapping (1/2)

Boolean criteria ESGA methods	Coverage	GRI G4	GRI Standards	Common Good Balance Sheet	B Impact Assessment	CDP	UN Global Compact	EFQM	Fair Trade Software Foundation	GDRC	Data Centre Assessment	ISO 14001	ISO 26000	Measurabl	S-CORE	SDG Compass	SMETA	STARS	UniSAF	World Fair Trade Organization	XES Social Balance	AA1000 Assurance Standard	TIESS
Cost																							
Free self-assessment option	90.91%	✓	✓	✓	✓	✓	✓	✓	x	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	✓	✓
Obtain certification																							
Certification	31.82%	x	x	✓	✓	x	x	x	✓	x	x	✓	x	x	x	x	x	✓	x	✓	✓	x	x
Scoring	36.36%	x	x	✓	✓	✓	x	✓	x	x	x	x	x	x	✓	x	✓	✓	x	x	✓	x	x
Publishability of results	22.73%	x	x	x	✓	x	✓	x	✓	x	x	x	x	x	x	x	x	✓	x	x	✓	x	x
Indicators																							
Predefined indicators	77.27%	x	x	✓	✓	✓	x	✓	✓	✓	✓	x	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	✓
Extendable with indicators	63.64%	x	✓	x	x	✓	✓	✓	✓	✓	x	✓	✓	✓	✓	✓	✓	x	✓	x	x	x	✓
Indicator explanation	68.18%	x	x	✓	✓	✓	x	x	✓	✓	✓	x	✓	x	✓	✓	✓	✓	✓	✓	✓	x	✓
Tool support																							
Official tool support	68.18%	✓	✓	✓	✓	✓	x	✓	✓	x	✓	x	x	✓	✓	x	✓	✓	✓	✓	✓	x	x
Offline tool	22.73%	x	x	✓	x	x	x	x	x	x	x	x	x	x	✓	x	✓	x	✓	✓	x	x	x
Online tool	45.45%	✓	✓	x	✓	✓	x	✓	x	x	✓	x	x	✓	✓	x	x	✓	x	x	✓	x	x
Whistleblowing mechanism	13.64%	x	x	x	x	✓	x	x	x	x	x	x	x	x	x	x	x	✓	x	✓	x	x	x
Built-in survey tool	18.18%	x	x	x	x	✓	x	✓	x	x	x	x	x	✓	x	x	x	x	x	x	✓	x	x
Infographic generation	18.18%	x	x	x	x	x	x	✓	x	x	x	x	x	✓	✓	x	x	x	x	x	✓	x	x
Networking tool	4.55%	x	x	x	x	x	x	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Multiple users per account	18.18%	x	x	x	✓	✓	x	x	x	x	x	x	x	✓	x	x	x	✓	x	x	x	x	x
Continuous improvement of the tool	54.55%	✓	✓	✓	✓	✓	x	✓	✓	x	x	x	x	✓	✓	x	✓	✓	x	x	✓	x	x
Audit																							
Internal validation	31.82%	x	x	✓	✓	x	x	✓	x	x	x	✓	x	x	x	x	x	✓	✓	x	✓	x	x
Peer review	13.64%	x	x	✓	x	x	x	✓	x	x	x	x	x	x	x	x	x	x	x	✓	x	x	x
External audit	40.91%	x	x	✓	✓	✓	x	✓	x	x	x	x	x	x	x	x	✓	✓	x	✓	✓	✓	x
Network																							
Existence of network	68.18%	✓	✓	✓	✓	✓	✓	✓	✓	x	✓	x	x	x	x	x	✓	✓	x	✓	✓	✓	✓
Democratic method development	9.09%	x	x	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	✓	x	x
Evolvability of the method	72.73%	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	✓	x	x	x	x	✓	✓	x	✓	✓	✓	✓
Input from the community	45.45%	✓	✓	✓	✓	x	✓	x	x	x	x	x	x	x	✓	x	✓	✓	x	x	✓	x	✓
Local network groups	36.36%	✓	✓	✓	✓	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x	✓	✓	x	x
Network specific events	59.09%	✓	✓	✓	✓	✓	✓	✓	x	x	✓	x	x	x	x	x	✓	✓	x	x	✓	✓	✓
Help desk	54.55%	✓	✓	x	✓	✓	✓	x	✓	x	x	x	x	✓	x	x	✓	✓	x	x	✓	✓	✓
Training material	59.09%	✓	✓	✓	✓	✓	✓	✓	x	x	x	x	x	✓	✓	x	✓	x	x	✓	✓	x	✓
visualization mechanisms																							
Online directory	68.18%	✓	✓	✓	✓	✓	✓	✓	✓	x	✓	x	x	✓	x	x	✓	✓	x	✓	✓	✓	x
Map visualization	13.64%	x	x	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	✓	✓	x	x
Official trademark for members	27.27%	x	x	✓	✓	x	✓	x	x	x	x	x	x	x	x	x	x	✓	x	✓	✓	x	x
Newsletter	54.55%	✓	✓	✓	✓	✓	✓	x	x	x	x	x	x	✓	x	x	✓	✓	x	✓	✓	x	✓
Disclosure topics																							
Social topics	86.36%	✓	✓	✓	✓	x	✓	✓	✓	✓	x	x	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Environmental topics	100.00%	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table A1. The Boolean criteria mapping (2/2)

Boolean criteria ESGA methods	Coverage	GRI G4	GRI Standards	Common Good Balance Sheet	B Impact Assessment	CDP	UN Global Compact	EFQM	Fair Trade Software Foundation	GDRC	Data Centre Assessment	ISO 14001	ISO 26000	Measurabl	S-CORE	SDG Compass	SMETA	STARS	UniSAF	World Fair Trade Organization	XES Social Balance	AA1000 Assurance Standard	TIESS
Improvement areas																							
Support improvement planning	54.55%	✓	✓	x	✓	x	x	✓	x	x	x	✓	✓	x	✓	✓	x	x	x	✓	✓	✓	✓
Goal suggestion	50.00%	x	x	✓	✓	x	✓	x	✓	x	x	x	✓	x	✓	✓	✓	x	x	✓	✓	✓	x
Improvement action suggestion	36.36%	x	x	x	✓	✓	x	x	x	x	✓	x	x	x	✓	✓	✓	x	x	x	✓	✓	x
Social market																							
Existence of social market	18.18%	x	x	x	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	✓	✓	x	✓
Discount for members	4.55%	x	x	x	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Sustainable development goals																							
Mapping to SDGs	54.55%	✓	✓	✓	✓	✓	✓	✓	x	✓	x	x	x	x	x	✓	✓	x	x	✓	✓	x	x
Workshops on SDGs	22.73%	✓	✓	x	✓	x	✓	x	x	x	x	x	x	x	x	x	✓	x	x	x	x	x	x
Benchmarking																							
Existence of aggregated report	40.91%	✓	✓	x	x	✓	✓	x	x	x	x	✓	x	x	x	x	✓	✓	x	✓	✓	x	x
Comparing/benchmarking results	31.82%	✓	x	x	✓	✓	x	✓	x	x	x	x	x	✓	✓	x	x	✓	x	x	x	x	x
Featured press																							
Serious blogss	63.64%	✓	✓	x	✓	✓	✓	✓	x	✓	x	x	x	✓	x	✓	✓	✓	x	✓	✓	✓	x
Newspapers coverage	63.64%	✓	✓	✓	✓	✓	✓	x	x	x	x	✓	✓	x	x	x	✓	✓	x	✓	✓	✓	✓
Reputation																							
Expelling members	45.45%	✓	✓	✓	✓	✓	✓	x	✓	x	x	x	x	x	x	x	x	✓	x	✓	✓	x	x
Commitment statement	36.36%	x	x	x	✓	✓	✓	x	x	x	x	✓	x	x	x	✓	x	✓	x	✓	✓	x	x
Public manuals	86.36%	✓	✓	✓	✓	✓	✓	✓	x	✓	✓	x	x	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Scientific coverage	86.36%	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	✓	✓	✓	x	✓	✓	✓	✓	✓	✓	✓	x
Method flexibility																							
Organizational fit	81.82%	✓	✓	✓	✓	✓	✓	x	x	✓	x	✓	✓	✓	✓	✓	✓	x	✓	✓	✓	✓	✓
Principle-based	59.09%	✓	✓	✓	x	x	✓	✓	✓	x	x	x	✓	x	✓	✓	✓	x	x	✓	✓	✓	x

Table A2. The non-Boolean criteria mapping

Level criteria ESGA methods (L, M, H)		GRI G4	GRI Standards	Common Good Balance Sheet	B Impact Assessment	CDP	UN Global Compact	EFQM	Fair Trade Software Foundation	GDRC	Data Centre Assessment	ISO 14001	ISO 26000	Measurabl	S-CORE	SDG Compass	SMETA	STARS	UniSAF	World Fair Trade Organization	XES Social Balance	AA1000 Assurance Standard	TIESS
Name	**ID**																						
Popularity in the market	**C52**	H	H	H	H	H	H	H	H	M	H	H	M	H	M	H	H	H	M	H	H	H	M
Countries active	PV1	66	66	9	71	32	155	60	7	-	1	171	-	75	5	-	150	12	3	76	1	50	1
Members (x1000)	PV2	2.9	2.9	0.5	3.3	6.9	15	0.4	0.03	-	0.004	300	-	-	-	-	59.9	1	-	0.4	0.3	2	-
Google trends (12 month mean)	PV3	77.8	77.8	56	69.4	57	62.6	55.4	0	20.2	0	65	50	92.1	0	34.8	40.1	42.9	0	34.9	0	62.1	0
Twitter followers (x1000)	PV4	38.3	38.3	4.6	80	44.7	119.8	6.4	0	0	0	0	0	1.3	0	0.0	6.9	6.1	0	38	23.8	4.0	1.5
LinkedIn followers (x1000)	PV5	57	57	-	51	31	63	13	0.16	0.25	0	182	182	2.6	0	0	11.4	1.8	0	10.2	0	7.4	3
Facebook followers (x1000)	PV6	51	51	1.5	0.3	0.5	95.4	3.5	0.09	1.3	0	246.4	246.4	0.5	0	0	2	3.6	0	73	9.4	0	3
Network maturity	**C53**	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
Network founded	PV7	1997	1997	2010	2006	2002	2000	1989	2011	-	2019	-	-	-	-	-	2001	2005	-	1989	2002	1995	2013
Method developed	PV8	2013	2016	2010	2006	2002	2000	1992	2011	2000	2019	1996	2010	2013	2013	2015	2012	2011	2017	2013	2007	2008	2019
Multilingual documentation	PV9	✓	✓	✓	✓	✓	✓	✓	x	x	x	✓	✓	x	x	✓	✓	x	x	✓	✓	x	✓