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PROPOSAL OF MANAGEMENT INDICATORS FOR THE REUSE WATER PROGRAM IN BRAZILIAN BREWERIES FROM THE ECONOMIC, ENVIRONMENTAL, SOCIAL, AND GOVERNANCE PERSPECTIVES: AN APPROACH BY THE HYBRID METHOD OF THE ANALYTICAL HIERARCHY PROCESS IN GROUP DECISION-MAKING VERSUS BAYESIAN BELIEF NETWORKS

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ABSTRACT

Highlights: The EESG factors defined are essential for drainage network designs, according to the methodologies used. The factors were determined by the work described by Giordano (1999). The AHP-GDM x BBN methodology calculates the impact and probability of occurrence of the risk factors that may impact reuse water in Brazilian breweries. Five specialists answered the questionnaire sent by social networks. **Aim:** Present an original proposal for a sustainable indicator that allows combining the analysis of EESG risk factors influencing the reuse water process in Brazilian brewery industries through the AHP-GDM and BBN methodologies. **Design/Methodology/Approach:** For the modeling, the risk factors were identified in the literature, followed by applying questionnaires to experts to enable the comparative analysis between the criteria and subcriteria for the attribution of local and individual weights through the AHP-GDM and BBN methodologies. **Results:** Among the results, regional environmental legislation stands out as the most critical factor, while the environmental criterion was the most important within the EESG dimensions. **Research Limitations:** It should be emphasized that the model to be proposed in this study is limited to presenting an objective function that will be treated as a "Breweries EESG Indicator," leaving it up to each of the companies that opt to adhere to it to define the metrics and/or their internal indicators that are most suitable for each factor or subcriterion, according to their own business strategies. That is, in the manner presented in this paper, each company adopts the indicator that suits it for each of the subcriteria analyzed. **Practical Implications:** In this sense, the authors present a model that allows calculating the performance of the level of reuse water utilization in operations inherent to the Brazilian brewing industry, suggesting the model's replication in other areas. **Originality/Value:** The originality of the approach consisted in the fact that no similar study of a hybrid approach of the AHP and Bayesian Networks methods in the EESG context has been identified in the literature, thus creating a gap for the elaboration of a sustainability-oriented model using these methods concomitantly.

Keywords: Reuse water; AHP-GDM; BBN; EESG; Breweries.

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INTRODUCTION

Water consumption is one of the biggest modern concerns, aggravated mainly by the fact that a large part of the world's population does not have access to clean drinking water. Mitigating potential risks and keeping water clean are essential to maintaining life on Earth. Inserted in the context of Agenda 6 of the UN-SDGs (Sustainable Development Goals), which, according to United Nations Brazil (2021), addresses the main development challenges faced by people in Brazil and around the world, the agenda related to "Drinking Water and Sanitation" addresses the guarantee of availability and sustainable management of drinking water and sanitation for all.

Among the sub-goals listed by the United Nations are goals 6.3 and 6.4, the first of which deals with improving water quality by reducing pollution, eliminating dumping, minimizing the release of chemicals and hazardous materials, halving the proportion of untreated wastewater, and substantially increasing recycling and safe reuse globally (United Nations Brazil, 2021). The second goal aims to substantially increase water use efficiency in all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people affected by the year 2030 (United Nations Brazil, 2021).

Within Brazil, the 2019 annual report of the Brazilian National Water Agency (ANA) revealed important and alarming data on national consumption and management of water resources. This report brought to light that demand is growing, with an estimated increase of approximately 80% in total water withdrawals over the past two decades. The official report from the Ministry of Regional Development also reveals that the forecast is that by 2030, the Brazilian population's water withdrawal will increase by 26%. This history of the evolution of water uses is directly related to the country's economic development and urbanization process (Agência Nacional de Águas, 2019).

In this context, the following questions guiding this research arise: ***QP1:*** What is the degree of importance of the EESG dimensions regarding reuse water utilization in Brazilian brewery industries (approach using the AHP-GDM method)? ***QP2:*** What is the criticality level of the risk factors involved in the process of reuse water utilization in the industrial processes of Brazilian breweries (BBN method approach)? ***QP3:*** Would it be possible to build a model or function to establish a performance relationship for the operations (AHP-GDM x BBN method approach)?

The article is structured into five items. The first presents a brief contextualization of the theme and presents the research questions. The second presents a state-of-the-art literature review on the proposed theme. The third presents the methodological approach and, thus, the tools used to obtain the results. The fourth presents the results and a brief discussion comparing them with previous works. The fifth section contains the conclusion, the answers to the research questions, and the proposal for future work.

LITERATURE REVIEW

This topic mentions previous research on the subject (see Appendix I, theoretical framework), the context of reuse water utilization in industrial processes, the EESG dimensions, and the AHP-GDM and BBN methods.

Brazilian Legislation

The World Health Organization (WHO, 1973) classifies reuse water into indirect reuse (planned and unplanned), di-

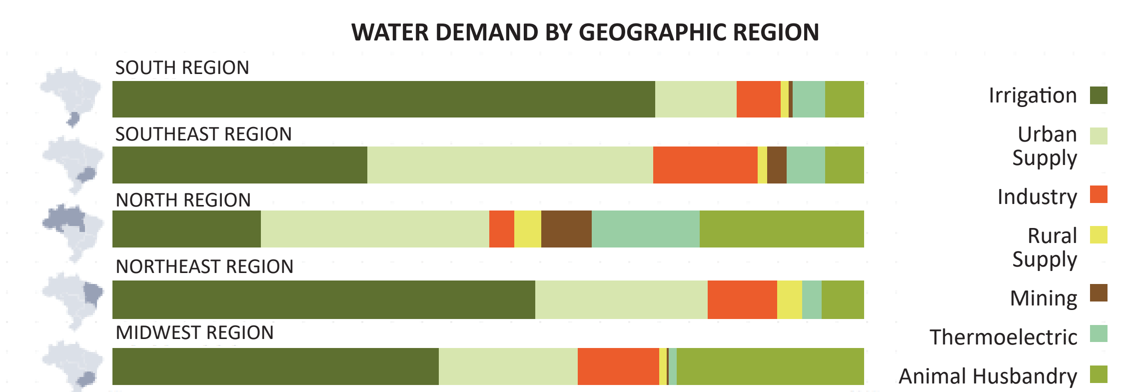

Figure 1. Brazilian demand for water in 2019
Source: Brazilian National Water Agency (2019)

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rect reuse, and internal recycling. The Brazilian Association for Technical Standards (ABNT) No. 13.969/97 (ABNT, 1997) classifies reuse differently by considering which form of reuse will be local reuse, planned direct reuse, and indirect reuse (planned and unplanned). Moura (2020) states that these parameters of Standard 13.969 of 1997 do not agree with the current legislation: bathing by CONAMA Resolution No. 274 (National Council of the Environment, 2001) and potability by the Consolidation Ordinance.

Since there are no specific laws and regulatory standards in the country for this environmental management input, research is crucial to understanding the reuse water utilization because what is experienced in Brazil and several other countries worldwide is a situation of extreme water scarcity, considering that thousands of people die every day due to a lack of water. The Conjuncture of Water Resources report (CRH) is the reference for the systematic and annual monitoring of statistics and indicators related to water in the country. The Brazilian National Water Agency (ANA) has also published the report "SDG 6 in Brazil: ANA's View on the Indicators and an Interactive Panel that Consolidates the Calculation of All Indicators of Sustainable Development Goal (SDG) 6: Clean Water and Sanitation for Brazil," comprising historical series and spatial disaggregations of data, detailing the reality of the country regarding the monitoring of its goals.

The National Council for Water Resources (CNRH) Resolution No. 54 of November 28, 2005 (CNRH, 2005), which establishes modalities, guidelines, and general criteria for regulating and encouraging the practice of direct non-potable water reuse throughout the country, is among the national regulations for the application of reused water. Article 3 of the resolution presents the modalities (and their components) of direct non-potable water reuse:

I. Reuse;

II. Reuse for agricultural and forestry purposes;

III. Reuse for environmental purposes;

IV. Reuse for industrial purposes;

V. Reuse in aquaculture.

The state of Rio de Janeiro has Law No. 7,424 of 2016 (Rio de Janeiro State Government, 2016), which requires the use of non-potable reuse water by the state's direct public administration, autarchies, foundations created or maintained by public authorities, companies that have a stake in the capital of the state of Rio de Janeiro, and other entities controlled directly or indirectly by the state. Besides this law, the state of Rio de Janeiro has Law No. 7,599 of 2017 (Government of the State of Rio de Janeiro, 2017), which establishes the obligation of industries located in the state to install water treatment and reuse equipment.

EESG Aspects

Considered one of the variations of ESG (Environmental, Social, and Governance), the acronym EESG has been used by organizations concerned with the economic dimension (aiming at an economic profit) but that do not neglect aspects related to environmental, social, and governance factors.

Because ESG indicators inform companies about the most important outcomes and specify what stakeholders expect of them, they can also serve as tools and inspiration to highlight the specific topics and targets on which organizations should focus (Veenstra and Ellemers, 2020). Analogously, through the EESG, with the addition of the economic dimension, the idea of profit perception through value addition is also present, a fact that would be directly related to the economic and financial sustainability of the companies in terms of business.

There are scientific studies published in journals that point to the trend of applying frameworks linked to the dimensions that make up the acronym EESG in various areas (García-Pérez, Muñoz-Torres, and Fernández-Izquierdo, 2016; Hiller *et al.*, 2013, Martin and Ritchie, 2018), leading to the belief that organizations are considering the interconnectedness of these dimensions, working on the development of indicators increasingly interconnected with their internal operations and the profitability of the business in which the company operates, focusing on reducing impacts and possible damage in the environmental, social, and governance spheres, which in turn are constantly demanded by external stakeholders (interested parties).

AHP-GDM x BBN Modeling

This section transcribes the methodologies applied in the preparation of this study.

AHP-GDM

On this topic, Bhushan and Rai (2004) bring a relevant study on the analytic hierarchy process (AHP), in which they describe that the AHP was developed in the 1970s by Thomas L. Saaty and has been extensively studied since then. It is currently applied in decision-making in various complex scenarios where people work together to make decisions, and human perceptions, judgments, and consequences have long-term repercussions (Lyu *et al.*, 2020). According to Liang *et al.* (2019), the first stage in the proposed methodology is to determine the optimal configuration designs of multiple optimization objectives and the posterior risk probabilities of various events, which occur using a model that reflects the risks associated with selecting the optimal product configuration. According to Liu and Liu (2008), to develop a total multi-objective optimization life cycle, almost always use the generation of a dependency diagram to define the optimization scope, model end-of-life recovery strategies, consider the multi-lifecycle flow, formulate the multi-objective optimization problem, and solve the optimization problem.

The analytic hierarchy process is widely used in group decision-making (GDM), with two traditional methods of collective preference aggregation in AHP-GDM: aggregation of individual judgments (AIJ) and aggregation of individual priorities (AIP). However, AHP-GDM is sometimes less reliable only under the conditions of AIJ and AIP because of the consensus and consistency of individual pairwise comparison matrices (PCMs) and prioritization methods (Lin *et al.*, 2020). The long-term survival of an AIP depends on ensuring that the benefit delivered is greater than its membership fee to overcome the problems of collective actions in heterogeneous groups, selective incentives by strategic groups, and a proper governance structure that can avoid internal conflicts and unnecessary costs (Conejero, 2011).

In a general context and assuming a scenario with multiple actors and a common hierarchy, the prioritization methods conventionally applied in AHP-GDM (Saaty, 1989) use filters to ''reduce'' initial judgments, although this restricts their overall scope. The two most widely employed methods for obtaining group priorities in AHP are (i) aggregation of individual judgments (AIJ) and (ii) aggregation of individual priorities (AIP). In the first case (AIJ), a matrix judgment is constructed for the group. Each entry in this reciprocal matrix of pairwise comparisons is obtained as the geometric weighted average of individual judgments, and the priorities for the compared alternatives are calculated on this basis using any prioritization procedure. In the second case (AIP), the local priorities of each individual are calculated first using any prioritization procedure, and the group priorities are then obtained. Based on these scores using a synthesis procedure, the most commonly used is the weighted geometric mean (Altuzarra, Moreno-Jimenez, and Salvador, 2006); however, there is no impediment to the decision maker in choosing the best mean to use.

In both cases, it is assumed that the pairwise comparison matrices containing the expressed judgments of the decision-makers are complete and accurate. However, when the analysis involves values for intangible attributes, it is not really appropriate to consider such values as accurate, as has been the case until now. At the same time, incomplete matrices, including empty positions, often have to be used in large problems. It may also sometimes be preferable, at least temporarily, to ignore judgments that include opposing positions to increase consensus among decision-makers, keeping only those entries in the pairwise comparison matrix that provide a degree of collective consensus. Given this, the approach employed in the AHP-GDM process should work adequately for both precise and imprecise matrices and for incomplete matrices (Altuzarra *et al.*, 2006).

BBN

One of the methods chosen to solve the problem was Bayesian networks, which emerged around the 1980s and have been applied in a wide variety of activities (Bobbio *et al.*, 2001). Bayesian belief networks are a graphical framework for modeling uncertainty (Shakeri *et al.*, 2020) and are often used for causal representation of the phenomena involved in a complex system or process where the information is based on expert knowledge. This approach allows a better analysis of a reliable system suitable for many applications in risk analysis in which the combined use of conventional and unconventional methods is necessary and used (Groth and Swiler, 2013). BBNs as support for decision-making in an environment of uncertainty for increasing process reliability have been the subject of several works in various fields of knowledge (Dias, Moreira, and Pereira, 2019). BBN usage in construction focuses on improving building operations and risk analysis in construction engineering (Adams, 2006; Mccabe, Abourizk, and Goebel, 1998).

AHP-GDM x BBN Applications

Regarding the relationship between both methods, some current applications of using the methodologies together are those connected to areas such as finance (Chang *et al.*, 2000), health and safety (Abicalaffe, Amaral, and Dias, 2004), game development, and information technology (Vieira Filho and Albuquerque, 2007). In other words, these are knowledge representation models that work with uncertain and incomplete knowledge. As simulation technology constantly progresses, simulation systems involve a wide range of disciplines, a large simulation scale, and a broad technical field. To avoid one-sided or fictitious preferences and error reduction, the evaluation of simulation system credibility requires that evaluation experts in different fields participate in the group. Therefore, group evaluation and simulation credibility methods are becoming hot topics for complex systems (Lin and Kou, 2015).

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METHODOLOGICAL APPROACH

This paper was structured to suggest a model capable of encompassing the importance of water reuse in breweries by the proposed hybrid method, aiming to conclude the research with the proposal of an EESG indicator.

The research stages were characterized by a bibliometric survey for defining critical factors and criteria based on Giordano (1999) for their definition, followed by data modeling as a combination of the AHP-GDM methods, BBN application, and risk matrix.

The originality of the approach consisted of the fact that no similar study of a hybrid approach of the AHP and Bayesian networks methods in the EESG context has been identified in the literature, thus creating a gap for developing a sustainability-oriented model using these methods concomitantly.

Bibliometric Survey

The study conducted in this article relied on a bibliographic analysis focused on hydric effluents, AHP (Analytic Hierarchy Process), and BBN (Bayesian Belief Network) methods. The documents selected for analysis were limited to academic materials extracted from the Web of Science (WoS) base, accessed through the Capes portal (www.capes.gov.br) in September, October, and November 2021. The WoS base was selected due to the variety of materials and ease of extraction and use of data, mainly due to the reliability and quality of the academic database.

The following string of key terms was used to obtain bibliographic material: brewery or water (all fields), Bayesian Belief Network, or BBN (all fields), or Analytic Hierarchy Process, or AHP (all fields), returning 33,968 documents. Regarding the data treatment, the minimum occurrence of words was restricted to 5, reducing the 382 words found to 12 terms. The VOSviewer software was used to analyze the bibliographic, generating the representations shown in **Figure 2**.

This analysis generated by the VOSviewer software allows verifying, through a map based on bibliographic information, the co-authorship, keywords, citations, and other search terms that have words related to the subject of this article in their composition. As a result of the co-occurrence analysis, two clusters were generated, showing the connection of the terms in a graph delimited by the colors green and red and presented in **Figure 2**. These terms were organized as shown in **Table 1**.

Table 1. Co-occurrence clusters

CLUSTER 1 (7 items)	bayesian belief network; ecosystem services; Knowledge; Management; risk uncertainty; water quality
CLUSTER 2 (4 items)	bayesian belief network (bbn); environment; methodology; risk

Source: The authors (2021)

With these results, a questionnaire was applied to stakeholders in the Brazilian brewing industry to identify the most important factors regarding the reuse of water resources by applying the AHP and BBN methods.

Definition of critical factors or criteria

A literature search was initially conducted to identify the critical factors that could cause the effluent treatment process to be adopted, and a field study was done to validate these factors with the professionals currently working with these processes. The survey conducted for this study, using Google Docs forms, was answered by experienced professionals. This study aimed to obtain the degree of importance in the perspective of each professional about each externality pointed out by Giordano (1999) in which, among the treatment processes to be adopted, their constructive forms and the materials to be used are considered based on the following factors: the regional environmental legislation; climate; local culture; investment costs; operating costs; the quantity and quality of the sludge generated in the industrial effluent treatment plant; the quality of the treated effluent; operational safety related to leaks of used chemicals or effluents; odor generation; the interaction with the neighborhood; reliability to comply with environmental legislation; and the possibility of reusing treated effluents.

Therefore, the treatment systems should be used not only with the minimum objective of treating the effluents but also to meet other requirements. It should be noted that unnecessary waste should not be generated through the treatment (Giordano, 2003).

AHP-GDM application

Based on the EESG construct, the critical factors identified in the previous topic were distributed and organized in a hierarchical decision-making tree, highlighting the interdependence between these factors and the respective EESG dimensions. The objective is to elaborate a model that quantitatively allows indicating breweries' performance in light of the EESG. See **Figure 4** below.

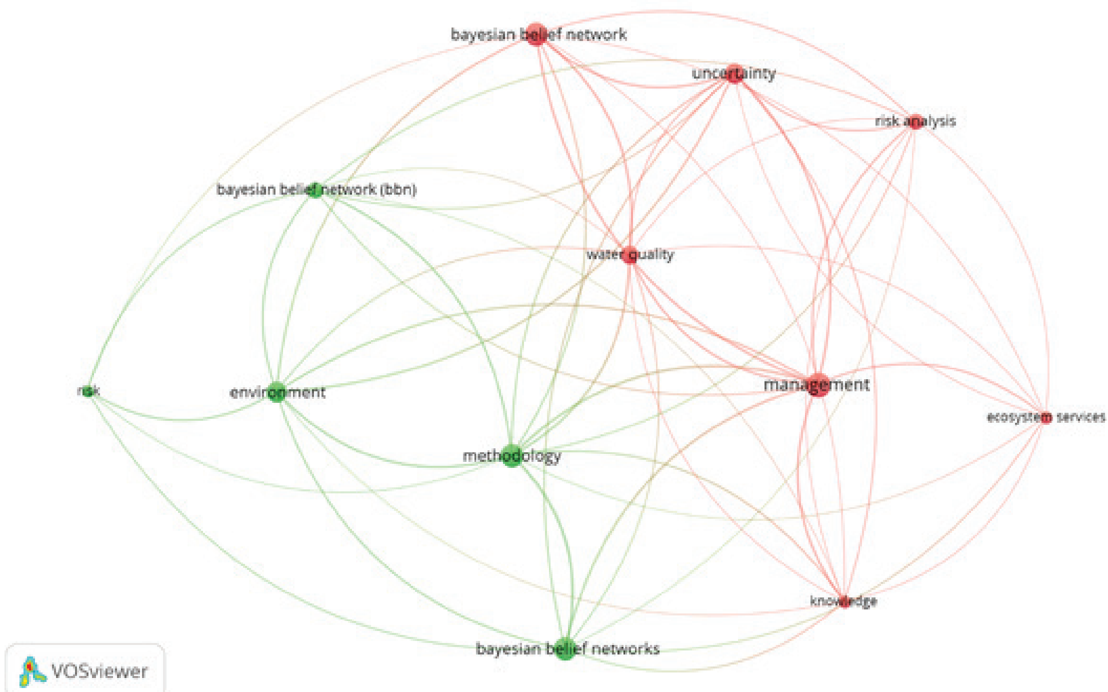

Figure 2. Network visualization
Source: The authors (2021)

The economic-related factors were reduced regarding the contribution of inequality, growing economic insecurity, and dissatisfaction experienced in the current period of this study, caused by the pandemic of the SARS-CoV-2 virus, the generator of COVID-19 worldwide (Strine, Smith, and Steel, 2020). As for the governance factor, there is a current challenge that cannot be ignored: the proliferation of different EESG approaches and this proliferation is inefficient, encouraging the mischaracterization of governance classifications (Strine, Smith, and Steel, 2020).

The economic factors considered were all those defined by Giordano (1999) involved in the cost of inserting effluent drainage networks. Environmental factors include local environmental legislation, the possibility of reusing water from effluents without causing pollution, the local climate as one of the determining factors of the environment (including flora and fauna), and the possibility of pollution that may occur. The social aspect is determined by those factors that depend on the population of the surroundings where it will be inserted. Governance is the relationship between the population and the local drainage networks that must be managed.

Given the above, a free Google Forms questionnaire was prepared to find the relative weights of each of the EESG acronym dimensions (treated as criteria in this phase), and each critical factor (treated as subcriteria in this phase) that was submitted to professionals in the brewing industry whose attributions in the companies would have some affinity with the central object of analysis of this study: reuse water. In other words, it was up to the specialists, contacted via LinkedIn, e-mails, and telephone contacts, to contribute their perceptions on the subject.

Thus, as the questionnaire counted on the contribution of professionals from several different companies, among the AIJ and AIP approach options linked to the AHP method, the authors chose to use the aggregation of answers through the AIP approach to finding the matrices and the weights attributed by the AHP analysis since the AIP approach of the AHP would be the most suitable for cases like this, where the decision-makers are from different companies and tend not to be in tune with each other, acting according to their preferences (each decision-makers intrinsic interests or company guidelines to which they would be submitted, which usually change from one company to another). Thus, the simple geometric mean to calculate the decision matrix vectors meets the condition that aims to synthesize the individual priorities of the decision-makers for this case, which does not preclude the use of the geometric mean in some cases.

As Forman and Peniwati (1998) mention, AIJ employment violates the Pareto principle of choice theory. Insisting that the principle should be applied, they propose that a weighted API be used, considering that the Pareto principle is relevant and under what circumstances JIA or API should be

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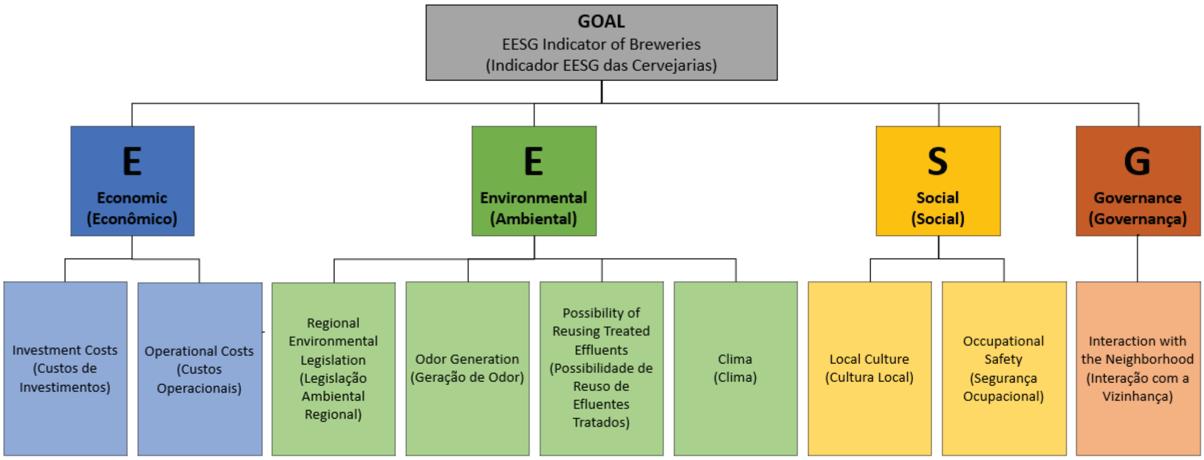

Figure 3. Model Hierarchy Tree

Source: The authors (2021)

Group	Economic	Environmental	Social	Governance	Autovetor	Norm.	lambda	mi
Economic	1	1/3	2/3	1 3/8	0,741	0,180	4,145	0,048
Environmental	3	1	1 2/9	1 2/9	1,452	0,352		
Social	1 5/9	4/5	1	8/9	1,030	0,250	CI	0,048
Governance	5/7	4/5	1 1/8	1	0,903	0,219	RI	0,900
	6,231	2,969	3,996	4,496	4,125	1,000	CR	0,054

Figure 4. Aggregate matrix of the experts' answers to the criteria (EESG)

Sources: The authors (2021)

used. The Pareto principle essentially states that given two alternatives, A and B, if each member of a group of individuals prefers A to B, then the group should prefer A to B. The principle has been formulated and applied in the social sciences in the AIP context (Forman and Peniwati, 1998).

Following these steps and in possession of the data obtained via questionnaires and responses from five (5) respondents, the matrices were elaborated and the respective priority vectors were calculated, both for the criteria (E, E, S, and G) and the subcriteria (critical factors) (see Appendix II), to then establish an aggregate matrix of the specialists' responses for the EESG criteria. See **Figure 5** below.

In the same way, Appendix III presents the individual answers of the five (5) experts regarding the subcriteria (Critical Factors), which, in turn, were aggregated into a single matrix (see **Figure 6** below).

It is noteworthy that the geometric mean of the values was used in aggregating the specialists' answers. That is, the geometric average of the answers of the five (5) respondents was calculated.

After applying the AHP-GDM analysis to both matrices, it was possible to get the results of the local and individual weights for each of the criteria and subcriteria used in the present work. See **Figure 7**.

BBN application

The first step was to conduct a literature search in databases to identify the state-of-the-art literature on water-related problems in industries. Thus, it was possible to determine the critical factors that most impact the reuse water.

As part of the elicitation process, the questionnaires were answered by a sample of a hundred (100) specialists (professionals from different areas of the wastewater treatment industry). These professionals were contacted via the LinkedIn social network, considering the branch of the company in which they work or worked, focusing on the brewing industry, and/or if they knew the industrial process.

The respondents were asked to rank the listed factors using the following criteria: "it is important," "high importance", "mean importance," and "low importance." The criterion "it is important" was considered something that should not be left out of the project, and the other three criteria ("high importance," "medium importance," and "low importance") expressed that, although they were impor-

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Group	Regional Environmental Legislation	Odor Generation	Possibility of Reusing Treated Effluents	Climate	Autovetor	Norm.	lambda	mi
Regional Environmental Legislation	1	2 5/8	4/7	8/9	1,075	0,242	4,253	0,084
Odor Generation	3/8	1	1/6	8/9	0,481	0,108		
Possibility of Reusing Treated Effluents	1 3/4	6 1/3	1	1	1,823	0,411	CI	0,084
Climate	1 1/8	1 1/8	1	1	1,061	0,239	RI	0,900
	4,251	11,077	2,731	3,778	4,440	1,000	CR	0,094

Figure 5. Aggregate matrix of the experts' answers for the subcriteria (Critical Factors)
Sources: The authors (2021)

Criteria	Weight	Critics Factors	Weight	Ind. Weight
E - Economic	17,95%	Investment Costs	50,00%	8,98%
		Operational Costs	50,00%	8,98%
E - Environmental	35,20%	Regional Environmental Legislation	24,22%	8,53%
		Odor Generation	10,83%	3,81%
		Possibility of Reusing Treated Effluents	41,06%	14,45%
		Climate	23,89%	8,41%
S - Social	24,96%	Local Culture	50,00%	12,48%
		Occupational Safety Relating to Leaks of Chemicals Used of Effluents	50,00%	12,48%
G - Governance	21,89%	Interaction with the Neighborhood	100,00%	21,89%
	100,00%			100,00%

Figure 6. Local and individual weights of the criteria (EESG) and subcriteria (Critical Factors)
Sources: The authors (2021)

tant, they were not classified as essential. **Table 2** shows the results in percentages.

After identifying the main risk factors, it was possible to assign their respective probabilities of occurrence, defining the most relevant factors for the operation. BayesFusion software was used to generate the BBN network.

To better illustrate the interdependency relationship between the EESG criteria and the identified critical factors, **Figure 8** was elaborated.

In view of the answers obtained in the questionnaires, a matrix was drawn up in descending order with the values of the probabilities related to the occurrence of risk factors. See **Table 3** below.

Table 3. Probability of occurrence of risk factors

Risk Factors	Probability
Regional environmental legislation	0.88
Climate	0.87
Local culture	0.85
Investment costs	0.84
Operational costs	0.83
Operational safety related to leaks of chemicals or effluents	0.83
Odor generation	0.79
Interaction with the neighborhood	0.74
Possibility to reuse the treated effluents	0.65

Source: Pereira and Dorino (2021)

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Table 2. Percent of results

Risk Factor	It is important	High importance	Mean importance	Low importance
Regional environmental legislation	74%	26%	0%	0%
Climate	15%	85%	0%	0%
Local culture	5%	26%	34%	35%
Investment costs	27%	16%	42%	15%
Operational costs	61%	22%	0%	17%
Operational safety related to leaks of used chemicals or effluents	67%	30%	3%	0%
Odor generation	88%	11%	1%	0%
Interaction with the neighborhood	78%	10%	7%	5%
Possibility to reuse the treated effluents	95%	4%	1%	0%

Source: Dorino, Moreira, and Póvoas (2021)

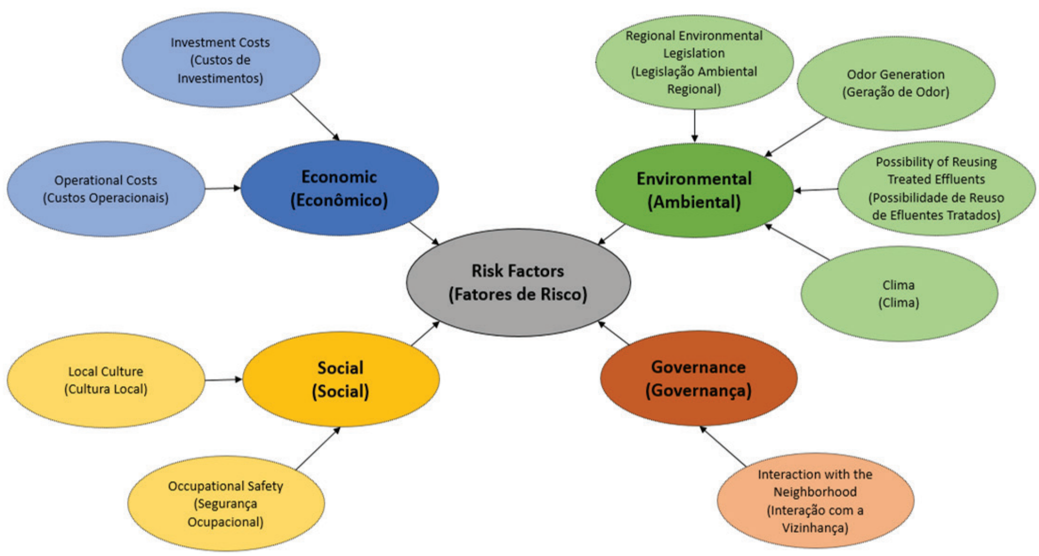

Figure 7. Bayesian network of results

Source: The authors (2021)

Risk Matrix

With the impact values from the AHP and the probabilities obtained with the BBN, **Table 4** was used to obtain the respective points to use in the risk matrix in **Table 5**. The risks present the probabilities of occurrence and impact in percentages; however, for using the matrix of probability x impact, these risks in percentages must receive values (called points) according to the range of variation presented in **Table 5** so that the classification of the matrix of probability x impact occurs through the multiplication of points.

After performing the multiplication and risk ranking of each step, the final risk score values for each risk category were finally found using **Table 5**, which shows a representation using colors to facilitate understanding: light yellow, insignificant risks for the study; "egg" yellow, or darker, tolerable risks; orange, undesirable risks that must be mitigated; and red, risks that must be urgently eliminated or at least mitigated. The probability x impact matrix with the appropriate colors is described in **Table 6**.

It is defined as a risk management tool that allows you to visually identify which risks should receive more attention.

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Table 4. Level of probability and impact points. Impact and probability are measured in levels: limited, low, moderate, elevated, and high, according to the normalized AHP matrix. The values found in the normalized in the weights column are transformed into points (integer numerical values from 1 to 5) using this methodology scoring table.

Probability Score Level			Probability Impact Level		
Score	**Probability Level**	**Probability**	**Score**	**Impact Level**	**Impact**
5	Expected	More than 0.80	5	High	More than 0.16
4	Very Likely	0.51 - 0.80	4	Elevated	0.12 - 0.16
3	Likely	0.31 - 0.50	3	Moderate	0.08 - 0.11
2	Unlikely	0.11 - 0.30	2	Low	0.04 - 0.07
1	Almost no probability	Less than 0.11	1	Limited	Less than 0.04

Source: The authors (2021)

Table 5 shows the risks classified by multiplying the scores defined in **Tables 4** and **5**.

			Risks				
			Limited	Low	Moderate	Elevated	High
			1	2	3	4	5
Probability	Almost no probability	1	1	2	3	4	5
	Unlikely	2	2	4	6	8	10
	Likely	3	3	6	9	12	15
	Very Likely	4	4	8	12	16	20
	Expected	5	5	10	15	20	25

1 – 5 Insignificant	6 – 9 tolerable	10 - 16 Undesirable	17 - 25 Intolerable

Fonte: Os próprios autores (2021)

Table 6. Probability x Impact Table

Risk Factors	Probability	Impact	Probability	Impact	Final
Economic	0,83	0,19	5	5	25
Environmental	0,80	0,35	5	5	25
Social	0,84	0,24	5	5	25
Governance	0,74	0,22	4	5	20

Source: The authors (2021)

As it is a tool for prioritizing risks, it can be applied in the risk assessment stage.

The EESG factors are colored red, meaning that all are of utmost importance for drainage network projects. Probability and impact assessments are done for each identified risk through interviews, meetings, or other techniques. The probability and impact can be classified through a specific domain, a visual tool that allows a quick view of which risks should receive more attention, making it much easier to understand and engage the teams in the process.

Modeling

By combining the weights found in the AHP-GDM method and the BBN probabilities, it was possible to establish the following equations:

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$$f(Econ.) = Ec1.prob\ (inv.costs) + Ec2prob(oper.costs)$$
$$f(Env.) = En1.prob(reg.env.leg.) + En2.prob(odor\ gen.) + En3.prob\ (p.reuse\ efflu.) + En4.prob(clim.)$$
$$f(Soc.) = S1.prob(loc.cult.) + S2.prob(occup.safety)$$
$$f(Gov.) = G1.prob(int.neighborhood)$$

Equation 1. Functions of the EESG dimensions

$$f(EESG) = (0{,}08976.0{,}84.X1 + 0{,}08976.0{,}83.X2) + (0{,}08526.0{,}88.X3 + 0{,}03812.0{,}79.X4 + 0{,}14450.0{,}65.X5 + 0{,}08407.0{,}87.X6) + (0{,}12481.0{,}85.X7 + 0{,}12481.0{,}83.X8) + (0{,}21885.0{,}74.X9)$$

Equation 2. Formula of the objective function of the problem

In this way, it was possible to arrive at the following equation:

f(EESGi) = f(EESGc) / f(EESGp)

Equation 3. Performance Ratio

Where *f(EESGi)* is the performance ratio between the calculated value for the firm *f(EESGc)* and the maximum value for the model in question *f(EESGp)*, and: X1 = X2 = X3 = X4 = X5 = X6 = X7 = X8 = X9 = 1.

That is, the model compares the company's result *f(EESGi)* with the maximum value obtained by model *f(EESGp)*.

DISCUSSION OF RESULTS

The reuse of effluents can occur for potable and non-potable purposes. It generates high costs and can pose risks to human health. Its practice is conditioned by situations of scarcity. Reuse for non-potable purposes occurs in the following activities: agricultural (irrigation of edible plants or not) and urban (fire prevention, toilet flushing, street washing, cooling towers, among others). Reuse in a brewery requires first the adoption of good operational practices capable of guiding decision-making, such as monitoring, production improvements, and water and energy consumption data (Nordheim and Barrasso, 2007).

Regarding odor, people's responses vary, as demonstrated in this research. This variability results from different odor perceptions (perception varies due to different classes of odor compounds). Furthermore, whether an odor is accepted or rejected depends greatly on previous experiences, the circumstances in which it is experienced, and the age, health, and attitudes of the human recipient. Care should be taken in the choice of materials that will be used in the treatment, as they can influence the odor more than the effluent itself. Easily recognized by its rotten egg odor, hydrogen sulfide (H_2S) is responsible for most odor problems associated with brewery and food processing effluent treatment. Heavier than air, colorless, corrosive, and extremely toxic, it raises serious health and safety issues in the workplace (Robbins and Brillat, 2002).

Another factor considered relevant was the interaction with the neighborhood. A good study of this factor should consider establishing parameters in case renovations are necessary for the project's viability and environmental impact studies presenting proposals for environmental adjustments. Companies that implement such practices can see concrete benefits such as adding value to the product, winning new markets, making better use of natural resources, reducing costs, and increasing productivity (Leite, Santos, and Oliveira, 2011).

Legislation is the first condition for a wastewater treatment project. It is worth noting that differences in legislation often make it impossible to copy a successful treatment project from one state to another. A wastewater treatment plant (STP) may be sufficient to meet the legislation in one state but does not meet all the limits set by another state. Companies such as Ambev have programs such as Basins & Forests, which is an initiative with the mission to collaborate in the recovery and preservation of important water basins in the country through a broad diagnosis of each basin, bringing together various partners and outlining a local plan with actions that include environmental education, ecological restoration, conservation practices, and payment for environmental services (Ambev, n. d.).

The organic load control parameters are applied very differently between states. In the state of Rio de Janeiro, the evaluation is done based on the parameters of biological oxygen demand and chemical oxygen demand. Regarding the biological oxygen demand, the efficiency is directly linked to the organic load in two ranges: up to 100 kg BOD/d at 70% and above 100 kg BOD/d at 90%. Regarding the chemical oxygen demand, the control is done by concentration, with a table in which the typology of the industry is the indicator (Giordano, 2003). Concerning metals, the concentration of the parameters varies between the different state laws.

The AHP-GDMxBBN multiplication factors showed that all EESG factors are of paramount importance, requiring mitigation for the insertion to occur with quality and safety. The equations found are important sources of information for companies that want to implement EESG using risk analysis methodologies.

CONCLUSIONS

However, it should be noted that the model to be proposed in this study is limited to presenting an objective function that will be treated as a "Breweries EESG Indicator," leaving it up to each of the companies that opt to adhere to it to define the metrics and their internal indicators that are most appropriate for each of the factors and sub-criteria, according to their business strategy. In other words, as presented in this paper, each company adopts the indicator that suits it for each subcriterion analyzed.

Therefore, the answers to the research questions are presented:

QP1: What is the degree of importance of the EESG dimensions regarding reuse water utilization in Brazilian breweries (the AHP-GDM approach)?

Answer: Table 7 presents the degree of impact found on the EESG dimensions according to this study:

Table 7. Probability x Impact Table

Risk Factors	Impact
Economic	0.19
Environmental	0.35
Social	0.24
Governance	0.22

Source: The authors (2021)

QP2: What is the criticality level of the risk factors involved in the process of using reuse water in the industrial processes of Brazilian breweries (BBN approach)?

Answer: Table 8 presents the degree of probability of occurrence found in the EESG dimensions according to this study:

Table 8. Probability x Impact table

Risk Factors	Probability
Economic	0.83
Environmental	0.80
Social	0.84
Governance	0.74

Source: The authors (2021).

QP3: Would it be possible to build a model or function that allows establishing a performance relationship for the operations (AHP-GDM x BBN hybrid method approach)?

Answer: Yes, it is possible, as demonstrated by **Equations 1**, **2**, and **3** found in Chapter 3, Section 3.6 of this paper.

Given the context of the delimitations of the research to propose an indicator that would allow analyzing the EESG perspective of brewing companies, among the suggested developments of the research are potential reflections as to:

Conducting a bibliographic survey or direct consultation with the companies in the industry to verify the indicators most frequently used by breweries when they need to quantify each critical factor detected in this work to assess whether there is a range of similar or converging indicators among the companies that can quantify or assign values to the variables of the proposed objective function so that it can be an alternative tool to perform benchmarking among the companies in the industry in the form of a ranking (ranking according to the score obtained in the objective function).

Conduct a case study with some companies that allow them to use their data so that it is possible to analyze it with a focus on generating new models.

Application of the model in other companies or sectors that use water intensively in their processes, such as the civil, steel, chemical, food, and energy (thermoelectric) industries.

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Appendix I - Theoretical framework

Number	Title	Keywords	Year	Authors	Journal	Method	Results
1	Aggregation of the nearest consistency matrices with the acceptable consensus in AHP-GDM	Group decision making (GDM), Pair-wise comparison matrix (PCM), Consistency, Consensus, Nearest consistent matrix	2020	Chang-sheng Lin, Gang Kou, Yi Peng, Fawaz E. Alsaadi	Annals of Operations Research	In this paper, they propose the aggregation of the closest Consistent Matrices (ANCM) with acceptable consensus in AHP-GDM simultaneously considering the consensus and consistency of individual PCMs. ANCM is independent of prioritization methods following the Pareto principle of social choice theory.	Two numerical examples illustrate the applications and advantages of the proposed ANCM.
2	A Bayesian priorization procedure for AHP-group decision making	Analytic Hierarchy Process (AHP), Group decision making, Bayesian priorization procedure (BPP), MCMC, Negotiation	2007	Alfredo Altuzarra, José Mária Moreno--Jiménez, Manuel Salvador	European Journal of Operational Research	The procedure is based on a Bayesian analysis of the problem and generally provides more efficient estimates than the techniques conventionally applied in the literature for AHP-GDM: individual judgment aggregation (AIJ) and individual priority aggregation (AIP).	The proposed procedure naturally extends to the analysis of incomplete and imprecise pairwise comparison matrices, increasing realism, practicality, and scope. The methodology was illustrated by the analysis of a case study.
3	Aggregating individual judgments and priorities with the Analytic Hierarchy Process	Analytic Hierarchy Process, Aggregating individual judgments, Aggregating individual priorities, Geometric mean	1988	Ernest Forman, Kirti Peniwati	European Journal of Operational Research	It proposes that the choice of method depends on whether the group is assumed to act together as a unit or as separate individuals and explains why AIJ is appropriate for the former while AIP is appropriate for the latter. Also the relationships between the choice of method, the applicability of the Pareto principle, and the use of arithmetic or geometric means in aggregation.	They discuss Ramanathan and Ganesh's method for deriving priorities for individual decision-makers that can be used when aggregating the group preferences of individuals whose judgments are not all equally weighted. They conclude that while this method can be useful, it is only applicable in special circumstances.

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Appendix II - Matrices

R.01	Economic	Environmental	Social	Governance	Autovetor	Norm.	lambda	mi
Economic	1	1/9	1/9	1	0,333	0,069	4,470	0,157
Environmental	9	1	1	1	1,732	0,361		
Social	9	1	1	1	1,732	0,361	CI	0,157
Governance	1	1	1	1	1,000	0,208	RI	0,900
	20,000	3,111	3,111	4,000	4,797	1,000	CR	0,174

Figure 8 - Matrix - Respondent 01

R.02	Economic	Environmental	Social	Governance	Autovetor	Norm.	lambda	mi
Economic	1	1/5	1	5	1,000	0,177	4,348	0,116
Environmental	5	1	5	5	3,344	0,593		
Social	1	1/5	1	5	1,000	0,177	CI	0,116
Governance	1/5	1/5	1/5	1	0,299	0,053	RI	0,900
	7,200	1,600	7,200	16,000	5,643	1,000	CR	0,129

Figure 9 - Matrix - Respondent 02

R.03	Economic	Environmental	Social	Governance	Autovetor	Norm.	lambda	mi
Economic	1	1/5	1/5	1/5	0,299	0,044	5,333	0,444
Environmental	5	1	1/9	1/9	0,498	0,074		
Social	5	9	1	1/9	1,495	0,221	CI	0,444
Governance	5	9	9	1	4,486	0,662	RI	0,900
	16,000	19,200	10,311	1,422	6,779	1,000	CR	0,494

Figure 10 - Matrix - Respondent 03

R.04	Economic	Environmental	Social	Governance	Autovetor	Norm.	lambda	mi
Economic	1	1/5	1	1	0,669	0,125	4,000	0,000
Environmental	5	1	5	5	3,344	0,625		
Social	1	1/5	1	1	0,669	0,125	CI	0,000
Governance	1	1/5	1	1	0,669	0,125	RI	0,900
	8,000	1,600	8,000	8,000	5,350	1,000	CR	0,000

Figure 11 - Matrix - Respondent 04

R.05	Economic	Environmental	Social	Governance	Autovetor	Norm.	lambda	mi
Economic	1	5	5	5	3,344	0,625	4,000	0,000
Environmental	1/5	1	1	1	0,669	0,125		
Social	1/5	1	1	1	0,669	0,125	CI	0,000
Governance	1/5	1	1	1	0,669	0,125	RI	0,900
	1,600	8,000	8,000	8,000	5,350	1,000	CR	0,000

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Figure 12 - Matrix - Respondent 05

R.01	Regional Environmental Legislation	Odor Generation	Possibility of Reusing Treated Effluents	Climate	Autovetor	Norm.	lambda	mi
Regional Environmental Legislation	1	5	1/9	1	0,863	0,123	4,493	0,164
Odor Generation	1/5	1	1/9	5	0,577	0,082		
Possibility of Reusing Treated Effluents	9	9	1	9	5,196	0,740	CI	0,164
Climate	1	1/5	1/9	1	0,386	0,055	RI	0,900
	11,200	15,200	1,333	16,000	7,023	1,000	CR	0,182

Figure 13 - Matrix - Respondent 01

R.02	Regional Environmental Legislation	Odor Generation	Possibility of Reusing Treated Effluents	Climate	Autovetor	Norm.	lambda	mi
Regional Environmental Legislation	1	5	1	1	1,495	0,313	4,000	0,000
Odor Generation	1/5	1	1/5	1/5	0,299	0,063		
Possibility of Reusing Treated Effluents	1	5	1	1	1,495	0,313	CI	0,000
Climate	1	5	1	1	1,495	0,313	RI	0,900
	3,200	16,000	3,200	3,200	4,785	1,000	CR	0,000

Figure 14 - Matrix - Respondent 02

R.03	Regional Environmental Legislation	Odor Generation	Possibility of Reusing Treated Effluents	Climate	Autovetor	Norm.	lambda	mi
Regional Environmental Legislation	1	1/9	1/9	1/9	0,192	0,025	5,333	0,444
Odor Generation	9	1	1/9	1/9	0,577	0,075		
Possibility of Reusing Treated Effluents	9	9	1	1/9	1,732	0,225	CI	0,444
Climate	9	9	9	1	5,196	0,675	RI	0,900
	28,000	19,111	10,222	1,333	7,698	1,000	CR	0,494

Figure 15 - Matrix - Respondent 03

R.04	Regional Environmental Legislation	Odor Generation	Possibility of Reusing Treated Effluents	Climate	Autovetor	Norm.	lambda	mi
Regional Environmental Legislation	1	9	1	1	1,732	0,375	4,411	0,137
Odor Generation	1/9	1	1/5	1	0,386	0,084		
Possibility of Reusing Treated Effluents	1	5	1	1	1,495	0,324	CI	0,137
Climate	1	1	1	1	1,000	0,217	RI	0,900
	3,111	16,000	3,200	4,000	4,613	1,000	CR	0,152

Figure 16 - Matrix - Respondent 04

R.05	Regional Environmental Legislation	Odor Generation	Possibility of Reusing Treated Effluents	Climate	Autovetor	Norm.	lambda	mi
Regional Environmental Legislation	1	5	5	5	3,344	0,612	4,653	0,218
Odor Generation	1/5	1	1/5	5	0,669	0,122		
Possibility of Reusing Treated Effluents	1/5	5	1	1	1,000	0,183	CI	0,218
Climate	1/5	1/5	1	1	0,447	0,082	RI	0,900
	1,600	11,200	7,200	12,000	5,460	1,000	CR	0,242

Figure 17 - Matrix - Respondent 05

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