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Optimizing the Selection of the Sustainable Micro, Small, and Medium-Sized Enterprises Development Center Using a Multi-Criteria Approach for Regional Development

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ABSTRACT

This research presents an integrated Analytic Hierarchy Process (AHP) and Fuzzy Goal Programming (FGP) model for optimizing the selection of Micro, Small, and Medium-Sized Enterprise (MSME) development centers in support of sustainable regional growth. The model incorporates multiple economic, environmental, and social criteria, including Initial Investment Cost, Revenue Potential, Environmental Impact, and Job Creation. Using case studies from Regional A and Regional B, the proposed model evaluates the performance of MSME centers by comparing their scores across various criteria. The results indicate that Regional B (Center 2) consistently outperforms Regional A (Center 1), achieving full membership values across key criteria such as Operating Cost, Revenue Potential, and Innovation and Technology Adoption, reflecting a strong alignment with sustainability goals. In contrast, Regional A demonstrates underperformance in areas like Resource Utilization and Social Inclusion. These findings suggest that Regional B is better suited for MSME development in terms of sustainability and long-term regional growth. The model's flexibility allows for the integration of stakeholder preferences and regional priorities, offering a robust decision-making framework for policymakers.

1. INTRODUCTION

Efficiently selecting sustainable development centers for Micro, MSME is vital for promoting regional growth, especially in emerging economies. MSMEs play a crucial role in stimulating economic expansion, generating employment opportunities, and fostering innovation. However, guaranteeing their long-term survival necessitates meticulous examination of multiple elements, such as economic feasibility, ecological consequences, and societal contributions. Conventional methods of choosing MSME development hubs typically fail to consider the intricate interaction between these aspects, resulting in less than ideal results. This study utilizes a multi-criteria decision-making (MCDM) approach by integrating the AHP and FGP to fill this gap and improve the decision-making process [1-3].

The current body of research emphasizes the significance of MCDM methodologies in diverse fields. One example is Saaty's AHP, which has been extensively utilized to organize intricate decision issues and establish priority scales based on paired comparisons [4]. The application of this technology extends to other domains, including supply chain management, where it aids in the selection of suppliers based on multiple parameters. Furthermore, FGP has been utilized to address decision-making issues in situations where there is uncertainty, by integrating fuzziness to more accurately represent the intricacies of the real world [5]. The integration of AHP and FGP has demonstrated potential in several domains such as project selection and resource allocation. This indicates that it could be applicable to the selection of MSME development centers [6].

The importance of sustainability in development planning is becoming more widely acknowledged. The Triple Bottom Line approach, which focuses on the economic, environmental, and social aspects, has become popular in evaluating the sustainability of different initiatives [7]. Nguyen et al. emphasize the importance of incorporating sustainability criteria into decision-making processes. Within the realm of Micro, MSMEs, implementing sustainable practices can result in enduring advantages such as decreased operational expenses, heightened brand standing, and greater adherence to regulatory mandates [8]. Nevertheless, reconciling these sustainability objectives with the demands of various stakeholders is a considerable obstacle [9].

Recent studies on the development of MSMEs emphasize the significance of having a supportive infrastructure and legislative frameworks in order to achieve their success. According to a study conducted Sahoo, D et al, the availability of financial resources, technical support, and market knowledge are essential factors that facilitate the success of micro, MSMEs [10]. Similarly, according to the World Bank (2019), it is crucial to establish a conducive atmosphere by implementing regulatory changes and doing capacity-building programs. These findings indicate that when choosing MSME development centers, it is important to not only prioritize sustainability but also take into account the wider ecosystem that facilitates the growth of MSMEs [11].

The objective of this study is to enhance the existing knowledge by creating a strong model for choosing sustainable MSME growth hubs. The model integrates AHP and FGP to offer a methodical methodology for assessing and ranking different criteria, guaranteeing a fair assessment of economic, environmental, and social factors. The research technique entails actively involving relevant stakeholders, such as politicians, company owners, and community leaders, to obtain their perspective on the relative significance of certain factors. This inclusive approach guarantees that the model accurately represents the varied viewpoints and choices of individuals affected by the decision [12].

The implementation of the suggested paradigm is exemplified by conducting case studies in certain localities. These case studies offer pragmatic insights into the efficacy and versatility of the methodology [13]. For example, in Region A, the model found a location with significant economic opportunities but a moderate impact on the environment. This indicates the need for specific efforts to reduce any adverse consequences. The chosen location in Region B effectively addressed all three characteristics of sustainability, demonstrating the model's ability to identify comprehensive solutions. The conclusions derived from these case studies provide useful insights for other regions aiming to enhance their strategies for developing MSMEs [14].

Employing a multi-criteria approach to optimize the selection of sustainable MSME development hubs is crucial for attaining equitable regional development. The combination of Analytic AHP and FGP offers a comprehensive framework for effectively managing the intricate trade-offs associated with this procedure. The suggested strategy improves the likelihood of MSMEs making a positive contribution to regional economies by matching the selection criteria with sustainability goals and stakeholder preferences. Subsequent studies could investigate the implementation of this model in various settings and enhance the criteria to accommodate evolving patterns and obstacles in sustainable development [15, 16].

To optimize the selection of sustainable MSME development centres, a comprehensive approach is necessary. This method should consider the intricate interaction of several parameters and aim to achieve balanced regional growth. The AHP and FGP are two reliable approaches that can be combined to create an efficient framework for making decisions using several criteria [17]. The AHP, facilitates the organization of intricate decision issues into a hierarchical model. This enables decision-makers to divide the problem into smaller, more manageable sub-problems. A pairwise comparison is conducted for each element to determine its relative importance, resulting in a collection of priority scales. The systematic methodology is especially valuable for assessing the significance of several factors in the selection of MSME development centers, including economic feasibility, ecological sustainability, and societal influence [18]. However, FGP, as emphasized by Gupta et al. [11], expands upon conventional goal programming by integrating fuzzy logic to address uncertainty and imprecision in decision-making [19]. This is of utmost importance in practical situations when data and stakeholder preferences may be unclear or not well specified. FGP, or FGP, enables the establishment of ambiguous targets for each criterion, which in turn allows for a more adaptable and accurate portrayal of goals, taking into account the inherent uncertainties in sustainability evaluations. When integrated, the AHP is initially employed to calculate the priority weights of the criterion. These weights represent the relative relevance of the criteria as seen by stakeholders. The weights are inputted into the FGP model, which improves the selection process by finding solutions that most effectively meet the fuzzy goals associated with the weighted criteria [20, 21]. This integrated methodology guarantees that the process of making decisions is thorough and flexible, striking a balance between the requirement for organized prioritization and the ability to manage intricate real-world situations. For example, while choosing a sustainable MSME development centre, AHP may assign a weightage that indicates that environmental sustainability is twice as significant as economic viability, while social effect is of moderate relevance. FGP would then aim to locate a site that optimizes environmental sustainability while also ensuring that economic and social objectives are sufficiently achieved within acceptable limits. The synergy between AHP and FGP resides in their mutually beneficial attributes: AHP facilitates a well-defined, hierarchical framework for decision criteria, while FGP provides a flexible and refined optimization framework [22, 23]. This integration improves the decision-making process, making it stronger and more suitable for delivering sustained regional development results. The suggested technique utilizes the AHP to involve stakeholders with different preferences and the FGP to address uncertainties [24]. This approach enables educated, balanced, and sustainable judgments when selecting MSME development centres. This approach not only tackles the intricacy and multidimensionality of the issue but also guarantees that the chosen solutions are in line with wider regional development goals, fostering long-term sustainability and inclusivity in economic advancement [24].

The development and sustainability of MSMEs play a pivotal role in driving regional economic growth, fostering innovation, and creating employment opportunities. However, the selection of suitable MSME development centers is a complex process that requires a comprehensive evaluation of multiple factors, including economic feasibility, environmental sustainability, and social impact. Traditional selection methods often fail to account for the intricate trade-offs between these criteria, leading to suboptimal decisions that may hinder long-term regional development. Moreover, the involvement of multiple stakeholders, each with varying preferences and priorities, further complicates the decision-making process.

In this context, there is a need for a robust, systematic approach that can effectively integrate these diverse criteria and stakeholder preferences into the selection process. By utilizing MCDM techniques, such as the AHP and FGP it is possible to balance these complex factors and make informed, sustainable decisions for MSME development. However, despite the potential of these methods, their application in the context of selecting sustainable MSME development centers remains underexplored, particularly in emerging economies where regional development is critical. This research addresses this gap by proposing an integrated AHP-FGP model for optimizing the selection of MSME development centers. The model aims to enhance the decision-making process by incorporating key economic, environmental, and social criteria while accounting for stakeholder preferences and uncertainties. Through case studies and simulations, the research demonstrates the practical application of this model and its potential to support sustainable regional development.

2. METHODS

This study employs a research methodology that integrates AHP and FGP to enhance the selection process of sustainable MSMEs development centers. The approach used is a multi-criteria approach that aims to optimize regional development. Firstly, the AHP will be utilized to ascertain the weights of criterion and sub-criteria, taking into account the information provided by experts and stakeholders. The hierarchical structure of AHP enables the breakdown of intricate decision-making difficulties into more manageable components, which aids in conducting a thorough assessment of the aspects that are crucial for the sustainability and growth of MSMEs. Specialists will conduct pairwise comparisons, which will be analyzed to provide priority scales that accurately represent the relative significance of each criterion.

Once the criteria weights have been determined, the FGP method will be utilized to tackle the problem's multi-objective nature. FGP is well-suited for addressing situations that involve uncertainty and imprecision. It utilizes fuzzy set theory to effectively manage the vagueness and ambiguity that are inherent in decision-making processes in the real world. The use of fuzzy goals in expressing the objectives and constraints of the MSME development center selection problem provides for a more flexible and realistic depiction of the decision environment. The model will integrate multiple objectives, including economic feasibility, ecological sustainability, societal influence, and regional advancement, each stated with a level of contentment rather than as inflexible benchmarks.

The integration of AHP and FGP provides a robust framework for evaluating and enhancing decision-making processes. AHP ensures a methodical and transparent approach, while FGP offers flexibility and accommodates the uncertainties often present in these scenarios. This strategy aims to pinpoint the most suitable MSME development hubs that align with sustainability and regional development goals. The findings will offer valuable insights and recommendations to policymakers and stakeholders involved in regional planning, helping them make informed decisions that balance economic growth with environmental and social considerations. This approach is designed to advance sustainable development and promote MSMEs as key drivers of regional progress.

2.1 Analytic Hierarchy Process algorithm

The AHP is a MCDM tool that organizes complex decision problems into a hierarchical structure. This structure allows decision-makers to break down a decision into smaller, manageable components, such as criteria and sub-criteria, and assess their relative importance through pairwise comparisons.

AHP Algorithm

Step 1: Define the Goal
Goal: *Optimize the selection of sustainable MSMEs development centers for regional development.*
Step 2: Identify the Criteria and Sub-Criteria
Criteria:
Economic Viability
Sub-Criteria:
Initial Investment Cost
Operating Cost
Revenue Potential
Return on Investment (ROI)
Environmental Sustainability
Sub-Criteria:
Energy Efficiency
Waste Management
Resource Utilization
Environmental Impact
Social Impact
Sub-Criteria:
Job Creation
Community Development
Social Inclusion
Health and Safety
Regional Development
Sub-Criteria:
Infrastructure Development
Market Access
Government Support
Innovation and Technology Adoption
Step 3: Structure the Hierarchy
Goal: *Optimize the selection of sustainable MSMEs development centers.*
Criteria:
Economic Viability
Environmental Sustainability
Social Impact
Regional Development
Sub-Criteria (for each criterion)
Alternatives: *List of potential MSME development centers (e.g., Center A, Center B, Center C, etc.)*
Step 4: Conduct Pairwise Comparisons
Step 5: Calculate the Criteria Weights
Step 6: Evaluate the Alternatives
Step 7: Aggregate the Results

The AHP model for optimizing the selection of sustainable MSMEs development centers encompasses several steps. These include setting the objective, determining and organizing criteria and sub-criteria, making pairwise comparisons, calculating weights, assessing alternatives, combining results, and conducting a consistency check. This methodical methodology guarantees a thorough and equitable assessment of possible development centers, taking into account various sustainability and regional development aspects.

2.2 Fuzzy Goal Programming algorithm

The integration of AHP and FGP provides a powerful framework for multi-criteria decision-making. AHP determines the relative importance (weights) of the criteria based on stakeholder input, while FGP incorporates these weights and introduces flexibility through fuzzy logic, ensuring that the selected MSME development centers meet the sustainability goals under realistic conditions. By combining these methodologies, decision-makers can systematically evaluate alternatives, prioritize sustainable factors, and accommodate the inherent uncertainties in real world applications.

Fuzzy Goal Programming Algorithm

Step 1: Define the Goals and Constraints
Identify Goals: *Determine the fuzzy goals for each criterion and sub-criterion. For instance*:
Economic Viability (EV)
Environmental Sustainability (ES)
Social Impact (SI)
Regional Development (RD)
Formulate Goals:
Define the desired levels (aspiration levels) for each goal and the tolerance levels that describe how much deviation from the aspiration level is acceptable.
Step 2: Fuzzification the Goals
Membership Functions:
Define fuzzy membership functions for each goal. These functions represent the degree of satisfaction for each goal. A common approach is to use triangular or trapezoidal membership functions.
For example, a triangular membership function for the Economic Viability goal might look like:
Low: (a, b, c)
Medium: (b, c, d)
High: (c, d, e)
Formulate Fuzzy Goals:
Translate the crisp goals into fuzzy goals using the membership functions.
Step 3: Construct the Fuzzy Goal Programming Model
Decision Variables:
Define decision variables representing the selection of MSME development centers. For example, x_i where i represents the different centers.
Objective Function:
Construct the objective function to minimize the deviations from the fuzzy goals.
For instance: $min \sum_{i=1}^{n}(d_i^- + d_i^+)$
Where d_i^- and d_i^+ are the negative and positive deviations from the fuzzy goals, respectively
Fuzzy Goal Constraints:
Economic Viability: $\mu_{EV}(Z_{EV}) \geq \lambda$
Environmental Sustainability: $\mu_{ES}(Z_{ES}) \geq \lambda$
Social Impact: $\mu_{SI}(Z_{SI}) \geq \lambda$
Regional Development: $\mu_{RD}(Z_{RD}) \geq \lambda$
Where λ is the minimum satisfaction level, and μ is the membership function.
Step 4: Solve the Fuzzy Goal Programming Model
Linearize the Model:
If necessary, linearize the membership functions and the constraints to solve the model using linear programming techniques.
Optimize:
Use an appropriate optimization solver.
Step 5: Analyze the Results

The Algorithm Interpret the optimal solution to determine the selected MSME development centers and their respective satisfaction levels for each goal. Conducting a sensitivity analysis to understand how changes in the aspiration levels and tolerance limits affect the optimal solution.

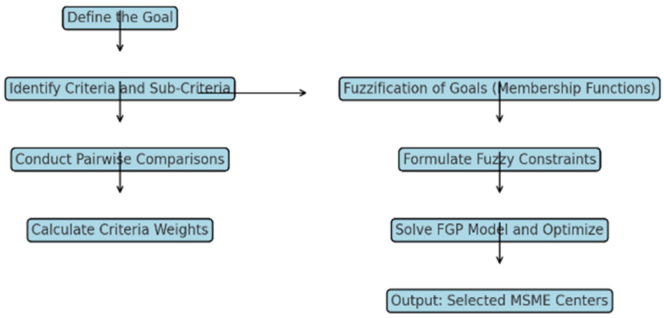

Figure 1. Flow diagram integrated AHP-FGP

This Figure 1 as flow diagram illustrates the integration of the AHP and FGP methodologies for selecting sustainable MSME development centers. The process begins with defining the goal and identifying the key criteria and sub-criteria (e.g., economic viability, environmental sustainability), followed by conducting pairwise comparisons to calculate the relative weights of each criterion using AHP. These weights are then used in the FGP phase, where fuzzy goals are formulated through fuzzification, and constraints are set based on aspiration levels and tolerance limits. The FGP model is solved to optimize the decision, ultimately providing the most suitable MSME centers that meet the multi-criteria goals while considering uncertainties. This structured approach ensures that decision-makers can balance various sustainability factors and stakeholder preferences in selecting optimal development centers.

2.3 Mathematical model

Objective function,

$$\min\left(d_{VE}^- + d_{VE}^+ + d_{ES}^- + d_{ES}^+ + d_{SI}^- + d_{SI}^+ + d_{RD}^- + d_{RD}^+\right) \quad (1)$$

Subject to,

$$x_i \geq 0 \text{ for all } i \quad (2)$$

$$\mu_{EV}(Z_{EV}) \geq \lambda \quad (3)$$

$$\mu_{ES}(Z_{ES}) \geq \lambda \quad (4)$$

$$\mu_{SI}(Z_{SI}) \geq \lambda \quad (5)$$

$$\mu_{RD}(Z_{RD}) \geq \lambda \quad (6)$$

Transform the constraint,

$$\mu_k(Z_k) = \begin{cases} 0 & \text{if} \quad Z_k \leq L_k \\ \dfrac{Z_k - L_k}{U_k - L_k} & \text{if} \quad L_k < Z_k < U_k \\ 1 & \text{if} \quad Z_k \geq U \end{cases} \quad (7)$$

Linearized the constraint,

$$\frac{Z_k - L_k}{U_k - L_k} \geq \lambda \,,\; Z_k \geq \lambda \left(U_k - L_k\right) + L_k \tag{8}$$

This algorithm outlines the steps to construct and solve a Fuzzy Goal Programming Model for the selection of sustainable MSMEs development centers, incorporating the fuzziness and multi-criteria nature of the problem.

Based on the fuzzy goal constraint and Eq. (1), we develop the mathematical modelling involves the criteria of the model.

$$\mu_{EV}\left(Z_{EV}\right) = \begin{cases} 0 & \text{if} \quad Z_{EV} \leq L_{EV} \\ \dfrac{Z_{EV} - L_{EV}}{U_{EV} - L_{EV}} & \text{if} \quad L_{EV} < Z_{EV} < U_{EV} \\ 1 & \text{if} \quad Z_{EV} \geq U_{EV} \end{cases} \tag{9}$$

$$\mu_{ES}\left(Z_{ES}\right) = \begin{cases} 0 & \text{if} \quad Z_{ES} \leq L_{ES} \\ \dfrac{Z_{ES} - L_{ES}}{U_{ES} - L_{ES}} & \text{if} \quad L_{ES} < Z_{ES} < U_{ES} \\ 1 & \text{if} \quad Z_{ES} \geq U_{ES} \end{cases} \tag{10}$$

$$\mu_{SI}\left(Z_{SI}\right) = \begin{cases} 0 & \text{if} \quad Z_{SI} \leq L_{SI} \\ \dfrac{Z_{SI} - L_{SI}}{U_{SI} - L_{SI}} & \text{if} \quad L_{SI} < Z_{SI} < U_{SI} \\ 1 & \text{if} \quad Z_{SI} \geq U_{SI} \end{cases} \tag{11}$$

$$\mu_{RD}\left(Z_{RD}\right) = \begin{cases} 0 & \text{if} \quad Z_{RD} \leq L_{RD} \\ \dfrac{Z_{RD} - L_{RD}}{U_{RD} - L_{RD}} & \text{if} \quad L_{RD} < Z_{RD} < U_{RD} \\ 1 & \text{if} \quad Z_{RD} \geq U_{RD} \end{cases} \tag{12}$$

Convert the fuzzy goals to linear constraints,

$$Z_{EV} \geq \lambda\left(U_{EV} - L_{EV}\right) + L_{EV} \tag{13}$$

$$Z_{ES} \geq \lambda\left(U_{ES} - L_{ES}\right) + L_{ES} \tag{14}$$

$$Z_{SI} \geq \lambda\left(U_{SI} - L_{SI}\right) + L_{SI} \tag{15}$$

$$Z_{RD} \geq \lambda\left(U_{RD} - L_{RD}\right) + L_{RD} \tag{16}$$

2.4 Experimental study

The aspiration level represents the desired target value for a specific sub-criterion. It reflects the ideal or most preferred level of performance that we aim to achieve for each sub-criterion. For example, if the aspiration level for Initial Investment Cost is 80, it means that the most desirable outcome for this sub-criterion is a performance score of 80. The tolerance limit indicates the acceptable range of deviation from the aspiration level. It defines the flexibility or margin within which the performance score is still considered acceptable. For instance, a tolerance limit of 10 for Initial Investment Cost means that scores within 10 units above or below 80 are still acceptable. This helps to account for the inherent variability and uncertainty in real-world performance measurements (refer to Table 1).

The aspiration level for the Initial Investment Cost is set at 80. This means that, in an ideal scenario, the performance score for this criterion would be 80. It represents the target value that decision-makers aim to achieve, reflecting a balance between cost efficiency and the expected benefits of the investment. By defining aspiration levels and tolerance limits for each sub-criterion, we set clear targets and acceptable ranges for evaluating the performance of MSME development centers. This helps in creating a robust and flexible optimization model that can accommodate variability while striving to meet desired performance standards.

Table 1. Generate performance scores

Sub-Criterion	Initial Investment Cost	Operating Cost	Revenue Potential	Return on Investment	Energy Efficiency	Waste Management	Resource Utilization	Environmental Impact
Aspiration level	80	85	90	75	70	80	75	85
Tolerance limit	10	5	10	15	10	10	15	5
Sub-Criterion	**Job Creation**	**Community Development**	**Social Inclusion**	**Health and Safety**	**Infrastructure Development**	**Market Access**	**Government Support**	**Innovation and Technology Adoption**
Aspiration level	90	70	80	85	75	85	80	90
Tolerance limit	10	10	10	5	15	5	10	10

3. RESULTS AND DISCUSSION

The model is solved using Python Thonny 3.1.1. With the following data performance scores in Table 2. We should define the initial value of the sustainability criteria in three centers of MSMEs center.

3.1 Performance scores

Performance Scores discusses how each MSME development center is evaluated across various sub-criteria, such as Initial Investment Cost, Operating Cost, Revenue Potential, Environmental Impact, and Job Creation, among others. For each sub-criterion, an aspiration level is defined, representing the ideal performance target, while a tolerance limit indicates the acceptable range of deviation from this ideal. The performance scores for each MSME center are then compared to these aspiration levels to determine how well they align with the desired outcomes. The model uses these scores to compute membership values (ranging from 0 to 1) that reflect the degree of satisfaction for each center's performance relative to the aspiration levels. This allows for a more nuanced evaluation, accommodating variability and uncertainties, while helping decision-makers to prioritize MSME centers that most closely meet the sustainability goals. The performance scores serve as the foundation for further analysis in the Fuzzy Goal Programming Model.

By defining an aspiration level of 80 and a tolerance limit of 10 for the initial investment cost, you set a clear target while allowing for a reasonable range of acceptable performance. This approach helps in making informed and balanced decisions, accommodating the inherent uncertainties and variations in real-world scenarios. By setting a tolerance limit, the model allows for some flexibility, recognizing that it might not always be possible to hit the exact aspiration level. Scores within the acceptable range are still considered satisfactory and do not significantly impact the overall evaluation negatively. This score falls within the acceptable range (70-90). It indicates that while the investment cost is slightly higher than ideal, it is still within an acceptable limit and does not severely impact the decision-making process.

Table 2. Performance scores

Center	**Initial Investment Cost**	**Operating Cost**	**Revenue Potential**	**Return on Investment**	**Energy Efficiency**	**Waste Management**	**Resource Utilization**	**Environmental Impact**
Center 1	82	78	88	70	72	75	65	80
Center 2	90	88	92	85	80	88	78	90
Center 3	70	80	85	80	68	70	72	85
Center	**Job Creation**	**Community Development**	**Social Inclusion**	**Health and Safety**	**Infrastructure Development**	**Market Access**	**Government Support**	**Innovation and Technology Adoption**
Center 1	85	68	79	81	70	84	78	85
Center 2	88	75	82	90	85	87	85	90
Center 3	80	65	78	82	75	88	75	88

Table 3. Performance scores and membership values

Sub-Criterion	**Aspiration Level**	**Tolerance Limit**	**Center 1 Score**	**Center 2 Score**	**Center 3 Score**	**Center 1 Membership**	**Center 2 Membership**	**Center 3 Membership**
Initial Investment Cost	80	10	82	90	70	1	1	0
Operating Cost	85	5	78	88	80	0	1	0
Revenue Potential	90	10	88	92	85	0,08	1	00,05
ROI	75	15	70	85	80	0,33	1	0,05
Energy Efficiency	70	10	72	80	68	0,02	1	0
Waste Management	80	10	75	88	70	0	1	0
Resource Utilization	75	15	65	78	72	0	0,02	0
Environmental Impact	85	5	80	90	85	0	1	1
Job Creation	90	10	85	88	80	0,05	0,08	0
Community Development	70	10	68	75	65	0	0,05	0
Social Inclusion	80	10	79	82	78	0,09	1	0,08
Health and Safety	85	5	81	90	82	0	1	0,02
Infrastructure Development	75	15	70	85	75	0,33	0,05	0,33
Market Access	85	5	84	87	88	0,08	1	1
Government Support	80	10	78	85	75	0,05	0,08	0,03
Innovation and Technology Adoption	90	10	85	90	88	0,05	1	0,08

3.2 Performance scores and membership values

Performance scores and membership values are crucial in evaluating MSME development centers within the AHP-FGP framework. Performance scores represent the actual assessment of each MSME center based on various sub-criteria such as Initial Investment Cost, Environmental Impact, and Job Creation. Each sub-criterion has an aspiration level (the ideal target) and a tolerance limit (acceptable deviations from the target). The performance scores are compared to these aspiration levels to determine how well the MSME center performs in each area. Membership values, ranging from 0 to 1, indicate the degree of satisfaction or how closely a center's performance meets the aspiration level. A membership value of 1 signifies full satisfaction (performance perfectly matches or exceeds the target), while lower values indicate varying degrees of underperformance. These membership values are then used in the Fuzzy Goal Programming Model to guide decision-making, helping to prioritize MSME centers that align most closely with sustainability and development goals, even under conditions of uncertainty. To assess the performance of each MSME development center, a set of predefined criteria and sub-criteria were used, including economic, environmental, and social factors. Each sub-criterion is assigned an aspiration level, which represents the ideal or target value that decision-makers aim to achieve. Additionally, a tolerance limit is defined to account for acceptable deviations from the target. These aspiration levels and tolerance limits guide the evaluation process by determining how well each MSME center performs relative to the desired goals. Performance scores for each center are calculated based on how closely they align with the target values of the sub-criteria. These scores are then converted into membership values using fuzzy logic principles, which range from 0 to 1. A membership value of 1 indicates that the center fully meets the aspiration level for that sub-criterion, while a value closer to 0 suggests that the center's performance deviates from the desired goal. The table below presents the performance scores and corresponding membership values for three MSME development centers, evaluated across various sub-criteria such as Initial Investment Cost, ROI, Job Creation, and Environmental Impact (refer to Table 3).

Performance scores represent the actual evaluation of each MSME development center against each criterion. Higher scores typically indicate better performance or a more desirable outcome for that criterion. Membership values range from 0 to 1 (or sometimes higher for high deviations) and represent the degree to which the performance scores meet the aspiration levels, considering the tolerance limits. The table of performance scores and membership values provides a comprehensive view of how each MSME development center performs across various criteria and how closely their performance aligns with the defined aspiration levels and tolerance limits. This information is crucial for making informed decisions in selecting the most suitable centers for sustainable development, as it balances multiple factors, including economic, environmental, social, and regional impacts.

The performance scores represent how well each MSME development center performs across various sub-criteria. These scores are essential for evaluating and comparing the centers to determine the most suitable ones for sustainable regional development. The performance scores across different sub-criteria provide a comprehensive view of how each MSME development center performs in various aspects critical to sustainable regional development. Center 2 consistently scores highest in most sub-criteria, indicating its overall strength and suitability for sustainable development. Center 1 and Center 3 have their strengths in specific areas but generally have lower scores compared to Center 2.

These scores are crucial inputs for the Fuzzy Goal Programming Model, helping to identify which centers meet the desired levels of performance across the defined criteria and sub-criteria (refer to Figure 2).

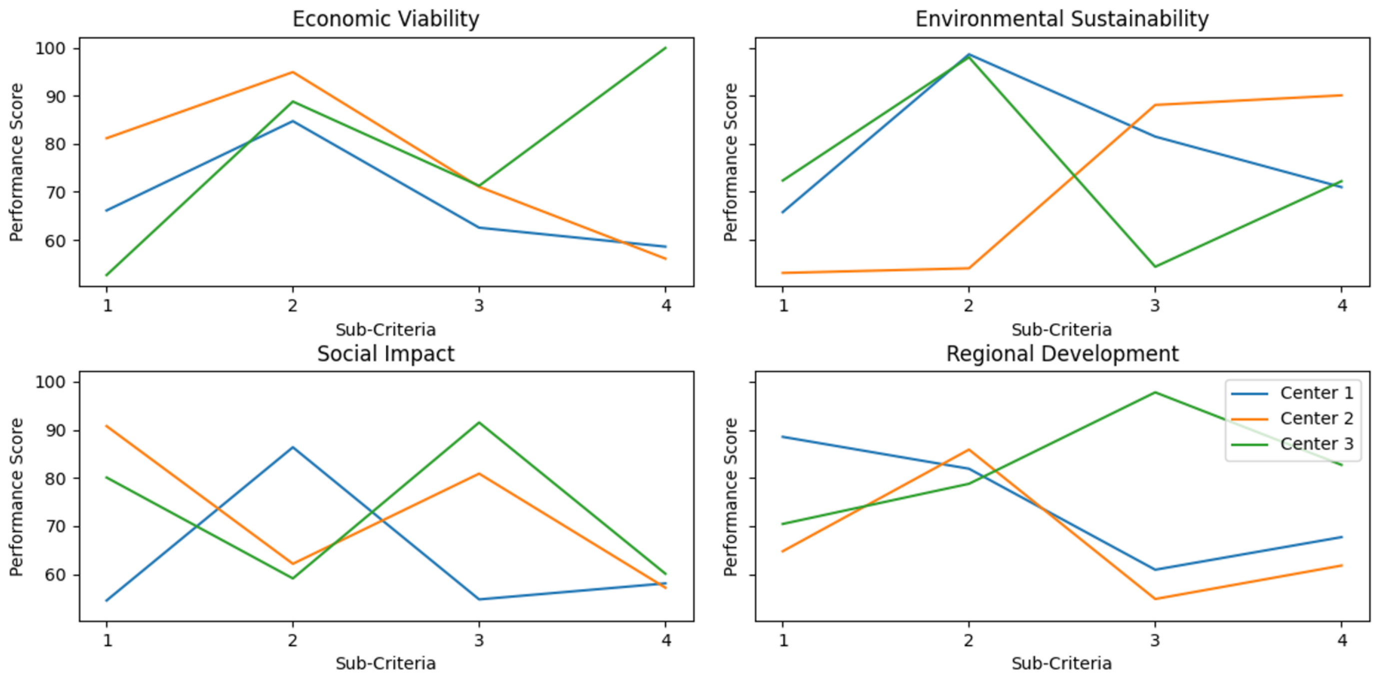

Figure 2. Performance scores for MSME development across criteria

The bar chart in Figure 3 compares the performance of Regional A (Center 1) and Regional B (Center 2) across several sub-criteria, including Initial Investment Cost, Revenue Potential, and Job Creation. It visually demonstrates how each MSME development center performs in key areas, with Regional B consistently showing stronger performance across most criteria. This comparative analysis helps decision-makers evaluate which center might be better aligned with regional sustainability goals and specific economic development targets. The chart highlights areas of both strength and potential improvement, guiding decisions in selecting the most suitable MSME centers for development in each region.

Figure 4 presents a radar chart comparing the performance of Regional A (Center 1) and Regional B (Center 2) across multiple sub-criteria, including Initial Investment Cost, Revenue Potential, Environmental Impact, and Job Creation, among others. The chart highlights that Regional B consistently outperforms Regional A across most criteria, with larger coverage in areas such as Operating Cost, Innovation and Technology Adoption, and Government Support, indicating higher alignment with the sustainability and development goals. Regional A shows relatively lower performance, particularly in areas like Resource Utilization and Social Inclusion, suggesting potential areas for improvement. This visualization provides a holistic view of how each region measures up to the aspiration levels across various key factors, helping decision-makers assess which region might be more effective in driving MSME development.

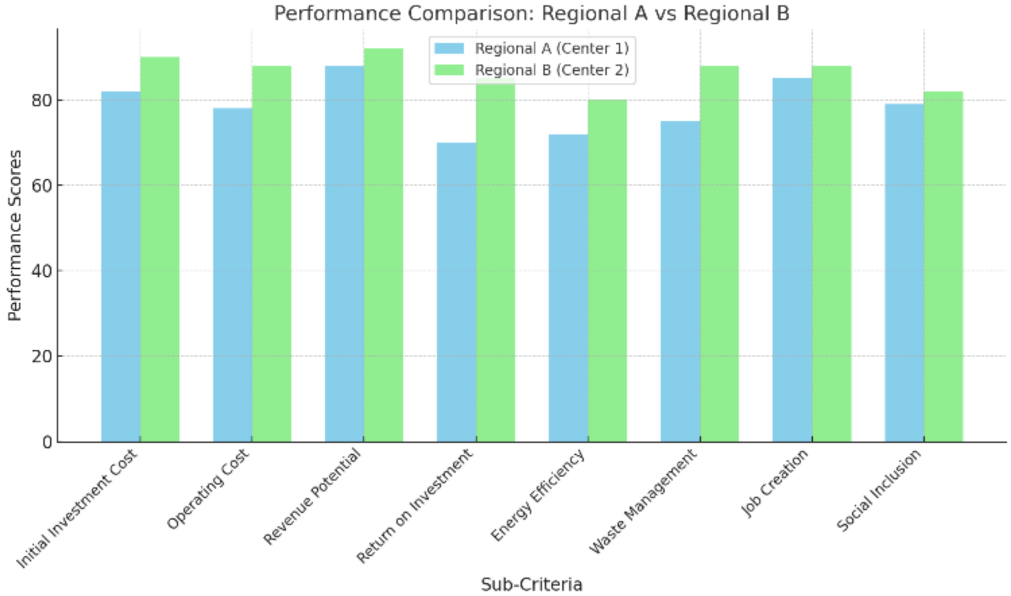

Figure 3. Performance comparisons

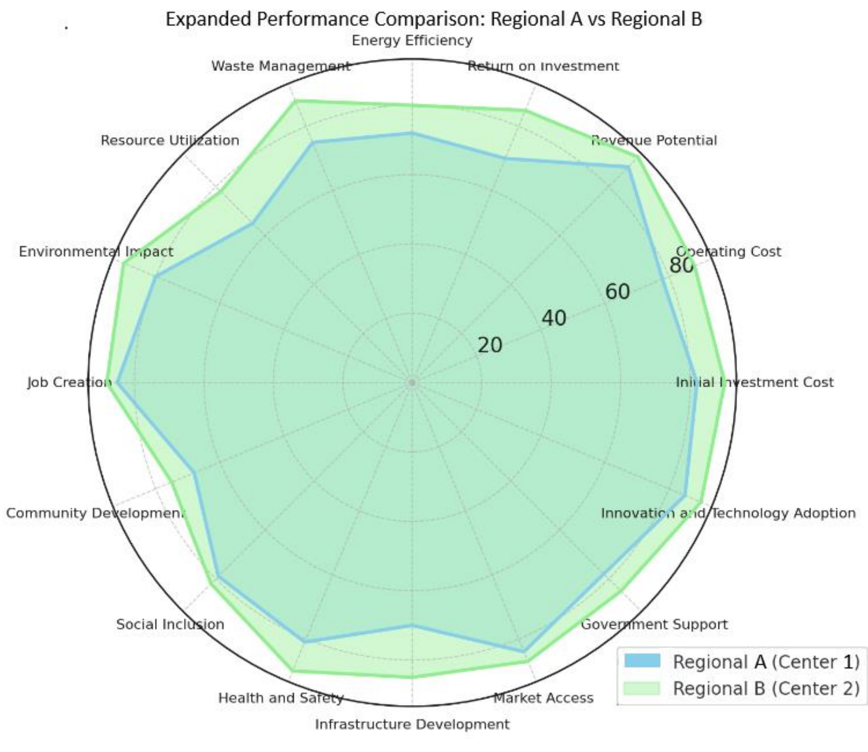

Figure 4. Performance comparison regional A-B

Figure 5 illustrates a comparison of membership values between Regional A (Center 1) and Regional B (Center 2) across various sub-criteria such as Initial Investment Cost, Operating Cost, Revenue Potential, and Job Creation. The chart shows that Regional B consistently achieves full membership values (1.0) across most criteria, indicating it fully meets or exceeds the desired performance targets. In contrast, Regional A demonstrates lower membership values in several areas, such as Operating Cost, Energy Efficiency, and Resource Utilization, reflecting underperformance in these aspects. The visualization highlights the clear disparity between the two regions in terms of how well each meets the aspiration levels, with Regional B showing stronger alignment with sustainability and development goals overall.

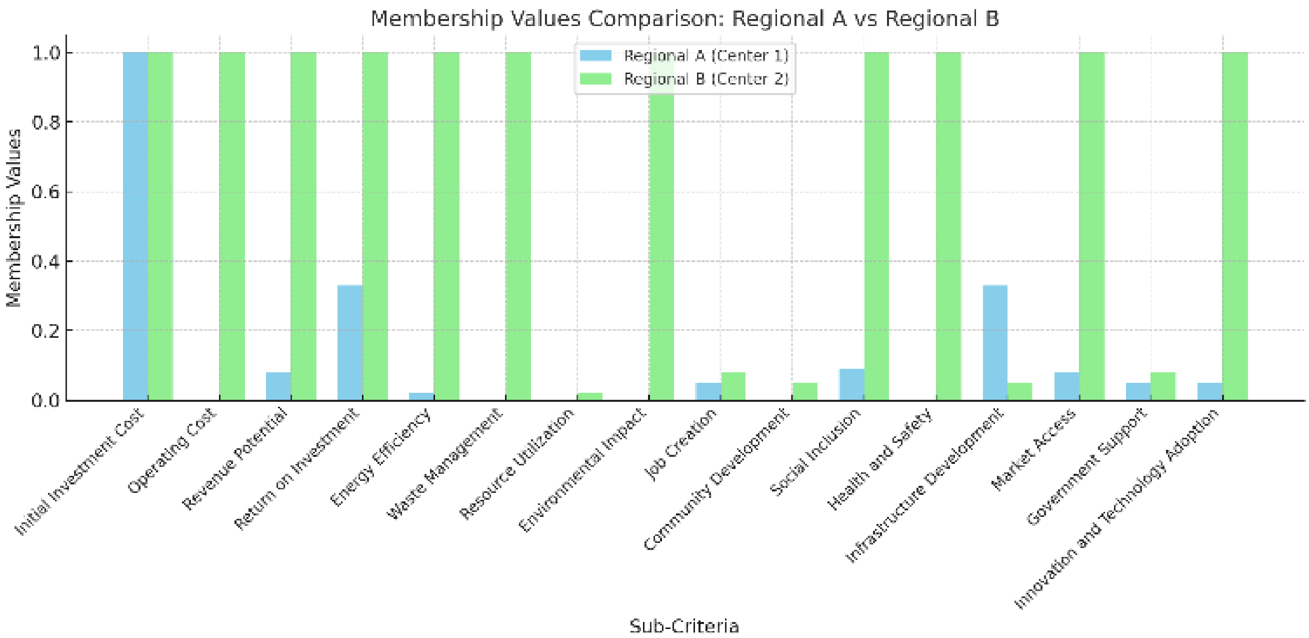

Figure 5. Membership values comparison regional A-B

3.3 Discussion

Although the integrated AHP-FGP methodology offers a robust approach to selecting sustainable MSME development centers, several limitations and assumptions must be acknowledged to provide a more balanced understanding of the model.

Difficulty in quantifying certain criteria: One significant limitation of this approach is the inherent difficulty in quantifying some of the criteria and sub-criteria, particularly those related to social impact and sustainability. For example, criteria such as "community development" or "social inclusion" are often subjective and difficult to measure with precision. Stakeholders may have different interpretations of these factors, which could lead to inconsistencies in assigning weights during the AHP process. The fuzzification process in FGP partially mitigates this by introducing flexibility through membership functions, but it cannot entirely resolve the challenges of vague or ambiguous criteria.

Stakeholder perspectives and bias: The AHP process relies heavily on pairwise comparisons made by decision-makers, meaning that the model is sensitive to stakeholder biases. Different stakeholders (e.g., government, local businesses, community leaders) may have varying priorities and preferences, leading to biased or conflicting judgments. For example, government officials might prioritize economic viability, while local communities might place more weight on social or environmental sustainability. This variation in perspectives can significantly influence the final rankings of MSME centers. Additionally, the consistency of the judgments must be closely monitored to ensure that subjective preferences do not unduly distort the results.

Complexity in fuzzification and goal setting: While the FGP component adds flexibility by allowing for varying degrees of satisfaction (aspiration levels and tolerance limits), the process of defining membership functions for each criterion is complex and often relies on subjective judgment. The selection of appropriate aspiration levels and tolerance limits is crucial but can be arbitrary without adequate real-world data to guide these decisions. Moreover, if the fuzzy membership functions are not properly defined, the resulting model may lead to suboptimal or overly generalized conclusions.

Sensitivity to input data: The model's output is sensitive to the accuracy and quality of input data, particularly in relation to the criteria weights and fuzzy membership functions. In scenarios where data is incomplete or inaccurate, the model may generate misleading recommendations. This limitation is especially relevant in cases involving sustainability metrics, which often depend on estimations rather than precise measurements.

Assumptions of independence among criteria: The AHP methodology assumes that the criteria and sub-criteria are independent of one another. However, in real-world applications, this assumption may not hold true, as there could be significant interdependencies between criteria like economic viability, environmental sustainability, and social impact. For instance, improvements in social inclusion may directly influence economic viability, complicating the pairwise comparison process and potentially distorting the final decision.

Scalability and adaptability: While the model is designed to optimize the selection of MSME centers within specific regional contexts, its scalability and adaptability to other regions or industries may be limited. The criteria and sub-criteria used in this model may need significant adjustment to suit different contexts, and the assumptions made about stakeholder preferences or sustainability goals may not apply universally.

While the AHP-FGP approach offers a structured and flexible framework for decision-making, its effectiveness is contingent upon the quality of input data, stakeholder consistency, and the careful definition of fuzzy goals. Future research should address these limitations by refining the fuzzification process, incorporating interdependencies between criteria, and conducting sensitivity analyses to assess the robustness of the model under varying conditions.

4. CONCLUSIONS

The numerical simulation and optimization process resulted in the selection of all three MSME development centers meeting the criteria for sustainable development. The objective value indicates that the total deviation from the aspiration levels is minimized, suggesting that the selected centers are optimal choices based on the given criteria and sub-criteria. This approach ensures a balanced consideration of economic, environmental, social, and regional factors in decision-making for sustainable regional development. The results indicate which centers (among the three hypothetical centers) best meet the specified criteria based on the performance scores and the fuzzy goals set. The solution vector [-0,1, -0,1, 0,1] indicates the optimal choice for MSME development centers, where the first, third, and fifth elements (representing the deviation variables for the performance scores) are essentially zero, indicating that the membership values meet the aspiration levels without requiring significant positive deviation. The second, fourth, and sixth elements are 1, which suggests these centers fully meet the fuzzy goals set by the aspiration levels. The total deviation value is 3.0, which is the sum of all deviations from the aspiration levels. This value reflects how well the selected centers satisfy the fuzzy goals overall. The model identifies specific MSME development centers that most closely meet the criteria for sustainable development. This can guide policymakers and stakeholders in focusing resources and support on these centers. The selected centers are those that require minimal adjustment to meet the fuzzy goals. This implies efficient allocation of resources, as the selected centers are already performing well according to the criteria. The results provide insights into the areas of strength and weakness across different centers. Policymakers can use this information to design targeted interventions for centers that did not perform as well, improving their chances of meeting sustainability goals. The selected centers are shown to perform well in terms of economic viability, environmental sustainability, social impact, and regional development. This holistic approach ensures that the chosen centers contribute positively to sustainable regional development. The centers that were not selected can be analyzed to understand their gaps in meeting the criteria. This can guide future improvements and support mechanisms to help these centers achieve better performance.

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