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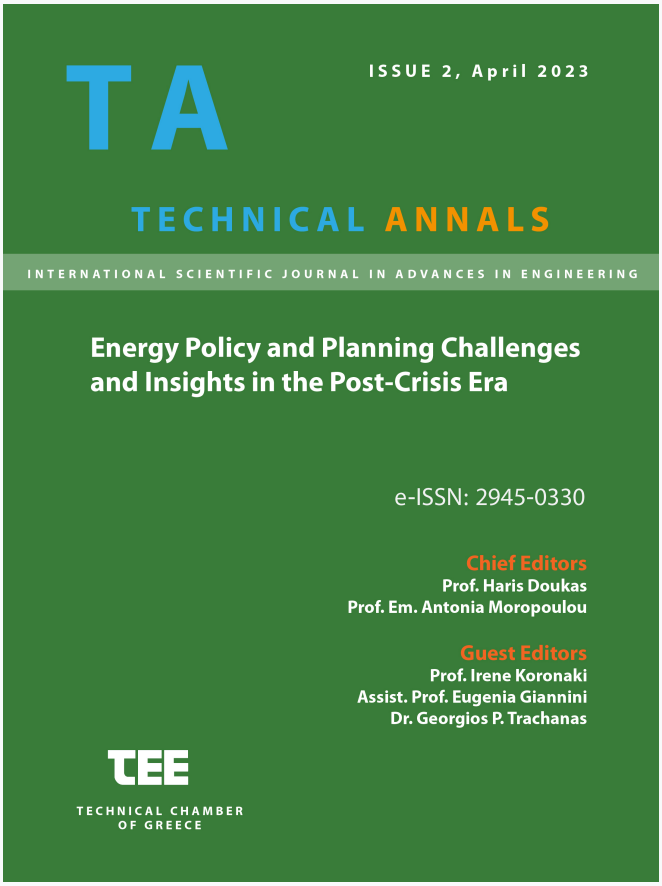

An ESG materiality methodology combining criterion level and sector-based approaches

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An ESG materiality methodology combining criterion level and sector-based approaches

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Abstract. As the Environmnetal, Social, and Governance (ESG) principles are rapidly becoming critical in the decision making process of investment undertaking, companies must deal with ESG reporting, either to fulfil obligatory requirements according to EU legislation, or to stay competitive and in line with the investing trends. In the market, several ESG rating methodologies exist consisting of numerous criteria and indicators that companies must consider in their reporting. Nevertheless, neither all ESG rating frameworks consider the same criteria, nor do all criteria have the same materiality weighting when estimating the final ESG rating. Thus, the establishment of a standardised and normalised ESG criteria materiality framework is considered crucial. This will enable the fine-tuning and calibration of the ESG evaluation, with materiality values that reflect accordingly the significance of the most important criteria. In addition, this methodology will enhance the comparability of the results of the different companies' evaluations while creating a harmonised framework. The present paper introduces an integrated methodology for the estimation of the ESG materiality factors by putting emphasis on the most frequent criteria of the main economic sectors. The methodology analyses data from several sources, including academic papers and methodologies, companies' reports and globally established rating frameworks. The proposed approach results in the estimation of the materiality values for each criterion of a specific ESG rating scorecard, as well as introduces an overview of the materiality issues for each economic sector.

Keywords: ESG, ESG materiality, performance measurement, risk management, sustainable finance,

1 Introduction

Investors, funds, and financial institutions are increasingly considering non-financial information to guide their investment decision-making [1]. Therefore, emphasis has been put on the Environmental, Social and Governance (ESG) performance of companies. Companies that demonstrate good performance in ESG-related matters and consistently disclose ESG information, showcase enhanced transparency and reap the

benefits of better access to funding as well as more favourable financing terms [2]. For that reason, many ESG methodologies have been developed by several reporting and consulting entities and the number of rating agencies that provide ESG information and assessments has grown significantly. Nevertheless, the lack of a concrete ESG framework creates discrepancies among the reporting standards while blurring the lines on the actual ESG performance of the companies under assessment [3].

In general, materiality refers to the relevance of the disclosure information for stakeholder analysis and decision making. The materiality concept of accounting is an accounting convention that refers the relative importance or significance of an item to an informed decision maker [4]. For instance, if a minor item has the impact of changing a profit figure into a loss figure, then it will be considered material regardless of how small the amount is. Similarly, if by including a transaction, a ratio that needs to comply with changes, it would be considered material [5].

Regarding sustainability, materiality refers to the level of importance that an entity gives to certain sustainability issues in terms of its investment strategy, its business model or its product development [6]. In the context of sustainability reporting, double materiality is gaining momentum since it reflects the essence of sustainable development and long-term value creation. Double materiality consists of the contexts of financial materiality and impact materiality affecting the firm's operational performance and financial health [7]. Financial materiality deals with information on economic value creation at the level of the reporting company for the benefit of investors or shareholders [8], whereas impact materiality focuses on information on the reporting company's impact on the economy, environment, and people for the benefit of multiple stakeholders [9].

Academic investigation of materiality reflects the diverse aspects of this important concept [10]. In literature, various materiality analyses have been performed, both at an academic level [1], [11-13] and in a business-oriented framework [14-16]. Materiality can affect the accuracy and inclusiveness of ESG scores and ratings [17], while enhancing the ambiguity around rating divergence among the different rating agencies and systems. When it comes to the final ESG reporting, not all firms are able to report the same criteria, nor do all criteria have the same materiality. Therefore, it becomes necessary to provide a framework that can determine the materiality of reported indicators for a company in a standardised manner.

Several materiality methodologies exist, mostly developed by consulting, and reporting companies, thoroughly introduced in the following section of the present paper. Alhtough, the scientific community has demonstrated interest for identifying, analysing and normalising existing materiality methodologies, while also attempts have been made to combine and explore new approaches. Busco et al. [18] realised a preliminary analysis of Sustainability Accounting Standards Board (SASB) reporting, while Madison and Schiehll [19] analysed the effect of financial materiality on ESG performance assessment. Garst et al. [20] focused their research on identifying ESG topics for sustainability reports, within the scope of materiality assessment. To the best of our knowledge, the number of scientific publications that introduce new approaches with regards to materiality assessment are limited. The methodology described in this paper introduces a holistic approach in materiality assessment, taking into account real data

from businesses in order to establish and fine-tune the methodology, while providing a normalised approach.
The methodology introduces a typology, introducing an integrated process for estimating the ESG Materiality of the most common criteria of the major economic sectors. The ESG materiality has been structured in two distinct levels: Economy and Industry-dependent and Performance and Operation Criteria-dependent. The typology identifies and analyses existing standards, in combination with data from businesses to estimate the Industry-dependent materiality weighting per E, S, G pillar. Each organisation needs to determine its material topics according to specific circumstances, such as its business model. Nevertheless, specific topics can be identified as likely material for organisations in a given sector. Data from various sources, including academic research, business reports, and similar approaches, are analysed to conclude a concrete process, producing normalised results. In order to test the methodology, an application has been realised in the hospitality sector.
Apart from this introductory section, the rest of the paper is organised as follows: Section 2 holds the analysis of the methodology, including tables listing the criteria and weight used. Section 3 describes the application of the methodology in the hospitality sector, while Section 4 holds the paper's Conclusions.

2 Methodology

The ESG materiality has been structured in two distinct levels: Economy and Industry dependent materiality and Performance and Operation Criteria dependent materiality. This categorization is necessary to ensure that the materiality values assigned to each criterion accurately reflect its significance in a specific economic sector. Economy and Industry dependent materiality considers factors such as the economic sector, geography, and industry-specific risks, which influence the materiality of ESG criteria. On the other hand, Performance and Operation criteria dependent materiality focuses on factors that relate to a company's performance and operations, such as emissions, waste management, and labor practices. By categorizing materiality into these two categories, the proposed methodology provides a more nuanced and accurate assessment of ESG performance, enhancing the comparability of results between different companies and sectors. Overall, this classification scheme ensures that the materiality values assigned to each criterion accurately reflect the significance of the most important criteria in a specific economic sector, leading to a more effective ESG evaluation. In Figure 1, the complex systemic interaction of ESG pillars, materiality criteria, business inputs and the respective financial impact is presented.

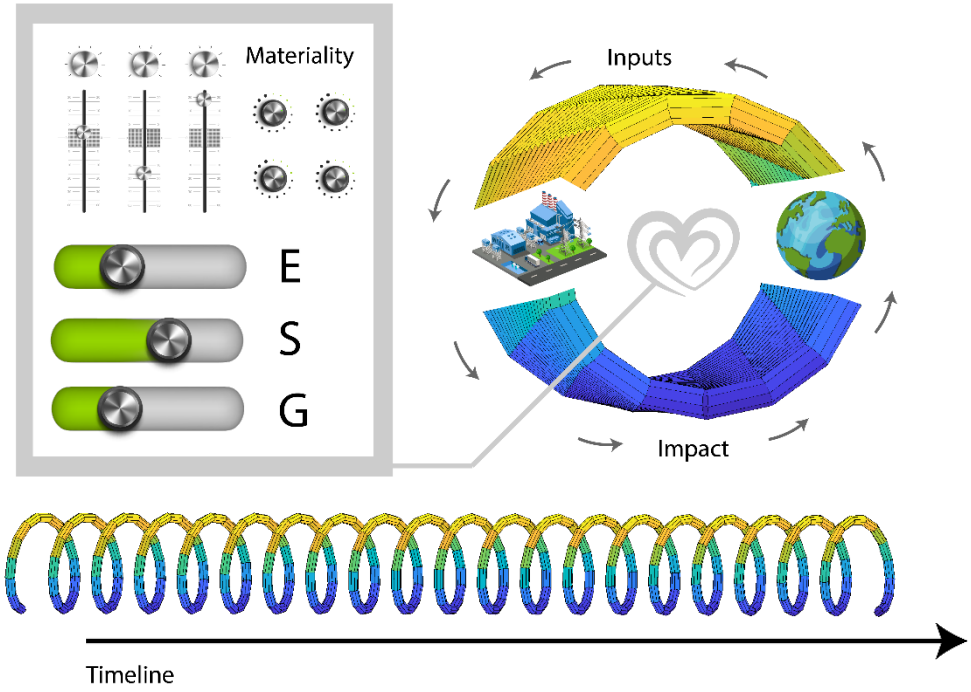

Fig. 1 Visualisation of the complex systemic interaction of ESG pillars, materiality criteria, business inputs and the respective financial impact.

2.1 Economy and industry dependent materiality

Materiality constitutes a key concept that helps companies to connect the dots between sustainability disclosure standards, stakeholders' expectations, and business strategy. The material sustainability issues that a company targets should tie back to the company's core, like its business model and purpose, and provide the initiatives to drive positive environmental change and organisational performance improvement. Mapping the material issues plays a crucial role both in the preparation of the disclosures and the verification by an auditor, since particular information is considered as material if it could influence the decision making of stakeholders in respect of the reporting company. Thus, each company should proceed with a materiality market screen that takes into account its specific circumstances, like geographic, cultural, and legal operating context; ownership structure; and the nature of its impacts while analysing industry benchmarks, peers, and leading sustainability standards, which will help provide an initial universe of materiality issues to select from.

Material topics in ESG vary from industry to industry depending on the specific risks and opportunities each sector has. For example, the Information and Communication Technologies (ICT) sector considers as material issue the cybersecurity vulnerabilities while the healthcare sector might have material issues concerning disparities in patient care and medication distribution. Thus, a one-size-fits-all approach will dilute impact

since the material indicators of each company's sector and specific context needs adjustment stemming from a bottom-up analysis.

Moreover, materiality analysis heavily relies on the competitive landscape since investors and other stakeholders shape the needs and expectations of each sector to accomplish financial stability. Therefore, it is crucial that each entity understands what its peers are focusing on when it comes to ESG and sustainability, mapping successfully its materiality issues. Companies that fully consider materiality create stronger, more resilient, and thoughtful businesses that can outperform their competitors with regards to addressing ESG impacts, risks, and opportunities and better inform all industry players, like investors and regulators.

An initial analysis of the various industries (sectors) has been realised to extract materiality weightings for each sector. The analysis consisted of a rigorous literature review, primarily focusing on similar methodologies and reports. The review included the SASB sustainability standards and materiality analysis [16], the ESG Risk Atlas of Standard and Poor's (S&P) Global Ratings [21], Morgan Stanley Capital International (MSCI) ESG Ratings [14] and Global Reporting Initiative (GRI) Standards [22]. It should be highlighted that a correspondence between the industry classification used by the MSCI ESG Ratings, the Global Industry Classification Standard System (GICS), and the industry classification proposed by the SASB's financial materiality framework, the Sustainable Industry Classification System (SICS), for each sub-industry was established to be able to correlate the materiality factors per industry [23].

A first issue that had to be clarified concerns the degree to which each one of the sustainability dimensions (Environment, Society and Governance) affects the final evaluation score according to each sector's sustainability impacts. To be more precise, each dimension affects the final score in a different weight according to the degree to which a company's enterprise value is exposed to its material issues. The results of thorough research showed that Governance issues are significant material for all entities regardless of their industry and scope of work. This can be attributed to the fact that a successful ESG strategy has as a starting point a strong Governance structure and the right mechanisms to promote a clear strategy, and an effective corporate landscape. A robust Governance structure drives the success of ESG programs, affects investor confidence and influences workplace culture.

Statistical analysis of ESG research ratings and data led to the development of a set of materiality weightings for each industry. The values of the Governance materiality weightings range from 29% to 45% according to each industry's specifications. The total sum of the materiality factors of all sustainability dimensions per industry is equal to 100%.

The results of the analysis are summarised in Table 1, while in Figure 2, the relative position on the ESG spectrum of the industry-dependent materiality vectors of 16 industries is presented.

Table 1 Industry-dependent materiality weighting per E, S, G pillar.

Industry No.	E	S	G
Agriculture, Forestry, Fishing, and Mining	40%	29%	31%
Mining and Quarrying	40%	29%	31%
Manufacturing	45%	22%	33%
Energy (Production, Distribution, Trade)	42%	29%	29%
Water and Waste Management	45%	25%	30%
Infrastructure and Construction	38%	25%	37%
Wholesale and Retail Trade	25%	36%	39%
Transportation and Storage	40%	31%	29%
Shipping	40%	31%	29%
ICT	30%	35%	35%
Financial and Insurance Activities	17%	38%	45%
Services	32%	29%	39%
Hotel and Lodging	32%	30%	38%
Public Administration	25%	40%	35%
Health	22%	41%	37%
Real Estate and Real Estate Management	31%	30%	39%

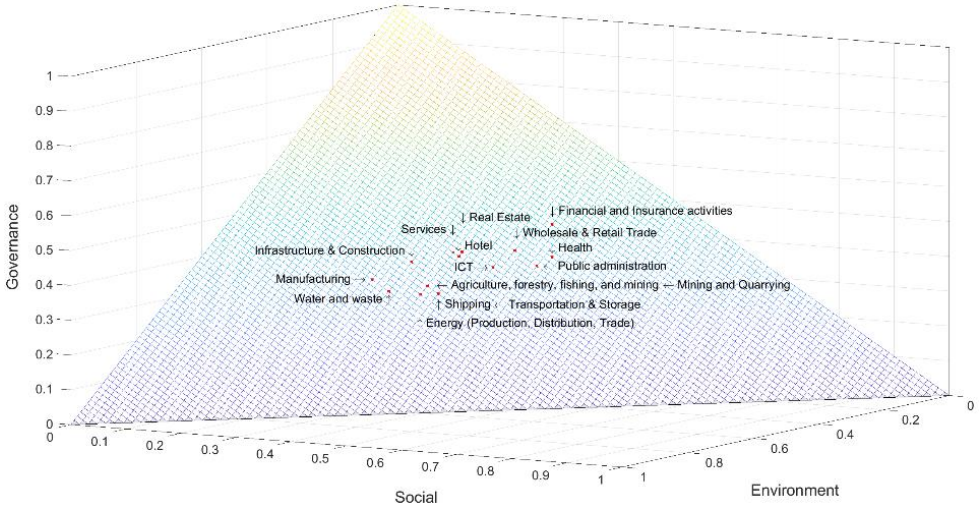

Fig. 2 The relative position of the industry-dependent materiality vectors (16 industries) on the ESG plane.

2.2 Performance and operation criteria dependent materiality

In this section, a criteria-level materiality analysis is performed to extract a materiality index for the specific criteria that contribute to a company's overall ESG rating. Depending on the sustainability impacts of each industry, a specific set of criteria can be developed to depict the most common material issues of the industry. The set of criteria

for each industry is derived from an extensive research analysis of publicly available information on companies' ESG scores, as well as a literature review on key sustainability issues per sector. These sets of criteria form an ESG rating framework.
The materiality values of this analysis emerge from actual reports and real ESG data to reflect the actual significance of each criterion and depict the specific circumstances that apply in each sector.

Intensity Values

The first step of defining the criteria-level materiality is an extensive literature review to assign weights for each applicable criterion. These weights are characterised as "Intensity Values" and reflect the importance of each criterion for a specific industry. The literature review performed includes the assessment of academic publications, existing companies' ESG reports, international standards and stakeholders' consultation, so as to define the impact of each criterion on the economy, society and the environment.
The process is performed in two distinct phases. The first phase consists of a separate analysis of the criteria materiality for each reported company of a specific sector. Then, the individual results are aggregated to estimate the materiality of each criterion for the specific sector.

Phase 1– Individual results for each company

An important step of this stage is to create a system of weighting factors to be used when indexing the respective ESG reports on a case-to-case basis. This step results in the creation of materiality matrices. By this means, three distinct levels of materiality were defined with specific factors, called intensity values, to be quantified as follows:

- Low materiality → α
- Medium materiality → β
- High materiality → γ

Example materiality matrices are shown in Figure 3, where the low, medium and high materiality zones can be seen. It should be noted that in Figure 3 (a) the isocurves that demonstrate the same materialisation level appear to be concave, in Figure 3 (b) linear and in Figure 3 (c) convex, indicating the subjective nature of the materiality analysis. Given that a function $f(x)$ is convex on an interval $[a, b]$ if for any two points x_1 and x_2 in $[a, b]$ and any λ where $0 < \lambda < 1$, $f[\lambda x_1 + (1-\lambda)x_2] \leq \lambda f(x_1) + (1-\lambda)f(x_2)$ it can be directly extracted that the mixtures of impact on business and stakeholder interest lead to higher materiality level. Although the latter seems the rational approach, in practice it is common to adopt specific thresholds on each dimension, splitting the plane into quadrants and defining inverted L-shape concave isocurves.
Figure 4 constitutes a sample mathematical extension of the materiality matrix, that utilises functions of two variables for assigning materiality values.

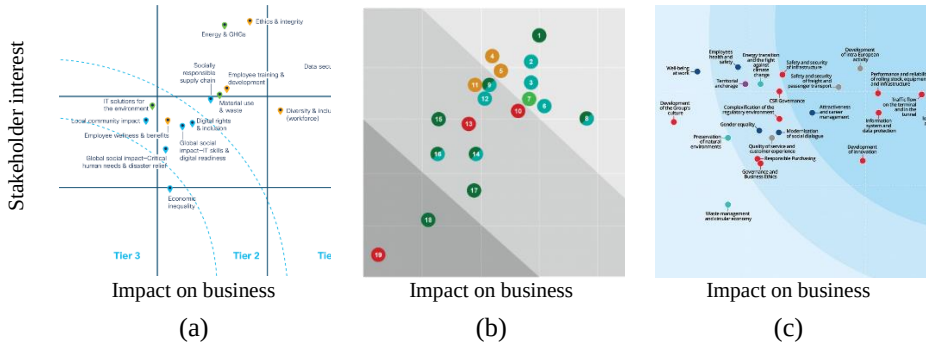

Fig. 3 Materiality matrix examples of different materiality isocurves defining the low, medium and high materiality zones. (a) Concave [24], (b) Linear [25], (c) Convex [26].

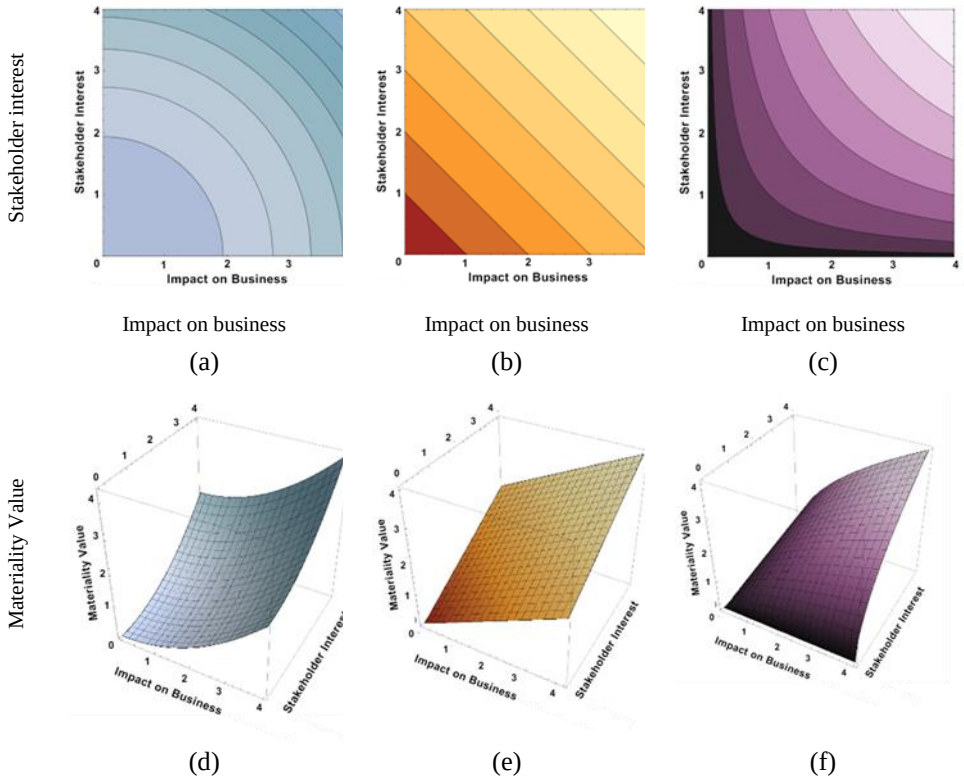

Fig. 4 Contour plots resampling materiality matrices and materiality zones. (a) Concave, (b) Linear, (c) Convex and the corresponding functions (d), (e), (f) that assign a materiality value.

Alternatively, in an effort of barycentric interpolation [27], the suggested methodology proceeds with classification according to the materiality zones (presented in Figure 5),

by assigning the distinct values α, β and γ to each indicator according to the zone it belongs.

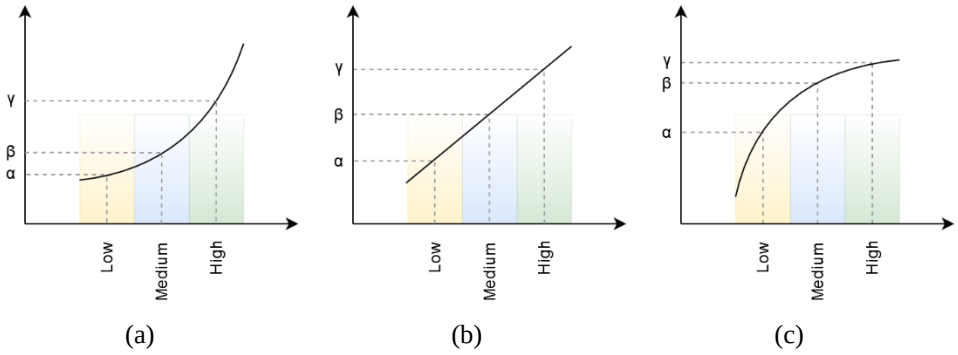

Fig. 5 Value assignment process according to materiality zones. Example cases for (a) Concave, (b) Linear, (c) Convex mapping approaches.

An *intensity value* is assigned for all the criteria reported by each company, with the corresponding *materiality values* calculated for each criterion. The calculation procedure is described below:

i. Calculation of the Pillar Gravities

The Pillar Gravities refer to each ESG pillar (E, S & G) and consist of the Intensity Values' total sum for the reported company's indicators (i), e.g. Plastic Waste, GHGs emissions etc. The pillar gravities are used later for the proper normalisation of the materiality values.

$$PG_x = \sum_{i \in \mathcal{H}_x} IV_{x_i} \tag{1}$$

where $x \in \{E, S, G\}$ is the index denoting the corresponding ESG pillar, PG_x is the Pillar Gravity for each ESG pill*ar*, $\mathcal{H}_x$ is the set containing all the criteria of pillar x reported by the company, and IV_{x_i} is the Intensity Value of the criterion i of pillar x.

ii. Calculation of the Materiality Values

The materiality value of each criterion i is calculated as the ratio of its Intensity Value over the Pillar Gravity according to the pillar that the specific criterion is included.

$$m_{x_i} = \frac{IV_{x_i}}{PG_x} \tag{2}$$

The materiality values of each ESG Pillar should sum to 1:

$$\sum_{i \in \mathcal{H}_x} m_{x_i} = 1\,, \quad \forall x \in \{E, S, G\} \tag{3}$$

Phase 2 – Aggregated sector-based results

In the ESG rating framework under consideration, each industry has a set of criteria that relate to material issues concerning the three pillars of sustainability (E, S, G). To assign materiality Intensity Values to the individual criteria of pillar $x \in \{E, S, G\}$ that compose the scorecard of each industry, it is necessary to aggregate the results of the research analysis mentioned above regarding the ESG materiality analysis of the individual companies operating in the industry. Therefore, an Intensity Value is attributed to each criterion that has been derived as the average of the IV_{x_i} of the corresponding criteria of the companies that have been considered as a sample.
Due to slight divergences among the companies' criteria, further analysis took place to compare the content of each criterion (scope, included actions, measures etc.) so that a correct matching is accomplished among the criteria of the companies, their respective intensity values and the criteria of the ESG framework under consideration.
Let $j \in \mathbb{C}$ denote that the company is part of the sample set of companies considered in the analysis of the sector. The average Intensity Values $\overline{IV}_{x_i}$ is then calculated for each of the criteria reported by the various companies.

$$\overline{IV}_{x_i} = \frac{1}{N} \cdot \sum_{j=1}^{N} IV_{x_i}^{j} \tag{4}$$

where N is the number of companies, i.e. the cardinality of $\mathbb{C}$ and $IV_{x_i}^{j}$ stands for the Intensity Value of the criterion i of pillar x for company j.
Then, similarly to the 1st phase, the average pillar gravities for each one of the 3 ESG pillars are calculated as follows:

$$\overline{PG}_x = \sum_{i \in \mathcal{H}_x} \overline{IV}_{x_i} \tag{5}$$

Finally, the average sector materiality $\widetilde{m}_{x_i}$ of each criterion i for the pillars x is normalised, based on the calculated pillar gravities:

$$\widetilde{m}_{x_i} = \frac{\overline{IV}_{x_i}}{\overline{PG}_x} \tag{6}$$

The results of the calculated pillar gravities are presented in Figure 6.

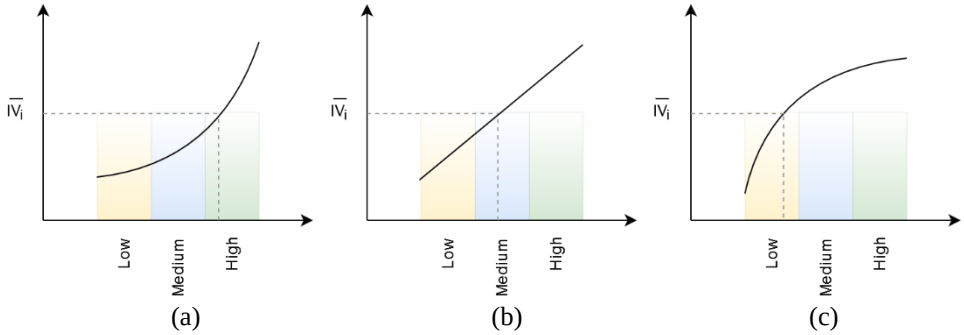

Fig. 6 Reverse engineering assignment process for retrieving the materiality zone for sector-based average intensity values. Example cases for (a) Concave, (b) Linear, (c) Convex mapping approaches.

3 Application in the hospitality industry

The proposed methodology has been applied to the Hotel and Lodging industry [28-31], exploiting data from 6 companies (hotels) that have disclosed ESG information in their sustainability reports.

The ESG scorecard of this specific industry consists of 39 criteria across the 3 sustainability pillars. The intensity values and materiality factors have been calculated based on the methodology analysed in Section 2. A set of indicative criteria are listed in Table 1, while the calculated values regarding the reported Scorecard, the Intensity values and Materiality factors are described in Table 2.

Only a few indicators are included in this paper in order to introduce our approach on how it can be adaptive to different economic industries.

Table 2: Indicative indicators used in the methodological application

No	Code	Pillar	Title
1	CE-1	Environmental	GHG Emissions
2	CE-2	Environmental	Energy Management
3	CE-3	Environmental	Water management
4	CE-4	Environmental	Waste management & Pollution
…	…	…	…
9	HTE-3	Environmental	Biodiversity
13	CS-1	Social	Human Resources
14	CS-2	Social	Health & Safety
15	CS-3	Social	Employee engagement
16	CS-4	Social	Diversity & Inclusion
…	…	…	…
24	HTS - 2	Social	Customer safety
25	HTS - 3	Social	Customer satisfaction
26	CG-1	Governance	Board Diversity & Composition
27	CG-2	Governance	Code of Conduct
28	CG-3	Governance	Ethics (Bribery & Corruption)
…	…	…	…
38	HTG - 2	Governance	Green measures
39	HTG - 3	Governance	Supply chain from local communities

The identified criteria have been mapped to match the respective criteria identified as material issues by the companies in their sustainability reports. Each company reports the criteria using different typologies; hence their content remains the same when investigating further their information regarding their scope, actions taken and/or measures for improvement. Due to this, a thorough mapping took place to set in tune the criteria and correlate the respective data to detect possible overlaps. This procedure is tailored to each case and application, therefore is not possible to create a uniform, automated process to map the criteria of the various reports and perform the process seamlessly.

The intensity values and materiality factors calculated are listed in Table 3.

Table 3: Indicative intensity values and materiality factors

No	Code	Title	Pillar	Average materiality intensity	Average intensity description	Normalised Materiality
1	CE-1	GHG Emissions	Environmental	3.0	High	0.10
2	CE-2	Energy Management	Environmental	2.8	High	0.09
3	CE-3	Water management	Environmental	2.0	Medium	0.07
4	CE-4	Waste Management and Pollution	Environmental	2.3	Medium	0.08
…	…	…	…	…	…	…
9	HTE-3	Biodiversity	Environmental	1.7	Low	0.05
…	…	…	…	…	…	…
13	CS-1	Human Resources	Social	1.0	Low	0.03
14	CS-2	Health and Safety	Social	3.6	High	0.104
15	CS-3	Employee Engagement	Social	3.3	High	0.096
16	CS-4	Diversity and Inclusion	Social	3.3	High	0.096
…	…	…	…	…	…	…
24	HTS - 2	Customer Safety	Social	3.5	High	0.101
25	HTS - 3	Customer Satisfaction	Social	2.7	Medium	0.077
26	CG-1	Board Diversity and Composition	Governance	4.0	High	0.118
27	CG-2	Code of Conduct	Governance	2.0	Medium	0.059
28	CG-3	Ethics (Bribery and Corruption)	Governance	4.0	High	0.118
…	…	…	…	…	…	…
38	HTG - 2	Green Measures	Governance	2.0	Medium	0.059
39	HTG - 3	Supply Chain from Local Communities	Governance	4.0	High	0.118

Table 3 provides information on the calculated materiality intensity, average intensity description and normalized materiality values for various sustainability criteria across the three pillars of ESG (Environmental, Social, Governance) for the Hotel and Lodging industry. The average materiality intensity is a measure of the importance of the sustainability criteria for the industry, with higher values indicating more significant criteria. For instance, GHG Emissions and Energy Management are scored as high priority criteria, while Biodiversity is deemed to be low priority. The average intensity description shows the distinct levels of materiality resulted from the reverse engineering assignment process that is used for retrieving the materiality zone given the sector-

based average intensity values. The normalized materiality values are calculated by dividing the average materiality intensity by the sum of all the materiality intensities. They provide a way to compare the relative importance of each criterion. For example, Health and Safety and Supply Chain from Local Communities are deemed to be the material criteria with the highest normalized materiality values of 0.104 and 0.118, respectively. Overall, Table 3 provides a comprehensive view of the sustainability criteria, their importance and the level of performance reported by the hotels, which can help stakeholders identify areas for improvement and monitor progress towards sustainable development goals.

4 Conclusions

The proposed methodology establishes a framework to fine-tune and enhance ESG rating procedures by introducing the materiality context to highlight the significance of the various criteria that comprise an ESG rating. The methodology exploits real data, as provided by business actors, fine-tuning them with the results from other methodologies and reports. By focusing on materiality analysis in the context of ESG consideration, the importance of materiality in connecting sustainability disclosure standards, stakeholder expectations, and business strategy was found inevitable. The analysis involved the identification of the material sustainability issues that are specific to a company's industry and context, and the mapping of these issues to the company's core business model and purpose. The need for a bottom-up analysis of materiality issues, taking into account the unique circumstances of each company, complemented the literature review of existing sustainability standards, such as SASB and GRI, and ESG ratings, such as MSCI, to identify the materiality factors per industry.

To test and fine-tune the methodology, as well as to provide preliminary insights, an application of the methodology has been realised, focused on the hospitality industry. Governance issues are found to be significantly material for all entities, and materiality weightings are established for each industry based on statistical analysis of ESG research ratings and data. The performed criteria-level materiality analysis enabled the development of a set of criteria for each industry that reflect the most common material issues. These criteria are derived from an extensive research analysis of publicly available information on companies' ESG scores and a literature review on key sustainability issues per sector. Ultimately, the methodology aims to help companies identify the material sustainability issues that are most relevant to their industry and context and develop strategies to address them effectively.

The suggested approach can be perceived as an additional instrument and effort in the normalisation and standardisation of the various existing ESG methodologies that aim to support decision makers and business actors in identifying material topics and prioritising subjects of interest. The produced materiality matrices could be exploited to enhance and calibrate existing ESG evaluation frameworks. The methodology outlined aims to provide a systematic approach for companies to identify and prioritize the material sustainability issues that are most relevant to their business.

The key outcomes of this methodology are the identification of materiality issues through a market screen that takes into account the specific circumstances of each company, including its geographic, cultural, and legal operating context, as well as an analysis of industry benchmarks, peers, and leading sustainability standards. Materiality issues are also identified through a criteria-level materiality analysis that assigns weights to each applicable criterion for a specific industry. This process enables companies to understand the specific sustainability risks and opportunities they face and develop strategies to address them effectively. Ultimately, the goal of this methodology is to help companies create stronger, more resilient, and thoughtful businesses that can outperform their competitors with regards to addressing ESG impacts, risks, and opportunities and better inform all industry players, like investors and regulators.

Fuzzy inputs in the model can lead to vagueness in the results and can affect the accuracy of the materiality index. However, the methodology attempts to address this issue by using a comprehensive literature review, stakeholder consultation, and real ESG data to assign weights to each criterion. This helps to mitigate the impact of fuzzy inputs on the overall results. The methodology is sensitive to biased intensity values used for each criterion, as these values directly affect the materiality index. Biased intensity values can lead to incorrect prioritization of material issues and undermine the effectiveness of sustainability initiatives. To minimize this risk, the methodology employs a rigorous and transparent process for assigning intensity values, including extensive research and consultation with stakeholders. Additionally, the methodology involves aggregating individual results from multiple companies to estimate the materiality of each criterion for the specific sector, which helps to reduce the impact of any biased intensity values. Overall, the methodology seeks to ensure that the intensity values used are as accurate and unbiased as possible, to ensure that the materiality index reflects the true sustainability impacts of each industry.

In the context of this methodology, robustness refers to the ability of the model to produce consistent and reliable results even when faced with different input values or data sources. A robust methodology should be able to produce similar results even if the data used in the analysis is incomplete or uncertain. The approach outlined in the paper appears to be robust to a certain extent. For example, it uses a combination of different data sources and analysis techniques to derive the materiality weights for each industry, which helps to reduce the impact of bias in the data. Additionally, a sensitivity analysis could test the impact of different input values on the final results, which would help to identify the factors that are most sensitive to change and adjust the model accordingly. However, there are also some limitations to the methodology's robustness. For example, the intensity values used to weight each criterion are based in certain cases on experts' judgment and may be subject to bias or uncertainty. Additionally, the methodology relies heavily on publicly available data, which may be incomplete or inconsistent. As a result, the authors acknowledge that the results of the analysis should be interpreted with caution, and that further research is needed to validate and refine the methodology. To address the issue of fuzzy inputs, the methodology could consider the use of alternative methods that can handle uncertainty and imprecision, such as fuzzy logic, fuzzy sets, or probabilistic methods. These methods can provide a more accurate representation of the uncertainty associated with the intensity values used in the analysis.

Regarding the issue of biased intensity values, one possible solution is to increase the transparency and inclusiveness of the materiality analysis process. This could involve wider stakeholder consultation and engagement, which could help to identify and correct for potential biases in the intensity values used. Additionally, sensitivity analysis could be performed to assess the robustness of the results to variations in the intensity values.

As for next steps, further research could be conducted to test the sensitivity of the methodology to different input values, such as the weights assigned to each dimension of sustainability (environment, society, governance) or the criteria-level materiality weights. The methodology could also be applied to different industries or contexts to assess its generalizability and identify any necessary adaptations. Finally, ongoing monitoring and evaluation could be put in place to track the performance of the methodology and ensure its continued effectiveness and relevance over time.

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