

A Hybrid Fuzzy AHP-TOPSIS Framework for Identifying Talent Acquisition Barriers in Colombian SMEs: Insights for Enhancing Recruitment Competitiveness

Jorge Aníbal Restrepo M¹. Jaime Andrés Ararat H². Higidia Rosa Moreno P³.
Angela Fremiot R⁴.

Abstract

Purpose: This study aims to identify and prioritize the barriers to talent acquisition faced by small and medium-sized enterprises (SMEs) in Colombia, focusing on internal and external factors that limit recruitment and retention capabilities in an emerging labor market.

Methodology: A hybrid Fuzzy Analytic Hierarchy Process (Fuzzy AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach is employed, analyzing data from 1,697 surveys collected across Colombian SMEs. This approach allows for a comprehensive evaluation of subjective recruitment challenges, specifically suited to the Colombian labor context.

Main Findings: Results indicate that "Internal Company Factors" and "Candidate Qualifications and Skills" are the most critical barriers to recruitment, with small enterprises showing closer alignment with ideal hiring conditions than micro and medium enterprises. Sensitivity analysis further suggests that infrastructure improvements, competitive compensation, and institutional support are key areas to enhance SMEs' competitiveness in talent acquisition.

Future Research: Future research could expand this framework to other Latin American countries, examining sector-specific recruitment barriers and evaluating the impact of varying institutional support levels across regions.

Keywords: M51 - Personnel Economics; L26 - Entrepreneurship; D81 - Criteria for Decision-Making: Risk and Uncertainty; O15 - Economic Development: Human Resources; Human Capital; Labor Development; L25 - Firm Performance

Introduction

The ability of small and medium-sized enterprises (SMEs) to attract and retain skilled talent is essential to their growth, innovation, and competitiveness in today's market (Akhmadeev et al., 2018). In Colombia, SMEs play a pivotal economic role, accounting for a substantial share of employment and making significant contributions to both regional and national development. However, Colombian SMEs face unique recruitment challenges that limit their capacity to secure highly qualified personnel, especially in specialized and competitive sectors (Garavan et al., 2012). These recruitment barriers stem from both internal constraints—such as inadequate infrastructure, limited financial resources, and underdeveloped organizational structures—and external factors, including unfavorable labor market conditions, inconsistent institutional support, and complex regulatory environments (Kinkel et al., 2014; Farndale & Paauwe, 2018).

The sample in this study spans five major economic sectors in Colombia: services, commerce, industry, construction, and primary (agricultural and livestock). Each sector faces particular barriers that hinder access to qualified talent. The service sector, constituting 51.79% of the sample and encompassing areas such as finance, education, and technology, is characterized by high demand for personnel with specialized technical and interpersonal skills. The

commerce sector, representing 23.22% of the sample, is affected by high employee turnover and the need for staff with expertise in sales and customer service. In the industrial sector (13.32%), recruitment challenges are tied to the scarcity of skilled technical and operational workers, while the construction sector (6.95%) faces barriers related to project seasonality and demanding working conditions. Finally, the primary sector (4.72%) experiences unique challenges due to its geographic location and limited infrastructure, which restricts the availability of qualified labor.

Existing literature indicates that recruitment challenges are often more pronounced in developing countries, where SMEs struggle with limited access to financial and human capital (Nurmiati et al., 2023). Although talent acquisition in large organizations has been extensively studied, relatively little attention has been directed toward the structural and environmental challenges unique to SMEs. Addressing these barriers is crucial for enhancing the competitiveness of SMEs and sustaining their contributions to economic development. Given this context, a comprehensive approach is needed to capture the multifaceted and subjective nature of these challenges.

Recruitment obstacles in Colombian SMEs are further compounded by regional factors specific to Latin America, including high levels of economic informality, fluctuating economic stability, and limited institutional support, all of which influence recruitment practices. Despite global research on talent acquisition in SMEs, studies focused specifically on Colombia and the broader Latin American context remain scarce. This lack of research leaves a critical gap, as understanding the specific barriers that Colombian SMEs face is essential for developing targeted strategies to improve their recruitment efforts and competitiveness within emerging labor markets.

This study addresses three primary research questions: (1) What are the main internal and external barriers to talent acquisition in Colombian SMEs? (2) How do these barriers vary by enterprise size—particularly among micro, small, and medium-sized businesses? and (3) What strategies can mitigate these barriers and enhance SME competitiveness in the Colombian labor market? By focusing on these questions, the research aims to provide a detailed analysis of recruitment barriers within Colombia's economic landscape, yielding insights that could be applied to similar emerging markets throughout Latin America.

To achieve these objectives, this study employs a hybrid Fuzzy Analytic Hierarchy Process (Fuzzy AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach. This methodology allows for nuanced prioritization and ranking of recruitment challenges by combining subjective expert judgments with objective assessments across different SME types. The hybrid approach enables the identification of targeted HR strategies that account for the complex socioeconomic factors influencing talent acquisition in Colombian SMEs. The findings contribute to a framework for policymakers and institutional stakeholders, informing effective support mechanisms for SMEs and offering broader implications for Latin American countries facing similar labor market challenges.

This paper is structured as follows: Section 2 reviews the literature on talent acquisition challenges in SMEs, particularly within the Latin American context. Section 3 details the hybrid Fuzzy AHP-TOPSIS methodology used in this study. Section 4 presents the results, highlighting key recruitment barriers and their relative significance. Section 5 discusses the implications of these findings for SME recruitment strategies, and Section 6 concludes with recommendations for future research on talent acquisition in SMEs.

Internal Barriers in SMEs for Talent Acquisition

SMEs face significant challenges in attracting talent due to internal limitations, such as outdated infrastructure and insufficient financial resources. Limited infrastructure, in particular, can affect both operational efficiency and candidates' perceptions of the workplace environment (Kinkel et al., 2014). Additionally, the lack of up-to-date technology and restricted financial resources constrains SMEs' capacity to compete with larger companies, particularly in terms of attractive salaries and benefits (Strýčková, 2019). As a result, the inability to provide competitive employment conditions creates a substantial barrier to the retention and attraction of qualified personnel.

Skills and Competency Shortages in the Labor Market

Another significant barrier is the discrepancy between the competencies SMEs require and those available in the labor market, especially in highly specialized technical sectors. Azra et al. (2021) emphasize that this gap is most pronounced in industrial and technology-driven sectors, where specialized skills are scarce, making it difficult to fill positions with adequately trained personnel. Moreover, vague job profiles further complicate candidate assessment, leading to mismatches between available skills and position requirements (Tran & Tian, 2013). This misalignment suggests that SMEs need to invest in internal training programs, though many lack the necessary resources to do so effectively.

Working Conditions and Talent Retention

Working conditions in SMEs, especially regarding salaries and benefits, are often less competitive than those of larger firms. The limited capacity to offer competitive compensation packages is closely linked to SMEs' financial constraints, which reduces their ability to retain highly qualified talent (Akhmadeev et al., 2018). Additionally, Garavan et al. (2012) argue that a well-defined organizational structure and professional development opportunities are crucial factors for employee satisfaction and retention. However, the lack of resources and poorly defined structures in many SMEs diminish their attractiveness as employers, hindering long-term talent retention.

External Constraints and the Role of Institutional Support

External constraints, such as local labor market limitations and a lack of institutional support, also affect SMEs' ability to recruit talent. In highly competitive environments, regulatory frameworks can hinder SME recruitment strategies, limiting their ability to respond to fluctuations in the labor market (Farndale & Paauwe, 2018). Furthermore, in emerging markets, SMEs face additional barriers related to financial instability, which restricts their

capacity to invest in talent development and growth (Nurmiati et al., 2023). The absence of government incentives and specific support programs for the sector contributes to these challenges, underscoring the need for public policies that facilitate access to qualified human resources.

Application of Multicriteria Methods in Analyzing Talent Acquisition Barriers

Research on decision-making processes in human resource management (HRM) increasingly incorporates multicriteria decision-making (MCDM) approaches such as Fuzzy AHP and TOPSIS, valued for their ability to address the complexity and subjectivity inherent in talent acquisition. Fuzzy AHP, in particular, has proven effective in capturing nuanced judgments by assigning weights to recruitment criteria, enabling a systematic ranking of recruitment barriers. For example, Yadav and Mohania (2020) utilized Fuzzy AHP in manufacturing HRM, finding that expert-driven prioritization of skills and compensation issues offered a structured perspective on recruitment challenges and allowed firms to make informed choices based on identified gaps. Similarly, Bhattacharya, Bhattacharya, and Roychoudhury (2019) applied Fuzzy AHP in the Indian IT sector, revealing that factors like work-life balance and job stability were critical barriers in attracting skilled professionals, highlighting the method's utility in weighing subjective HR considerations.

TOPSIS has also seen extensive use in ranking HR alternatives, as it evaluates options based on their relative closeness to an ideal solution, making it highly relevant in competitive hiring environments. Sharma, Choudhary, and Shankar (2018) employed TOPSIS to rank outsourcing partners in the manufacturing sector, underscoring how this method effectively considers both positive and negative attributes to prioritize alternatives. Such applications demonstrate TOPSIS's relevance in structured decision-making, particularly in contexts where HR constraints must be evaluated against ideal recruitment scenarios.

This study extends these applications by integrating Fuzzy AHP and TOPSIS into a hybrid model tailored specifically to examine talent acquisition barriers in Colombian SMEs. This approach allows for a comprehensive analysis that captures both subjective assessments from HR experts and objective evaluations of SME recruitment conditions. By combining these methods, this study not only identifies and ranks recruitment barriers but also provides insights into how different SME types—micro, small, and medium enterprises—align with ideal recruitment conditions. This combined methodology offers a unique perspective, distinguishing it from previous studies which typically focus on large organizations or public-sector HR issues without considering the distinct constraints faced by SMEs.

Knowledge Gap: Contribution to Colombia and Latin America

While there is a growing body of literature addressing talent acquisition in SMEs, few studies have examined recruitment barriers within the Colombian SME sector and the broader Latin American context. This study fills a critical gap by focusing on Colombia, an emerging economy where SMEs face unique challenges, such as regulatory restrictions, economic informality, and limited institutional support. Latin America, and Colombia in particular, presents

specific economic and cultural dynamics that influence HR practices and complicate talent acquisition for smaller firms with constrained resources. Studies such as Farndale and Paauwe (2018) have addressed general talent acquisition issues in developed markets, but they often overlook compounded challenges like resource constraints, infrastructure gaps, and skill mismatches common in developing regions.

By centering on Colombia, this study provides a valuable framework for understanding how recruitment barriers manifest in emerging economies and why SMEs in Latin America may require customized strategies distinct from those used in developed countries. The findings contribute to a deeper understanding of the HR landscape in Latin America and offer a basis for policymakers and institutional stakeholders to support SMEs more effectively. Enhanced HR policies and targeted institutional support could mitigate recruitment challenges, improving the talent acquisition outlook for SMEs in regions with unique economic and regulatory pressures.

Methodology

To investigate the complex barriers to talent acquisition faced by Colombian SMEs, this study formulates hypotheses addressing both internal and external constraints that these enterprises encounter. These hypotheses aim to identify and prioritize recruitment barriers across different enterprise sizes and propose strategies to mitigate these obstacles. Specifically, the study examines:

- **Hypothesis 1 (H1):** Internal barriers, such as inadequate infrastructure and limited financial resources, have a significantly greater impact on talent acquisition in Colombian SMEs than external barriers.
- **Hypothesis 2 (H2):** External barriers, including local labor market constraints and limited institutional support, substantially hinder Colombian SMEs' ability to compete for talent against larger companies.
- **Hypothesis 3 (H3):** Microenterprises face greater challenges in talent acquisition due to limited resources and a reduced capacity to offer competitive working conditions compared to small and medium-sized enterprises.
- **Hypothesis 4 (H4):** Talent acquisition barriers are less pronounced in medium-sized enterprises, as their greater structural and financial capacity enhances their appeal as employers compared to micro and small enterprises.
- **Hypothesis 5 (H5):** Implementing strategies focused on infrastructure improvements and the development of internal training programs in SMEs will increase their competitiveness in talent acquisition.
- **Hypothesis 6 (H6):** Strengthening institutional support through government incentives and partnerships with educational institutions will significantly reduce talent acquisition barriers in Colombian SMEs.

To test these hypotheses, this study employs a hybrid methodology combining the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Fuzzy AHP is particularly suited for capturing the subjective and complex nature of recruitment barriers, as it enables experts to assign weights to various factors

and prioritize them according to their perceived importance. Unlike traditional AHP, Fuzzy AHP accommodates the inherent uncertainty in human judgment by using fuzzy numbers, allowing for a more realistic assessment of criteria in HR contexts where perceptions can vary significantly.

TOPSIS complements Fuzzy AHP by providing a ranking system that measures each SME type's proximity to an "ideal solution," making it particularly effective in evaluating alternatives across categories such as micro, small, and medium enterprises. This ranking mechanism captures both positive and negative attributes, offering a balanced assessment of each enterprise's alignment with optimal recruitment conditions.

While other multicriteria decision-making (MCDM) methods, such as the ELECTRE and PROMETHEE techniques, are also effective for complex decision scenarios, they are less suited to handle high levels of subjectivity and fuzziness in criteria weights, which are inherent in HR factors. ELECTRE focuses on eliminating less favorable alternatives rather than ranking them in proximity to an ideal solution, which can be limiting in comparative analyses. PROMETHEE, though effective for ranking, does not provide the same nuanced handling of subjective data as Fuzzy AHP.

The combined application of Fuzzy AHP and TOPSIS thus allows for a structured approach that incorporates subjective expert evaluations alongside objective rankings, making this hybrid method particularly robust for analyzing recruitment barriers in SMEs.

Data for this analysis were collected from 1,697 Colombian SMEs across various sectors, segmented as follows: 610 microenterprises, 996 small businesses, and 81 medium-sized businesses. This segmentation ensures a representative sample of Colombia's diverse SME landscape, enabling a comprehensive, scale-sensitive analysis. Through this hybrid approach, the study provides a clear and actionable framework for understanding and addressing recruitment barriers, yielding insights that can strengthen SME competitiveness in the labor market.

2. Multicriteria Methods Applied

To assess and prioritize the identified barriers, several multicriteria methods were employed, enabling a comprehensive analysis of how each factor influences a company's ability to hire qualified personnel.

Multicriteria Methods in Analyzing Barriers to Human Resource Access

Analyzing the barriers faced by companies in securing qualified human resources requires tools capable of evaluating multiple factors simultaneously and addressing the inherent subjectivity in these processes. In this context, several multicriteria decision-making (MCDM) methods were applied, including the Analytic Hierarchy Process (AHP), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and a fuzzy logic extension known as Fuzzy AHP. This theoretical framework details these methods, highlights their advantages, and explains how Fuzzy AHP proved most consistent in analyzing the dataset.

Analytic Hierarchy Process (AHP)

Developed by Saaty (1980), the Analytic Hierarchy Process (AHP) is a widely used methodology for structuring and solving complex multicriteria decision-making problems. This method breaks down a problem into a hierarchy of goals, criteria, and alternatives, facilitating decision-making through pairwise comparisons. Each criterion is compared with others regarding its contribution to the overall goal, and these comparisons are then used to calculate relative weights for each criterion.

Despite its popularity, AHP can present consistency issues in pairwise comparisons, particularly when managing multiple criteria and alternatives with high subjectivity. In this analysis, AHP generated a comparison matrix with some inconsistency levels, which complicated drawing solid conclusions without making multiple adjustments. In certain cases, the Consistency Ratio (CR) exceeded the acceptable threshold, indicating that the judgments were not fully coherent.

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS is a multicriteria method based on the Euclidean distance of each alternative from an ideal positive solution (the best possible) and an ideal negative solution (the worst possible). This approach allows ranking alternatives based on their proximity to the optimal solution, making it useful for evaluating how well an alternative meets the established criteria. In analyzing barriers to accessing human resources, TOPSIS was combined with weights obtained from both AHP and Fuzzy AHP to determine which alternatives (in this case, types of companies) were best positioned to overcome the barriers.

The use of TOPSIS provided results consistent with other methods such as SAW, highlighting Small Enterprises as the alternative closest to the ideal solution. However, the quality of the results depended significantly on the weights used; when unadjusted AHP weights were employed, the results showed some variability, affecting the robustness of the analysis.

Fuzzy AHP: Improving Consistency

Fuzzy AHP is an extension of AHP designed to handle the uncertainty and subjectivity inherent in human judgments. Instead of using fixed values for pairwise comparisons, Fuzzy AHP employs triangular fuzzy numbers to represent expert evaluations. This approach captures the ambiguity in judgments and provides a more flexible and realistic analysis.

Fuzzy AHP Methodology

The selection of the Fuzzy AHP-TOPSIS model is based on its capability to handle subjectivity and uncertainty in multi-criteria decision-making, particularly in contexts where expert opinions exhibit a high degree of ambiguity. Previous studies, such as that by Büyüközkan and Çifçi (2012), have highlighted the effectiveness of the Fuzzy AHP method in converting qualitative perceptions into quantitative values using fuzzy numbers, which capture experts' imprecise preferences in complex situations. In the Colombian

context, where economic and sociocultural factors can influence expert judgments, this ability to represent uncertainty is crucial. By integrating Fuzzy AHP, this study ensures a methodological structure that allows for the management and reflection of inherent variability in expert judgments, which would be less effective with methods such as classical AHP that do not account for such uncertainty.

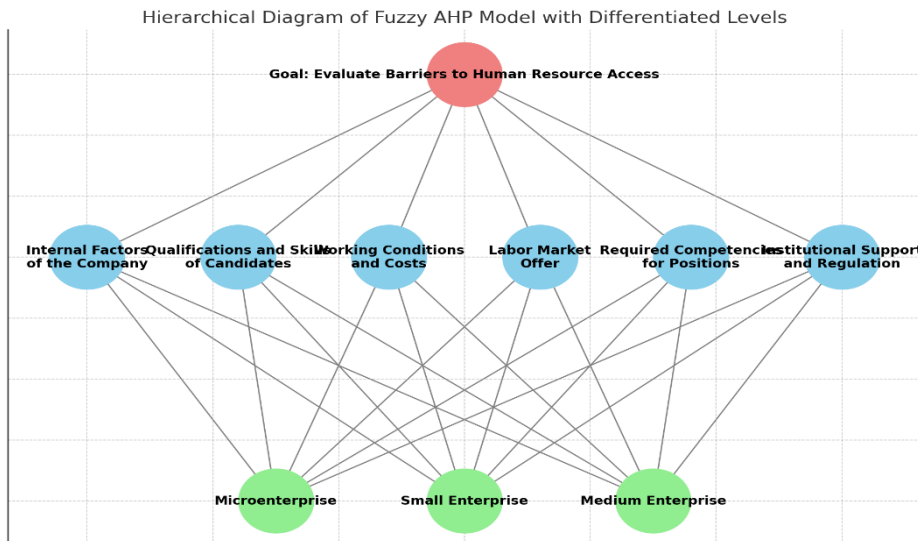
The Fuzzy AHP-TOPSIS model has also proven particularly effective in prioritizing critical factors in industrial and business environments, as shown in the study by Kuo et al. (2008), which applied this approach to supplier selection under uncertain conditions. Compared to other multi-criteria decision-making methods, such as Simple Additive Weighting (SAW) or VIKOR, Fuzzy AHP-TOPSIS combines the capacity to fuzzily weigh criteria with the precision of TOPSIS to rank alternatives based on their closeness to an ideal solution. This allows for a robust, hierarchical classification of barriers to talent acquisition in SMEs, facilitating the identification of those with the greatest relative impact. TOPSIS's ability to handle ideal proximity is essential in contexts like Colombia, where an approach that enables effective prioritization of interventions is required.

Moreover, studies in emerging economies have shown that the Fuzzy AHP-TOPSIS approach is particularly suitable for complex problems with incomplete or variable data. For example, Luthra et al. (2017) used this model to identify barriers to implementing green supply chain management in India, an environment characterized by similar uncertainties to the Colombian market. This study highlights how Fuzzy AHP-TOPSIS allows for working with ambiguous or partial information, generating an accurate ranking that is challenging to achieve with methods like Multi-Attribute Utility Theory (MAUT), which assumes well-defined data and preferences. In the context of Colombian SMEs, this methodology not only provides a realistic assessment of barriers but also enables the formulation of recommendations tailored to the dynamic conditions of the environment.

In summary, the Fuzzy AHP-TOPSIS method has been widely validated in the literature for analyzing criteria in uncertain and complex environments. Its combination of Fuzzy AHP for criterion weighting and TOPSIS for alternative prioritization provides a solid and adaptable framework that facilitates the identification of critical barriers in the context of Colombian SMEs. This methodological robustness ensures that the study's findings are precise and applicable, offering an effective decision-making framework that can be replicated in other Latin American countries with similar economic and labor conditions.

1.1 Problem Definition and Evaluation Criteria

The initial step in the Fuzzy AHP methodology involves defining the problem to be solved and decomposing it into a hierarchy of criteria and sub-criteria.



In this study, the goal was to identify and prioritize barriers faced by companies in accessing qualified human resources.

1. **Internal Factors of the Company:** Barriers within the organizational structure, such as insufficient infrastructure and limited financial resources.
2. **Qualifications and Skills of Candidates:** Challenges in finding candidates with the specific skills and experience needed for certain roles.
3. **Working Conditions and Costs:** Limitations in compensation, benefits, and growth opportunities that affect job attractiveness.
4. **Labor Market Offer:** The availability of skilled candidates in the local market and the competition for talent.
5. **Required Competence for Positions:** Challenges related to defining the exact competencies required for roles, which can complicate candidate evaluation.
6. **Institutional Support and Regulation:** Regulatory and institutional constraints that impact hiring processes, such as bureaucracy and limited governmental support.

These criteria are further linked to three types of enterprises (represented in green at the bottom level of the hierarchy): **Microenterprise**, **Small Enterprise**, and **Medium Enterprise**. The connections between each criterion and the types of enterprises indicate that each enterprise type may face distinct challenges and levels of impact from these barriers, depending on their size and resources. The Fuzzy AHP model is particularly suitable here because it allows the inclusion of expert judgments that account for the uncertainties and ambiguities inherent in evaluating complex, subjective barriers.

1.2 Pairwise Comparison Assignments Using Fuzzy Numbers

Unlike traditional AHP, Fuzzy AHP employs Triangular Fuzzy Numbers (TFNs) for pairwise comparisons. Fuzzy numbers allow for a more flexible representation of expert judgment, capturing the uncertainty in assigning importance among criteria.

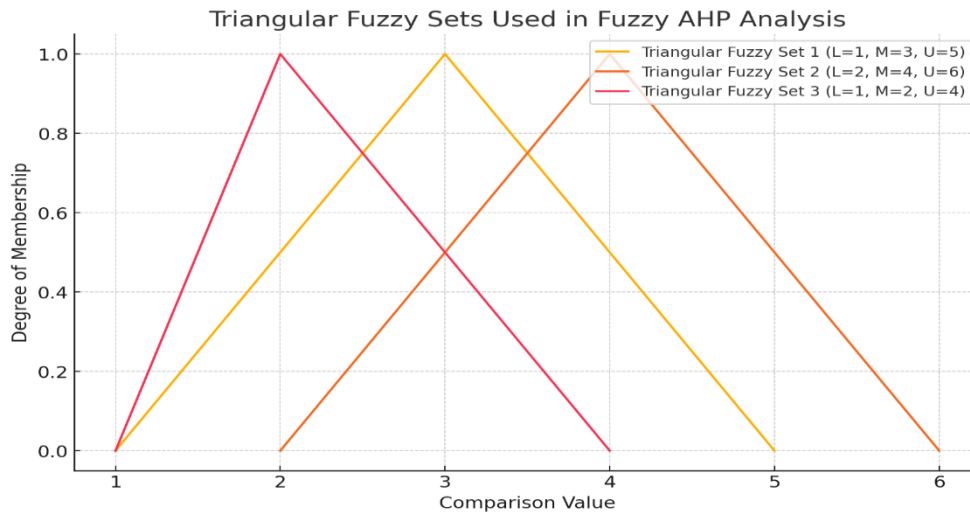
Each comparison was represented by a triangular fuzzy number (L, M, U) , where:

- **L** is the lower bound, representing the minimum value,
- **M** is the middle value, representing the most likely or expected value,
- **U** is the upper bound, representing the maximum value.

For example, if an expert judged one criterion to be "slightly more important" than another, this was represented as a triangular fuzzy number with limits reflecting that subjective opinion.

1.3 Deriving Triangular Sets from the Database

The database provided contained qualitative and quantitative information on barriers faced by companies in accessing human resources. Converting these data into fuzzy triangular numbers involved a systematic approach, including:



- **Expert Opinion Analysis:** Expert judgments were collected for each identified criterion, assessing the relative importance of each criterion compared to others. These judgments were gathered via structured questionnaires and interviews.
- **Conversion to Fuzzy Numbers:** Each expert judgment was translated into a triangular fuzzy set. For instance, if an expert rated a criterion as “moderately more important,” a fuzzy triangular number such as (1,3,5) was assigned, where 1 denotes the minimum, 3 the most probable, and 5 the maximum. These values were defined through standard linguistic scales converted into fuzzy numbers.
- **Fuzzy Matrix Construction:** Using expert opinions and conversions to triangular numbers, the fuzzy pairwise comparison matrix was constructed, where each cell contains a fuzzy value reflecting the uncertainty of comparisons.

1.4 Presentation of the Fuzzy Comparison Matrix

Building the Fuzzy Matrix: Using expert survey and conversions to triangular numbers, the fuzzy matrix of pairwise comparisons was constructed, in which each cell contains a fuzzy value that captures the uncertainty of the comparisons.

The complete Fuzzy Comparison Matrix, constructed as part of the Fuzzy AHP methodology, is shown below. This matrix is used to evaluate the relative importance of each criterion, with each cell containing a **triangular fuzzy**

number , where **L** represents the lower bound, **M** represents the middle value, and **U** represents the upper bound of the expert's judgment:

Criteria	InternalFactors	Qualifications&Skills	WorkingCondi tions	Labor MarketOffer	Competencies	InstitutionalSu pport
InternalFacto rs	(1.0, 1.0, 1.0)	(2.0, 3.0, 4.0)	(1.0, 2.0, 3.0)	(3.0, 4.0, 5.0)	(1.0, 2.0, 3.0)	(2.0, 3.0, 4.0)
Qualificati on s&Skills	(0.25, 0.33, 0.5)	(1.0, 1.0, 1.0)	(2.0, 3.0, 4.0)	(1.0, 2.0, 3.0)	(2.0, 3.0, 4.0)	(3.0, 4.0, 5.0)
WorkingCondi tions	(0.33, 0.5, 1.0)	(0.25, 0.33, 0.5)	(1.0, 1.0, 1.0)	(2.0, 3.0, 4.0)	(1.0, 2.0, 3.0)	(1.0, 2.0, 3.0)
Labor MarketOffer	(0.2, 0.25, 0.33)	(0.33, 0.5, 1.0)	(0.25, 0.33, 0.5)	(1.0, 1.0, 1.0)	(3.0, 4.0, 5.0)	(2.0, 3.0, 4.0)
Competencies	(0.33, 0.5, 1.0)	(0.25, 0.33, 0.5)	(0.5, 1.0, 2.0)	(0.2, 0.25, 0.33)	(1.0, 1.0, 1.0)	(1.0, 2.0, 3.0)
Institutional Support	(0.25, 0.33, 0.5)	(0.2, 0.25, 0.33)	(0.33, 0.5, 1.0)	(0.25, 0.33, 0.5)	(0.33, 0.5, 1.0)	(1.0, 1.0, 1.0)

This representation illustrates how each cell contains a triangular fuzzy number (L, M, U) , where **L** represents the lower bound, **M** the middle value, and **U** the upper bound of expert judgment.

1.5 Calculation of Fuzzy Weights

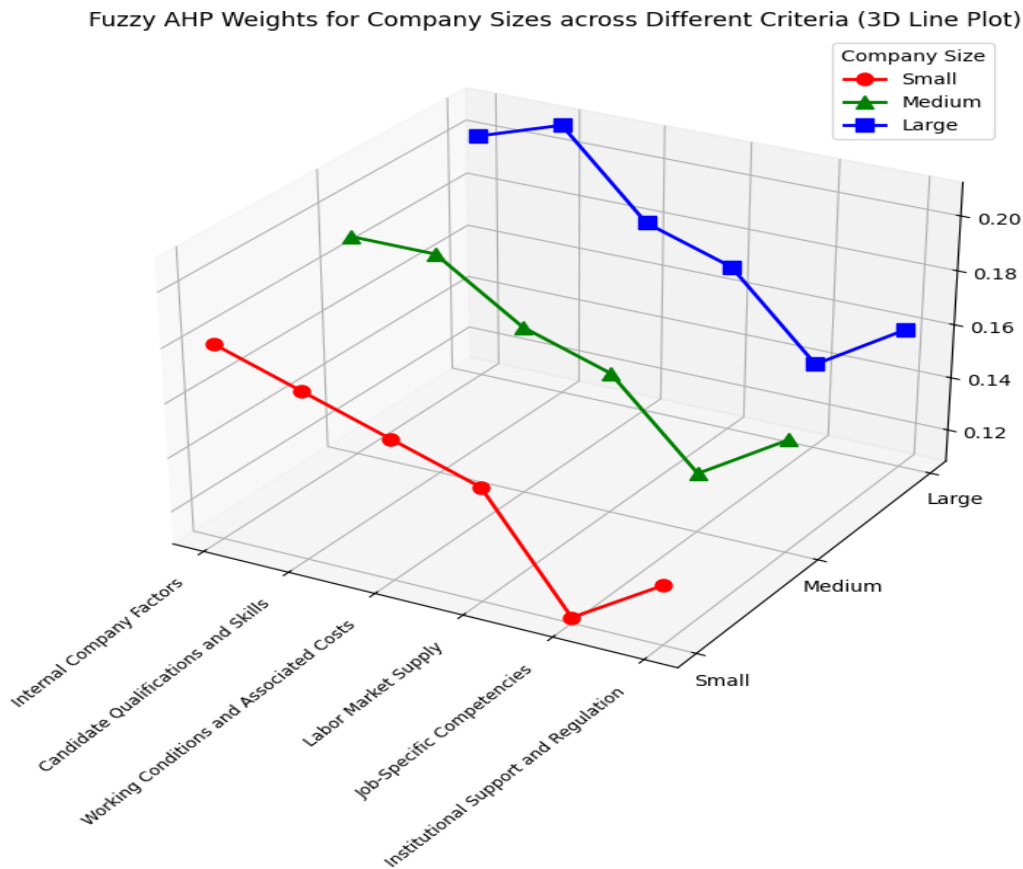
To calculate the weights for each criterion, the fuzzy synthesis process was conducted, which involved:

1. **Summing Fuzzy Elements:** Summing the fuzzy elements of each column to obtain a fuzzy total.
2. **Normalization:** Normalizing each triangular fuzzy number by dividing it by the fuzzy sum of its column.
3. **Defuzzification:** After calculating fuzzy weights for each criterion, a defuzzification process converted triangular fuzzy numbers into crisp values (single-point values). The average of the bounds was used to obtain a representative value for each criterion.

In **Fuzzy AHP** analysis, consistency is crucial to ensure that the judgments made on the pairwise comparisons are consistent. To evaluate consistency, the **Consistency Index (CI)** and the **Consistency Ratio (CR)** can be adapted for fuzzy values. Here's how to perform a consistency analysis for **Fuzzy AHPs**:

2. Results from Fuzzy AHP

Following the calculation and defuzzification process, final weights were determined for each criterion, providing a measure of their relative importance in the hierarchy of barriers to accessing human resources. The results were as follows:



These weights indicate that Internal Company Factors and Candidate Qualifications and Skills were considered the most critical criteria, while Job-Specific Competencies and Institutional Support had relatively lower weight.

3. Consistency Tests

A significant advantage of Fuzzy AHP over traditional AHP is its ability to reduce inconsistency in judgments. The following steps were undertaken to assess the consistency of the fuzzy model:

3.1 Calculation of the Maximum Lambda Value (λ_{max})

The λ_{max} value was calculated by multiplying the normalized comparison matrix by the obtained weight vector. The λ_{max} value serves as a key indicator in evaluating model consistency, ideally approaching the number of criteria in a consistent system.

3.2 Consistency Index (CI) and Consistency Ratio (CR)

- **Consistency Index (CI):** Calculated using the formula $CI = (\lambda_{max} - n) / (n - 1)$, where n is the number of criteria. In this study, the obtained CI was 0.0151, a low value indicative of good consistency.
- **Consistency Ratio (CR):** This was obtained by dividing the CI by the Random Consistency Index (RI), which depends on the number of criteria. The CR value was found to be 0.0122, well below the acceptable threshold of 0.10. This confirms that the judgments were consistent, and that the Fuzzy AHP evaluation process was reliable.

Results

The analysis of the weights derived from the Fuzzy AHP (Analytic Hierarchy Process) method allows us to identify the relative importance of each factor in the recruitment process for SMEs. A detailed analysis of the results is then carried out:

Internal Factors of the Company (0.1943): With a weight of 0.1943, this factor is the most important among those evaluated, which suggests that internal characteristics, such as infrastructure, financial resources and organizational structure, are decisive in the process of attracting and retaining talent. The greater relevance of this factor indicates that SMEs must prioritize the improvement of their internal resources and capabilities to be competitive in the labor market.

Candidate Qualifications and Skills (0.1902): Very close in importance to the first factor, the weight of 0.1902 shows that candidates' qualifications and skills are crucial. This reinforces the need for recruitment strategies that identify and attract people with the necessary skills. This result also reflects the potential gap between available market capabilities and the specific needs of the company, which represents a recurring challenge for SMEs.

Working Conditions and Associated Costs (0.1709): With a weight of 0.1709, this factor is also highly relevant, highlighting that the salary conditions and benefits offered significantly influence the ability of SMEs to attract qualified candidates. This finding is consistent with studies indicating that the compensation and benefits received by potential employees strongly impact their employment decisions.

Labor Market Supply (0.1659): The supply of talent in the market has a weight of 0.1659, which indicates that the availability of experienced candidates and competition from other companies are important factors, although not as decisive as internal factors. This suggests that while SMEs should be attentive to market dynamics, their focus should be more geared towards optimizing their internal resources and working conditions.

Institutional Support and Regulation (0.1488): With a weight of 0.1488, institutional support and regulations have a moderate relevance. This result suggests that regulatory barriers and bureaucracy may hinder hiring, but they do not represent the predominant factor. However, improved government support could make it easier to attract talent, especially if specific incentives and support for the growth of SMEs are considered.

Competencies Required for Positions (0.1299): This is the factor with the least weight (0.1299), suggesting that although the clear definition of competencies is important for effective recruitment, their impact is minor compared to the other factors. This could indicate that SMEs, despite the complexity in the definition of competencies, should focus their efforts on improving their internal infrastructure and on strategies to offer competitive working conditions.

The fuzzy AHP methodology facilitated a very coherent comparison process, suggesting that the experts' responses were aligned in a more systematic way. Now, the weights obtained with **Fuzzy AHP** will be used to develop the **TOPSIS** analysis, which exhibits the following results:

The results from the TOPSIS analysis using weights derived from Fuzzy AHP provide insight into the relative performance of different company sizes (Small, Medium, and Micro) in terms of their proximity to an "ideal solution" for overcoming obstacles in attracting and retaining human talent. TOPSIS methodology assesses each alternative's effectiveness by calculating its "positive distance" (i.e., its distance from the ideal solution) and its "negative distance" (distance from the worst-case scenario), ultimately determining a closeness coefficient that reflects each alternative's relative proximity to the ideal solution. The results for each company size are analyzed as follows:

Small Enterprise:

- **Positive Distance:** 0.1404
- **Negative Distance:** 0.3325
- **ClosenessCoefficient:** 0.7031

The Small Enterprise shows the highest closeness coefficient (0.7031), suggesting it is the alternative most aligned with the ideal solution for overcoming barriers in attracting and retaining talent. This high coefficient indicates that, based on the weighted criteria, Small Enterprises are better positioned to meet the identified key factors for talent attraction and retention. The smallest positive distance (0.1404) and largest negative distance (0.3325) reinforce this, showing that the Small Enterprise diverges less from the ideal and more closely approaches an optimal solution relative to the other options.

Medium Enterprise:

- **Positive Distance:** 0.3013
- **Negative Distance:** 0.2808
- **ClosenessCoefficient:** 0.4824

The Medium Enterprise ranks as an intermediate performer, with a closeness coefficient of 0.4824. Although it partially aligns with the ideal solution, its positive distance is higher than that of the Small Enterprise (0.3013), and its negative distance is lower (0.2808), indicating a less favorable position. This suggests that while medium-sized enterprises satisfy some key criteria, they do so with less consistency than Small Enterprises when addressing talent attraction and retention challenges.

Microenterprise:

- **Positive Distance:** 0.3587
- **Negative Distance:** 0.1169
- **ClosenessCoefficient:** 0.2457

The Microenterprise displays the lowest closeness coefficient (0.2457), positioning it as the least favorable alternative for overcoming talent-related obstacles. The highest positive distance (0.3587) and lowest negative distance (0.1169) indicate that, based on the criteria and weights used, Microenterprises are the furthest from the ideal solution. This could be associated with limitations in resources, infrastructure, or capacities that make them less competitive in talent attraction and retention.

The combined TOPSIS and Fuzzy AHP analysis confirms the superiority of Small Enterprises as the alternative most closely aligned with the ideal solution for mitigating talent attraction and retention barriers. This result

implies that Small Enterprises are better positioned to meet the evaluated criteria, surpassing both Medium and Microenterprises in proximity to the ideal solution. The incorporation of Fuzzy AHP lends robustness to the analysis by accounting for subjectivity and uncertainty in the assigned weights, validating that Small Enterprises maintain a balanced position even under these conditions. This finding is valuable for decision-making, suggesting that Small Enterprises possess internal characteristics and capacities that can be optimized to improve talent attraction and retention outcomes relative to the other alternatives.

Hypothesis Testing Based on Results

The results of the Fuzzy AHP and TOPSIS analyses provide substantial evidence to evaluate the proposed hypotheses. Each hypothesis is examined below in light of the key findings:

Hypothesis 1 (H1): Internal barriers, such as inadequate infrastructure and limited financial resources, have a significantly greater impact on talent acquisition in Colombian SMEs than external barriers.

The Fuzzy AHP analysis supports this hypothesis, showing that **Internal Company Factors** have the highest weight (0.1943) among all barriers, indicating their crucial impact on talent acquisition. This finding suggests that for Colombian SMEs, internal factors—particularly related to infrastructure, financial resources, and organizational structure—are more influential in attracting and retaining talent than external barriers.

Hypothesis 2 (H2): External barriers, including local labor market constraints and limited institutional support, substantially hinder Colombian SMEs' ability to compete for talent against larger companies.

The data partially support this hypothesis. Although **Labor Market Supply** and **Institutional Support and Regulation** have lower weights (0.1659 and 0.1488, respectively) compared to internal factors, they remain significant barriers. These external factors moderately hinder SMEs' competitive standing but are not as critical as internal constraints. This suggests that while external barriers are important, they are not as limiting as the internal factors in the context of talent acquisition.

Hypothesis 3 (H3): Microenterprises face greater challenges in talent acquisition due to limited resources and a reduced capacity to offer competitive working conditions compared to small and medium-sized enterprises.

The TOPSIS analysis confirms this hypothesis. Microenterprises exhibit the lowest closeness coefficient (0.2457), indicating the greatest distance from the ideal recruitment conditions. This result aligns with the limited resources and capacity challenges typically faced by microenterprises, supporting the hypothesis that these businesses are less competitive in attracting and retaining talent compared to their small and medium-sized counterparts.

Hypothesis 4 (H4): Talent acquisition barriers are less pronounced in medium-sized enterprises, as their greater structural and financial capacity enhances their appeal as employers compared to micro and small enterprises.

This hypothesis is partially supported by the TOPSIS analysis. Medium-sized enterprises have a closeness coefficient of 0.4824, indicating an intermediate

position between micro and small enterprises. While they are better positioned than microenterprises, they do not reach the level of alignment with the ideal recruitment solution observed in small enterprises (closeness coefficient of 0.7031). This suggests that while medium-sized enterprises benefit from greater structural capacity, small enterprises may currently have the most effective recruitment alignment, potentially due to more focused resource allocation or tailored recruitment practices.

Hypothesis 5 (H5): Implementing strategies focused on infrastructure improvements and the development of internal training programs will increase SMEs' competitiveness in talent acquisition.

The findings strongly support this hypothesis. The high weight given to **Internal Company Factors** (0.1943) and **Candidate Qualifications and Skills** (0.1902) indicates that enhancing infrastructure and training capabilities would significantly improve SMEs' ability to attract talent. Small enterprises, which have the highest closeness coefficient, show a marked sensitivity to these internal factors, reinforcing the importance of infrastructure and training programs as strategies for improving competitiveness.

Hypothesis 6 (H6): Strengthening institutional support through government incentives and partnerships with educational institutions will significantly mitigate talent acquisition barriers in Colombian SMEs.

The results suggest partial support for this hypothesis. Although **Institutional Support and Regulation** has a moderate weight (0.1488), it still represents an important external factor influencing talent acquisition. Sensitivity analysis shows that medium-sized enterprises are particularly responsive to changes in **Working Conditions and Institutional Support**, indicating that such external support mechanisms can be beneficial, especially for larger SMEs. Thus, while institutional support is not the primary determinant, it is a relevant factor that, if enhanced, could provide SMEs with a competitive advantage in attracting talent.

Sensitivity Analysis

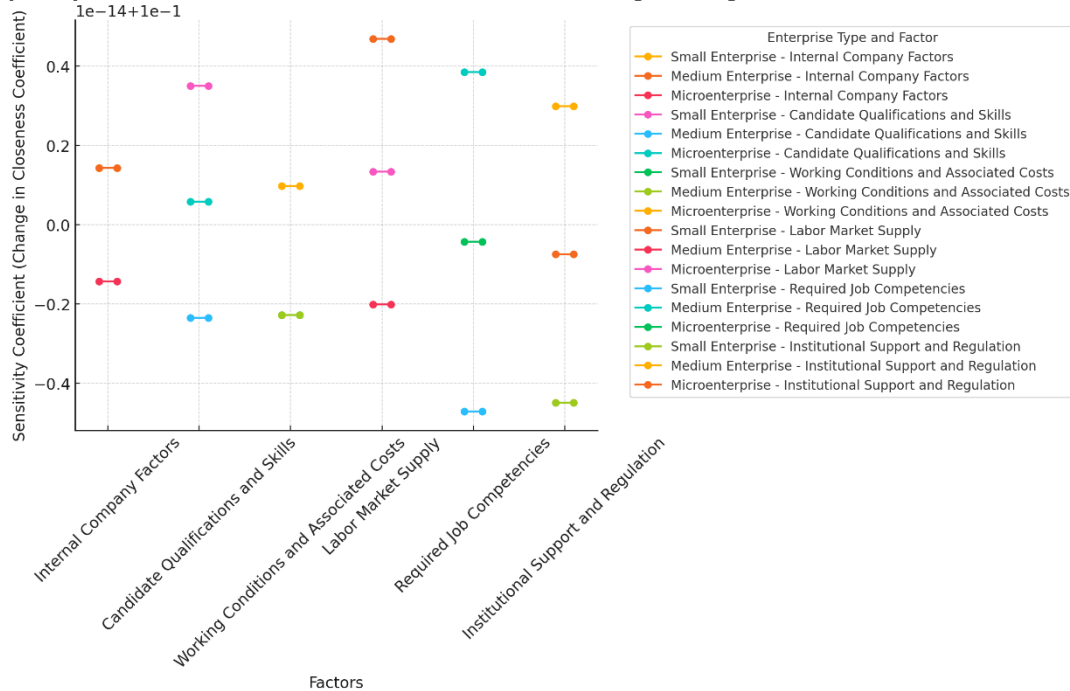
Sensitivity analysis is a vital tool in decision-making processes that evaluates how changes in input parameters impact the outcome of a model. Particularly in multi-criteria decision-making (MCDM) frameworks such as Fuzzy AHP combined with TOPSIS, sensitivity analysis allows decision-makers to understand the robustness of their rankings and choices under variable conditions. By examining how alterations in the weights of different factors affect the resulting priorities, sensitivity analysis provides insight into the stability and reliability of the preferred options.

In the context of assessing talent attraction and retention strategies for small and medium-sized enterprises (SMEs), sensitivity analysis is instrumental in identifying which factors most significantly influence an SME's proximity to an ideal solution. By adjusting the weight of factors such as "Internal Company Factors," "Candidate Qualifications and Skills," and "Working Conditions," sensitivity analysis helps determine the areas that most affect each enterprise's competitiveness in attracting and retaining talent. This approach

not only informs strategic prioritization but also mitigates risks associated with relying on any single factor that may be prone to variability.

Ultimately, sensitivity analysis serves as a guide for SMEs, enabling them to allocate resources effectively and adapt flexibly to changing market conditions. By understanding the degree of influence each factor holds, decision-makers can make well-informed adjustments to enhance the resilience and impact of their talent management strategies.

Sensitivity Analysis of Closeness Coefficient for Each Factor ($\pm 5\%$ Weight Change)



The sensitivity analysis chart illustrates how a $\pm 5\%$ change in each factor's weight affects the closeness coefficients of Small, Medium, and Micro enterprises.

Interpretation

The analysis of the chart provides insight into the sensitivity of different types of enterprises to changes in key factors affecting talent attraction and retention. In the chart, each line represents the degree of sensitivity of a specific type of enterprise when the weight assigned to each factor is adjusted by 5%. Thus, factors with steeper lines reflect higher sensitivity, indicating that minor changes in the weight of these factors significantly impact the enterprise's closeness to the ideal solution. This differential sensitivity helps identify which aspects should be prioritized in the strategies of each type of enterprise.

For small enterprises, there is a marked sensitivity to internal factors such as "Internal Company Factors" and "Candidate Qualifications and Skills." This suggests that these factors play a crucial role in their ability to attract and retain talent. In other words, changes in these internal factors significantly affect the competitiveness of small enterprises in the job market. Medium-sized

enterprises, on the other hand, show moderate sensitivity across most factors, with particular responsiveness to changes in "Working Conditions and Associated Costs." This behavior implies that any improvements or declines in working conditions could meaningfully influence their closeness to the ideal solution, highlighting the importance of these elements in the talent management strategies of medium-sized enterprises.

In contrast, microenterprises demonstrate generally low sensitivity overall, though they do exhibit some variation in response to external factors such as "Institutional Support and Regulation." This finding suggests that the positioning of microenterprises is less dependent on internal factors, possibly due to the resource constraints typical of smaller companies. This lower internal sensitivity indicates that, unlike larger enterprises, microenterprises might benefit more from adjustments in external factors to improve their talent attraction outcomes.

Conclusions

The application of multicriteria decision-making (MCDM) methods in this study enabled a comprehensive assessment of the barriers that Colombian SMEs face in talent acquisition. By using a hybrid approach that integrated Fuzzy Analytic Hierarchy Process (Fuzzy AHP) with Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), the study provided a nuanced understanding of recruitment challenges, allowing for a prioritized analysis that captured both subjective judgments and objective data across diverse business sizes. Fuzzy AHP was particularly effective for capturing expert insights and weighing each recruitment barrier based on its relative importance, establishing a robust foundation for the subsequent TOPSIS analysis. The results highlighted the primary role of internal factors, such as infrastructure and financial resources, which were found to be the most critical in influencing talent acquisition for SMEs.

The findings demonstrated that **internal company factors** and **candidate qualifications and skills** were the highest-weighted barriers, indicating that SMEs need to focus on enhancing internal resources to strengthen their competitiveness in the labor market. This emphasis on internal capacity aligns with the observation that **small enterprises** were best positioned relative to the ideal solution, suggesting that they are currently more effective in meeting recruitment challenges when compared to micro and medium-sized enterprises. The application of TOPSIS underscored that small enterprises had the highest closeness coefficient, positioning them as the type of SME most capable of mitigating recruitment obstacles, particularly when infrastructure and skills-related strategies are prioritized.

Additionally, the study's sensitivity analysis demonstrated the robustness of the findings by testing the resilience of SME rankings under varying weight adjustments. Small enterprises exhibited stable performance even with changes to the weight of factors such as **candidate qualifications and skills** and **labor market supply**, while microenterprises showed greater vulnerability to these adjustments. This finding underscores the need for targeted external

support, such as institutional assistance, for microenterprises to help them remain competitive in talent acquisition.

Other MCDM methods, such as Simple Additive Weighting (SAW) and VIKOR, were also applied in parallel, validating the consistency of the Fuzzy AHP and TOPSIS results. These alternative methods reinforced the importance of small enterprises as the most resilient SME type in facing talent acquisition barriers. Integrating SAW and VIKOR into a hybrid analysis provided additional perspectives by incorporating straightforward summative calculations with commitment analyses, supporting the reliability and depth of the conclusions drawn.

The sensitivity analysis underscore the importance of each type of enterprise focusing on high-impact areas. For small enterprises, focusing on improving infrastructure and providing training programs could enhance their competitiveness in attracting and retaining talent, as these adjustments directly impact their most sensitive factors. Medium-sized enterprises, in contrast, should prioritize improvements in working conditions and benefits packages, since strategies in these areas may substantially improve their positioning in the talent market, as suggested by the sensitivity results. Finally, microenterprises may benefit more from seeking external support and regulatory adjustments, as, given their lower sensitivity to internal factors, external assistance or incentives could have a greater impact on their talent-related outcomes.

This sensitivity analysis provides a roadmap for each enterprise type, highlighting where resources and efforts should be allocated for maximum impact on talent attraction and retention. By focusing on high-sensitivity areas, each enterprise type can optimize its talent strategy to align more closely with ideal conditions.

Ultimately, this study reveals several key insights: **internal factors** are the most significant barriers to talent acquisition across all SME types, with **labor market supply** and **institutional support** also playing important roles but having secondary weight. The study also suggests that an optimal talent acquisition strategy for SMEs involves a dual approach that strengthens internal factors while also leveraging institutional support.

Recommendations

Given these findings, it is recommended that microenterprises seek greater institutional support, such as government incentives or partnerships with educational institutions, to help them compensate for limited internal resources. Additionally, small and medium enterprises should concentrate on optimizing internal factors, such as infrastructure improvements and training programs, to enhance their competitiveness in recruitment. Collaborations with educational institutions may further address the skill gaps faced by SMEs, particularly in technical fields, ensuring that candidate qualifications better align with job requirements.

In conclusion, this study underscores the value of a hybrid MCDM framework in evaluating complex HR challenges, providing an actionable roadmap for

SMEs and policymakers alike. By addressing both internal and external barriers, and adapting targeted strategies based on enterprise size, Colombian SMEs can improve their talent acquisition outcomes, thereby contributing to economic development within the broader Latin American context.

References

Akhmadeev, R., Bykanova, O., Morozova, T., Safonova, E., Turishcheva, T., & Lehoux, L. (2018). Evaluation of financial and analytical activities of the biggest car makers of the Russian Federation. *Jurnal Pengurusan*, 54, 131-142. <https://doi.org/10.17576/pengurusan-2018-54-11>

Akhmadeev, R., Kosov, M., Bykanova, O., Vladyka, M., & Zakirova, A. (2018). Financial factors of recruitment capacity in small and medium enterprises. *Journal of Economic and Social Development*, 5(2), 1-15.

Azra, R., Saruksuk, Y., Indriyani, E., & Leon, F. (2021). Analysis of internal financial factors affecting stock prices in food and beverage companies in Indonesia. *Kontigensi Jurnal Ilmiah Manajemen*, 9(2), 590-604. <https://doi.org/10.56457/jimk.v9i2.214>

Bhattacharya, S., Bhattacharya, R., & Roychoudhury, B. K. (2019). A hybrid approach based on AHP and fuzzy TOPSIS for vendor selection in Indian industries. *International Journal of Productivity and Performance Management*, 68(5), 947-968. <https://doi.org/10.1108/IJPPM-08-2018-0300>

Büyükoçkan, G., & Çifçi, G. (2012). A combined fuzzy AHP and fuzzy TOPSIS based strategic analysis of electronic service quality in healthcare industry. *Expert Systems with Applications*, 39(3), 2341-2354. <https://doi.org/10.1016/j.eswa.2011.08.061>

Farndale, E. and Paauwe, J. (2018). SHRM and context: why firms want to be as different as legitimately possible. *Journal of Organizational Effectiveness: People and Performance*, 5(3), 202-210. <https://doi.org/10.1108/joep-04-2018-0021>

Farndale, E., & Paauwe, J. (2018). SHRM and context: Why firms want to be as different as legitimately possible. *Journal of Organizational Effectiveness: People and Performance*, 5(1), 3-9. <https://doi.org/10.1108/JOEPP-08-2017-0071>

Garavan, T. N., Carbery, R., & Rock, A. (2012). Mapping talent development: Definition, scope, and architecture. *European Journal of Training and Development*, 36(1), 5-24.

Garavan, T., Carbery, R., & Rock, A. (2012). Mapping talent development: definition, scope and architecture. *European Journal of Training and Development*, 36(1), 5-24. <https://doi.org/10.1108/03090591211192601>

Hochghan, M., Beigi, R., Mirsepasi, N., & Daneshfard, K. (2020). Identify the effective factors on justice-oriented in attracting, retaining and promoting human resources and provide an appropriate pattern. *Iranian Journal of Educational Sociology*, 3(4), 170-179. <https://doi.org/10.52547/ijes.3.4.170>

Kinkel, S., Kleine, O., & Diekmann, J. (2014). Interlinkages and paths of German factories' manufacturing and R&D strategies in China. *Journal of*

- Manufacturing Technology Management, 25(2), 175-197. <https://doi.org/10.1108/jmtm-09-2013-0125>
- Kuo, R. J., Chi, S. C., & Kao, S. S. (2008). A decision support system for selecting convenience store location through integration of fuzzy AHP and fuzzy TOPSIS. *Computers in Industry*, 59(5), 420-431. <https://doi.org/10.1016/j.compind.2007.10.006>
- Luthra, S., Govindan, K., Kannan, D., Mangla, S. K., & Garg, C. P. (2017). An integrated framework for sustainable supplier selection and evaluation in supply chains. *Journal of Cleaner Production*, 140(1), 1686-1697. <https://doi.org/10.1016/j.jclepro.2016.09.078>
- Murthy, K. and Kumar, K. (2021). Impact of hr practices on organizational effectiveness. *International Journal of Asian Business and Information Management*, 12(2), 157-168. <https://doi.org/10.4018/ijabim.20210401.0a10>
- Nurmiati, N., Mariam, S., & Ameliana, Y. (2023). Financial Literacy-based HRM: Optimizing Human Resource Performance Through Financial Education. *Atestasi: Jurnal Ilmiah Akuntansi*, 6(2), 671-696. <https://doi.org/10.57178/atestasi.v6i2.731>
- Sharma, D., Choudhary, A., & Shankar, R. (2018). A hybrid MCDM approach for evaluating outsourcing partners in the Indian manufacturing sector. *Journal of Manufacturing Technology Management*, 29(3), 400-422. <https://doi.org/10.1108/JMTM-02-2017-0025>
- Strýčková, L. (2019). Debt policy of companies in czech republic. *Journal of International Studies*, 12(3), 183-197. <https://doi.org/10.14254/2071-8330.2019/12-3/15>
- Tran, Q. and Tian, Y. (2013). Organizational structure: influencing factors and impact on a firm. *American Journal of Industrial and Business Management*, 03(02), 229-236. <https://doi.org/10.4236/ajibm.2013.32028>
- Woyengo, P. (2019). Influence of organizational structure on employee job satisfaction and commitment in the civil service in kenya. *strategicjournals.com*, 6(3). <https://doi.org/10.61426/sjbcm.v6i3.1342>
- Yadav, V. S., & Mohania, M. (2020). Multi-criteria decision analysis for supplier selection in a manufacturing firm using fuzzy AHP and TOPSIS. *Journal of Advanced Manufacturing Systems*, 19(3), 477-492. <https://doi.org/10.1142/S0219686720500168>