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A New Application with Conditional Risk Matrix and Decision Rules: An Assessment of the Sustainability and Performance Electric Power Company

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Abstract. The 2030 Agenda for Sustainable Development of the United Nations General Assembly focuses on economic development, poverty cessation, environmental sustainability, and good governance at all levels, including peace and safety. For electric power distribution concessionary companies in Brazil, it is necessary to evaluate their sustainability and performance according to the parameters laid by the National Electric Power Agency (ANEEL). For that purpose, sixty-two indicators were assembled that were directly and indirectly associated with sustainability for 38 companies in the period–2013-2021. This study proposes a new application with a conditional risk matrix and decision rules aimed at the integrated assessment of sustainability and performance of electric power companies using the conditional probability of indicators in the ascent or descent of the companies' classification. A set of "*if..., then...*" decision rules were inferred by the algorithm VC-DomLEM using concepts from the Rough Sets Theory and the Dominance principle, Dominance-based Rough Set Approach (DRSA).

Keywords: Sustainability, Performance, Energy companies, Conditional risk matrix, Rough Sets Theory, Dominance principle.

1. Introduction

According to the World Commission on Environment and Development [51], sustainable development is development that meets current necessities without jeopardizing future generations' ability to tend to their own necessities. Sustainable development is a process of

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change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional changes are in harmony.

According to [44], sustainability is based on the correlation of economic, social, and environmental dimensions and is internationally known as the Triple Bottom Line (TBL) of a business's sustainability. The TBL concept questions and ponders the companies' necessity to base their strategic decisions on this tripod, in which they ought to maintain the economic sustainability of their business through the management of lucrative and value-generating companies, as well as social sustainability by stimulating activities connected to education, culture, leisure, well-being, and social justice of the community in which the company is located. This is accomplished while maintaining environmental care, such as recycling and preservation programs.

The interrelationships become necessary for understanding that companies do not exist in a vacuum: businesses can only prosper if society prospers, which in turn requires that the life support systems of Earth be safeguarded. With time and increased uncertainty, "focusing on the value of the system will gradually become more critical for successful business" [19].

In September 2015, during the United Nations' General Assembly, 193 Member States adopted the 2030 Agenda for Sustainable Development after a global participative process involving governments, civil society, the private sector, and research institutions. Agenda 2030 encompasses economic development, elimination of poverty, misery, and hunger; social inclusion; environmental sustainability; and good governance at all levels, including peace and safety. Commitments are present in 17 Sustainable Development Goals (SDG) and 169 targets of global action to be reached by 2030 [36, 37].

Consequently, the National Electric Power Agency (ANEEL), the regulatory agency of the Brazilian Government, through Normative Resolution no. 605/2014, approved the Accounting Manual of the Electricity Sector (MCSE), in which it was established, among other goals, contributing to the optimization of environmental performance through an explanation of costs derived from the implementation of the Environment National Policy, necessary for the environmental and sustainable conformity of the concessions attributed by the Federal Union, aiming to elaborate the Socio-environmental and Economic-Financial Responsibility Report (RSA) [4, 5]. The MCSE connects over two hundred qualitative indicators related to general dimensions, corporate governance, economic-financial, social, sectorial, and environmental for authorized companies (generation, transmission, and electric power distribution) mandated and/or suggested by ANEEL beyond specific indicators of environmental performance for companies of generation, transmission, and/or distribution [5]. MCSE also mentions qualitative indicators such as corporate governance [4, 5].

Following a systematic literature review, we identified the absence of an integrated assessment of the sustainability and performance of electric power distribution companies associated with a conditional risk matrix. The current study proposes a new application with a conditional risk matrix and decision rules aimed at the integrated assessment of sustainability and performance of electric power companies using the conditional probability of indicators in the ascent or descent of the companies' classification. A set of "*if..., then...*" decision rules were inferred by the algorithm VC-DomLEM [12, 13] using concepts from the Rough Sets Theory (RST) and the Dominance principle, Dominance-based Rough Set Approach (DRSA).

The current study is divided into the following sections: 1) Introduction, 2) Systematic literature review, 3), Rough Sets Theory and Dominance principle, 4), Analysis of electric power distribution companies, and 5) Conclusions and future studies.

2. Systematic literature review

For the systematic literature review, ProKnow-C (Knowledge Development Process – Constructivist) [2, 20] was used. Table 1, consisting of eight phases and sub-phases, shows the procedures used in the method ProKnow-C, aiming to build a final bibliographic portfolio (BP5) through intermediate bibliographic portfolios (BP, 0 to 4).

Initially, the following research questions were posed: "Which studies assess or model sustainability and performance for energy or electric power companies?". The following research databases were used: Scopus, Web of Science, Compendex, IEEE Xplore, Emerald Insight, SciELO Citation Index, Academic Search Premier (EBSCO), ACM Digital Library, Digital Library of Theses and Dissertations, Catalog of Theses and Dissertations (Coordination for the Improvement of Higher Education Personnel, Brazil Government), and the Wiley Online Library. The following research string was used: *("sustainability" OR "sustainable") AND "performance" AND ("indicator" OR "indice" OR "index" OR "measurement" OR "assessment" OR "evaluation" OR "appraisal" OR "metric" OR "model" OR "framework" OR "template" OR "example") AND ("energy companies" OR "electricity companies" OR "energy firms" OR "electricity firms" OR "energy industry" OR "power industry" OR "energy sector" OR "electricity sector" OR "electric sector" OR "energy enterprises")*. This study was conducted from January/2000 to August/2023.

In Phase 4, a total of 1,218 (a thousand, two-hundred eighteen) studies were taken into account for the initial bibliographic portfolio (BP0). As the subsequent phases were performed, verifying if the titles and abstracts of the studies adhered to the research, excluding repeated studies, and final verification to check if the remaining studies were adherent to the research resulted in 65 (sixty-five) studies for the final bibliographic portfolio (BP5), Phase 8. Next, based on BP5, studies that had a significant relation to the term "risk" were searched. The search yielded 8 (eight) studies, as shown in Table 2. It is important to note that, out of these eight studies, none mentions the "risk matrix."

Table 1. Systematic literature review. Source: Authors; adapted from [2, 20].

PHASE 1	PHASE 2	PHASE 3	PHASE 4	PHASE 5	PHASE 6	PHASE 7	PHASE 8
Defining keywords for the research	Defining the research foundations aligned with the research theme	Researching through the title, abstract, and keywords of the publications on each base	Accounting for the number of publications and base aiming to set up the initial bibliographic portfolio (BP0)	Raising the number of citations from BP1 on Google Scholar	Selecting most cited publications (up to 85% of the total of citations)	Selecting less cited publications (15% of the rest of the total of citations)	Gathering BP2, BP3 and BP4 publications
Creating the boolean expression ("and"; "or")	Defining research filters (time period, subject, publication type, etc.)	Checking if the searched keywords are adherent to the publications' keywords	Selecting publications adherent to the research (reading the title); excluding repeated publications (BP1)	Ranking publications in descending order of citations	Selecting publications adherent to the research (reading the abstract) (BP2)	Selecting publications in the last 2 years adherent to the research (reading the abstract) (BP3); Selecting the remaining publications that have authors on BP2 and are adherent to the research (reading the abstract) (BP4)	Selecting publications that adhere to the research (integral reading) in order to create the final bibliographic portfolio (BP5)

Table 2. Systematic literature review, final bibliographic portfolio BP5, searched by "risk". Source: Authors.

Author(s)	Study	Relevant aspect(s) of risk
Adamkaite *et al.* (2022) [1]	The impact of social responsibility on corporate financial performance in the energy sector: Evidence from Lithuania	- The most used indicator to measure risk is leveraging, and it reflects the management's tolerance to risk, which influences its attitudes toward social performance. It is measured by the relation between the total debt and the assets.
Ahmad *et al.* (2021) [3]	Artificial intelligence in sustainable energy industry: Status Quo, challenges and opportunities	- Systems guided by artificial intelligence in the energy industry need qualified employees to develop risk management strategies when facing enormous amounts of data, predictive modeling included; - It can include a wide range of risks: energy stealing, the introduction of false information, malware attacks, internal attacks, etc.
Colla *et al.* (2020) [14]	A critical review of competitiveness indicators for energy projects	- Necessity of identifying additional indicators in order to capture risks and opportunities in energy projects; - The relevant indicators include social ones, such as job creation (direct and indirect), impacts on human health, safety risks, and social acceptability; - Other risks: financial, associated with investments in the project; construction, operation, fuel supply, safety, electric power supply, production, etc.
Dong *et al.* (2023) [16]	A Sustainable Development Evaluation Framework for Chinese Electricity Enterprises Based on SDG and ESG Coupling	- The evaluation's results show that the themes with the highest scores were environmental risks, shareholder structure and other managerial operations, and stakeholder relationships.
Gardazi *et al.* (2020) [21]	Board of Directors Attributes and Sustainability Performance in the Energy Industry	- The Board of Directors plays an essential role in defining the strategies and policies to reduce social and environmental risks.
Milojevic *et al.* (2020) [34]	Impact of Non-Financial Factors on the Effectiveness of Audits in Energy Companies	- Audit to assess the material distortion risks of financial demonstrations due to error or fraud and the implementation of procedures to mitigate risks.

Table 2 (cont.). Systematic literature review, final bibliographic portfolio BP5, searched by "risk". Source: Authors.

Author(s)	Study	Relevant aspect(s) of risk
Shahbaz *et al.* (2020) [48]	Board attributes, CSR engagement, and corporate performance: What is the nexus in the energy sector?	- The ESG (*Environmental, Social, Governance*) indicators can turn a better understanding of the opportunities and risks associated with potential Investments of a company easier; - The Committee of Social Responsibility (CSR) can play a core and crucial role in aligning the CSR and the risk management policies in energy companies.
Zhou *et al.* (2019) [53]	Balanced Scorecard-Based Evaluation of Sustainable Energy Investment Projects with IT2 Fuzzy Hybrid Decision-Making Approach	- Market Risk: the possibility of loss in companies due to price changes in the market caused by the volatility of exchange rates or interest rates.

Furthermore, related to the term "risk," there is an example of Rough Sets application in the analysis of the financial risk of countries: [24]; sovereign rating analysis of countries through Dominance-based Rough Set Approach: [15]; application of Fuzzy-Rough Sets for risk analysis in energy projects: [49]; application of Variable Precision Dominance-based Rough Set Approach (VP-DRSA) and Variable Consistency DRSA (VC-DRSA) in risk analysis in Machine Learning: [31]; the use of Fuzzy-Rough Sets in the risk assessment in incineration plans of energy residues through public-private partnership: [33].

Therefore, the current study proposes a new application with a conditional risk matrix and decision rules aimed at the integrated assessment of the sustainability and performance of electric power companies by analyzing the conditional probability of indicators in the ascent or descent of a company's classification. The conditional risk matrix has decision rules inferred by the VC-DomLEM algorithm as a basis, using concepts from the Dominance-based Rough Set Approach (DRSA).

3. Rough Sets Theory and Dominance principle

According to [38, 39, 42, 43, 50], Rough Sets Theory (RST) originated with Zdzislaw Pawlak at the beginning of the 80s as a mathematical tool for the treatment of imprecision and uncertainty of data. The approach provided by the RST is of fundamental importance for Artificial Intelligence (AI) and cognitive sciences, especially in areas such as Machine Learning, knowledge acquisition, decision-making analysis, knowledge discovery in databases, specialist systems, decision-making support systems, inductive thinking, and pattern recognition. RST does not compete with Fuzzy Logic [18], which is frequently compared, but complements it. However, these theories are independent approaches to imperfect knowledge. One of RST's main advantages of RST is that it does not require preliminary or additional information about data, such as the probability distribution or pertinence level in fuzzy set theory.

As a fundamental concept, RST has an indiscernibility relation, that is, the relation that identifies objects with the same property. Therefore, objects that have the same properties are "indiscernible" and, consequently, are treated as identical or similar ("granules"). These granules are known as "elementary sets" and constitute "concepts" of knowledge about something of interest [40]. Granularity can be the origin of inconsistencies in decisions, given the ambiguity in explaining and prescribing based on inconsistent information [43].

An Information System is conceptualized as K = (U, A), where U is a finite and non-empty set of objects; A is a finite and non-empty set of attributes, such that a: U → V_a for every $a \in$ A, V_a is the value set that can be attributed to attribute a. In a complementary way, given an information system (U, A) and for any B $\subseteq$ A, an indiscernibility relation (equivalence or classification, indistinctly) R_B is defined as [46], Equation (1):

$$R_B(x,y) = \{(x,y) \in U^2 | \forall a \in B, a(x) = a(y)\} \quad (1)$$

If $(x,y) \in R_B(x,y)$, then x and y have the same values for attributes in B. According to [39], it is not always possible to express exactly a set of objects with the available knowledge. Therefore, it becomes possible to express a set of objects using two other subsets: the lower approximation ($\underline{R}$) and the upper approximation ($\overline{R}$), given X $\subseteq$ U and an equivalency relation R, as shown in Equation (2):

$$\underline{R}X = \cup \{Y \in U|R: Y \subseteq X\}; \overline{R}X = \cup \{Y \in U|R: Y \cap X \neq \emptyset\} \quad (2),$$

in which $\underline{R}X$ is the subset of elements from U that certainly can be categorized as elements from X; $\overline{R}X$ is the subset of elements from U that possibly can be categorized as elements from X. Therefore, a set is "roughly" related to R if and only if $\underline{R}X \neq \overline{R}X$.

According to [39], from the concept of Information System (K = (U, A)), the concept of a Decision Table can be obtained: when A is formed by two subsets, C and D, condition and decision attributes, respectively, and (C, D $\subset$ A); or, T = (U, A, C, D). The equivalency classes of relations R_C and R_D are known as the condition and decision classes, respectively. For each $x \in$ U, a function d_x: A → V is associated, such that $d_x(a) = a(x)$ for each $a \in C \cup D$, function is known as decision rule (in T). According to [39, 46], the region "positive-B" is defined as the set of objects in U that can certainly be categorized using conditional B attributes, Equation (3):

$$POS_B = \bigcup_{x \in U} \underline{R}X \quad (3)$$

Furthermore, the level of dependency of decision attribute in relation to the set of condition B attributes can be computed using Equation (4):

$$\gamma_B = |POS_B| / |U| \quad (4)$$

Therefore, a decision table A is considered consistent if $\gamma_A = 1$.

According to [46], a superreduct is a set of attributes B $\subset$ A such that $R_B = R_A$, where R_B and R_A are the indiscernibility relations defined by B and A, respectively. If this relation is also minimum, it is treated as a "reduct." The intersection of all reducts is a "core" of an information system.

According to [50], three types of attributes exist a) essential, an attribute included in the core; b) exchangeable, an attribute included in a reduced but not in the core; and c) redundant, an attribute not included in any reduce.

According to [25, 41], a decision rule in the S information system is an expression Φ → Ψ, reading as "if Φ then Ψ," where Φ ∈ For(C), Ψ ∈ For(D), C and D are condition and decision attributes, respectively. Three factors are identified.

a) *Strength* or support, as defined in Equation (5):

$$\sigma_s = supp_s(\Phi, \Psi) / card(U) \quad (5),$$

$supp_s(\Phi, \Psi) = card(||\Phi \wedge \Psi||_s)$, and represents the ratio between all facts that can be classified by a certain rule and all facts on the table;

b) *Certainty*, defined in Equation (6):

$$cer_s = card(\|\Phi \wedge \Psi\|_s) / card(\|\Phi\|_s) \quad (6),$$

and represents the estimation of the conditional probability that Ψ is true in S, given that Φ is true in S; if $0 < cer_s < 1$ for a decision rule, it is said that this rule is uncertain. This factor is broadly used in Data Mining and is known as the trust coefficient.

c) *Coverage*, defined as in Equation (7):

$$cov_s = card(\|\Phi \wedge \Psi\|_s) / card(\|\Psi\|_s) \quad (7),$$

and represents the estimation of conditional probability that Φ is true in S, given that Ψ is true in S.

Certainty and *coverage* express precisely the knowledge about the considered reality; they are not taken as arbitrary but are calculated from the data and are objective. Furthermore, RST provides another way of connecting conditions and decisions in decision rules without referring to probabilities a priori or posteriori, as in the Bayes' theorem approach [41].

According to [50], the RST ignores not only the preference order in the attribute value set, but also the monotonic relation of object assessment in relation to the condition values and the preference order of decision attribute values (categorization or preference level). Therefore, [50] presents the dominance principle, the Dominance-based Rough Set Approach (DRSA): "Objects that have a better evaluation or that have at least the same evaluation (decision class) cannot be associated with a worse decision class; all criteria are considered." Therefore, the indiscernibility relations are replaced by dominance relations in the decision class. Because of the preference order between decision classes, the sets become rough and are known as the union of the decision classes: upward classes ($Cl_t^{\geq}$) and downward classes ($Cl_t^{\leq}$).

Therefore, to maintain the monotonic dependency between the condition and decision criteria, the upward and downward classes are defined as shown in Equations (8) and (9), respectively [50].

$$Cl_t^{\geq} = \bigcup_{s \geq t} Cl_s, \; t = 1, ..., n \text{ ("at least" class } Cl_t) \quad (8)$$

$$Cl_t^{\leq} = \bigcup_{s \leq t} Cl_s, \; t = 1, ..., n \text{ ("at most" class } Cl_t) \quad (9).$$

According to [50], it is said that x dominates y with relation to $P \subseteq C$, denoted by xD_Py, if xS_qy, that is, x is at least as good as y with relation to the q criterion for every $q \in P$. The dominance relation is reflexive and transitive. Given that $P \subseteq C$ and $x \in U$, the "granules of knowledge" used in the DRSA approaches are: a set of dominant objects over x, named P-dominant set: $D_P^+(x) = \{y \in \bigcup : yD_Px\}$; and a set of objects dominated by x, named P-dominated set $D_P^-(x) = \{y \in \bigcup : xD_Py\}$. Using the $D_P^+(x)$ sets, the approaches P-downward and P-upward of $Cl_t^{\geq}$ are respectively: $\underline{P}(Cl_t^{\geq}) = \{x \in \bigcup : D_P^+(x) \subseteq Cl_t^{\geq}\}$, $\overline{P}(Cl_t^{\geq}) = \bigcup_{x \in Cl_t^{\geq}} D_P^+(x)$, where $t = 1,..,n$. Similarly, the approaches P-downward and P-upward of $Cl_t^{\leq}$ are respectively: $\underline{P}(Cl_t^{\leq}) = \{x \in \bigcup : D_P^-(x) \subseteq Cl_t^{\leq}\}$, $\overline{P}(Cl_t^{\leq}) = \bigcup_{x \in Cl_t^{\leq}} D_P^-(x)$, where $t = 1,..,n$. The P-boundaries of $Cl_t^{\geq}$ and $Cl_t^{\leq}$ are, respectively, $Bn_P(Cl_t^{\geq}) = \overline{P}(Cl_t^{\geq}) - \underline{P}(Cl_t^{\geq})$ and $Bn_P(Cl_t^{\leq}) = \overline{P}(Cl_t^{\leq}) - \underline{P}(Cl_t^{\leq})$, for t = 1,.., n.

According to [11, 50], the approaches of the upward and downward union of classes can be used to induct decision rules "*if…then…*". For a given upward or downward union of classes, $Cl_t^{\geq}$ or $Cl_s^{\leq}$, the decision rules induced under a hypothesis that objects belonging to $\underline{P}(Cl_t^{\geq})$ or $\underline{P}(Cl_s^{\leq})$ are positive examples, and all the others are negative, suggesting a certain assignment to "class Cl_t or better" or to "class Cl_s or worse," respectively. On the other hand, the decision rules induced under a hypothesis that objects belonging to $\overline{P}(Cl_t^{\geq})$ or $\overline{P}(Cl_s^{\leq})$ are positive examples, and all the others are negative, suggest a possible assignment to "class Cl_t or better," or to "class Cl_s or worse," respectively. Finally, the decision rules induced under a hypothesis that objects belonging to the intersection $\overline{P}(Cl_s^{\leq}) \cap \overline{P}(Cl_t^{\geq})$, are positive examples, and all the others are negative, suggesting an approximate assignment to some classes between Cl_s and Cl_t ($s < t$).

Furthermore, some studies deal with hybrid models such as Rough-Fuzzy, Fuzzy-Rough, and Rough-Neural [17, 22, 23, 27, 28, 29, 30, 35, 46, 47, 52].

4. Analysis of the electric power distribution companies

4.1. Definition of indicators

Based on indicators defined by ANEEL [4, 5, 6, 7, 8], there was the capture of constant information in the RSAs of 41 (forty-one) electric power distribution concessionary companies in the time (year-base) between 2013 and 2021, out of a total of 53 (fifty-three). The decline in the number of companies was due to insufficient information to create a quantitative analysis of the indicators. To preserve the companies' identification, an encoding for each company was established, except for the economic group ENEL, which comprised four companies when a unique code was established. Therefore, the companies were designated sequentially from E01 to E38.

Although the set of established indicators was meaningful (over 200), no search indicator was complete for all the companies that were researched. Therefore, the only indicators considered were the ones of numeric content with a minimum of 40% of quick response fill for 38 (thirty-eight) companies and in the time between 2013-2021, which resulted in a total of 62 (sixty-two) indicators: 33 (thirty-three) indicators directly (dirSU) and 29 (twenty-nine) indicators indirectly (indSU) associated with sustainability, including corporate governance indicators, as shown in Tables 3 to 6. The Accounting Manual of the Electricity Sector (MCSE) distinguishes the indicators directly related to sustainability, "dirSu" (acronym suggested by the research authors), when there is a reference to the standard of GRI/Sustainability Reporting Guidelines & Electric Utility Sector Supplement [26]. Those indirectly related to sustainability, "indSu" (acronym suggested by the research authors), when there is no reference to the standard of GRI. Examples of indicators directly and indirectly related to sustainability are the total consumption of water by source (m^3) (EN8, GRI standard) and policies to support the development of small and micro suppliers, respectively. The indicators are categorized according to the following dimensions: E, economic; S, social; A, environmental; and GC, corporate governance. Each indicator also has its own nature: G, gain; C, cost; and N, neutral.

Table 3. ESA indicators directly associated with sustainability and performance (dirSU). Source: [5, 26].

Code	Indicator	Dimension	Unit	G-C-N
IE01	Consumers served	E	un	G
IE02	Energy bought	E	GWh	C
IE03	Global energy losses	E	GWh	C
IE04	Sub-station	E	un	G
IE05	Installed capacity	E	MVA	G
IE06	Gross payroll	E	R$ mil	C
IE07	Sold energy, Industrial sector	E	GWh	G
IE08	Sold energy, Rural sector	E	GWh	G
IE09	Sold energy, Public lighting sector	E	GWh	G
IE10	Sold energy, Public power sector	E	GWh	G
IS01	Number of in-house employees	S	un	G
IS02	Employees aged between 31 and 40 years old	S	%	G
IS03	Employees aged between 41 and 50 years old	S	%	G
IS04	Women to total of employees ratio	S	%	G
IS05	Employees hired through the Apprenticeship program	S	%	G
IS06	Benefits with Education	S	R$ thousand	G
IS07	Benefits with Food	S	R$ thousand	G
IS08	Benefits with Health	S	R$ thousand	G
IS09	Benefits with Daycare or daycare support	S	R$ thousand	G
IS10	Turnover rate	S	%	C
IA01	Direct energy consumption, source Diesel	A	GJ	C
IA02	Direct energy consumption, source Gasoline	A	GJ	C
IA03	Total water consumption, source Public Network	A	m^3	C

Table 4. GC indicators directly associated with sustainability and performance (dirSU). Source: [26].

Code	Indicator	Unit	G-C-N
IG01	Governance structure of the organization, including Committees under the highest governance body responsible for specific tasks, such as configuring the organizational strategy or supervision. Describe the office term and the composition (including the number of independent and/or non-executive members) of such committees and indicate any direct responsibility for economic, social, and environmental development matters	un	G
IG02	Indicate if the president of the highest governance body is also an executive director; if yes, your function inside the organization	un	G
IG03	For organizations that have a unitary board structure, indicate the number of independent and non-executive members of the highest governance body. State how the organization defines independent and non-executive. This element applies only to organizations that have unitary board structures	un	G
IG04	Mechanisms so that shareholders and employees provide recommendations or orientation for the highest governance body. Include references to procedures related to: • The use of shareholder' resolutions or other mechanisms to allow the minority of shareholders to express opinions to the highest governance body; and • Inform and consult employees about the work relationships with the representative bodies, such as organization, level of work boards, and representation of employees from the highest governance body. Identify topics related to economic, environmental, and social performance aspects generated through these mechanisms during the period covered by the report	un	G

Table 4 (cont.). GC indicators directly associated with sustainability and performance (dirSU). Source: [26].

Code	Indicator	Unit	G-C-N
IG05	Relation between compensation for members of the highest governance body, sênior managers and executves, and the organization's performance (including social and environmental actions)	un	G
IG06	Current procedures for the highest governance to ensure that conflicts of interest are avoided	un	G
IG07	Procedures to determine the qualifications and experience of the members from the highest governance level to orient the organization regarding the economic, environmental, and social strategy	un	G
IG08	Mission statements are developed internally, as well as values, codes of conduct, and relevant principles for economic, environmental, and social performance, as well as the status of its implementation. Explain the level in which these: • Are applied in all of the organization in different regions and departments/units; • Relate it with the standards accepted internationally	un	G
IG09	Procedures from the highest governance body to supervise the organization: economic, environmental, and social performance management, including relevant risks and opportunities, and adherence or conformity to internationally agreed standards, codes of conduct, and principles. Includes the Frequency with which the highest Governance body assesses the sustainability performance	un	G
IG10	Procedures to evaluate the highest governance, particularly regarding economic, environmental, and social performance	un	G

Table 5. ESA indicators indirectly associated with sustainability and performance (indSU). Source: [5].

Code	Indicator	Dimension	Unit	G-C-N
IE01	Locations served (mini-municipality)	E	un	G
IE02	Commercial offices	E	un	G
IE03	Distribution transformers	E	un	G
IE04	Energy sold by employee	E	MWh	G
IE05	Consumers by employee	E	un	G
IS01	Average overtime by employee/year	S	h	C
IS02	Received calls	S	un	C
IS03	Average Number of Staff	S	un	G
IS04	IAb – Abandonment Rate	S	%	C
IS05	ICO - Busy Call Index	S	%	C
IS06	AST – Average Service Time	S	s	C
IS07	DER (Equivalent Duration of Complaint)	S	h	C
IS08	FER (Equivalent Frequency of Complaint)	S	un	C
IS09	Services provided	S	un	G
IS10	Services provided after the deadline	S	un	C
IA01	Water consumption by employee	A	m^3	C
IA02	Students served	A	un	G

Table 6. GC Indicators indirectly associated with sustainability and performance (indSU). Source: [45].

Code	Indicator	Unit	G-C-N
IG01	Issue of preferred shares	un	G
IG02	Preferred shareholders have the right to vote in relevant matters	un	G
IG03	Mechanisms for dissemination of themes deliberated in meetings	un	G
IG04	Administrative procedures, arbitral or legal, against the company, the managers, or the controller involving non-equitative treatment of minority shareholders, in the last five years	un	C
IG05	Ban on loans and warranties in favor of the controller, the managers, and other related parties	un	G
IG06	Existence of a channel for anonymous communications intended for receiving whistleblowing, queries, and suggestions	un	G
IG07	Annual and/or sustainability report with accessibility for people with disabilities	un	G
IG08	Programs for education about sustainability and target audiences	un	G
IG09	Adherence to voluntary commitments related to sustainable development	un	G
IG10	Existence of a sustainability committee	un	G
IG11	Independent audit opinion	un	G
IG12	Commitment to fighting corruption that includes the internal public	un	G

4.2. Companies' classification

It consists of obtaining classes through direct (dirSu) or indirect (indSu) sustainability indexes. For each company, there are normalized indicators (variation from 0 to 1) on the economic, social, environmental, and corporate governance dimensions. Each indicator's value (v_i) will then be normalized (v_{in}) and aims to obtain a percentage related to the maximum found value (v_{max}) (if indicator "profit," the bigger, the better) or minimum (v_{min}) (if indicator "cost or loss"; the smaller, the better): $v_{in} = v_i / v_{max}$ ou $v_{in} = 1 / (v_i / v_{min})$, respectively. Therefore, for each company and indicator, a relative position (%) of the company that can be considered a paradigm in that indicator (that obtained the maximum or minimum values according to the type of indicator, profit, or cost, respectively) is always considered. For each set of indicators of the same dimension, for example, social, there is a corresponding index calculated using a simple arithmetic average. Finally, a final index is calculated using the arithmetic average of the economic, social, environmental, and corporate governance indices directly related to sustainability (dirSu). Procedure analogous to obtaining an indirect sustainability index. The collection of indicators (condition criteria) and classes (decision classes) directly related to companies' sustainability will constitute a decision table, an analogous case for indicators and classes indirectly associated with sustainability.

Thus, for 38 companies, over the period 2013-2021, there is a decision table with 33 indicators (Tables 3 and 4) and classes directly related to sustainability in a total of 342 tuples or records (Table 7). Another decision table contains 29 indicators (Tables 5 and 6) and classes indirectly related to sustainability in 342 tuples or records (Table 7). Aiming to obtain a distribution of the companies' classification, it is proposed a model "quartiles-percentile 93%": the quartiles Q1, Q2 (median), and Q3, and the 93% percentile (P93%), among Q3 and 1, as shown in Figures 1 and 2.

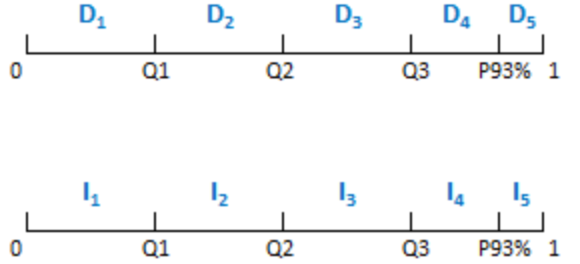

Figure 1. Ascending order of strong preference for classes directly (Dn) and indirectly (In) related to sustainability. Source: Authors.

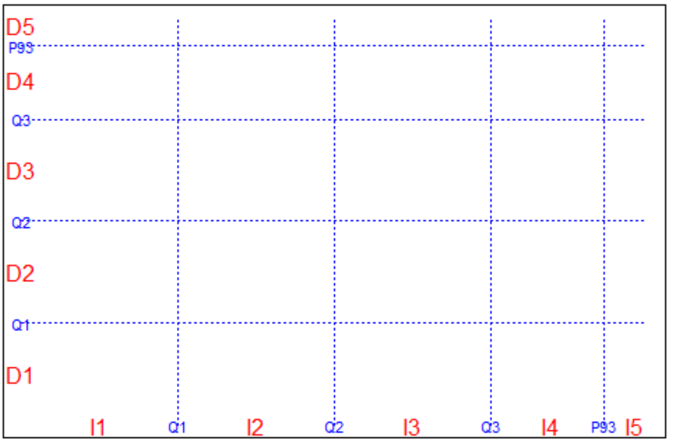

Figure 2. Sustainability Matrix for the quartiles-percentile 93% model. Source: Authors.

As each quartile identifies a part that represents ¼ of a sample or population, the 93% percentile represents approximately a third quartile of the last part ¼ × ¼ = 0.0625 or 0.7, considering the rounded-up value; therefore, the 93% percentile would be 100%–7%. Among the direct classes, ascending orders of strong preferences were instituted: D_1, D_2, D_3, D_4, and D_5. This is analogous to the indirect classes I_1, I_2, I_3, I_4, and I_5.

Why do companies classify them in the current context? Initially, since Aristotle's time, there was concern about naming, defining, and categorizing. With cognitive science, the categorization shifted from an individual cognitive process to a cultural and social process of reality-building that organizes concepts partially based on the psychology of thought. In categorization, the recognition of similarities and differences leads to the creation of new knowledge by clustering entities according to the observed similarities and differences. Consequently, categorizing things has been inherent to human beings since the first moments of life because the brain gives form to structures that mirror the external environment in a categorical form; it is an alternative to structured information because it aims to mirror the organization of the informational structure of a person about a certain subject [32]. Therefore, identifying those companies with likely similarities under the same class or adjacent classes, for example, the use of best practices in sustainability, allows us to obtain a larger range of knowledge about sustainability practices instead of a simple ranking of the companies.

Table 7 illustrates the distribution of dirSU and indSU classes for the company set. The classes were perfectly balanced when it came to the record sets dirSU and indSU; however, among the classes, there was an imbalance in class D5 (7.9%).

Table 7. Distribution of dirSU and indSU classes, period of 2013-2021. Source: Authors.

dirSU class	quant.	%	indSU class	quant.
D1	90	26.3	**I1**	90
D2	81	23.7	**I2**	81
D3	81	23.7	**I3**	81
D4	63	18.4	**I4**	63
D5	27	7.9	**I5**	27
Total	**342**	**100.0**		**342**

Figure 3 illustrates the benchmarking results for 38 (thirty-eight) electric power distribution companies in the general dimension in 2021, considering the vertical (dirSU classes) and horizontal (indSU classes) axes.

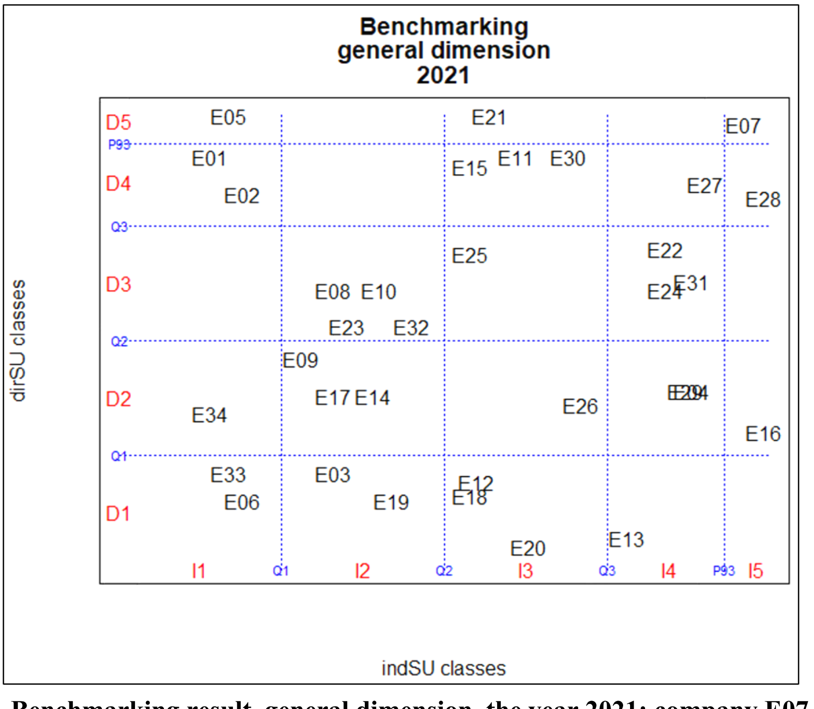

Figure 3. Benchmarking result, general dimension, the year 2021; company E07 as a benchmark. Source: Authors.

Therefore, the set of indicators and decision classes dirSU constitutes a decision table, which is an analogous procedure to indSU. Each decision table was then exported according to the pattern established by the software jMAF Dominance-based Rough Set Data Analysis

Framework (jMAF) [11], according to the following script and Figure 4 for dirSU indicators. The "Examples" section illustrates the three first registers out of a total of 342. An analogous procedure was executed for indSU indicators. The decision tables were processed individually.

```
**ATTRIBUTES
+ company_code: (nominal), none, description
+ year (nominal), none
+ IE01: (continuous), gain
+ IE02: (continuous), cost
+ IE03: (continuous), cost
+ IE04: (continuous), gain
+ IE05: (continuous), gain
+ IE06: (continuous), cost
+ IE07: (continuous), gain
+ IE08: (continuous), gain
+ IE09: (continuous), gain
+ IE10: (continuous), gain
+ IS01: (continuous), gain
+ IS02: (continuous), gain
+ IS03: (continuous), gain
+ IS04: (continuous), gain
+ IS05: (continuous), gain
+ IS06: (continuous), gain
+ IS07: (continuous), gain
+ IS08: (continuous), gain
+ IS09: (continuous), gain
+ IS10: (continuous), cost
+ IA01: (continuous), cost
+ IA02: (continuous), cost
+ IA03: (continuous), cost
+ IG01: (continuous), gain
+ IG02: (continuous), gain
+ IG03: (continuous), gain
+ IG04: (continuous), gain
+ IG05: (continuous), gain
+ IG06: (continuous), gain
+ IG07: (continuous), gain
+ IG08: (continuous), gain
+ IG09: (continuous), gain
+ IG10: (continuous), gain
+ CLASS: [D1, D2, D3, D4, D5], gain, decision
decision: CLASS

**PREFERENCES
company_code: none
year: none
```

IE01: gain
IE02: cost
IE03: cost
IE04: gain
IE05: gain
IE06: cost
IE07: gain
IE08: gain
IE09: gain
IE10: gain
IS01: gain
IS02: gain
IS03: gain
IS04: gain
IS05: gain
IS06: gain
IS07: gain
IS08: gain
IS09: gain
IS10: cost
IA01: cost
IA02: cost
IA03: cost
IG01: gain
IG02: gain
IG03: gain
IG04: gain
IG05: gain
IG06: gain
IG07: gain
IG08: gain
IG09: gain
IG10: gain
CLASS: gain

**EXAMPLES

Example_1: E01, 2021, 953647, 14879, 4882, 28, 2729.4, 147003, 448, 330, 188, 435, 1121, 24.35, 25, 30.24, 2.14, 118, 25.06, 20165663.81, 443, 9, 93059, 10959, 15200, 1, 0, 0, 0, 0, 1, 0, 1, 1, 0, D4

Example_2: E02, 2021, 136949.5, 961.415, 143.84, 17, 212.8, 45115, 22714, 60.76, 34389, 85140, 350, 38.735, 26.8, 23.1, 4.28, 120, 2877, 6486, 433, 10, 2953, 1583.61, 8063, 1, 0, 0, 0, 0, 1, 0, 1, 0, 0, D4

Example_3: E03, 2021, 3228811, 19070.82, 2272.29, 166, 3829, 654010, 2563.495, 1357.725, 620.3, 434.305, 3747, 25.45, 24.71, 18.65, 4.875, 591.5, 34750.5, 47891, 1433.5, 10.3, 6129, 22143, 59045, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, D1

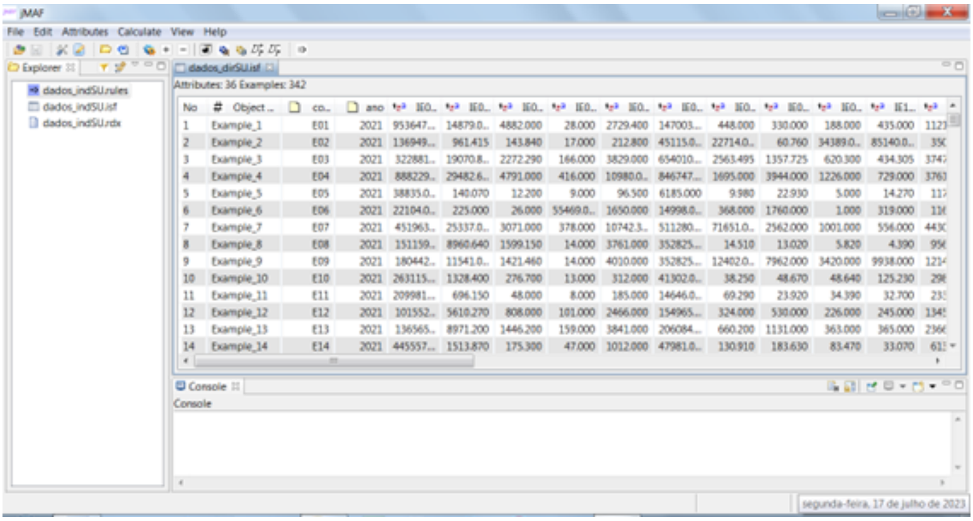

Figure 4. Decision table processing, indicators and dirSU classes, as jMAF software support. Source: Authors.

Next, the following steps were taken: *Calculate: P-Dominance sets, DP+ Calculate dominating set, DP− Calculate dominated set; Unions of classes, standard, consistency level, 1.0; Reducts, all reducts; Rules, VC-DOMLEM algorithm, consistency level, 1.0, type of rules, certain, type of unions, standard*. Consequently, the core {IE01, IE05, IA03, IG08, IG09} and 664 (six-hundred sixty-four) reducts were generated for the decision table dirSU. The core {IS02, IS06, IA02, IG02, IG06, IG09} and 338 (three-hundred thirty-eight) reducts were generated for the decision table indSU.

Aiming to obtain ascending or descending risks of the electric power distribution concessionary companies in classes dirSU and indSU, and considering all of the indicators' set and classes through the 2013-2021 period, the elaboration of the "conditional risk matrix" is proposed: when there is risk associated with some previous and specific knowledge, and consequences [9, 10].

According to [9], an alternative risk description is obtained by focusing on possible consequences or consequence categories instead of expected consequences. It is common to use categories for the probability dimension, and the risk description can alternatively be presented as in Figure 5 (C_1: the person recovers in one month; C_2: the person recovers in one month to one year; C_3: the person never recovers; C_4: the person dies as a result of illness).

Consequences Probability	C_1	C_2	C_3	C_4
Highly probable Higher than 50%	x			
Probable 10% – 50%		x		
Low probability 10% – 2%			x	x
Unlikely Less than 2%				

Figure 5. Example of a risk matrix: the "x" in column C_1 shows that there is a probability greater than 0.5 for consequence C_1; the numbers are conditional that the person is ill. Source: [9].

Starting from the highest values of the coverage factor (Equation 7) and the respective inferred decision rules, but not exhaustively and with the support of the VC-DomLEM algorithm, the proposed conditional risk matrices are listed in Tables 8 and 9. These matrices show that given the fact that a company belongs to a certain class or subset of classes, there is a conditional probability determined because of the coverage factor associated with the respective inferred decision rule.

Table 8. Conditional risk matrix for indicators and dirSU classes. Source: Authors; adapted from [9, 10].

			dirSU classes				
#	**conditional probability**	**rule**	**D1**	**D2**	**D3**	**D4**	**D5**
1	44.4%: (IA01 <= 0.204)	1					✓
2	44.4%: (IE02 <= 25751.0) & (IE07 >= 71651.0)	4					✓
3	22.8%: (IE07 >= 21565.0) & (IG08 >= 1.0)	9				✓	✓
4	77.7%: (IS03 <= 26.8) & (IA02 >= 1583.61)	172	✓	✓	✓	✓	
5	18.0%: (IS03 <= 16.5) & (IS09 <= 535.0)	153	✓	✓	✓		
6	29.1%: (IS03 <= 18.37) & (IS09 <= 359.0)	125	✓	✓			
7	22.3%: (IE01 <= 1365659.0) & (IS03 <= 15.22) & (IS04 <= 13.61)	99	✓				

Table 9. Conditional risk matrix for indicators and indSU classes. Source: Authors; adapted from [9, 10].

			indSU classes				
#	conditional probability	rule	I1	I2	I3	I4	I5
1	29.6%: (IS03 >= 404.0) & (IS08 <= 8.21)	2					✓
2	45.5%: (IE03 >= 182079.0) & (IS07 <= 199.32)	13				✓	✓
3	31.3%: (IE05 <= 562.0) & (IA01 >= 4.5)	111	✓	✓	✓		
4	47.9%: (IE01 <= 72.0) & (IG10 <= 0.0)	92	✓	✓			
5	48.8%: (IE05 <= 390.45) & (IS07 >= 128.0)	71	✓				

From Table 8, it is noted by conditional probability #4 that there is a 77.7% probability that electric power distribution concessionary companies that do not belong to class D5 to show "(IS03 <= 26.8) & (IA02 >= 1583.61)", that is, they have 26.8% or less employees with age that range between 41 and 50 years old, and use gasoline as a direct energy source in quantity equal or above 1,583.61 GJ (gigajoule). And from Table 9, conditional probability #1: there is a 29.6% probability of those companies that have a higher classification (I5) to show "(IS03 >= 404.0) & (IS08 <= 8.21)", that is, having the minimum average of 404 clerks, and Equivalent Frequency of Complaint every one-thousand consumer units (FER) of a maximum of 8.21.

For conditional probability #4 in Table 8, Figure 6 illustrates the probability of a company belonging to a hatched region, given that the dirSU class is not D5. This conditional probability can be perfectly verified and proven through dirSU decision table analysis: 245 records fit the rule "(IS03 <= 26.8) & (IA02 >= 1583.61)" out of the total of 315 records were categorized as D1, D2, D3 or D4; or, 245 / 315 = 0.777.

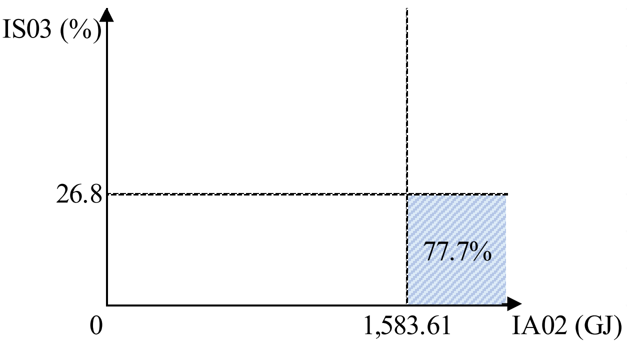

Figure 6. Conditional probability #4, Table 8, and likelihood of a company belonging to the hatched region given that the dirSU class is not D5. Source: Authors.

From Table 9, by conditional probability #5, there is a 48.8% probability that companies belonging to class I1 to show "(IE05 <= 390.45) & (IS07 >= 128.0)", that is, a maximum number of 390 consumers by employee, and a minimum of 128 hours for the Equivalent Duration of Complaint (DER) by consumer unit, connected to the average solution term. Figure 7 illustrates this conditional probability.

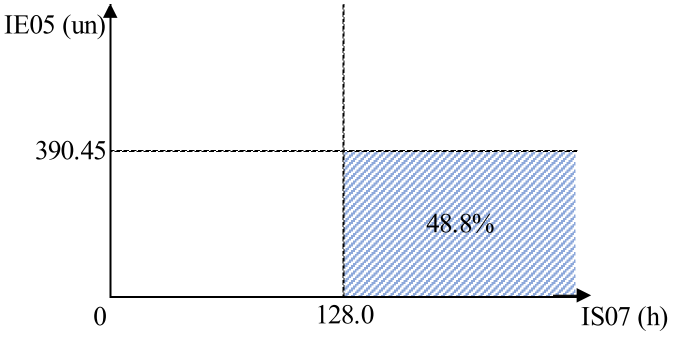

Figure 7. Conditional probability #5, Table 9, and the likelihood of a company belonging to the hatched region given that the indSU class be I1. Source: Authors.

Based on Tables 8 and 9, Figures 8 and 9 simultaneously exemplify the most (hatched in green) and less (hatched in red) advantageous regions in the Sustainability Matrix, vis-a-vis to the conditional probabilities.

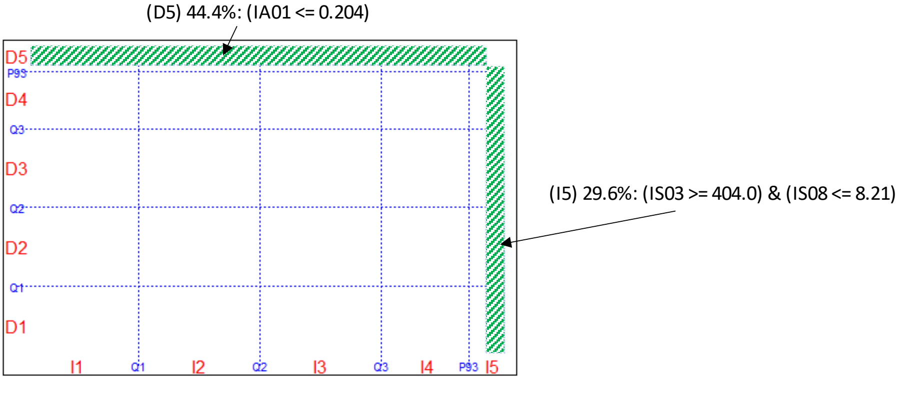

Figure 8. Most advantageous regions (hatched in green) in the Sustainability Matrix vis-a-vis to the conditional probabilities. Source: Authors.

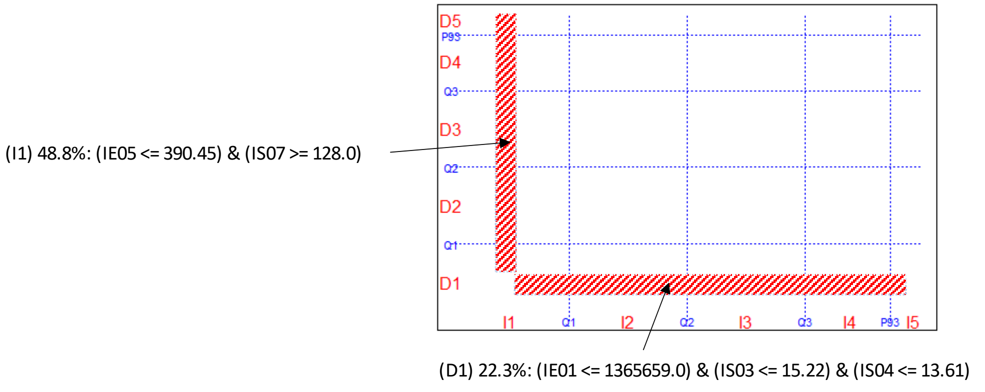

Figure 9. Less advantageous regions (hatched in red) in the Sustainability Matrix vis-a-vis to the conditional probabilities. Source: Authors.

5. Conclusions and future studies

The indicators defined by ANEEL in the Accounting Manual of the Electricity Sector (MCSE) constitute a means to evaluate energy companies based on international standards, such as the GRI, as well as in specific necessities, with the intention of observing those companies' performance. For example, water consumption in m^3 per employee is a necessity from ANEEL, and the total water consumption (m^3) is a GRI standard. Therefore, the indicators provide measurement options when analyzing a company individually and comparatively when it constitutes a set of electric power distribution companies.

However, the indicators are distributed in their respective dimensions, such as the environmental dimension. Analyzing all or some indicators of a single dimension constitutes an important management element, but it does not allow a broad vision when all the indicators are combined to obtain a global assessment. Therefore, benchmarking companies constitute a useful management tool, especially for risk management, even in an individualized manner.

Consequently, the current study innovates by proposing a new application using a conditional risk matrix and decision rules aimed at the integrated assessment of the sustainability and performance of electric power companies when analyzing the conditional probability of indicators in the ascent or descent of the companies' classification.

In future studies, it would be beneficial to expand the set of sustainability and performance indicators, aiming for improved precision in evaluating the classification of electric power distribution companies.

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