Journal of Infrastructure, Policy and Development 2024, 8(12), 7116.
https://doi.org/10.24294/jipd.v8i12.7116

Article

Cultural profiles evaluation and their impact on the performance of production systems in Colombian companies using data analytics

Gabriel Rivera-Leon[1], Fernando Ceballos[2,*], Luis Eduardo Muñoz-Guerrero[3]

[1] Escuela de Ciencias Básicas, Tecnología e Ingeniería, Universidad Nacional, Abierta y a Distancia, Medellín 050012, Colombia
[2] Grupo de investigación Ingeniería y sociedad, Departamento de Ingeniería industrial, Facultad de ingeniería, Universidad de Antioquia, Medellín 050010, Colombia
[3] Facultad de Ingenierías, Universidad Tecnológica de Pereira, Pereira 660003, Colombia
*** Corresponding author:** Fernando Ceballos, yony.ceballos@udea.edu.co

CITATION

Rivera-Leon G, Ceballos F, Muñoz-Guerrero LE. (2024). Cultural profiles evaluation and their impact on the performance of production systems in Colombian companies using data analytics. Journal of Infrastructure, Policy and Development. 8(12): 7116. https://doi.org/10.24294/jipd.v8i12.7116

ARTICLE INFO

Received: 13 June 2024
Accepted: 16 July 2024
Available online: 30 October 2024

Abstract: Strategically managing production systems is crucial for creating value and enhancing the competitive capabilities of companies. However, research on organizational culture within these systems is scarce, particularly in the Colombian context. This research aims to evaluate cultural profiles and their impact on the performance of production systems in Colombian firms. The regional focus is vital as cultural and contextual factors can vary significantly between regions, influencing organizational behavior and performance outcomes. To achieve this, we make a study in a sample of Colombian companies, with participation from working students of the Universidad Nacional Abierta y a Distancia (UNAD). We used a data analytics approach to collected data. The results will be relevant to both the scientific community and business practitioners. This research seeks to determine whether the perception of the work environment within a company influences the perceived performance of the company. The findings will provide a deeper understanding of the relationship between organizational culture and production system performance, offering a foundation for business decision-making and enhancing competitiveness in Latin American context.

Keywords: strategic management; production systems; value creation; competitive capabilities; organizational culture; business performance; data analytics

1. Introduction

Strategic management of production systems plays a crucial role in creating value and strengthening the competitive capabilities of enterprises. In this context, organizational culture has become a topic of great interest, as it significantly influences the performance of production systems (Itohan et al., 2024; Mariani and Dwivedi, 2024). Latin America Organizational culture has a strong emphasis on hierarchical structures and personal relationships. Authority is highly respected, and the upper management levels oversee decision-making. This hierarchical nature is often complemented by a familial atmosphere within organizations, where personal relationships and loyalty play a significant role. Trust and interpersonal connections are vital, and there is a strong preference for face-to-face communication and direct interaction.

Additionally, cultural values such as collectivism and the importance of group harmony influence organizational behavior, leading to a greater emphasis on teamwork and collaboration. Understanding these cultural nuances is crucial for effective management and business operations in Latin American countries (House et al., 2004).

Research in this field not only seeks to characterize and measure organizational culture, but also to generate knowledge about how it influences organizational processes and results This will make it possible to propose strategies and actions based on a solid understanding of the organizational culture and its impact on the achievement of organizational goals. In response to this knowledge gap, this article aims to address the issue of organizational culture and its impact on the performance of production systems in Colombian companies (Cújar Vertel et al., 2013). The main goal of this research is to evaluate the cultural profiles present in these systems and to analyze how they are related to the belief of results obtained in terms of efficiency, quality, and competitiveness.

The research identifies a significant gap in the study of organizational culture within production systems, particularly in the Colombian context. While existing literature (Hofstede and Hofstede, 2005), emphasizes the importance of organizational culture as a collective mental programming that differentiates members of one organization from another, there is limited empirical research examining how these cultural traits influence the performance of production systems. Additionally, most studies have treated organizational culture as a homogeneous entity within a company, overlooking the potential existence and impact of subcultures within different subsystems of the organization. This gap is highlighted by Ruiz and Naranjo (2013), who pointed out the nascent state of research on this topic in Colombia, despite its evident importance. The lack of in-depth exploration into these subcultural dynamics presents an opportunity for further investigation. For these reasons, we addressed the research question "What are the interdependencies between cultural profiles and the performance of production systems in Colombian firms?" with this study.

Research on organizational culture within production systems is important for creating value and enhancing competitive capabilities, yet remains limited, particularly in Colombia. This study aims to evaluate cultural profiles and their impact on production system performance in Colombian firms. Given the significant variation in cultural and contextual factors across regions, understanding these dynamics is needed for influencing organizational behavior and outcomes. The utility of this research is underscored by the need to develop sustainability-productive cultures, as highlighted by studies focusing on the deeper cultural assumptions and beliefs that drive corporate sustainability practices (Assoratgoon and Kantabutra, 2023). Additionally, the role of organizational culture in maximizing the benefits of lean production methods is critical; a supportive, flexible culture significantly enhances operational improvements in quality, delivery, and flexibility (Hardcopf et al., 2021). Furthermore, research on family businesses in Pasto, Colombia, demonstrates a strong correlation between innovation and market orientation, illustrating the positive impact of cultural attributes on business performance (Solarte Solarte et al., 2019). This study, involving a sample of Colombian companies with, utilizes a data analytics approach to explore whether the perception of the work environment influences perceived company performance. The findings will contribute valuable insights for the scientific community and business practitioners, providing a foundation for informed decision-making and competitiveness enhancement in the Latin American context.

To achieve this goal, we make an empirical study involving a sample of Colombian companies, with the collaboration of the students of the course "Operations

Management", belonging to the UNAD (a virtual university in Colombia). These students, who are actively employed across various sectors, bring practical, real-world experiences to the research, ensuring that the findings are grounded in actual business practices. This diversity enables the study to identify common cultural factors and industry-specific practices, making the results relevant and applicable to a broad range of industries. Moreover, the involvement of working professionals ensures that the insights gained are current and reflective of contemporary organizational dynamics in Colombia. A data analytics approach will be applied to evaluate the interdependencies between cultural profiles and the performance of production systems. The results of this research will not only be relevant to the academic community, but also to the business world, as they will provide a greater understanding of how organizational culture influences the results of production systems.

2. Materials and methods

There is little information available on the specific cultural elements present in the production systems of Colombian firms. However, few sources discuss the importance of organizational culture in the performance and productivity of companies in Colombia (Castillo Rico and Socarras, 2021; Octavo et al., 2014). Organizational culture is a series of symbols, ceremonies, and myths that communicate a company's values and beliefs to its employees.

Measuring and evaluating organizational culture in production systems is a key step in properly understanding and managing the cultural aspects that influence company performance. One way to measure organizational culture is to conduct surveys or questionnaires that ask employees about their beliefs of the company's values, beliefs, and practices (Octavo et al., 2014; Santamaria Medina, 2016). Another method is to conduct interviews or focus groups with employees to gain a deeper understanding of their experiences and perspectives on the company's culture (Gálvez Albarracín and García Pérez de Lema, 2010).

Additionally, there are studies that characterize the organizational culture of Colombian companies in general (Gentilin, 2020; Santamaria Medina, 2016). These studies analyze the state of the economy and social system in Colombia and the impact of cultural indicators on development (Santamaria Medina, 2016). There are also studies on the impact of cultural industries on Colombia's economy (Gálvez Albarracín and García Pérez de Lema, 2010; Isaza Vélez, 2013). In general, although there is limited information on the specific cultural elements present in the production systems of Colombian companies, we identify that organizational culture is important in the performance and productivity of companies.

On the other hand, another study suggests that seeing the practices and behaviors of the company can also provide information about its culture (Gonnet, 2013). Similarly, a cultural audit is used as an instrument for the systematic analysis of an organization's culture that can find strengths, weaknesses, and areas for improvement (Llumiguano Poma et al., 2021). In addition, it is essential to explore the relationships and interactions between organizational culture and other relevant constructs and variables. Understanding how organizational culture relates to continuous improvement, productivity, competitiveness, and other crucial aspects will allow you

to find the influences and effects that culture has on organizational behavior and results (Cújar Vertel et al., 2013).

Organizational culture characterization involves finding and understanding the distinctive features of the culture in these organizations. Organizational culture refers to the values, beliefs, norms, symbols, and behaviors shared by members of a company. Below are some key aspects compiled by Ruiz and Naranjo (2013) that can be considered when characterizing organizational culture in Colombian companies: Values and beliefs, Interpersonal relationships, Hierarchy and authority, Team culture, Adaptability to change, Attention to detail, Innovation, Results orientation, Aggressiveness, Team orientation, Stability and People orientation.

The survey begins with general company information, including the company name, year of establishment, sector (industry, services, commerce, other), subsector (specific products/services), and size (micro, small, medium, large). It also queries whether the company is a family business and gathers details about the number of employees across various departments. The survey then evaluates the production system's performance on multiple fronts: cost efficiency, product quality, responsiveness to production changes, innovation capacity, and environmental impact. It further explores worker-related aspects such as performance, motivation, competence, effort, future orientation, and loyalty. Human resource management practices assessed, including recruitment, training, compensation, promotion, and workplace safety. The organizational structure examined for its effectiveness in coordination, problem-solving, information flow, and documentation. Additionally, the survey covers supply chain management, strategic planning, technological integration, and overall company culture, including leadership styles, alignment of interests, cultural traits, and the impact on performance. The survey initially collected 1268 responses; however, after ensuring data completeness, we left 960 responses for analysis.

In this survey, we utilized content validity to ensure that the instrument comprehensively covers all relevant aspects of the constructs being measured. To achieve this, we engaged a panel of experts familiar with organizational culture and production systems to review the survey items. These experts evaluated whether each question on the Likert scale accurately represented the dimensions of organizational culture, such as employee satisfaction, managerial support, and innovation capacity. Their feedback was instrumental in refining the survey questions to cover all necessary facets comprehensively. By incorporating their insights, we ensured that the survey items collectively provided a thorough and representative measurement of the constructs under study, thus enhancing the content validity of the instrument.

For the analytical model, the unit of analysis is the information from surveys conducted by employees of different companies in Colombia who take part in the production/operations system using The Random Forest Classifier. A production/operations system is the subsystem within a company responsible for producing goods or delivering services. It achieves these goals through the coordinated use of people, materials, equipment, and support areas such as maintenance and quality control. This proposal looks to explore the organizational culture within these systems and assess its impact on organizational performance.

The Random Forest Classifier is a classification algorithm in the field of machine

learning. It is based on the assembly technique, which combines multiple simpler models to form a more robust and correct model. It belongs to the family of methods known as "random forests." This algorithm builds multiple decision trees during the training process. Each tree is trained on a random subsample of the training dataset, and the predictions from each tree are combined to make a final decision. "Randomness" is introduced into the process of building each tree, as, at each step, a random subset of features is selected to divide the nodes in the tree.

The Random Forest Classifier is known for its ability to efficiently manage large and complex data sets, as well as its resistance to overfitting. By combining multiple differently trained trees, it helps reduce the variance of the model and improve its predictive ability compared to a single decision tree.

Based on the above, the following question arises: How does organizational culture influence the belief of the overall performance of production systems and how does this belief impact strategic decision-making relate to the improvement and optimization of these systems? The above question was resolved using machine learning techniques.

With the above details of the survey, there are unnecessary variables in the study because they do not stand for relevant information at the time of asking the business question. These variables are those related to the characterization of these employees—students such as their code, name and other elements associated with specific characteristics of the respondent. We do not include questions associated with the quality of the survey and about the formulation of the questions. Finally, the variables drop: 'Código', 'Estudiante', 'Grupo', 'Nombre_emp', 'Tot. Emp. Oper.', 'Tot. Emp. Admin', 'E1. #Preg', '52 Manufactura. Job Shop', '52 Manufactura Flujo lotes', '52 Manufactura. Línea', '52 Manufactura. Continuo', '52 Manufactura JIT'. The column with missing data is the one associated with question 52, since it was only answered by those who work in manufacturing companies, therefore, these columns were eliminated from the analytical model.

All variables correspond to the assessment on a Likert scale from 1 to 5. except for the variables año_emp and Total_emp. The dispersion of the data differs if the variable of interest refers to the use of production techniques (JIT, Kaizen, and others).

Due to the considerable number of variables that are available, those that by their own concept do not provide information taken out, however, the EDA must conduct to define which variables do contribute to the goal numerically.

3. Results

For the process of exploratory analysis of the data using Python®, through a direct loading of the database using the Pandas library. The survey consists of 985 observations and ninety-one variables. The variable data types are: float64 (65 variables), int64 (1 variable), and object (25 variables).

We perform an analysis by categories for the qualitative variables of the model (see **Table 1**), but we conclude that the high combinatorics of these categories makes their use in the study overly complex.

Table 1. Categories in qualitative variables.

Variable	Unique Values
Departamento	29
Sector	11
Subsector	816
Tamaño	12
Familiar	8
Ciudad	419
E1 Cargo	640
E1 Dirige	13
E1 Formación	12
E1 Títulos	598

There are still problems due to the considerable number of variables present in the model, as seen in **Figure 1**, which is a correlation graph of the study's variables.

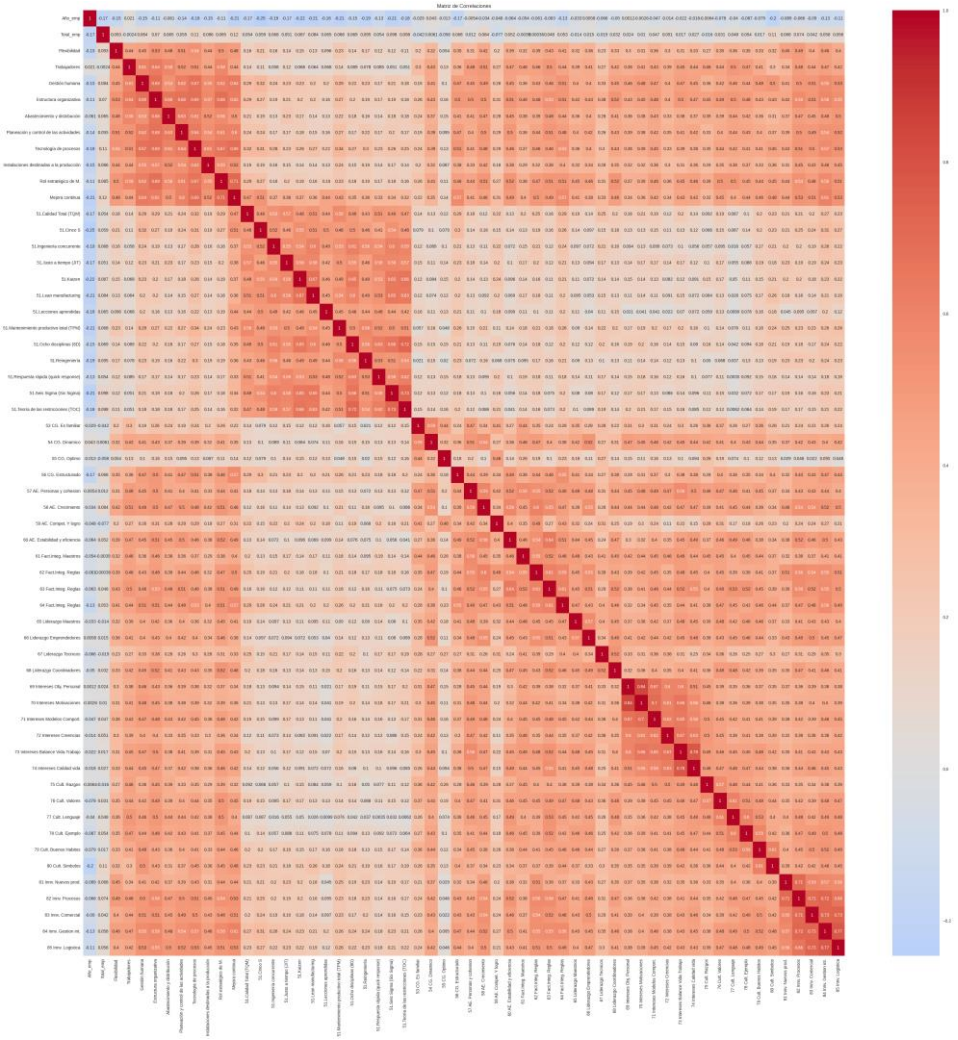


Figure 1. Correlation between all variables in the database.

However, we find that the model contains numerous variables. Therefore, we

conducted a principal component analysis to identify which variables explain the greatest amount of variability in the target variables. The variables related to years employed and total number of employees are numerical, while the rest of the selected variables are measured on a Likert scale (perception). This analysis defines that 12 variables explain 70% of the variability in the data (see **Figure 2**). These variables are: 'Año_emp', 'Total_emp', 'Flexibilidad', 'Trabajadores', 'Gestión humana', 'Estructura organizativa', 'Abastecimiento y distribución', 'Planeación y control de las actividades', 'Tecnología de procesos', 'Instalaciones destinadas a la producción', 'Rol estratégico de M.', 'Mejora continua'.

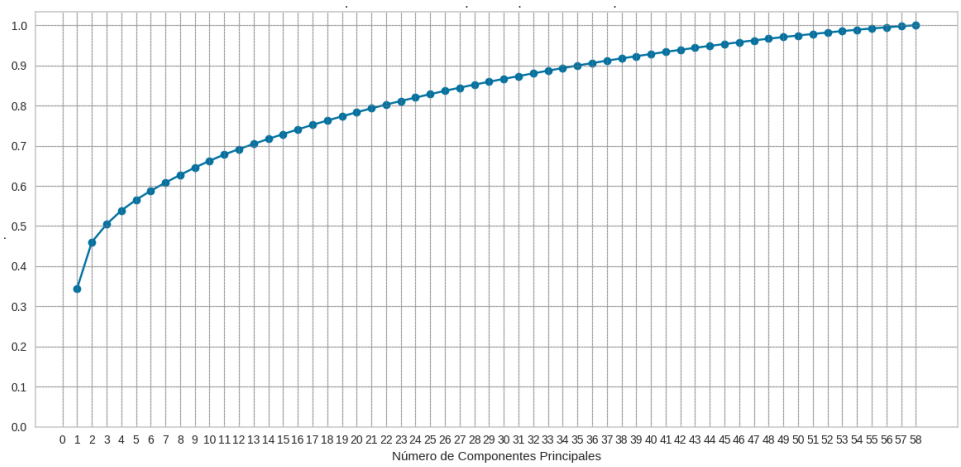


Figure 2. Principal component analysis (accumulated variance vs. explained variance).

For these variables used in the study, a percentage of less than 3% of the data is missing, then we conducted imputation with the median. After inspecting the data and correcting types of data, imputing by median, and dropping unnecessary columns in the study, you have the variables without problems to use in the analytical models.

The results of the statistical tests conducted on our dataset indicate strong suitability for Principal Component Analysis (PCA). Bartlett's test for sphericity yielded a chi-square value of 1177.847 with a *p*-value of 0.000286, suggesting that the correlation matrix significantly differs from an identity matrix. This implies that the variables are sufficiently correlated to justify the use of PCA. Furthermore, the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy was calculated to be 0.9516, which falls within the 'marvelous' range, indicating excellent adequacy for factor analysis.

For the machine learning model, we choose a set of target variables. Due to the survey's characteristics, the variables associated with the company's usual performance, we will estimate using the other variables. The variables that we will use as a target are: '86 DG. Rentabilidad', '87 DG. Ventas', '88 DG. Imagen', '89 DG. Percep. Clientes', '90 DG. Liquidez.', '91 DG. Productividad'. **Figure 3** shows the correlation between these variables.

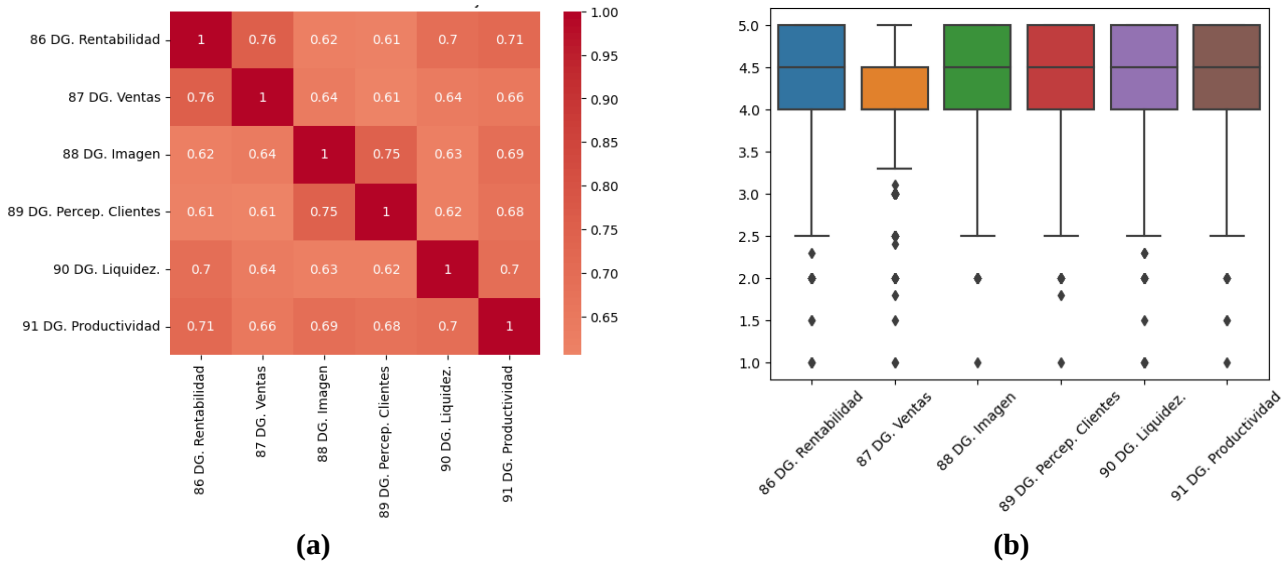


Figure 3. Behavior of target variables. **(a)** Correlation matrix; **(b)** boxplot graph.

The first two variables do not have a high correlation with the other variables, which shows that they stand for 46% of the variance explained. The other variables have correlations greater than 0.4 with each other, which gives the idea that they can be reduced even more; however, the model is considered without such a reduction since some results could be masked (see **Figure 4**).

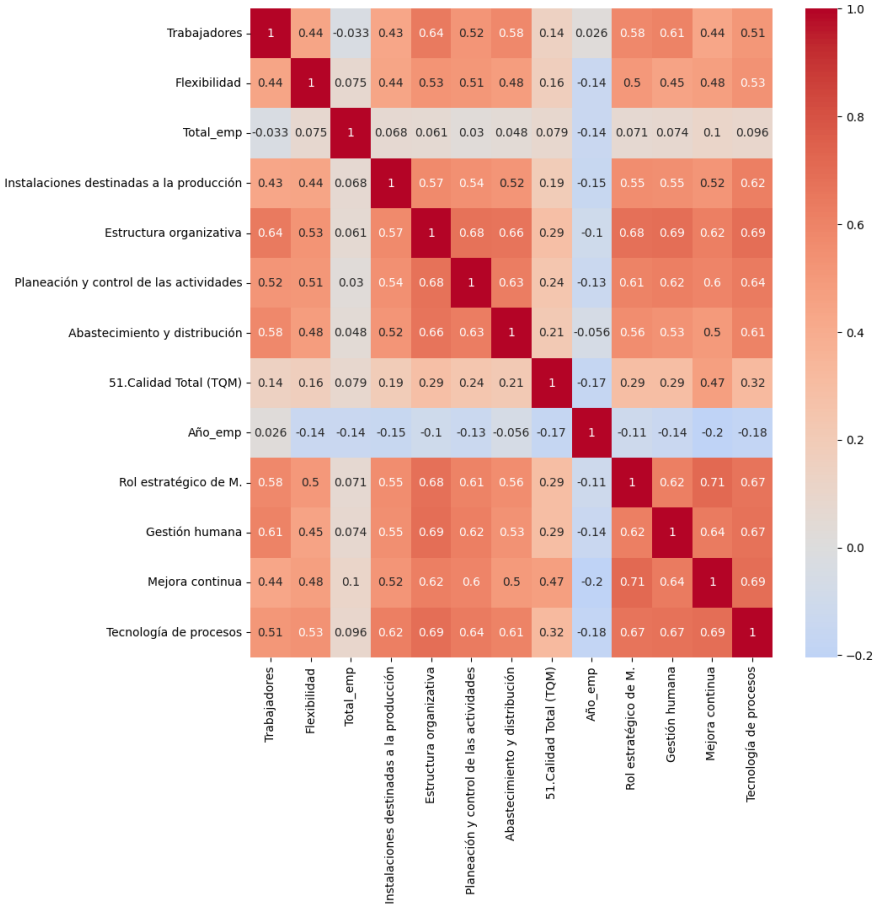
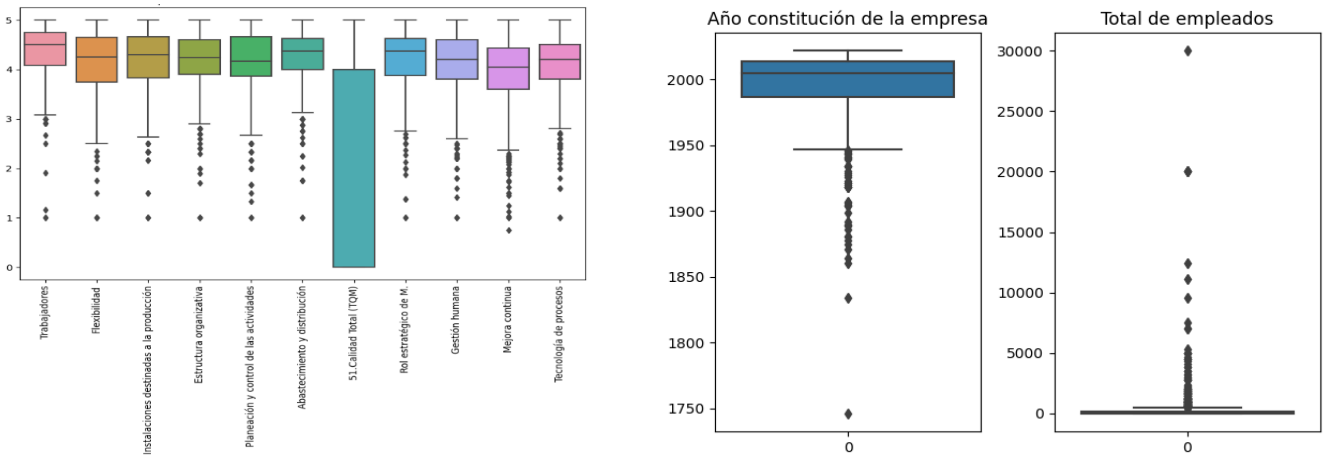


Figure 4. Correlation of selected variables.

For Independent Variables: Año_emp, Total_emp, Flexibilidad, Trabajadores, Gestión humana, Estructura organizativa, Abastecimiento y distribución, Planeación y control de las actividades, Tecnología de procesos, Instalaciones destinadas a la producción, Rol estratégico de M., Mejora continua. An exploratory analysis was performed again, finding that the correlation between variables is manageable for outcome estimation processes (see **Figure 5**). While the set can be further narrowed down, results from specific relationships between dependent and independent variables can be masked.



(a) **(b)**

Figure 5. Dispersion of selected variables. **(a)** Likert scale; **(b)** non-Likert variables.

To estimate the values of the target variables, different classification and adjustment models are constructed. However, in general the models have a low setting. Finally, he decided on the Random Forest Classifier model, which had the best fit.

As above, the independent variables are defined *(*'Año_emp', 'Total_emp', 'Flexibilidad', 'Trabajadores', 'Gestión humana', 'Estructura organizativa', 'Abastecimiento y distribución', 'Planeación y control de las actividades', 'Tecnología de procesos', 'Instalaciones destinadas a la producción', 'Rol estratégico de M.', 'Mejora continua') and dependent variables ('86 DG. Rentabilidad', '87 DG. Ventas', '88 DG. Imagen', '89 DG. Percep. Clientes', '90 DG. Liquidez.', '91 DG. Productividad'). Additionally, training and test data should be separated using the 70% and 30% criteria. The observation sets consist of 689 data for training and 296 data for testing.

4. Discussion

It is taken as a model of Random Forests. By having 6 output variables with different numbers of categories, a prediction is made for each of them. The results of the applied model can be seen in **Table 2**. Accuracy measures the proportion of correct predictions made by the model compared to the total number of predictions. Thus, an Accuracy of 0.52 means that 52% of the model's predictions were correct for the variable and the confusion matrix shows how the instances for each class are classified in a classification problem, it is organized into rows and columns, where the rows represent the actual classes, and the columns represent the classes predicted by the

model.

Table 2. Accuracy and confounding matrix of the estimated variables.

DG. Rentabilidad	**DG. Ventas:**	**DG. Imagen:**
Accuracy 0.488	**Accuracy 0.447**	**Accuracy 0.528**
0 0 0 0 1 1 0 0 0	0 0 0 0 0 1 0 1	0 0 0 0 0 0 0 1
0 0 0 0 1 0 0 0 0	0 0 0 0 1 2 0 0	0 1 0 0 0 2 0 0
0 0 0 0 1 1 2 0 1	0 0 0 0 0 1 1 0	0 0 0 0 0 0 1 0
0 0 0 0 0 1 3 0 0	0 0 0 3 4 8 4 0	0 1 0 1 0 6 0 0
0 0 0 0 1 3 9 1 1	0 0 0 3 4 11 8 1	0 0 0 2 0 12 0 0
0 0 0 0 1 3 9 5 1	0 1 0 1 7 64 23 7	0 0 0 2 2 44 10 17
0 0 0 0 7 6 47 13 6	0 0 0 0 2 28 25 12	0 0 0 0 0 22 14 37
0 0 0 0 0 1 19 39 25	0 0 0 1 1 19 15 36	0 0 0 0 0 12 12 96
0 0 0 0 0 2 11 19 54		

DG. Percep. Clientes:	**DG. Liquidez.:**	**DG. Productividad:**
Accuracy 0.515	**Accuracy 0.467**	**Accuracy 0.525**
0 0 0 0 0 0 0 1	0 0 0 0 0 0 2 1 0	0 0 0 0 0 0 0 1
0 1 0 0 0 0 1 0	0 0 0 0 0 0 2 0 0	0 1 0 0 1 0 0 0
0 0 0 0 0 2 1 0	0 0 0 1 0 2 0 1	0 0 3 0 8 3 0
0 0 0 0 2 6 3 0	0 0 0 2 1 15 1 3	0 0 0 1 8 5 1
0 0 0 0 0 5 4 2	0 0 0 0 4 11 1 1	0 0 2 46 18 11
0 0 0 0 0 50 14 13	0 0 0 4 3 41 9 14	0 0 1 22 31 30
0 0 0 0 1 24 33 30	0 0 0 0 3 29 20 25	0 0 0 13 16 73

In the predictions analysis of the Random Forest model for various target variables, certain patterns and challenges appear (See **Table 2**). For profitability (Rentabilidad) (Objective 86 DG), the model struggled to accurately predict a few classes, such as 1 and 2, showing the need for improvements in the prediction of this variable. Similarly, in the case of sales (Objective 87 DG), classes 4 and 5 show incorrect predictions, suggesting the need for adjustments to improve the accuracy of the model.

In terms of the company's image (Objective 88 DG), the model proved moderate performance with correct predictions in classes 5, 6 and 7. However, confusion was seen in class 1. When analyzing customer belief (Objective 89 DG), the model was successful in predicting classes 5 and 6 but faced challenges in classes 3 and 4. Opportunities for improvement were found to achieve greater accuracy in this variable.

Liquidity (Objective 90 DG) showed variability, especially in classes 3 and 6, showing the need to adjust the model to accurately capture these categories. Finally, when assessing productivity (Objective 91 DG), reliable performance was seen in

classes 5, 6 and 7, but challenges were found in classes 3 and 4, pointing to areas for improvement.

The approach of using a dataset divided into 70% for training and 30% for validation with the same random seed provided consistency in comparisons. The results suggest that the Random Forest model has a variable performance depending on the target variable. Reasonable performance is seen in some categories, but there is scope to improve overall accuracy by adjusting model parameters or considering alternative modeling methods.

For the assembled model, with the 6 output variables, we use the F1 Score, a metric that combines the accuracy and recall of the model into a single score. It is especially useful when you have unbalanced classes in your data. For example, an F1 Score of 0.260 shows that the model has a balance between accuracy and recall, where values closer to 1 are better.

F1 Weighted score for assembly: 0.47732830932087256. The weighted F1 Score is a measure that calculates the F1 Score for each class separately and then takes a weighted average of these values. A value of 0.477 shows that the model performs moderately on average across all classes, with a greater emphasis on larger (size-weighted) classes.

F1 Macro Score for assembly: 0.26064443946847216. The F1 Score macro is a measure that calculates the F1 Score for each class separately and then takes an unweighted (simple) average of these values. A value of 0.260 shows that the model has an average performance across all classes regardless of size. Each class contributes equally to the value.

It should be noted that all classes have the same weight, so the F1 Score macro for the assembly is taken as a better metric for this Model and this data.

The MSE is an important metric for evaluating the performance of a regression model, as it measures the average of the squared errors between the model's predictions and the actual values in the test set. A lower MSE indicates better performance, as it implies that the model's predictions better match the actual data. In this case the test MSE was 1.5305084745762716.

It is taken as a business question; How does organizational culture influence the belief of the overall performance of production systems and how does this belief impact strategic decision-making relate to the improvement and optimization of these systems? This is applied by classifying the information in the input data by simple averaging and classifying it as belonging to a threshold of 4 on the problem's Likert scale. This allows companies to make decisions in which areas they should improve and how the employees themselves show us the good and bad points of the organization, that is, by knowing how to identify the data that the model gives us, we can invest and make better decisions at the organizational level, considering all the factors that influence the organizational climate.

Figure 6 shows a pair plot that includes the business rule category. For all the variables, two categories are seen, differentiated by the business rule, which allows us to properly classify the belief of the employees. As the target variable is derived from the simple average of the preceding ones, the resulting categories do not show clear distinctions. This is typical in this type of survey, where aggregated measures can blur individual category boundaries, making them appear more similar than they are.

For all the variables, we evaluate two categories differentiated by the business rule, which allows us to properly classify the belief of the employees. As the target variable obtained from the simple average of the earlier surveys, the categories are not perfectly differentiated, which is normal in this type of survey.

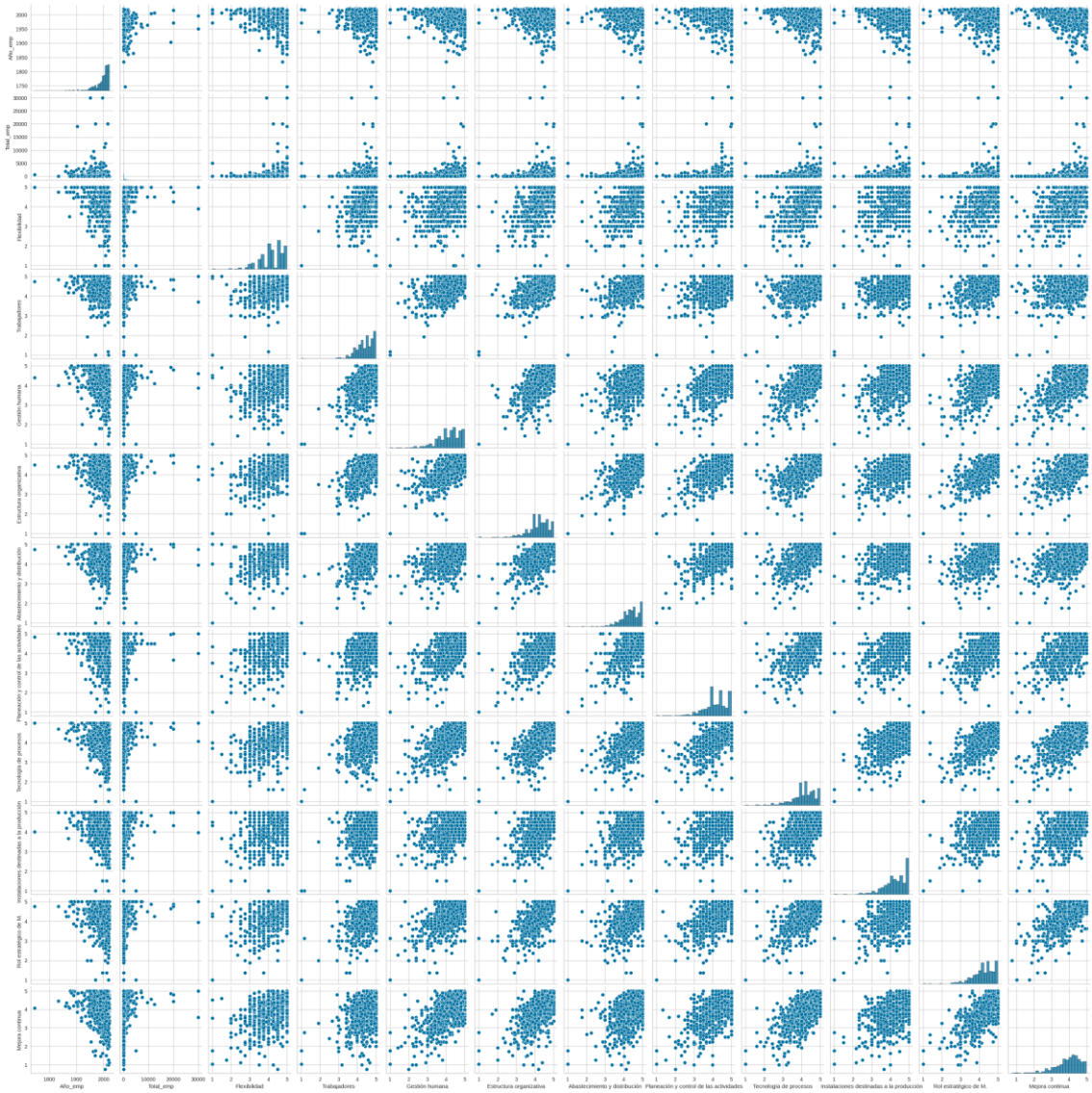


Figure 6. Pair plot including the business rule category.

5. Conclusions

By characterizing organizational culture in Colombian companies, we can obtain a deeper understanding of cultural elements and their impact on business performance and results. This information can be useful for strategic decision-making and the implementation of practices that promote an organizational culture aligned with the company's goals and values.

There is increasing evidence of the determining role of organizational culture in achieving better levels of performance and competitiveness of companies in Colombia (Ruiz and Naranjo, 2013). Organizational culture influences how employees perceive, interpret, and respond to work situations. Organizational values reflect a company's

core principles and beliefs and can have a significant impact on decision-making, attitudes toward work, collaboration, and achievement orientation (Rodríquez et al., 2017).

In the Colombian context, where companies run, organizational culture gets a special importance due to the particularities and characteristics of Colombian society and business environment. Organizational culture in Colombia can influence by factors such as the country's history, traditions, social norms, and cultural diversity. On the other hand, there is a relationship between organizational culture and innovation in Colombian companies.

When analyzing the specific cultural and performance patterns of Colombian firms related to their production systems, the results in the literature suggest that organizational culture influences the productivity of firms and that there are cultural differences between Colombian subsidiaries and the North American parent evaluated in (Florez Hurtado and Flórez Rodríguez, 2018). The findings of Calderón and Naranjo (2007) show that organizational culture influences the sustainability and adaptability of production systems. As well as the cultural and socio-structural systems of the organization, they are also strongly related, influencing the innovation capacity of companies (Calderón and Naranjo, 2007).

However, socio-cultural patterns in Colombia must consider as they can also affect the performance of companies. For example, Montenegro (2016) emphasizes how migration can have an impact on the social, economic, political, and sociocultural performance of firms.

The model showed moderate performance, accurately predicting outcomes in certain categories, yet there remains scope for enhancing overall precision. The variables that proved the lowest performance included profitability, sales, and customer belief. It suggests that the model's effectiveness enhance by adjusting its parameters or by exploring alternative modeling techniques. Further investigation might focus on refining the accuracy associated with profitability, sales, and customer belief. The model proves useful in finding potential areas for improvement within the organizational culture, thereby helping strategic decision-making processes aimed at augmenting and refining production systems. Also, the model serves as a tool for discerning the strengths and weaknesses of the organizational culture, allowing targeted strategic initiatives to bolster or remedy specific aspects of the organization.

Author contributions: Conceptualization, GRL and FC; methodology, GRL; software, FC; formal analysis, FC; research, GRL and FC; resources, LEMG; data curation, GRL; writing—original draft preparation, GRL and FC; writing—review and editing, FC and LEMG; visualization, FC; supervision, LEMG; project management, GRL. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

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