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STUDY OF LABOR RELATIONS IN BRAZILIAN SUGAR-ETHANOL COMPANIES THROUGH FUZZY LOGIC

ESTUDIO DE LAS RELACIONES LABORALES EN EMPRESAS BRASILEÑAS DE AZÚCAR Y ETANOL A TRAVÉS DE LA LÓGICA DIFUSA

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Abstract

The sugar-ethanol sector is a vital agro-industrial production chain in Brazil, focused on the production of sugar, alcohol, and energy, with significant economic relevance. However, it faces challenges such as environmental impacts and problematic labor relations. The current global context, with legislative changes, emphasizes Corporate Social Responsibility (CSR). This research evaluated CSR in labor relations, highlighting health and occupational safety in the sector in the state of São Paulo, Brazil. Through a literature review and mapping of companies, the aim was to understand the state of CSR. A fuzzy mathematical model was applied, using a questionnaire with 15 closed questions based on the Likert scale. The data were analyzed using Matlab® software, allowing for the measurement of CSR in human capital development. The results showed that CSR is linked to variables such as safety committees, preventive actions, and health programs. Cultural and social restrictions on the implementation of CSR were identified. The perception of CSR highlights its role in regional development, employability, and social inclusion of employees.

Keywords: Fuzzy Logic, Corporate Social Responsibility, Labor Relations, Occupational Health and Safety, Sugar-Ethanol Sector.

Resumen

El sector de azúcar y etanol es una cadena productiva agroindustrial vital en Brasil, centrada en la producción de azúcar, alcohol y energía, con una relevancia económica significativa. Sin embargo, enfrenta desafíos como impactos ambientales y relaciones laborales problemáticas. El contexto global actual, con cambios legislativos, enfatiza la Responsabilidad Social Empresarial (RSE). Esta investigación evaluó la RSE en las relaciones laborales, destacando la salud y la seguridad ocupacional en el sector en el estado de São Paulo, Brasil. A través de una revisión bibliográfica y un mapeo de empresas, el objetivo fue comprender el estado de la RSE. Se aplicó un modelo matemático fuzzy, utilizando un cuestionario con 15 preguntas cerradas basado en la escala Likert. Los datos fueron analizados utilizando el software Matlab®, lo que permitió medir la RSE en el desarrollo del capital humano. Los resultados mostraron que la RSE está vinculada a variables

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como comités de seguridad, acciones preventivas y programas de salud. Se identificaron restricciones culturales y sociales para la implementación de la RSE. La percepción de la RSE resalta su papel en el desarrollo regional, la empleabilidad y la inclusión social de los empleados.
Palabras clave: Lógica Difusa, Responsabilidad Social Empresarial, Relaciones Laborales, Salud y Seguridad Ocupacional, Sector Sucroenergético.

Introduction

Social Responsibility is becoming increasingly relevant in contemporary companies, both due to socio-environmental impacts and the demands of stakeholders. The concept of ESG (Environmental, Social, and Governance) and, complementarily, Corporate Social Responsibility (CSR) emerge in a context of significant technological transformations and innovations, representing a crucial challenge for the competitiveness and strategic improvement of organizations. In this context, three aspects stand out: the adoption of digital technologies, including artificial intelligence; the strategic alignment of business objectives with ESG criteria; and the effects of technological changes on company operations, especially regarding their performance (TRUANT et al., 2023).

Corporate Social Responsibility (CSR) and the concepts of ESG are becoming an increasingly significant trend and a growing demand in the global economy, with impacts that extend beyond Brazil's borders. The various groups that make up the business environment play a crucial role in shaping values and influencing organizational practices, highlighting the increasing importance of CSR in a global context (WELZEL et al., 2017)

The production chain of the sugar-energy sector is extensive and presents various complexities, encompassing everything from agriculture in sugarcane production to logistical aspects and the industry responsible for manufacturing the main products: ethanol, sugar, and electricity. In Brazil, this sector has over 400 years of history, intertwining with the country's economic formation. Over time, it has often been associated with negative environmental impacts and labor-related issues. Currently, these challenges represent a significant obstacle for the sector

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in a global context that demands the adoption of Corporate Social Responsibility and ESG concepts (MACIEL et al., 2011; CERDAS VEGA, 2023)

The Brazilian production system is part of a global subsystem and has undergone significant evolution at the local level, driven by changes in legislation. Local political dynamics and global pressures have promoted important transformations in labor relations, highlighting the importance of Corporate Social Responsibility in this context. Furthermore, the interactions of organizations with their stakeholders, such as workers, governments, and society, have become increasingly relevant in recent decades (CRISÓSTOMO et al., 2014; LEDUCHOWICZ et al., 2024).

One of the main challenges in demonstrating the importance of Corporate Social Responsibility (CSR) for organizations is the quantitative measurement of its impact on financia and economic performance. There is a common misconception that CSR is merely a cost, leading to the belief that its implementation may compromise competitiveness compared to rivals, especially when considering the price comparison of the products and services offered by companies.

The mistaken belief that CSR is limited to a cost and that its adoption may lead to a decrease in competitiveness compared to rivals is linked to the comparison of the prices of the products and services offered by companies. Furthermore, one of the main challenges in demonstrating the importance of CSR in organizations is the difficulty in quantitatively measuring its impact on financial and economic performance (LÓPEZ et al., 2007; PERIA et al., 2020).

Understanding Corporate Social Responsibility (CSR) in the context of the sugar-energy sector and measuring it through indicators is essential for the construction and implementation of this concept. This analysis should consider both macro aspects (countries, states, regions, and municipalities) and micro aspects of production units. Fuzzy mathematical models have increasingly been used to develop sustainable policies and achieve Sustainable Development Goals (SDGs), in alignment with the mission of CSR (OLIVEIRA et al., 2023; DINÇER et al., 2023).

The use of fuzzy logic as an analytical tool to evaluate CSR in labor relations in this study is based on the literature review conducted, which in recent years has proven effective in solving complex problems similar to the focus of this work. Labor relations are inherently complex and involve a range of factors that can be difficult to measure and quantify (HUANG et al., 2020).

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The main objective of the research was to develop a fuzzy inference mathematical model to analyze labor relations in the sugar-energy sector companies in the state of São Paulo, the largest sugarcane producer in Brazil, with a specific focus on Occupational Health and Safety (OHS) actions. The secondary objectives include mapping and conducting comparative analyses among the companies in the São Paulo sugar-energy sector.

Theoretical Framework

The sugarcane agroindustry was one of the main pillars of the Brazilian colonial economy, distinguished by its sugar production, which ensured the supply of the domestic market and became the primary commodity in Brazil's exports over the centuries. This sector drove the development of various regions, especially in coastal areas where climatic conditions were favorable for sugarcane cultivation. The increasing demand for sugar resulted in the expansion of plantation

and the adoption of more advanced production techniques, shaping the economic and social structure of the time (SZMERECSÁNYI, 1979).

In the 1960s, Brazil faced an excess of investment in the sugar industry, which was unable to meet demand in both the domestic and international markets, resulting in an overproduction of sugar. This led to a drop in prices in the global market, culminating in a severe crisis in the sector between 1973 and 1974. The situation worsened with the global oil crisis, which caused barrel prices to soar from $3 to $18 in just a few days. In response, the government and the sugarcane agroindustrial sector launched the ambitious National Alcohol Program (PROÁLCOOL) in 1974. This program aimed to coordinate government actions to stimulate demand for ethanol as a fuel, seeking to address the oil price crisis and utilize the idle capacity of the sugarcane industry by allocating part of the sugarcane production for ethanol production (GUEDES et al., 2013; CERDAS VEGA, 2023).

Subsidized investments led to the creation and consolidation of a sugar industry, especially in the interior of São Paulo. Although various authors have raised concerns about rapid expansion's environmental and social impacts, a new agro-industrial frontier for sugarcane was established, surpassing even the traditional northeastern region of Brazil as the main producer. According to

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data from the Sugarcane Agroindustry Union (UNICA), in the 2022/23 harvest, the state of São Paulo produced 314,508,678 tons of crushed cane, representing 51.78% of the national production of 607,413,483 tons (UNICA, 2023).

In addition to generating wealth for owners, the sugarcane agroindustry impacted social relations, being closely associated with the plantation system that utilized slave labor. Over time, the sector evolved, adapting to new market demands and diversifying its production, including the manufacture of ethanol. Currently, the sugarcane agroindustry remains an essential part of the Brazilian economy, reflecting its historical relevance and its role in the country's economic and environmental sustainability (EPIFÂNIO, 2023).

Figure 1 highlights the two main sugarcane production regions in Brazil, with an emphasis on the Center-South, which stands out as the primary production area.

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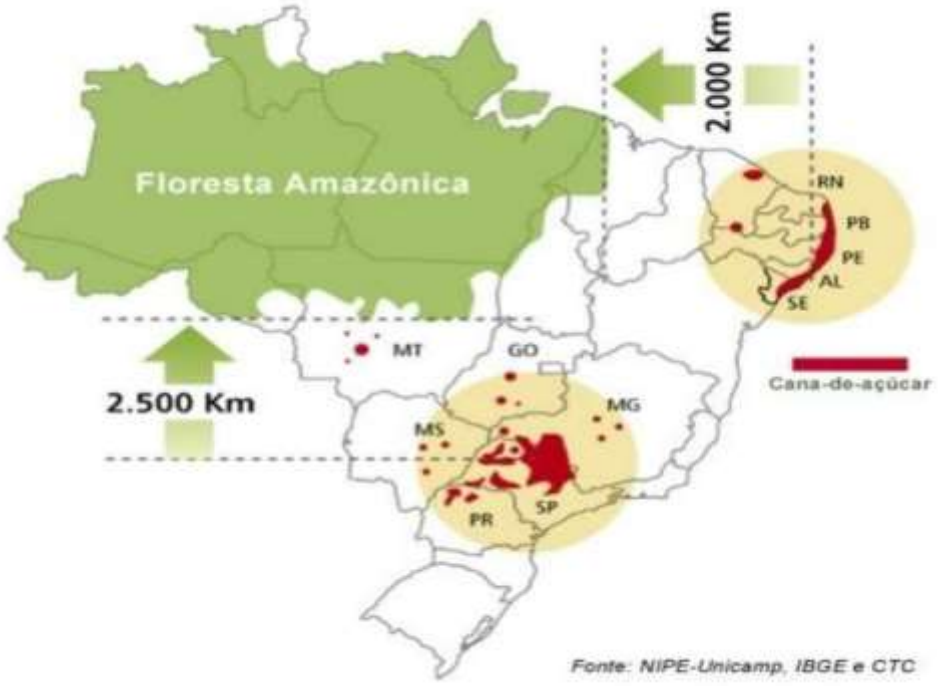
Figura 1: Map of Sugarcane Production in Brazil



Source: (NIPE-UNICAMP et al., 2017).

Figure 1, above clearly illustrates the geographical distribution of sugarcane in Brazil; in the Northeast region, cultivation is concentrated along the coast, encompassing the states of Sergipe, Alagoas, Pernambuco, Paraíba, and Rio Grande do Norte. On the other hand, in the Southeast region, the state of São Paulo stands out as the main producer of sugarcane.

The Brazilian sugarcane industry is vital to the national economy, and corporate social responsibility (CSR) is playing an increasingly critical role within it. Beyond generating sugar, ethanol, and energy and driving economic growth, sugarcane production provides significant opportunities for CSR. By implementing sustainable practices, investing in local communities, supporting education and healthcare initiatives, and adhering to ethical labor standards, Brazilian sugarcane companies can profoundly impact social and environmental well-being, demonstrating a genuine commitment to social responsibility (MANNARELLI FILHO, 2023).

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The incorporation of the Sustainable Development Goals (SDGs) from the UN's 2030 Agenda represents a significant strategic advantage for companies committed to responsible actions. Integrating these goals into strategies and operations, through the continuous adoption of best practices and sustainable innovations, is essential for this commitment (LORETO et al., 2018).

Among the 17 Sustainable Development Goals established by the UN, SDG 8 stands out for promoting sustainable and inclusive economic growth, as well as ensuring decent work for all.

Formal employment is considered essential for achieving both personal and collective goals, playing a vital role in reducing poverty and social inequality. In this context, the creation of quality jobs is a crucial aspect, especially regarding the development of human capital within organizations (SZCZEPANIK et al., 2022).

The relevance of Corporate Social Responsibility (CSR) should be understood as a humanistic phenomenon that integrates into the corporate context, rather than as an isolated activity. It represents a new management approach based on a commitment to society. This perspective requires all companies to generate some impact in the three dimensions of CSR: social, environmental, and economic. In the case of agro-industries in the sugar-energy sector, recognized as "transformation industries," the impact in these three areas is significant (LUPPI, 2007; NEVES & DE BENEDICTO, 2022).

Creating a healthy work environment requires the implementation of policies that value well-being, encourage diversity, and promote skill development. Investing in human capital not only improves employee satisfaction and retention but also enhances the competitiveness and sustainability of companies. Effectively managing these aspects is essential for organizational success in an ever-changing landscape.

Methodology

Qualitative research encompasses diverse methods and analytical styles, exploring the various aspects of participants. Unlike approaches based on pre-defined hypotheses, qualitative research prioritizes the data and evidence collected, which can either corroborate or refute initial

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assumptions (GODOY, 1995).

Content analysis allows for diverse interpretations, conditioned by the theoretical approach adopted and the researcher's objectives. This interpretation may draw on concepts from the statistical semantics of discourse or seek inferences through the objective identification of characteristics within the messages; the judicious application of content analysis is essential to dispel uncertainties and answer the research questions (BARDIN, 2011).

This research employed content analysis, applying a mathematical model of fuzzy logic for a more flexible and comprehensive interpretation of the data. Fuzzy logic, which deals with the uncertainty and imprecision common in social research, allows for capturing nuances that conventional analyses might miss, offering a richer and more detailed understanding of the phenomenon studied.

Furthermore, the adoption of a qualitative-quantitative perspective enables the combination of qualitative and quantitative data, enriching the analysis and allowing for a more robust triangulation of information. This integration is particularly valuable in research that seeks to explore the complexity of human behaviors and opinions, providing a more comprehensive view of the object of study.

The study included companies in the sugarcane industry in the state of São Paulo that process over 500,000 tons of sugarcane per harvest. This selection is justified by the understanding within the industry that companies processing less than this volume have little relevance and are virtually non-existent in the state.

Data were gathered using a questionnaire, delivered both in person and electronically through Google Forms®. The questionnaire included 15 questions, organized into 4 categories relevant to the research, and used a 5-point Likert scale for closed-ended responses. Before distribution, a panel of three professionals from the sugarcane industry helped define the fuzzy parameters for measuring labor relations and their impact on human capital development.

Data collection was conducted in selected companies based on convenience and ease of access, ensuring the representativeness of the sample in São Paulo. The questionnaires, consisting of 15 questions, were administered either in person or remotely. Although some companies did not

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authorize the disclosure of their names in the research, their identity was preserved, allowing only the use of the collected data; Figure 2 presents the map of the locations of the companies sampled in the study.

Figure 2: Map of the surveyed mills in the state of São Paulo, in the fuzzy questionnaire sample.

Source: elaborated by the authors, based on the Google Maps image, 05/25/23.

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The convenience sample chosen for this research includes 63 companies, which corresponds to 36.63% of the total of 172 companies in the state of São Paulo. In the 2021/22 harvest, these 63 companies processed 164,023,937 tons of sugarcane, representing 55.03% of the total milling in the state. This sample has significant statistical representativeness, as it encompasses companies responsible for more than 50% of the total milling in the state.

Fuzzy models offer a valuable tool that aids in decision-making by integrating qualitative and quantitative data. This represents an innovation in the classification of various variables used by companies. This tool is useful for reaching consensus, especially in situations with conflicting interests, and also contributes to the allocation of resources in CSR initiatives (POPLAWSKA et al., 2015).

Shaw e Simões (1999), they assert that the involvement of a human expert, previously interviewed, is essential for the development of the fuzzy rule set. This expert is responsible for defining the relationships between the linguistic inputs and outputs, which allows the fuzzy system to generate nonlinear estimates without the need for mathematical models, functioning as an autonomous method for evaluating inputs and outputs.

According to Santos (2008) and Martínez et al. (2020), fuzzy logic operates with fuzzy sets, which exhibit varying degrees of membership, unlike classical sets, which are binary. This process involves fuzzification (transformation of exact values into fuzzy values), the rule base (which connects inputs and outputs), the inference engine (which combines rules and input values), and defuzzification (which converts fuzzy values back into exact values). These components enable a more effective approach to dealing with uncertainty and imprecision.

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Results and Discussion of the Results

The questionnaire, consisting of 15 questions, is organized into four axes, which can be viewed in Table 1 below.

Table 01 - Abbreviations used for the sub-axis of Health and Occupational Safety - HOS.

SUB-AXES OF HEALTH AND OCCUPATIONAL SAFETY	ABBREVIATION
Existence of workplace safety committees.	CST
Affirmative prevention actions: obesity, smoking, alcoholism, etc	OTA
Health insurance plans, healthcare agreements, and related services.	PSC
Educational programs and employee assistance programs for employees and/or their families.	PEA

Source: Prepared by the author.

The expert panel for the 81 fuzzy rules was developed with the classification of responses as high, medium, or low, using a Mamdani-type controller in Matlab® software. This methodological procedure generated three-dimensional graphs and contour maps of the output variables. These graphs and maps provide information about the impact of the inputs on the system's results, illustrating how different input values can lead to distinct outputs.

The three-dimensional graphs, in turn, highlight the relationship between three fuzzy variables, allowing for the visualization of the fuzzy surface in different shades or colors, which represent the various degrees of membership of the variable values in a three-dimensional space. These graphs are essential for understanding complex fuzzy variables within a system (KLIR & YUAN, 1995; LAUREANO et al., 2018).

The standard color scale of Matlab® encompasses a wide range of shades, varying from lighter to darker tones. Lighter colors represent lower membership values, while darker colors indicate higher membership values. This distinction in colors facilitates the identification of

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membership intensity in different regions of the fuzzy sets. In this study, the standard colors were used without modifications, which are:

Red: Fuzzy sets with high membership or elevated levels of activity.

Green: Fuzzy sets with moderate membership and intermediate levels of activity.

Blue: Fuzzy sets with low membership or lower levels of activity.

Pink or purple: Indicate uncertainty in fuzzy sets, typically used for sets with unclear or undefined membership.

Gray: Indication of transition or mixing zones in fuzzy sets.

White: Represents null or empty values, where there is no membership.

Three-Dimensional Graphs and Contour Maps

The three-dimensional graphs and contour maps generated by the software always correlate two of the input variables: Existence of Occupational Safety Committees (CST), Affirmative Prevention Actions (such as obesity, smoking, alcoholism, etc.) - OTA, Health Plans and Health Area Agreements - PSC, and Educational and Assistance Programs for Employees and/or Family Members - PEA, which are positioned on the X-axis. The output variable, Corporate Social Responsibility (RSE), is represented on the Y-axis. It is important to note that the other two input variables related to Health and Occupational Safety, which are not correlated, remain constant, with the Matlab® software considering an average value of 2.5 for these constants.

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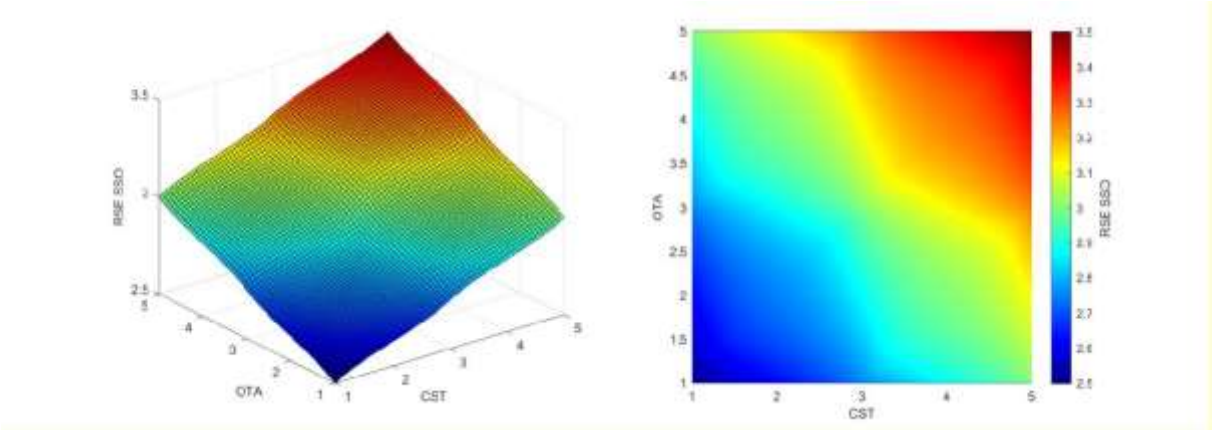
Additionally, the software generates both a three-dimensional graph and a contour map for each pair of correlated variables. These graphs allow users to visualize the relationship between the input and output variables, facilitating informed decisions on how to adjust the system to achieve the desired results.

Here, we present the three-dimensional graphs and the generated contour maps, which illustrate the possible correlations between the four variables, resulting in a total of six graphs.

Figure 3 - Three-dimensional chart and contour map of the OTA and CST input variables**.**



Source: Prepared by the author.

Figure 3 presents the three-dimensional graph and a contour map of the input variables: The existence of Occupational Safety Committees (CST) and Affirmative Prevention Actions, such as obesity, smoking, and alcoholism (OTA). In this figure, Corporate Social Responsibility (RSE) stands out at elevated levels (represented by the color red), with values exceeding 4 on the Likert scale for both variables. A transition range is observed, where the average RSE varies between 3 and 4, with colors ranging from green to yellow. Conversely, for values below 3 in both inputs, the RSE related to Health and Occupational Safety is low, evidenced by light blue and dark blue colors.

It should be emphasized that the software can only analyze the combination of two input

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variables. The other combinations of these variables will be presented next.

Figure 4 below combines the input variables: The existence of Occupational Safety Committees (CST) and Health Plans, including health area agreements (PSC).

Figure 4 – Three-dimensional graph and contour map of the PSC and CST.

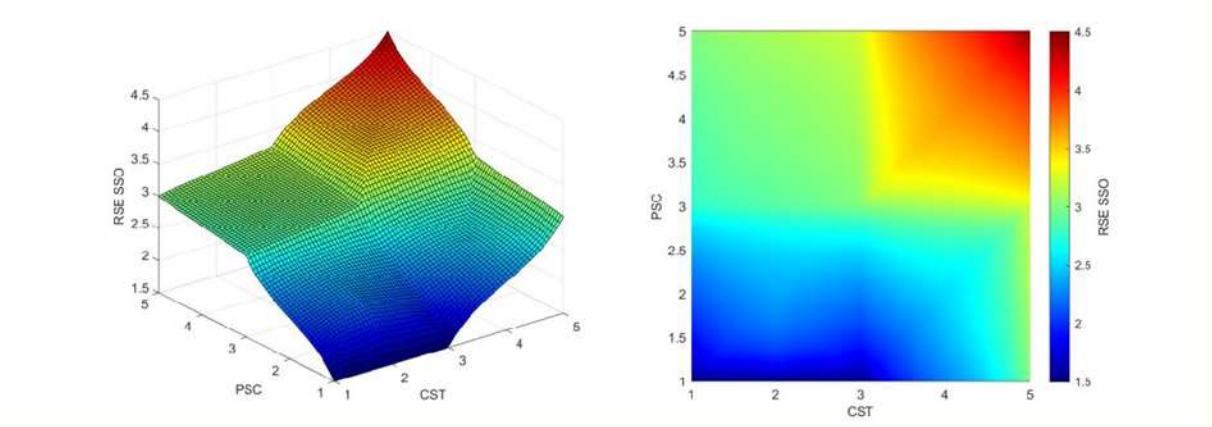

Figure 4 shows a higher RSE for Likert measures above 3.5 in both variables. The transition range, represented by the yellow and primarily green colors, indicates an average RSE, especially when the PSC exceeds 3.0. It is noted that for values below 3.0, which signal the absence or low quality of the PSC, the blue color highlights a low RSE on the SSO axis, even in the presence of CST.

It is observed that the higher RSE in SSO is influenced by factors related to companies' concern for health and the provision of health plans and agreements for their employees.

Figure 5 below integrates the input variables: the Existence of Occupational Safety Committees (CST) and Educational and Assistance Programs for Employees and/or their families (PEA).

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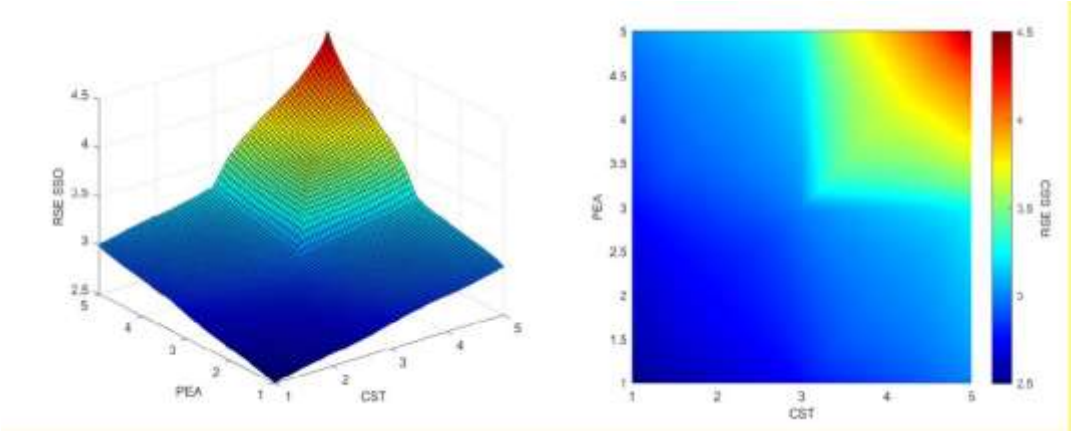
Figure 5 – Three-dimensional graph and contour map of the PEA and CST.



Source: Prepared by the author.

Figure 5 shows a broad blue area, indicating low RSE for the two variables when analyzed together. It is observed that only for values above 4 on the Likert scale, for both variables, does a transition occur that results in an increase in RSE. The PEA and CST variables do not appear to be significant for RSE in the analyzed companies.

Figure 6 below integrates the input variables: Affirmative Prevention Actions, such as obesity, smoking, and alcoholism (OTA), and the Health Plan, which includes health agreements (PSC).

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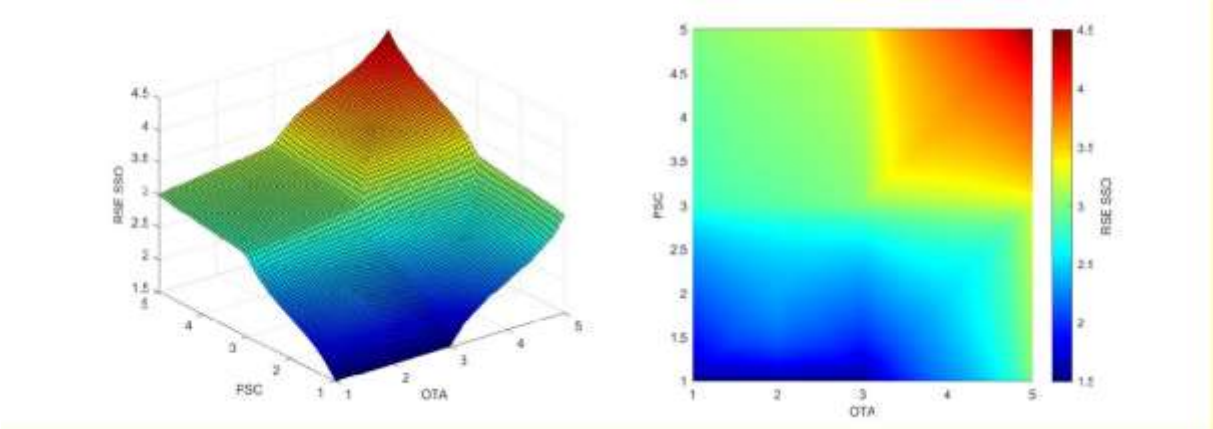
Figure 6 – Three-dimensional graph and contour map of the PSC and OTA variables.



Source: Prepared by the author.

The contour map, surface, and three-dimensional graph generated by Matlab® software, shown in this Figure, reveal a blue area of low RSE that covers Likert values of up to 3.0 for PSC and up to 4.5 for OTA. This suggests that OTA has little influence on the increase in RSE.

It was found that the presence of PSC, represented by the green, yellow, and red areas, is related to a higher level of RSE compared to the absence of OTA benefits. Furthermore, it was observed that the existence of PSC in the analyzed companies significantly contributes to the increase in RSE.

Figure 7 below integrates the input variables: Affirmative Prevention Actions, such as obesity, smoking, and alcoholism (OTA), and Educational and Assistance Programs for Employees and/or their Families (PEA).

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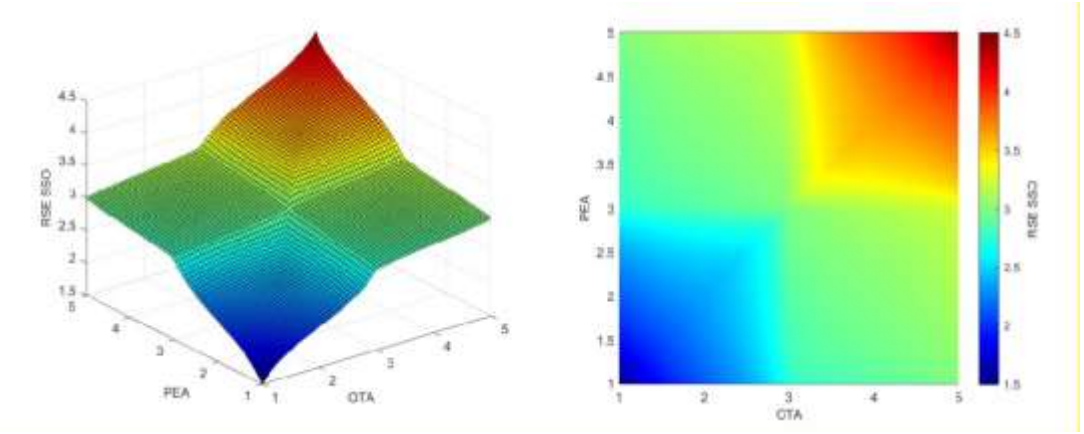
Figure 7 – Three-dimensional graph and contour map of the PEA and OTA variables.



Source: Prepared by the author.

Figure 7 demonstrates a considerable equity between the two analyzed variables concerning the output of RSE. A blue area indicates low RSE when both variables have values below 3, suggesting that, in this context, the effectiveness of affirmative prevention actions and educational and assistance programs is limited. On the other hand, when the values of both variables exceed 3, RSE increases, highlighting a positive relationship between the implementation of effective actions and the growth of corporate social responsibility. This analysis underscores the importance of promoting initiatives that raise the indices of these variables, as the combination of high values in both can result in a significant impact on the RSE of organizations.

Figure 8 integrates the variables: Health Plan, which includes health agreements (PSC), and Educational and Assistance Programs for Employees and/or their families (PEA).

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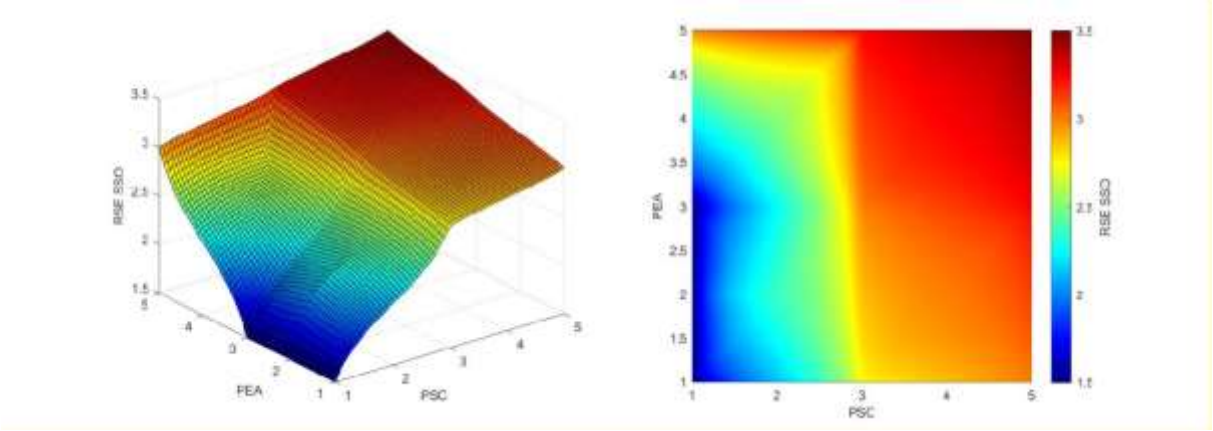
Figure 7 – Three-dimensional graph and contour map of the PEA and PSC variables.



Source: Prepared by the author.

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Figure 8 presents a large area in red, indicating a higher CSR (Corporate Social Responsibility) value for the input variable "Health Plans and Healthcare Agreements (PSC)." This predominance suggests that the presence of PSC is essential for increasing corporate social responsibility. On the other hand, the variable "Educational and Assistance Programs for Employees and/or their families (PEA)" does not demonstrate the same relevance as PSC, although it still plays a significant role. The area in blue, which represents low CSR, is limited, indicating that the effectiveness of PEA is restricted in comparison. Furthermore, the figure reveals a transition zone, with green and yellow colors, which signals the variation of CSR output in the context of occupational health and safety (OHS), emphasizing the importance of both variables in promoting a healthier and more responsible work environment. This analysis highlights the need for investment in PSC, while also underscoring the relevance of integrating educational and assistance programs to maximize the positive impacts on the CSR of organizations.

Figure 9 is presented below, in these three-dimensional graphs summarize the results obtained from the combination of the two fuzzy input variables, which were described, in Figures 3 through 8.

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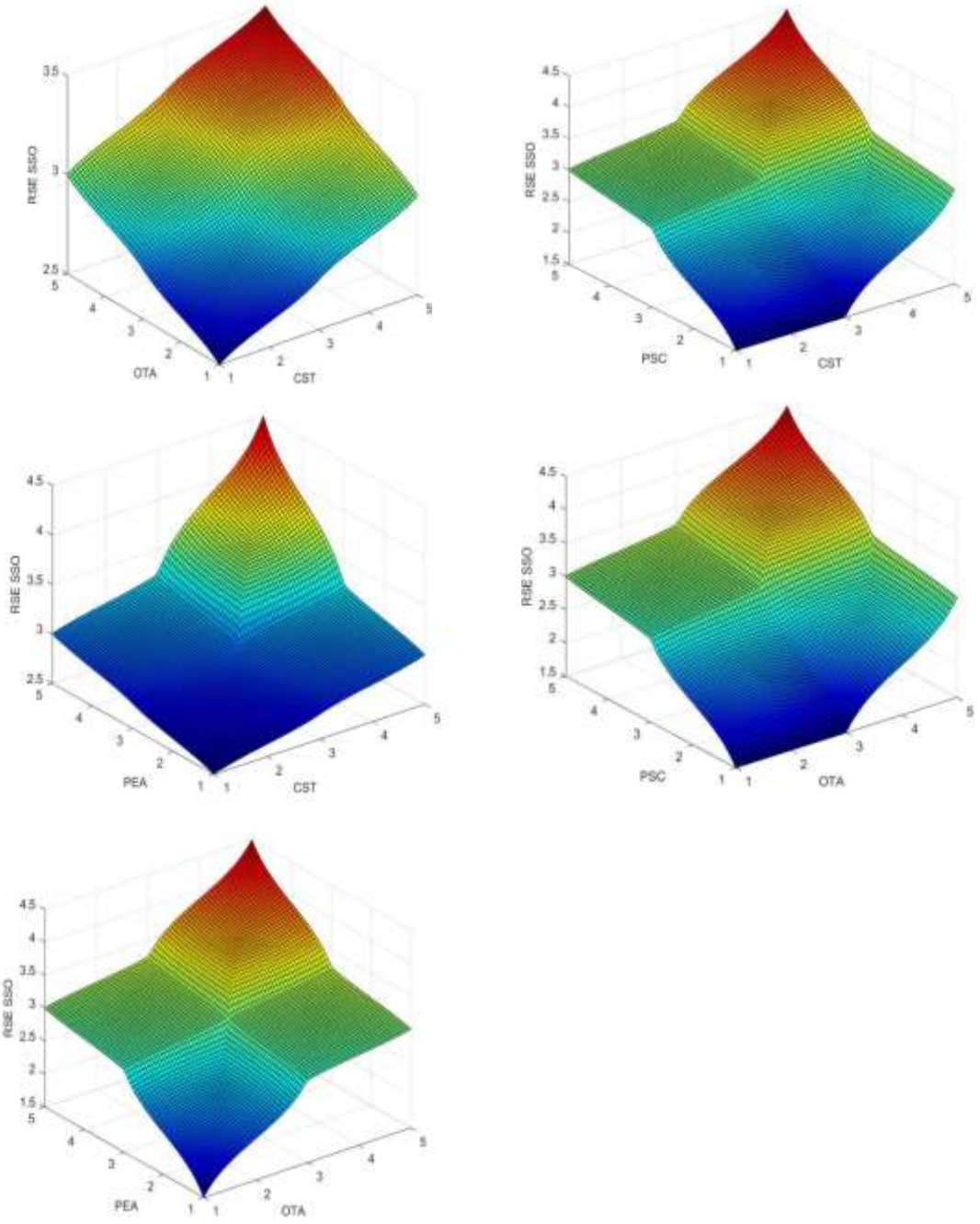
Figure 9 – Grouped three-dimensional graphs of SSO.



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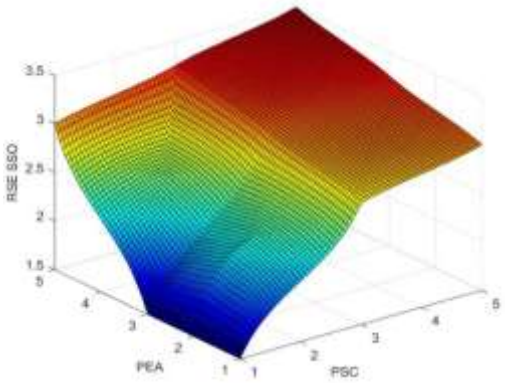

Source: Prepared by the author.

The integrated presentation in this format, encompassing various combinations of the investigated variables, allows for a more complete understanding of the Occupational Health and Safety (OHS) axis. The three-dimensional graphs, generated with Matlab® software for fuzzy analysis, offer a more comprehensive and detailed visualization. Each graph was previously

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analyzed in all six possible combinations. The combined analysis reveals that only in the combination between PEA and CST (likely referring to Social Labor Cost) is there a predominance of the color blue, indicating low CSR for both variables. The increase in CSR, signaled by the color red, only manifests for values close to 5.0 on the Likert scale.

The graphs for the OTA and PEA, and OTA and CST combinations show a similar pattern: low CSR (blue color) for values below 3.0 and high CSR for values above 4.0. Additionally, we observe an intermediate range (green color) between 3.0 and 4.0, representing a medium level of CSR.

The combinations shown in the two graphs, PSC and OTA, and PSC and CST, exhibit a similar pattern. In both graphs, the PSC variable shows a blue color, indicating low CSR, for values below 3.0. The OTA and CST variables, when combined with PSC, also display the blue color of low CSR for values close to 5.0. This suggests that increasing OTA and CST does not increase CSR while PSC is below 3.0.

Finally, the analysis of the combination of PSC and PEA reveals that the PSC variable drives the increase in CSR when its values exceed 3.0 (red color). The PEA variable, on the other hand, predominantly exhibits the blue color, indicating low CSR. This finding suggests that the increase in CSR is more strongly linked to the provision of health plans and agreements, rather than the implementation of educational programs.

Figure 10 presents a grouped two-dimensional graph, summarizing the six graphs of fuzzy combinations displayed in Figure 9. This representation complements the visualization of the fuzzy analysis results for the Occupational Health and Safety (OHS) axis.

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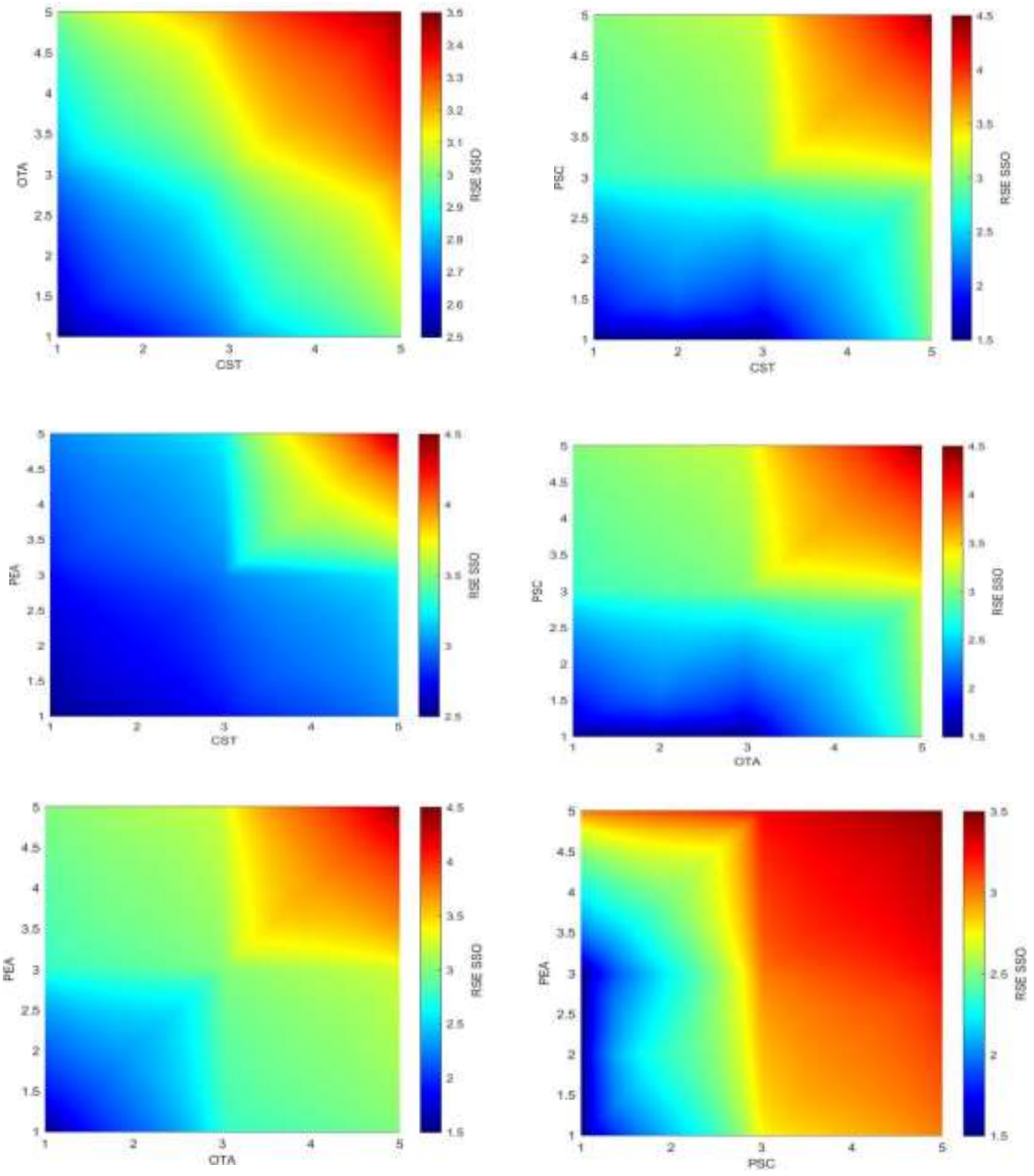
REVISTAS UNISON

"El saber de mis hijos hará mi grandeza"

Figure 10 – Grouped contour maps of SSO



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Source: Prepared by the author.

After the individual analysis of each graph across all six possible combinations, the combined analysis reveals that the predominance of the blue color, indicative of low CSR, occurs only in the combination between PEA and CST. The increase in CSR, signaled by the red color, only becomes evident with values close to 5.0 on the Likert scale.

The graphs related to the OTA and PEA, as well as the OTA and CST combinations, exhibit a similar pattern: low CSR (blue color) for values below 3.0 and high CSR for values above 4.0 on the Likert scale. Between these extremes, an intermediate range (green color) is observed, denoting a medium level of CSR.

The analysis of the combinations between the graphs of PSC with OTA and PSC with CST reveals similar patterns. For PSC values below 3.0, represented by the color blue, a low CSR (Corporate Social Responsibility) is observed in both graphs. On the other hand, the variables OTA and CST, when associated with PSC, also display the blue hue, indicating low CSR, even for values close to 5.0. These results suggest that an increase in OTA and CST values does not lead to a significant increase in CSR when the PSC variable remains below 3.0.

Finally, the combination of the PSC and PEA variables displays a visual pattern indicating that the PSC variable contributes to an increase in CSR (Corporate Social Responsibility) when its values exceed 3.0, represented by the color red. In contrast, the PEA variable shows a predominance of the color blue, indicating low CSR. These results suggest that health plans and agreements in the analyzed area are associated with an increase in CSR. In contrast, educational programs do not demonstrate the same impact.

Conclusões

This study aimed to evaluate Corporate Social Responsibility (CSR) in companies within the sugar-energy sector in the state of São Paulo, focusing on measuring and comparing aspects related to Occupational Health and Safety. Four main areas were analyzed: the existence of workplace safety committees, preventive actions (such as programs to combat obesity, smoking, alcoholism, etc.),

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health plans and medical agreements, as well as educational and assistance programs for employees and their families. The study seeks to map and conduct comparative analyses among these companies, in addition to developing a fuzzy inference mathematical model to examine labor relations within organizations in the São Paulo sugar-energy sector.

Although the sample used was one of convenience, it proved to be statistically robust, covering 36.63% of the companies in the São Paulo sugar-energy sector, which corresponds to 63 mills. This representativeness is significant, as these mills processed 55.03% of the sugarcane crushed in the state during the 2021/22 harvest, accounting for a considerable portion of the sugar and ethanol production in São Paulo and Brazil. The choice of this sample, even though non-random, allows for a comprehensive and consistent analysis of the sector, facilitating the identification of trends and patterns that can be extrapolated to the broader context of the industry.

The study analyzes the variables that impact Occupational Health and Safety (OHS) using three-dimensional graphs and contour maps, developed with the aid of Matlab® software. The integrated visualization of these variables allows for a more detailed understanding of Corporate Social Responsibility (CSR). The intensity of the red color observed in the graphs indicates a higher level of CSR, particularly when two variables exceed the value of three on the Likert scale used in the research.

The results are analyzed based on the visualization of the graphs and maps generated by the software. Figure 3 establishes the correlation between the variables: Existence of Workplace Safety Committees (WSC) and Affirmative Prevention Actions, which include obesity, smoking, and

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alcoholism (OSA). In it, it is observed that Corporate Social Responsibility (CSR) reaches high values, exceeding 4 on the Likert scale, for these two variables. There is also a transition zone, where the average CSR ranges between 3 and 4, represented by colors ranging from green to yellow. On the other hand, for values below 3 in both variables, CSR related to Occupational Health and Safety is considered low, represented by light blue and dark blue colors.

Figure 4 shows a higher level of Corporate Social Responsibility (CSR) for Likert scale values exceeding 3.5 in both variables. A transition zone, represented by yellow and, primarily, green colors, indicates a moderate CSR, especially when the Corporate Health Program (CHP) is above 3.0. It is observed that for values below 3.0, reflecting the absence or low quality of the CHP, the blue color indicates a low CSR in the Occupational Health and Safety (OHS) dimension, even in the presence of Workplace Safety Committees (WSC). Additionally, the higher CSR in OHS is driven by factors related to companies' commitment to employee health and the provision of health plans and medical agreements.

Subsequently, Figure 5 displays a wide blue area, indicating low CSR for both variables when analyzed together. Only values above 4 on the Likert scale for both variables lead to a transition that increases CSR. The variables PEA and CST do not show significant relevance for CSR in the companies studied.

The results presented in the contour maps, surface, and three-dimensional graph generated by the Matlab® software shown in Figure 6, reveal a blue area indicating low RSE, corresponding to Likert values of up to 3.0 for PSC and up to 4.5 for OTA. This suggests that OTAs have minimal influence on the increase of RSE. It was observed that the presence of PSC, evidenced by the green, yellow, and red areas, is related to a higher level of RSE compared to the absence of OTA benefits. Furthermore, it was found that the presence of PSC in the analyzed companies significantly contributes to the increase of RSE.

Figure 7 demonstrates a considerable equity between the two analyzed variables concerning the output of RSE. A blue area is observed, indicating low RSE when both variables have values below 3, suggesting that, in this context, the effectiveness of affirmative prevention actions and educational and assistance programs is limited. Conversely, when the values of both variables exceed 3, RSE increases, highlighting a positive relationship between the implementation of effective actions and the enhancement of corporate social responsibility. This analysis emphasize

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the importance of promoting initiatives that raise the indices of the variables, as the combination of high values in both can result in a significant impact on the RSE of organizations.

Figure 8 presents a wide red area, indicating a higher RSE associated with the input variable Health Plan and health agreements (PSC). This predominance suggests that the presence of PSC is essential for increasing corporate social responsibility. In contrast, the variable Educational and Assistance Programs for Employees and/or their families (PEA) does not demonstrate the same relevance as PSC, although it still plays a significant role. The blue area, representing low RSE, is limited, indicating that the effectiveness of PEA is constrained in comparison. Furthermore, the figure reveals a transition zone, with green and yellow colors, signaling the variation of RSE output in the context of health and occupational safety (SSO), emphasizing the importance of both variables in promoting a healthier and more responsible work environment. This analysis highlights the need for investment in PSC while also emphasizing the relevance of integrating educational and assistance programs to maximize positive impacts on the RSE of organizations.

The joint presentation of the analyzed variables provides a deeper understanding of the Health and Occupational Safety (SSO) axis. The three-dimensional graphs, generated with Matlab® software for fuzzy analysis, show that only in the combination of PEA and CST is there a predominance of the blue color, indicating low RSE. The increase in RSE, represented by the red color, occurs only for values close to 5.0 on the Likert scale. The combinations of OTA and PEA, and OTA and CST exhibit low RSE (blue color) for values below 3.0 and high RSE for values above 4.0, with an intermediate range (green color) between 3.0 and 4.0.

In the PSC graphs, the blue color represents low RSE for values below 3.0, and the combination with OTA and CST also shows low RSE for values close to 5.0. The interaction between PSC and PEA demonstrates that PSC contributes to the increase of RSE above 3.0 (red color), while PEA remains at low RSE (blue color). This suggests that RSE is more associated with the presence of health plans than with the implementation of educational programs.

The combinations of the contour maps in Figure 10 confirm the results of the three- dimensional graphs. Additionally, the combinations of the PSC and OTA graphs, as well as PSC and CST, show a similar pattern. The variable PSC, for values below 3.0, is represented by the blue color, indicating low RSE in both graphs. In contrast, the variables OTA and CST, when combined with PSC, also display the blue color of low RSE for values very close to 5.0. This suggests that

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the increase in OTA and CST does not result in an increment in RSE while the variable PSC remains below 3.0.

CSR is a fundamental issue today, and the adoption of socially responsible practices by companies is essential for building a fairer and more sustainable society. In this context, fuzzy logic, by integrating expert knowledge through the creation of a rule base, enabled the automation of the process and improved the accuracy of the analysis of the collected data.

The variables with the greatest potential to enhance CSR in companies have been identified, along with the combinations that can intensify this increase. These increments are essential for promoting CSR and creating a positive corporate culture. In this regard, the application of fuzzy logic represents a significant theoretical framework for measuring CSR in labor relations. With this approach, it was possible to evaluate the practices adopted by companies more accurately and comprehensively, fully achieving the objectives set by the study.

The literature review conducted shows that companies that invest in effective actions for the development of their employees tend to achieve better financial results and build a more positive image in society. Additionally, these initiatives promote employee retention and reduce turnover. The research findings confirm the conclusions found in the literature and discussed in the theoretical framework, highlighting them as an important factor for CSR.

During the research, several limitations were identified. The companies were selected for convenience, and the respondents had different hierarchical levels and educational backgrounds, resulting in varied perceptions. The questionnaire did not identify factors that influence the adoption of CSR, nor the presence of internal evaluation metrics. Additionally, aspects related to the generation of economic value through CSR or the impacts on the capital structure of companies, especially between national and international capital, were not explored.

This study opens new avenues for investigation to identify the factors that influence the adoption of CSR by companies, as well as the internal evaluation metrics. Future research can examine the level of satisfaction among employees, stakeholders, and consumers regarding the implemented CSR practices. Additionally, it is essential to investigate issues related to the disclosure of internal and external information about corporate social responsibility, as well as aspects related to corporate image.

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