

## Evaluation of Entrepreneurship Indicators in Small and Medium-Sized Enterprises Using the Fuzzy VIKOR Approach

*Reza Rostamzadeh<sup>1\*</sup>, Ali Altuğ Biçer<sup>2</sup>, Shahryar Ghorbani<sup>2</sup>, Jonas Saparauskas<sup>3</sup>, Zenonas Turskis<sup>4</sup> and Mahdi Abdsharafat<sup>5</sup>*

### Abstract

This paper introduces a hybrid decision-making model that integrates the fuzzy best-worst method with fuzzy VIKOR to determine the relative importance and prioritization of key indicators of entrepreneurship in small and medium-sized enterprises (SMEs), with a specific focus on enhancing SME competitiveness. By employing triangular fuzzy numbers to capture expert judgments, the proposed framework first applies F-BWM to evaluate the significance of six critical dimensions namely organizational innovation, risk-taking, external factors, competitiveness, responsiveness, and internal factors and subsequently uses fuzzy VIKOR, based on the derived weights, to rank four prominent SME sectors operating within a specific industrial setting. The findings indicate that organizational innovation (0.219) and risk-taking (0.217) exert the greatest influence on entrepreneurial competitiveness, whereas internal factors have the least impact (0.127). Among the sectors examined, the food and beverage industry emerge as the most favorable compromise solution ( $Q = 0.403$ ). Overall, the proposed hybrid approach enhances the coherence and reliability of decision-making under uncertainty and provides practical and policy-relevant insights for policymakers and SME managers seeking to strengthen competitiveness, innovation, and sustainability in regional industrial development.

**Keywords:** *Fuzzy VIKOR, Fuzzy Best-Worst Method, SMEs, Entrepreneurship Indicators, Innovation Capability, Industrial Competitiveness*

**JEL Classification:** L26; O31; C44; D81.

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**1 INTRODUCTION:** Entrepreneurship and innovation have played decisive roles in competitiveness in the industrial sectors, especially having a deep-seated effect on small and medium-sized enterprises (SMEs). These forces not only impact the structural and functional nature of the firms at the same time but also contribute to the economic growth and social development (Huang et al., 2023). Entrepreneurship is one of the key drivers of economic and social development, and the institutional context has been found to have a significant impact regarding the entrepreneurial behavior (Shepherd et al., 2009). Entrepreneurs are traditionally defined by their self-directed orientation, resilience, and capacity to learn from prior failures—attributes that enable transformative change across a wide range of industries (Wang et al., 2005). As Jaafar et al. (2011) emphasize, entrepreneurship often drives profound and radical transformations, sparking the emergence of diverse innovations in products, services, and technologies which have become ubiquitous in recent years, as the world of science and technology has accelerated at unprecedented rates, particularly in developing countries. In these contexts, entrepreneurship serves as an effective strategy for responding to technological disruptions and for facilitating the development of forward-looking products and services

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grounded in newly acquired knowledge (Huang et al., 2023; Ghorbani et al., 2026). The sustainability of any society and organization depends on the development of platforms that equip individuals with entrepreneurial skills and knowledge. Through such initiatives, there is an improvement in the effective use of resources and talent, thus maintaining constant growth, development, and management. The modern trend of work and business has led to an increase in free enterprise and self-employment, which underscores the importance of entrepreneurship in the global economy. Business owners promote economic growth and make a significant impact on unemployment rates, poverty alleviation, and the reduction of income inequality (Pérez-Gómez et al., 2018). To adopt a broad perspective in studying the interaction between entrepreneurship and institutional structures, it is imperative to pay close attention to the ways through which the formal and informal environments influence entrepreneurial behavior. This kind of insight provides a more comprehensive understanding of the ways in which it is possible to implement the effective support and promotion of the entrepreneurship phenomenon in the heterogeneous socio-economic environment (Huang et al., 2023). Despite the recorded growth of research work in this area, there is still no clear framework on what constitutes the markers that define the entrepreneurial ability of individuals and companies. The methodical process of identification and prioritization of such indicators is essential to assess and influence the entrepreneurial performance level of SMEs, and to provide practical guidance in policymaking and strategic decision-making (Rostamzadeh et al., 2014). SMEs are playing a central role in the national economy of developed and developing nations. Empirical data show that they significantly contribute to the creation of employment, fostering innovation, and expansion of exports, simultaneously becoming more agile amid market fluctuations and challenging macroeconomic environments (Pérez-Gómez et al., 2018). Despite this input, there still exist persistent barriers such as poor access to financial facilities, weak regulatory frameworks, and institutional roadblocks that have hindered the growth of SMEs in the context of a nation like Iran (Chila & Devarakonda, 2024). The ability of SMEs to leverage entrepreneurial skills can alleviate unemployment, increase value-added industrial output, as well as drive regional growth, hence, improving income and enhancing regional wealth distribution, strengthening economic resilience.

This study evaluates the specific effectiveness of key entrepreneurship indicators in SMEs using fuzzy VIKOR techniques. The fundamental research questions are as follows: What are the most impactful indicators in driving entrepreneurial activities in SMEs? Which indicators require attention to aid entrepreneurial development? Also, how do various sectors rank across these indicators? The goal is to fill the gaps identified by policymakers and provide guidance on fostering entrepreneurship and enhancing the international competitiveness of SMEs in different sectors.

This study contributes to the SME entrepreneurship assessment literature in three ways. First, it operationalizes entrepreneurship as a multidimensional construct by integrating six main criteria (organizational innovation, risk-taking, external factors, competitiveness, responsiveness, and internal factors) within a unified fuzzy decision framework. Second, it combines fuzzy best-worst method (F-BWM) for criteria weighting with fuzzy VIKOR for sectoral ranking, thereby strengthening methodological consistency and reducing subjectivity

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in weight elicitation under uncertainty. Third, the empirical application to four prominent SME sectors provides sector-specific insights that can support evidence-informed policy design and managerial prioritization in regional industrial development. Based on the entrepreneurship and SME competitiveness literature, and consistent with the evaluation-oriented nature of fuzzy MCDM, the present study formulates the following hypotheses regarding the relative influence of entrepreneurship dimensions on SME competitiveness:

H1. Organizational innovation is hypothesized to be among the most influential dimensions in enhancing SME competitiveness.

H2. Risk-taking is hypothesized to be among the most influential dimensions in enhancing SME competitiveness.

H3. External factors, competitiveness orientation, and organizational responsiveness are hypothesized to exert a stronger influence on SME competitiveness than internal organizational factors.

The remainder of this paper is structured as follows. Section 2 reviews the theoretical background and related literature. Section 3 describes the research methodology and the proposed fuzzy decision-making framework. Section 4 presents and discusses the empirical results. Section 5 provides a comparative analysis with existing studies, and section 6 concludes the paper by summarizing the main findings, implications, and limitations.

**2 THEORETICAL BACKGROUND:** The entrepreneurship studies in SMEs have shown significant growth over the last few years. Traditional theoretical frameworks, which have their origins in the understandings of innovation, risk-taking and proactive behavior, are continuously being replaced by more analytical frameworks that take into account the institutions, culture and the technologies. However, a significant proportion of the currently existing body of literature continues to employ a descriptive approach, as well as invoke the use of conceptual frameworks, which even though they may prove useful, can explain only to a limited extent the complex interaction between individual-level and structural causal factors.

Huang et al. (2023) demonstrate that well-developed institutional bases do not necessarily imply higher rates of both opportunity-driven and necessity-driven entrepreneurship. Using fuzzy-set qualitative comparative analysis at the national level across 39 countries, it was found that self-efficacy, as an individual-level construct, has a stronger influence than institutional frameworks in shaping entrepreneurial orientation. On the other hand, Chila and Devarakonda (2024) focus on the semiconductor industry and examine company-specific rewards, including employee stock options. They argue that such incentives reduce labor mobility, but also boost entrepreneurship among employees, particularly in knowledge-poor organizations. Taken together, these studies highlight the importance of re-evaluating traditional measures of entrepreneurship.

Fuzzy multi-criteria decision-making methods have evolved as effective tools to evaluate entrepreneurial activity under conditions of uncertainty. For instance, Yazdani et al. (2022)

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show that extended fuzzy VIKOR models are well suited to rank resilience measures implemented by SMEs, supported by consistency checks and sensitivity analysis. A comparative analysis of FAHP, VIKOR, and TOPSIS is presented in the work of Stanimirović et al. (2024), though the authors did not extend their analysis to justify the observed discrepancies in their findings.

Within this context, Stanimirović et al. (2024) employed fuzzy decision-making methods to show that in high-risk environments such as developing economies responsiveness can be a more decisive indicator than innovation. Their findings support the development of entrepreneurial models aligned with localized realities. In the digitalization domain, studies like Ortiz-Martínez et al. (2022) explored the link between sustainability, corporate social responsibility (CSR), and non-financial performance in Spanish SMEs. However, as Aksoy et al. (2022) note, existing digital maturity models remain too abstract and are poorly adapted to the limited technological capacities of SMEs.

Taken together, several research gaps emerge: a lack of multidimensional and contextual methodologies, insufficient differentiation among industrial sectors, and limited use of fuzzy comparative techniques. This study seeks to address these gaps by applying a structured fuzzy VIKOR approach to evaluate entrepreneurial performance across multiple industrial sectors within the SME context. Despite the increasing use of fuzzy MCDM in entrepreneurship-related evaluations, two methodological limitations persist. First, several studies rely on direct weighting schemes that may not adequately control consistency in expert judgments, which can bias compromise-based rankings. Second, limited attention has been paid to linking criteria-weight derivation explicitly to the subsequent ranking procedure in a coherent pipeline. To address these limitations, this study adopts F-BWM to derive consistent fuzzy weights and subsequently embeds those weights in the fuzzy VIKOR procedure to obtain compromise-based sector rankings.

Table 1. Summary of the internal and external background of research on multi-criteria decision making

Authors	Entrepreneurial indicators	Research aim	Methodology
Stetz et al. (2000)	Risk taking, reactivity, futurism	Examining the multidimensional nature of entrepreneurship in the organization	Conceptual model
George et al. (2001)	Risk taking, reactivity, independence, innovation, competitive desire	Networking strategy for the board of directors in SMEs	TOPSIS
Arbaugh et al. (2005)	Innovation, reactivity, risk taking	This study examines how national culture, strategic development, and entrepreneurial orientation interact to create value within organizations.	Conceptual model
Poon et al. (2006)	Risk taking, reactivity, innovation	The impact of self-concept attributes and entrepreneurial inclination on organizational performance.	Conceptual model
Erasmus & Scheepers (2008)	Risk taking, reactivity, innovation	The relationship between entrepreneurial intensity and creating value for shareholders	Correlation coefficient - regression analysis

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Stam & Elfring (2008)	Risk taking, reactivity, innovation	The correlation between entrepreneurial mindset and the success of newly established businesses.	Conceptual model
Tsai & Kuo (2011)	Reducing barriers to entry and exit (industrial), promotion, knowledge entrepreneurship, commercial and financial support	An integrated model for the assessment of entrepreneurial policy making	DEMATEL-ANP-ZOGP
Rezaei et al. (2012)	Risk taking, reactivity, innovation	Measuring entrepreneurship based on data	AHP
Klein & Braido (2024)	Organizational and regulatory influences shaping digital entrepreneurial activities in startups and small to medium-sized enterprises	To analyze institutional factors impacting digital entrepreneurship and propose institutional changes needed	Two case studies in Brazil, institutional theory as lens, qualitative analysis
Kiani Mavi (2014)	External and organizational determinants influencing the development of entrepreneurial universities	To develop an inclusive framework of indicators for assessing the performance of entrepreneurial universities	Literature review, survey with 12 academics/managers, Fuzzy AHP and Fuzzy TOPSIS
Rostamzadeh et al. (2014)	Independence, innovation, risk-taking, competitive desire, reactivity	Assessing the intensity of entrepreneurship among SMEs in Malaysia	FAHP-VIKOR-TOPSIS
Bajdor et al. (2021)	Sustainable entrepreneurship practices in Polish SMEs	To examine the understanding and attitudes of Polish SMEs toward sustainable entrepreneurial practices	Survey, cluster analysis
Pramono et al. (2021)	Personal-entrepreneurial characteristics influencing SME progress	To reveal demographic, business profiles and personal characteristics and associate them with SME business progress	Structured interviews with 21 respondents, descriptive stats, regression and stepwise regression analysis
Yazdani et al. (2022)	Resilience, adaptability, responsiveness	Prioritizing strategic criteria for SME resilience in uncertain environments	Extended Fuzzy VIKOR
Mishra et al. (2024)	Organizational flexibility, digital transformation	Enhancing entrepreneurial decision-making in Industry 4.0 SME environments	Fuzzy entropy & VIKOR with sensitivity analysis
Lafuente et al. (2025)	Gaining insights from the experiences of success and failure among entrepreneurs and small and medium-sized enterprises	To analyze how entrepreneurs and SMEs learn from success and failure and implications for policy and management	Literature overview of 11 studies, multidisciplinary theoretical framework

### 2.1. Investigating the indicators

This section provides an in-depth explanation of the six primary constructs considered in the present study: reactivity, organizational innovation, organizational risk-taking, organizational competitive desire, intra-organizational factors, and extra-organizational factors.

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### ***Reactivity***

Activity involves the ability of an organization to foresee and take advantage of the opportunities arising from launching new products or services earlier than other organizations. This kind of responsiveness plays a crucial role in managing market dynamics as well as the capability to anticipate future customer needs (Rauch et al., 2009). Further, reactivity captures the strategic position of the top management in both fostering competitiveness and encouraging initiative, along with a proactive market posture (Rostamzadeh et al., 2014). The sub-indicators associated with this construct include the following:

- Awareness of current and future customer preferences;
- Development of strategic programs;
- Forecasting future demand;
- Commitment to the timely exploitation of opportunities.

### **Organizational Innovation**

Organizational innovation is a long-term process of introducing new things in the existing systems, with aim of creating value and improvement in performance. According to Spence (1994) and King (1992), innovation is defined as a series of goal-oriented activities that lead to incorporation of new elements in the society with the primary aim of creation of societal value. Peled (2001) also develops the concept of innovation to be political and organizational activity, where institutions complete the full and new range of public projects to redesign rule, role, procedures and structures, restructuring the relations intra-organizational, as well as the external environments. Morris and Jones (1999) argued that innovation in the sector of public performance is an indication of the desire to launch new operations, present new services, and adopt a new system of organization. Such orientation will require an internal predisposition of innovation at organizational level. As Beaver and Prince (2002) asserted, risk-taking propensity, receptiveness to learning and orchestration of innovation with higher business aspirations characterize innovative businesses. The sub-indicators within this construct include the following:

- Technological innovation;
- Market product innovation.

### **Organizational risk taking**

Organizational risk-taking refers to the ability of a firm to undertake high-risk initiatives, pursue new markets, commit significant financial resources, and invest in environments characterized by high uncertainty and volatility (Rauch et al., 2009). This represents a core aspect of entrepreneurial orientation, where businesses actively engage with uncertainty in pursuit of potentially higher returns. Herron and Robinson (1993) highlight the strong relationship between venture capital and entrepreneurship, thus emphasizing the need for risk in entrepreneurial ventures involving venture capital. Over time, risk-taking has evolved beyond its psychological foundations and extended into sociological and economic domains. The current view of organizational risk no longer considers it merely an internal behavioral trait but also a construct shaped by external factors and system vulnerabilities. As such, this broadened

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perspective encompasses commitment to uncertain markets and debt dependence as sub-components of risk-taking behavior in entrepreneurial firms. The sub-criteria within this dimension include the following:

- Investment in unknown markets;
- High-risk financial leverage.

### **Organizational competitive desire**

In the contemporary global market, organizational competitiveness constitutes a strategic priority for firms that are serious about sustainable success (Gunasekaran & Ngai, 2004; Azzavi et al., 2025). There is an intrinsic link between entrepreneurship and competition: entrepreneurship is a driver of competitive dynamics through innovation and disruption, whereas competitive forces stimulate entrepreneurial responses (Ahmad & Hoffmann, 2008). Competitive desire refers to the proactive attitude an organization adopts to outperform competitors by relying on distinctive strategies, resources, and capabilities. This dimension reflects a company's commitment to succeed in its industry by pursuing aggressive or unconventional competitive strategies, such as intentional differentiation, bold market positioning, or strategic actions aimed at securing a competitive edge and a long-term advantage over similar established competitors. The sub-criteria of this dimension are as follows:

- Intensity of competitive engagement within the industry;
- Adoption of non-traditional or aggressive strategies to challenge rivals.

### **External organizational factors**

Internal organizational processes play a central role in developing firm-specific attributes, but external contingencies are also critically important in the development of strategic orientation and entrepreneurial behavior. Zahra and O'Neil (1998) assert the importance of an organization's interaction with the external environment, noting that environmental stimuli offer managers a pathway to respond through creativity, innovation, and strategic adaptation. According to organizational theory, changes in the external environment require adaptive adjustments in internal structures, strategies, procedures, and routines (Lawrence & Lorsch, 1967; Thompson, 1965). In the mid-20th century, mechanistic organizations thrived in relatively stable environments. However, contingency theorists argue that the more turbulent and unpredictable an organization's environment becomes, the smaller and more flexible the organization must be. Entrepreneurship, under these circumstances, emerges as a strategic tool for addressing external uncertainty and disruption (Burgelman, 1984; Miller, 1983). The external organizational factors considered in the current study include the following:

- Industry dynamics;
- Industry characteristics;
- Environmental complexity;
- Market size;
- Economic infrastructure;
- Strategic orientation of dominant firms.

### **Internal organizational factors**

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Corporate entrepreneurship literature has a long history of exploring how internal organizational conditions facilitate or hinder the entrepreneurial pursuit within large corporations. According to Zahra and Covin (1995), such initiatives are effective insofar as the intra-organizational enablers and constraints influencing them are well aligned. These internal determinants create the environment that shape entrepreneurial behavior. Therefore, researchers have attempted to identify the key organizational dimensions that foster a favorable environment for entrepreneurial ventures. Among core constructs identified in this area of investigation are incentive and control systems (Brazeal, 1993), structural flexibility (Naman & Slevin, 1993), and the level of managerial support (Stevenson & Jarillo, 2007). Individually or in combination, each variable influences the strategic position of an organization and its tolerance for ambiguity, experimentation, and long-term support of entrepreneurial projects. Besides, Burgelman (1983) and Hornsby et al. (2002) believe that internal dynamics are influenced by the nature and strength of the entrepreneurial actions to be taken. Laforet (2013) also shows that leadership qualities, firm size, organizational resources, and human capital play a crucial role in understanding how entrepreneurship can be embedded in organizational routines as well as in the decision-making process. The sub-criteria for this dimension are as follows:

- Attributes of top management;
- Firm size;
- Structural design;
- Availability of organizational resources;
- Human resource capacity.

## **2.2. VIKOR Method**

The VIKOR model, initially developed by Opricovic (1998), represents an algebraic process for evaluating and selecting among multiple alternative actions simultaneously. The acronym is a transliteration of a Serbian term, meaning multi-criteria optimization and compromise solution. The approach is designed to support decision-making in situations involving conflicting objectives, thereby contributing to the formulation of a well-justified decision. In the VIKOR framework, a compromise solution refers to the option that is, in essence, closest to the ideal solution—that is, the one considered acceptable to the majority. Operating within the framework of the algorithm proposed by Opricovic and Tzeng (2007), decision-makers can identify and rank the most suitable alternatives relative to the ideal solution, using the Lp-metric as the fundamental basis of the optimization process. In this context, the performance of each alternative with respect to the  $j$ -th criterion is denoted by  $f_{ij}$ , where  $f_{ij}$  represents the performance value of the  $i$ -th alternative concerning the  $j$ -th criterion, and  $n$  is the total number of criteria. In this study, all evaluation criteria are treated as benefit-type criteria, meaning that higher performance values indicate stronger entrepreneurial conditions. The VIKOR strategy parameter  $\nu$  reflects the decision-making preference toward group utility versus individual regret. Following common practice in compromise programming,  $\nu = 0.5$  is adopted as the baseline to represent a balanced preference. To ensure transparency and replicability, the same parameter setting is used across all industrial alternatives, and robustness is later examined by

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varying  $v$  within a plausible range. The fuzzy extension of the VIKOR method comprises the following steps:

Definition 1:

Let  $X$  be a universal set expressed as  $X = \{x_1, x_2, \dots, x_n\}$ . A fuzzy set  $\tilde{A}$  within  $X$  is defined as a collection of ordered pairs  $\{(x_1, \mu_A(x_1)), (x_2, \mu_A(x_2)), \dots, (x_n, \mu_A(x_n))\}$ , where  $\mu_A: X \rightarrow [0,1]$  is the membership function that assigns to each element in  $X$  a membership degree in the fuzzy set  $\tilde{A}$ .

Definition 2:

A fuzzy set is denoted by a tilde over a variable (e.g.,  $\tilde{M}$ ), indicating its association with fuzzy logic. Triangular fuzzy numbers (TFNs) are favored in decision-making for their simplicity and intuitive nature. This study utilizes TFNs to model uncertain or imprecise data effectively. A TFN is defined by a triplet  $(l, m, u)$ , where  $l \leq m \leq u$ , written as  $\tilde{M} = (l, m, u)$ . Here:

- $l$ : the smallest possible value,
- $m$ : the most probable value,
- $u$ : the largest possible value.

The membership function  $\mu_{\tilde{M}}(x)$  for a TFN  $\tilde{M}$  is defined as:

$$\mu_{\tilde{M}}(x) = \begin{cases} 0, & x < l \\ \frac{x-l}{m-l}, & l \leq x \leq m \\ \frac{u-x}{u-m}, & m < x \leq u \\ 0, & x > u \end{cases} \tag{1}$$

To represent a fuzzy element  $\tilde{M}$  parametrically, the left and right representations for a given membership degree  $y \in [0,1]$  are given by:

$$\tilde{M} = (M^l(y), M^r(y)) = (l + (m - l)y, u + (m - u)y) \tag{2}$$

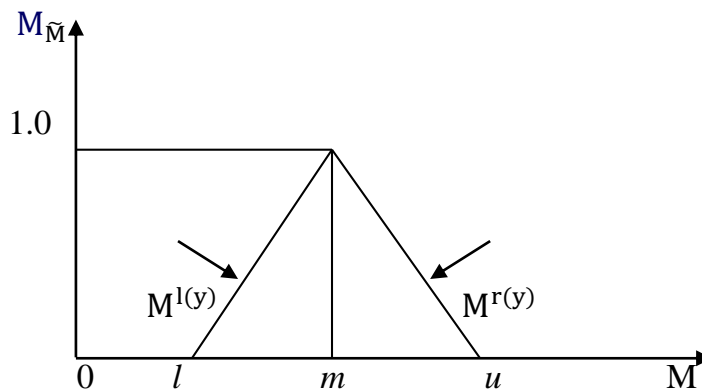


Figure 1. Triangular fuzzy number  $\tilde{M}$

Definition 3:

Let  $A = (a, b, c)$  and  $B = (a_1, b_1, c_1)$  be two TFNs. The fundamental arithmetic operations on TFNs are define as follows:

$$\text{Addition: } A \oplus B = (a + a_1, b + b_1, c + c_1) \tag{3}$$

$$\text{Subtraction: } A \ominus B = (a - c_1, b - b_1, c - a_1) \tag{4}$$

$$\text{Multiplication: } A \otimes B = (a \cdot a_1, b \cdot b_1, c \cdot c_1) \tag{5}$$

$$\text{Division: } A \oslash B = \left(\frac{a}{c_1}, \frac{b}{b_1}, \frac{c}{a_1}\right) \tag{6}$$

$$\text{Scalar Multiplication (} k > 0 \text{): } k \cdot A = (ka, kb, kc) \tag{7}$$

$$\text{Fuzzy Reciprocal: } A^{-1} = \left(\frac{1}{c}, \frac{1}{b}, \frac{1}{a}\right) \tag{8}$$

Definition 4:

Suppose  $A = (a, b, c)$  and  $B = (a_1, b_1, c_1)$  are two TFNs (Figure 2). The distance between phase members B and A is calculated as follows:

$$d(A, B) = \sqrt{\frac{1}{3} [(a - a_1)^2 + (b - b_1)^2 + (c - c_1)^2]} \tag{9}$$

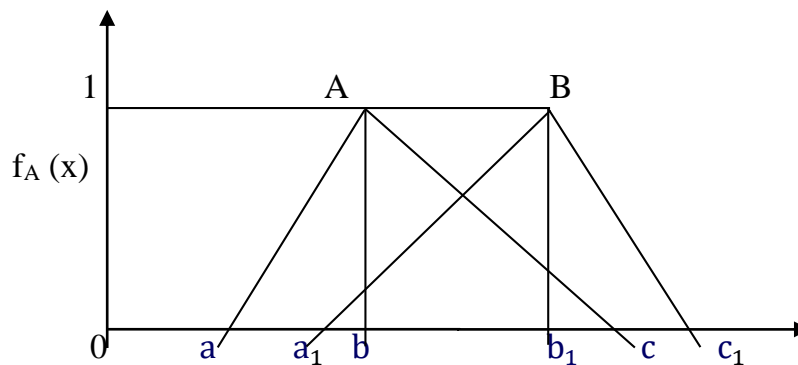


Figure 2. Two triangular fuzzy numbers

Definition 5:

Let  $D_k (k = 1, 2, \dots, K)$  be decision makers, each with fuzzy assessment  $\tilde{R}_k = (a_k, b_k, c_k)$  and membership function  $\mu(x)$ . Aggregated fuzzy rating  $\tilde{R} = (a, b, c)$  is:

- $a = \min_k \{a_k\}$
  - $b = \frac{1}{K} \sum_{k=1}^K b_k$
  - $c = \max_k \{c_k\}$
- (10)

Step 1: Identify objectives (prioritize entrepreneurial indicators in SMEs) and define research scope.

Step 2: Form decision-making team, define 6 main criteria, 21 sub-criteria, 4 alternatives (non-metallic mineral, food, textiles, unclassified machinery). See Table 1 and Figure 3.

Step 3: Use triangular fuzzy numbers (Table 2) as linguistic terms to evaluate criteria importance and rank alternatives.

Table 2. Linguistic variables

Verbal scale for importance	Triangular fuzzy scale	Verbal rating scale
Equal	(1, 1, 1)	Equal
Very Poor (VP)	(0.1, 0.1, 0.2)	Very Low (VL)
Poor (P)	(0.1, 0.2, 0.3)	Low (L)
Medium Poor (MP)	(0.3, 0.4, 0.5)	Medium Low (ML)
Medium (M)	(0.4, 0.5, 0.6)	Medium (M)
Medium High (MH)	(0.5, 0.6, 0.7)	Medium Good (MG)
High (H)	(0.7, 0.8, 0.9)	Good (G)

Very High (VH)	(0.8, 0.9, 1)	Very Good (VG)
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Step 4: Aggregate the fuzzy ratings from all decision makers using the following equations:

Fuzzy Ratings Aggregation:  $\tilde{x}_{ij} = (x_{ij}^{(1)}, x_{ij}^{(2)}, x_{ij}^{(3)})$  where:

$$\begin{aligned} x_{ij}^{(1)} &= \min_k \{x_{ijk}^{(1)}\} \\ x_{ij}^{(2)} &= \frac{1}{K} \sum_{k=1}^K x_{ijk}^{(2)} \\ x_{ij}^{(3)} &= \max_k \{x_{ijk}^{(3)}\} \end{aligned} \tag{11}$$

Fuzzy Weights Aggregation:  $\tilde{w}_j = (w_j^{(1)}, w_j^{(2)}, w_j^{(3)})$  where:

$$\begin{aligned} w_j^{(1)} &= \min_k \{w_{jk}^{(1)}\} \\ w_j^{(2)} &= \frac{1}{K} \sum_{k=1}^K w_{jk}^{(2)} \\ w_j^{(3)} &= \max_k \{w_{jk}^{(3)}\} \end{aligned} \tag{12}$$

Decision Matrix:

$$D = \begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \cdots & \tilde{x}_{mn} \end{bmatrix} \tag{13}$$

Step 5: Converting the fuzzy decision matrix and fuzzy weight of each criterion into crisp

$$x_{ai} = \frac{l_{ai} + (m_{ai} - l_{ai}) + (u_{ai} - l_{ai})}{3}, \forall a \tag{14}$$

Step 6: Determine ideal and anti-ideal solutions

$$f_j^* = \max_i \{f_{ij}\} \tag{15}$$

$$f_j^- = \min_i \{f_{ij}\} \tag{16}$$

Step 7: Compute  $S_i$  and  $R_i$  values:

$$S_i = \sum_{j=1}^n w_j \cdot \frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \tag{17}$$

$$R_i = \max_j \left\{ w_j \cdot \frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \right\} \tag{18}$$

Step 8: Calculate values using equation 19:

$$Q_i = v \frac{S_i - S^*}{S^- - S^*} + (1 - v) \frac{R_i - R^*}{R^- - R^*} \tag{19}$$

$v \in [0,1]$  is the weight of the majority criterion (commonly  $v = 0.5$ ).

Step 9: Rank alternatives based on ascending  $Q_i$  values. The smallest  $Q_i$  is the most preferred.

Step 10: Compromise solution validation

Following the calculation and ranking of alternatives based on the Q values (representing the overall compromise measure), the selection of the compromise solution is carried out according to the following procedure:

Let  $A[1]$  and  $A[2]$  denote the first and second-best alternatives in the ordered list of Q values (i.e.,

$$Q(A[1]) \leq Q(A[2]) \leq \dots \leq Q(A[m])). \quad (20)$$

Define the acceptable advantage threshold as:

$$\text{Define: } D_Q = \frac{1}{m-1} \quad (21)$$

where  $m$  is the total number of alternatives.

The decision rules for selecting the compromise solution are as follows:

1. If both of the following conditions are satisfied:

- Acceptable Advantage Condition:

$$Q(A[2]) - Q(A[1]) \geq DQ \quad (22)$$

- Majority Rule Condition:

$A[1]$  must also be ranked first in either the S (group utility) or R (individual regret) ranking,

Then:

$A[1]$  is selected as the unique compromise solution.

2. If the first condition is satisfied but the second is not:

Then Both  $A[1]$  and  $A[2]$  are selected as compromise solutions.

3. If the acceptable advantage condition is not satisfied.,

$$Q(A[2]) - Q(A[1]) < DQ \quad (23)$$

Then:

The set of compromise solutions is extended to include all top-ranked alternatives

$A[1], A[2], \dots, A[m]$  such that:

$$Q(A[m]) - Q(A[1]) < DQ \quad (24)$$

This ensures that the final compromise solution (or solution set) is not only the best in terms of the aggregated performance index (Q), but also satisfies a meaningful margin over the next best alternatives while maintaining consistency with group and individual decision-making preferences.

### 3 RESEARCH METHOD

The fuzzy evaluations were obtained from a structured expert panel formed to ensure domain relevance and decision quality. Experts were selected based on (i) practical experience with SMEs in the target industrial context, (ii) familiarity with entrepreneurship and innovation-related assessment, and (iii) willingness to participate in iterative elicitation. The elicitation process was conducted in two stages. In the first stage, experts confirmed the problem hierarchy, including six main criteria, associated sub-criteria, and the set of industrial

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alternatives. In the second stage, experts provided linguistic assessments using the predefined scales, which were then converted to triangular fuzzy numbers and aggregated for subsequent analysis. The study surveyed SMEs operating in industrial towns across the target province. Based on the most recent figures published by the national statistics authority (2013), the province hosts 755 factories, of which 644 fall into the SME category (see Table 3). Regarding sample validity and representativeness, the selected SMEs operate across multiple industrial sectors that are structurally significant within the regional economy, including food and beverage, manufacturing, and related industries. This diversity allows the sample to capture a broad range of entrepreneurial practices, competitive pressures, and organizational characteristics commonly observed in industrial SMEs. Although the empirical analysis is region-specific, the selected sectors reflect patterns that are comparable to those found in similar industrial regions, particularly in developing and emerging economies. Therefore, the results provide analytically generalizable insights into the relative importance of entrepreneurship indicators, rather than statistically generalizable conclusions.

Table 3. Number of industrial workshops in province according to ownership and number of employees

City	1-9	10-49	50-99	100 and more	Total
Total	0	529	114	111	755

In addition, in this research, among the industries, there are food and beverage industries (152), textile production (43), production of other non-metallic mineral products (142) and the production of machinery and equipment not classified elsewhere (55), which has the highest frequency in the SMEs of the province, is examined with entrepreneurship indicators, which show the frequency of a number of these industries in Table 4.

Table 4. The number of private industrial workshops according to the type of activity and the number of employees

Industry	10-49	50-99	Total
Food and beverage industries	116	36	152
Textile production	33	10	43
Tanning and processing of leather	42	1	43
Industries producing chemical materials and products	16	4	20
Production of rubber and plastic products	29	5	34
Production of non-metallic mineral products	126	16	142
Manufacture of unclassified machinery and equipment	43	12	55
Production of factory metal products except machines	28	7	35

According to Table 4, four alternatives (industry) and according to the highest frequency were selected to conduct this research, which are shown in Table 5.

Industry	10-49	50-99	Total
Food and beverage industries	116	36	152
Production of non-metallic mineral products	126	16	142
Manufacture of unclassified machinery and equipment	43	12	55

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Textile production	33	10	43
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5. Selected industries to examine entrepreneurship indicators

Table

In order to collect the information needed for this research, interviews, formation of expert groups to collect fuzzy VIKOR data and questionnaires have been used. Figure 1 shows the hierarchy structure of the problem.

### 3.1. Determination of Criteria Weights Using the Fuzzy Best-Worst Method (F-BWM)

To strengthen the methodological rigor of this study and ensure a coherent link between the evaluated indicators and their relative importance, the weights of the six decision criteria were determined using the fuzzy best-worst method (F-BWM). This method, introduced by Rezaei (2012) and extended into a fuzzy form to handle uncertainty and vagueness in expert judgments, has become a prominent approach in MCDM under fuzzy environments. The F-BWM was selected due to its several advantages: it requires fewer pairwise comparisons than other fuzzy methods such as FAHP; it maintains consistency in expert evaluations; and it integrates well with fuzzy-based decision models such as fuzzy VIKOR, which is used in this study. Additionally, F-BWM enables expert-derived weights to be incorporated without modifying the original decision matrix used in the VIKOR analysis. The use of F-BWM is particularly appropriate in this context because it reduces the cognitive burden of pairwise comparisons while preserving a formal mechanism for checking the internal consistency of expert judgments. This feature is essential when criteria are conceptually close, as is often the case in entrepreneurship and innovation assessments. Consequently, the resulting weights provide a more defensible basis for the subsequent compromise ranking stage performed by fuzzy VIKOR. The six criteria used to assess entrepreneurial performance in SMEs in East Azerbaijan province are

C1: Organizational Innovation

C2: Risk-taking

C3: External Factors

C4: Competitiveness

C5: Responsiveness

C6: Internal Factors

The relative importance of 15 criteria was evaluated by a panel of five persons with expertise in the domain using their practical experience. According to their agreement, organizational innovation (C1) represented the most important criterion and internal factors (C6) were classified as the least important. To support such judgments, comparisons were made in terms of pairwise linguistic terms that were later converted to triangular fuzzy numbers (TFNs) by the panel members. The vectors of the comparison were made up as follows:

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Best-to-others (B-O) vector:

- C1 to C1 = (1, 1, 1)
- C1 to C2 = (2, 3, 4)
- C1 to C3 = (3, 4, 5)
- C1 to C4 = (2, 3, 4)
- C1 to C5 = (2, 3, 4)
- C1 to C6 = (6, 7, 8)

Others-to-worst (O-W) vector:

- C1 to C6 = (6, 7, 8)
- C2 to C6 = (5, 6, 7)
- C3 to C6 = (4, 5, 6)
- C4 to C6 = (3, 4, 5)
- C5 to C6 = (4, 5, 6)
- C6 to C6 = (1, 1, 1)

The fuzzy linear programming model was then used to compute the optimal fuzzy weights for each criterion. The defuzzification was carried out using the centroid method. The results are shown in Table 6.

Table 6. Triangular Fuzzy and Defuzzified Weights of Entrepreneurship Criteria Derived via F-BWM

Criterion	Fuzzy Weight (TFN)	Defuzzified Weight
C1: Organizational Innovation	(0.19, 0.22, 0.25)	0.220
C2: Risk-taking	(0.18, 0.21, 0.24)	0.210
C3: External Factors	(0.14, 0.16, 0.18)	0.160
C4: Competitiveness	(0.13, 0.15, 0.17)	0.150
C5: Responsiveness	(0.12, 0.14, 0.16)	0.140
C6: Internal Factors	(0.10, 0.12, 0.14)	0.120

The consistency ratio (CR) calculated for expert judgments was found to be below 0.1, indicating a high level of consistency. The use of equal weights during the preliminary fuzzy VIKOR analysis was a pragmatic and partial solution to the employment of criteria importance assessment. The further utilization of F-BWM weights generates a more rigid hierarchy, thus adding a greater validity to the methodological aspect of the procedure as well as enhancing clarity of interpretation. The policy-makers and the SME managers thus find value in the enhanced understanding of the enhanced methodology

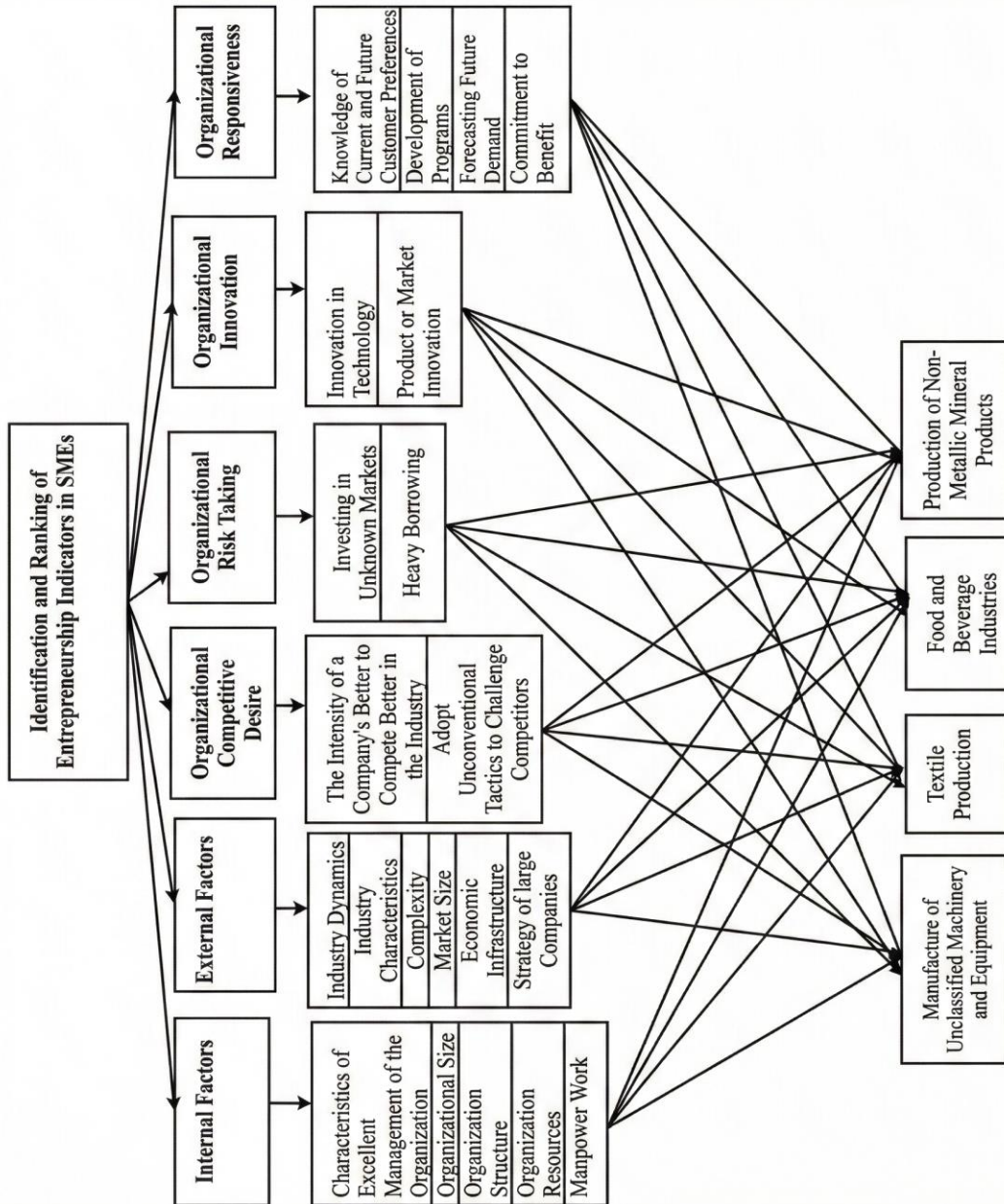


Figure 3. Hierarchical process diagram of research

#### 4 RESULTS AND DISCUSSION

After determining the criteria and options, the fuzzy VIKOR method was applied as follows: The objectives of the research were recognized as presented in Table 1 and Figure 3. For determining the criteria importance and ranking options, experts and decision makers have used the verbal expressions in Table 2. The importance weight of the criteria as well as the ranking of the options according to the evaluated criteria are shown in Tables 7 and 8. Then the fuzzy equivalent of these variables is given in Tables 9 and 10, respectively. In the same way, the weight and importance of the industries were evaluated according to the main criteria and the ranking of the industries according to the secondary criteria. Then the cumulative fuzzy values of the options were calculated in Table 11 and their cumulative fuzzy values in Table 12. In Tables 13 and 14, S, R, and Q values were calculated and

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ranked for selected industries, and food and beverage industries were selected as the best option. To examine the stability of the compromise ranking, a one-way sensitivity analysis is conducted with respect to the VIKOR strategy parameter  $v$ . Specifically, the ranking is recalculated for three settings:  $v_1 = 0.25$ ,  $v_2 = 0.5$ ,  $v_3 = 0.75$ . These values represent a higher emphasis on individual regret, a balanced stance, and a higher emphasis on group utility, respectively. Stability is assessed by comparing rank positions and the relative gaps among alternatives across these settings. Consistent results indicate that the compromise solution is robust to plausible variations in decision strategy.

Table 7. The weight of the importance of criteria by the decision maker

Criteria	D1	D2	D3	D4
C1	MH	M	MP	MH
C2	VH	VH	H	VH
C3	H	VH	H	VH
C4	M	M	MH	MH
C5	MH	M	H	H
C6	MP	M	M	MH
C11	VH	H	MH	VH
C12	P	VP	VP	M
C13	MH	M	MH	M
C14	MH	M	M	MH
C21	H	VH	H	VH
C22	VH	VH	VH	VH
C31	P	VP	E	MP
C32	VP	P	MP	MH
C41	P	P	VP	MP
C42	MP	MP	M	MH
C51	MH	H	H	H
C52	VP	MP	M	MH
C53	P	VP	MP	MP
C54	M	MH	H	M
C55	H	MH	MH	M
C56	MH	MH	M	MH
C61	H	H	MH	M
C62	E	P	MP	M
C63	M	MH	M	MH
C64	MH	M	MH	H
C65	M	H	H	H

Table 8. Ranking of options according to the criteria evaluated by decision makers

DM	A	C1	C2	C3	C4	C5	C6
<b>D1</b>	A1	VL	VL	L	M	L	VL
	A2	G	VG	G	G	MG	MG
	A3	VL	VL	L	L	ML	M
	A4	VG	G	VG	VG	G	MG
<b>D2</b>	A1	VL	ML	L	M	L	VL
	A2	VG	G	MG	G	L	MG
	A3	MG	VL	L	ML	ML	M
	A4	G	VG	VG	VG	VG	MG
<b>D3</b>	A1	ML	G	M	M	MG	ML
	A2	MG	G	G	VG	MG	M
	A3	M	MG	M	MG	MG	VL
	A4	VG	MG	G	VG	G	M

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<b>D4</b>	A1	E	G	ML	M	ML	L
	A2	G	VG	G	G	MG	M
	A3	M	MG	MG	MG	M	MG
	A4	G	VG	VG	VG	G	G

Table 9. Importance weight of criteria evaluated by decision makers

<b>C</b>	<b>D1</b>	<b>D2</b>	<b>D3</b>	<b>D4</b>
<b>C1</b>	(0.5, 0.6, 0.7)	(0.4, 0.5, 0.6)	(0.3, 0.4, 0.5)	(0.5, 0.6, 0.7)
<b>C2</b>	(0.8, 0.9, 1)	(0.8, 0.9, 1)	(0.7, 0.8, 0.9)	(0.8, 0.9, 1)
<b>C3</b>	(0.7, 0.8, 0.9)	(0.8, 0.9, 1)	(0.7, 0.8, 0.9)	(0.8, 0.9, 1)
<b>C4</b>	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.7)	(0.5, 0.6, 0.7)
<b>C5</b>	(0.5, 0.6, 0.7)	(0.4, 0.5, 0.6)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)
<b>C6</b>	(0.3, 0.4, 0.5)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.7)
<b>C11</b>	(0.8, 0.9, 1)	(0.7, 0.8, 0.9)	(0.5, 0.6, 0.7)	(0.8, 0.9, 1)
<b>C12</b>	(0.1, 0.2, 0.3)	(0.1, 0.1, 0.2)	(0.1, 0.1, 0.2)	(0.4, 0.5, 0.6)
<b>C13</b>	(0.5, 0.6, 0.7)	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.7)	(0.4, 0.5, 0.6)
<b>C14</b>	(0.5, 0.6, 0.7)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.7)
<b>C21</b>	(0.7, 0.8, 0.9)	(0.8, 0.9, 1)	(0.7, 0.8, 0.9)	(0.8, 0.9, 1)
<b>C22</b>	(0.8, 0.9, 1)	(0.8, 0.9, 1)	(0.8, 0.9, 1)	(0.8, 0.9, 1)
<b>C31</b>	(0.1, 0.2, 0.3)	(0.1, 0.1, 0.2)	(1, 1, 1)	(0.3, 0.4, 0.5)
<b>C32</b>	(0.1, 0.1, 0.2)	(0.1, 0.2, 0.3)	(0.3, 0.4, 0.5)	(0.5, 0.6, 0.7)
<b>C41</b>	(0.1, 0.2, 0.3)	(0.1, 0.2, 0.3)	(0.1, 0.1, 0.2)	(0.3, 0.4, 0.5)
<b>C42</b>	(0.3, 0.4, 0.5)	(0.3, 0.4, 0.5)	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.7)
<b>C51</b>	(0.5, 0.6, 0.7)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)
<b>C52</b>	(0.1, 0.1, 0.2)	(0.3, 0.4, 0.5)	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.7)
<b>C53</b>	(0.1, 0.2, 0.3)	(0.1, 0.1, 0.2)	(0.3, 0.4, 0.5)	(0.3, 0.4, 0.5)
<b>C54</b>	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.7)	(0.7, 0.8, 0.9)	(0.4, 0.5, 0.6)
<b>C55</b>	(0.7, 0.8, 0.9)	(0.5, 0.6, 0.7)	(0.5, 0.6, 0.7)	(0.4, 0.5, 0.6)
<b>C56</b>	(0.5, 0.6, 0.7)	(0.5, 0.6, 0.7)	(0/4, 0/5, 0/6)	(0.5, 0.6, 0.7)
<b>C61</b>	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.5, 0.6, 0.7)	(0.4, 0.5, 0.6)
<b>C62</b>	(1, 1, 1)	(0.1, 0.2, 0.3)	(0.3, 0.4, 0.5)	(0.4, 0.5, 0.6)
<b>C63</b>	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.7)	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.7)
<b>C64</b>	(0.5, 0.6, 0.7)	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.7)	(0.7, 0.8, 0.9)
<b>C65</b>	(0.4, 0.5, 0.6)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)

Table 10. Weight and importance of industries according to the main criteria evaluated by decision makers

<b>DM</b>	<b>A</b>	<b>C1</b>	<b>C2</b>	<b>C3</b>	<b>C4</b>	<b>C5</b>	<b>C6</b>
<b>D1</b>	A1	(0.1, 0.1, 0.2)	(0.1, 0.1, 0.2)	(0.1, 0.2, 0.3)	(0.4, 0.5, 0.6)	(0.1, 0.2, 0.3)	(0.1, 0.1, 0.2)
	A2	(0.7, 0.8, 0.9)	(0.8, 0.9, 1)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.5, 0.6, 0.7)	(0.5, 0.6, 0.7)
	A3	(0.1, 0.1, 0.2)	(0.1, 0.1, 0.2)	(0.1, 0.2, 0.3)	(0.1, 0.2, 0.3)	(0.3, 0.4, 0.5)	(0.4, 0.5, 0.6)
	A4	(0.8, 0.9, 1)	(0.7, 0.8, 0.9)	(0.8, 0.9, 1)	(0.8, 0.9, 1)	(0.7, 0.8, 0.9)	(0.5, 0.6, 0.7)
<b>D2</b>	A1	(0.1, 0.1, 0.2)	(0.3, 0.4, 0.5)	(0.1, 0.2, 0.3)	(0.4, 0.5, 0.6)	(0.1, 0.2, 0.3)	(0.1, 0.1, 0.2)
	A2	(0.8, 0.9, 1)	(0.7, 0.8, 0.9)	(0.5, 0.6, 0.7)	(0.7, 0.8, 0.9)	(0.1, 0.2, 0.3)	(0.5, 0.6, 0.7)
	A3	(0.5, 0.6, 0.7)	(0.1, 0.1, 0.2)	(0.1, 0.2, 0.3)	(0.3, 0.4, 0.5)	(0.3, 0.4, 0.5)	(0.4, 0.5, 0.6)
	A4	(0.7, 0.8, 0.9)	(0.8, 0.9, 1)	(0.8, 0.9, 1)	(0.8, 0.9, 1)	(0.8, 0.9, 1)	(0.5, 0.6, 0.7)
<b>D3</b>	A1	(0.3, 0.4, 0.5)	(0.7, 0.8, 0.9)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.7)	(0.3, 0.4, 0.5)
	A2	(0.5, 0.6, 0.7)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.8, 0.9, 1)	(0.5, 0.6, 0.7)	(0.4, 0.5, 0.6)
	A3	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.7)	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.7)	(0.5, 0.6, 0.7)	(0.1, 0.1, 0.2)
	A4	(0.8, 0.9, 1)	(0.5, 0.6, 0.7)	(0.7, 0.8, 0.9)	(0.8, 0.9, 1)	(0.7, 0.8, 0.9)	(0.4, 0.5, 0.6)
<b>D4</b>	A1	(1, 1, 1)	(0.7, 0.8, 0.9)	(0.3, 0.4, 0.5)	(0.4, 0.5, 0.6)	(0.3, 0.4, 0.5)	(0.1, 0.2, 0.3)
	A2	(0.7, 0.8, 0.9)	(0.8, 0.9, 1)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.5, 0.6, 0.7)	(0.4, 0.5, 0.6)
	A3	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.7)	(0.5, 0.6, 0.7)	(0.5, 0.6, 0.7)	(0.4, 0.5, 0.6)	(0.5, 0.6, 0.7)
	A4	(0.7, 0.8, 0.9)	(0.8, 0.9, 1)	(0.8, 0.9, 1)	(0.8, 0.9, 1)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)

Table 11. Cumulative fuzzy values of options and their weight of importance

C	Wi	A1	A2	A3	A4
C1	(0.3,0.525,0.7)	(0.1, 0.4, 1)	(0.5, 0.775, 1)	(0.1, 0.425, 0.7)	(0.7, 0.85, 0.9)
C2	(0.7,0.875,1)	(0.1, 0.525, 0.9)	(0.7, 0.85, 1)	(0.1, 0.35, 0.7)	(0.5, 0.8, 1)
C3	(0.7,0.85,1)	(0.1, 0.325, 0.6)	(0.5, 0.75, 0.9)	(0.1, 0.375, 0.7)	(0.7, 0.875, 1)
C4	(0.4,0.55,0.7)	(0.4, 0.5, 0.6)	(0.7, 0.825, 1)	(0.1, 0.45, 0.7)	(0.8, 0.9, 1)
C5	(0.4,0.675,0.9)	(0.1, 0.35, 0.7)	(0.1, 0.5, 0.7)	(0.3, 0.475, 0.7)	(0.7, 0.825, 1)
C6	(0.3,0.5,0.7)	(0.1, 0.2, 0.5)	(0.4, 0.55, 0.7)	(0.1, 0.425, 0.7)	(0.4, 0.625, 0.9)
C11	(0.5,0.8,1)	(0.4, 0.725, 1)	(0.5, 0.725, 1)	(0.4, 0.6, 0.9)	(0.7, 0.85, 1)
C12	(0.1,0.225,0.6)	(0.4, 0.55, 0.7)	(0.1, 0.1, 0.2)	(0.4, 0.55, 0.7)	(0.4, 0.7, 1)
C13	(0.4,0.55,0.7)	(0.5, 0.65, 0.9)	(0.3, 0.525, 0.7)	(0.4, 0.525, 0.7)	(0.4, 0.625, 0.9)
C14	(0.4,0.55,0.7)	(0.1, 0.5, 0.9)	(0.5, 0.65, 0.9)	(0.3, 0.575, 0.9)	(0.4, 0.675, 0.9)
C21	(0.7,0.85,1)	(0.1, 0.65, 1)	(0.8, 0.9, 1)	(0.7, 0.85, 1)	(0.7, 0.9, 0.9)
C22	(0.8,0.9,1)	(0.7, 0.875, 1)	(0.7, 0.875, 1)	(0.5, 0.75, 0.9)	(0.5, 0.75, 1)
C31	(0.1,0.425,1)	(0.1, 0.425, 0.7)	(0.1, 0.4, 0.7)	(0.3, 0.425, 0.7)	(0.1, 0.625, 1)
C32	(0.1,0.325,0.7)	(0.1,0.45,0.7)	(0.1, 0.4, 0.7)	(0.3, 0.55, 0.7)	(0.1, 0.5, 0.7)
C41	(0.1,0.225,0.5)	(0.1, 0.2, 0.3)	(0.3, 0.625, 0.9)	(0.1, 0.5, 0.9)	(0.1, 0.55, 0.9)
C42	(0.3,0.475,0.7)	(0.4, 0.675, 0.1)	(0.1, 0.325, 0.6)	(0.1, 0.3, 0.7)	(0.1, 0.575, 0.9)
C51	(0.5,0.75,0.9)	(0.3, 0.65, 0.9)	(0.4, 0.525, 0.7)	(0.1, 0.525, 0.9)	(0.4, 0.675, 0.9)
C52	(0.1,0.4,0.7)	(0.1, 0.375, 0.6)	(0.1, 0.475, 0.7)	(0.1, 0.525, 0.9)	(0.4, 0.525, 0.9)
C53	(0.1,0.275,0.5)	(0.3, 0.6, 0.9)	(0.1, 0.4, 0.9)	(0.1, 0.5, 0.9)	(0.1, 0.525, 0.9)
C54	(0.4,0.6,0.9)	(0.5, 0.675, 1)	(0.4, 0.6, 0.9)	(0.3, 0.575, 0.9)	(0.7, 0.875, 1)
C55	(0.4,0.625,0.9)	(0.1, 0.5, 0.9)	(0.3, 0.55, 0.9)	(0.4, 0.625, 1)	(0.1, 0.45, 0.7)
C56	(0.4,0.575,0.7)	(0.4, 0.55, 0.9)	(0.3, 0.6, 0.9)	(0.4, 0.6, 0.9)	(0.4, 0.75, 1)
C61	(0.4,0.675,0.9)	(0.4, 0.625, 0.9)	(0.4, 0.575, 0.9)	(0.4, 0.675, 1)	(0.7, 0.85, 1)
C62	(0.1,0.525,1)	(0.1, 0.375, 0.7)	(0.1, 0.4, 0.6)	(0.3, 0.4, 0.5)	(0.4, 0.55, 0.7)
C63	(0.4,0.55,0.7)	(0.1, 0.425, 0.7)	(0.1, 0.475, 0.9)	(0.1, 0.5, 0.9)	(0.4, 0.55, 0.7)
C64	(0.4,0.625,0.9)	(0.5, 0.7, 0.9)	(0.4, 0.675, 0.9)	(0.4, 0.6, 0.9)	(0.5, 0.725, 1)
C65	(0.4,0.725,0.9)	(0.1, 0.4, 0.9)	(0.1, 0.55, 0.9)	(0.1, 0.45, 0.9)	(0.4, 0.725, 1)

Table 12. Cumulative values of options de-fuzzy

C	Wi	Normalized $W_i^s$	A1	A2	A3	A4
C1	(0.508)	(0.129)	(0.5)	(0.758)	(0.408)	(0.817)
C2	(0.858)	(0.219)	(0.508)	(0.85)	(0.383)	(0.767)
C3	(0.85)	(0.217)	(0.342)	(0.717)	(0.392)	(0.858)
C4	(0.55)	(0.14)	(0.5)	(0.842)	(0.417)	(0.9)
C5	(0.659)	(0.168)	(0.383)	(0.433)	(0.492)	(0.842)
C6	(0.5)	(0.127)	(0.267)	(0.55)	(0.408)	(0.642)
C11	(0.767)	(0.357)	(0.708)	(0.742)	(0.633)	(0.85)
C12	(0.308)	(0.142)	(0.55)	(0.133)	(0.55)	(0.7)
C13	(0.55)	(0.253)	(0.683)	(0.508)	(0.542)	(0.642)
C14	(0.55)	(0.253)	(0.5)	(0.683)	(0.592)	(0.658)
C21	(0.85)	(0.484)	(0.583)	(0.9)	(0.85)	(0.833)
C22	(0.9)	(0.514)	(0.858)	(0.858)	(0.717)	(0.75)
C31	(0.508)	(0.575)	(0.408)	(0.4)	(0.475)	(0.575)
C32	(0.375)	(0.425)	(0.417)	(0.4)	(0.517)	(0.433)
C41	(0.275)	(0.358)	(0.2)	(0.608)	(0.5)	(0.517)
C42	(0.492)	(0.641)	(0.692)	(0.342)	(0.367)	(0.525)
C51	(0.717)	(0.221)	(0.617)	(0.542)	(0.508)	(0.658)
C52	(0.4)	(0.123)	(0.358)	(0.425)	(0.508)	(0.608)
C53	(0.292)	(0.09)	(0.6)	(0.467)	(0.5)	(0.508)
C54	(0.633)	(0.195)	(0.725)	(0.633)	(0.592)	(0.858)
C55	(0.642)	(0.198)	(0.5)	(0.583)	(0.675)	(0.417)

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C56	(0.558)	(0.172)	(0.617)	(0.6)	(0.633)	(0.717)
C61	(0.658)	(0.221)	(0.642)	(0.625)	(0.692)	(0.85)
C62	(0.542)	(0.183)	(0.392)	(0.367)	(0.4)	(0.55)
C63	(0.55)	(0.185)	(0.408)	(0.492)	(0.5)	(0.55)
C64	(0.542)	(0.183)	(0.7)	(0.658)	(0.633)	(0.742)
C65	(0.675)	(0.227)	(0.467)	(0.517)	(0.483)	(0.708)

Table 13. S, R and Q values for selected industries

Firm	S	R			Q
A1	4.582	0.038	$S_j^* = 1.582$	$R_j^* = 0.017$	0.989
A2	4.052	0.017			$S_j^- = 4.648$
A3	4.648	0.037			0.976
A4	1.582	0.036			0.452

Table 14. Ranking of Q, R, S options in descending order

Q		R		S	
A2	0.403	A2	0.017	A4	1.582
A4	0.452	A4	0.036	A2	4.052
A3	0.976	A3	0.037	A1	4.582
A1	0.989	A1	0.038	A3	4.648

Ranking results of the main indicators of entrepreneurship according to the research questions, which are the effective entrepreneurship indicators in small and medium industries and how they are prioritized. According to the calculations made with the fuzzy VIKOR method, the final weight of the main criteria is as follows. According to the fuzzy VIKOR calculations, the final weights and ranks of the six main entrepreneurship criteria are as follows: organizational innovation (0.219, rank 1), organizational risk-taking (0.217, rank 2), external organizational factors (0.168, rank 3), organizational competitiveness (0.140, rank 4), organizational responsiveness (0.129, rank 5), and internal organizational factors (0.127, rank 6). The criterion with the highest score is ranked first and the one with the lowest score is ranked last, as presented in Table 15.

Table 15. Prioritization of 6 main criteria of entrepreneurship

Main indicators	organizational innovation,	risk-taking,	external organizational factors,	organizational competitive desire,	organizational responsiveness,	Internal organizational factors,
Final weight	0.219	0.217	0.158	0.14	0.129	0.127
Rank	5	4	3	2	1	6

In the group of organizational innovation, innovation in product or market with final weight (0.514) ranked first and innovation in technology ranked last with final weight (0.486) as described in Table 16.

Table 16. Sub-criteria of organizational innovation index

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Sub-criteria of organizational innovation index	Innovation in technology	Product or market innovation
Final weight	0.486	0.514
Rank	2	1

In the group of organizational risk taking, investing in unknown markets with a final weight (0.575) ranked first and heavy borrowing with a final weight (0.425) ranked last, as shown in Table 17.

Table 17. Sub-criteria of organizational risk tolerance index

Sub-criteria of organizational risk-taking index	Investing in unknown markets	heavy borrowing
Final weight	0.575	0.425
Rank	1	2

In the organizational competitive desire group, adopting unconventional tactics to challenge competitors with a final weight (0.641) ranked first and the intensity of a company’s effort to compete better in the industry with a final weight (0.358) ranked last, which is shown in Table 18.

Table 18. Sub-criteria of organizational competitiveness index.

Sub-criteria of organizational competitiveness index	The intensity of a company's effort to compete better in the industry	Adopt unconventional tactics to challenge competitors
Final weight	0.358	0.641
Rank	2	1

In the group of extra-organizational factors, industry dynamism with final weight (0.221) ranks first, economic infrastructure with final weight (0.198) ranks second, market size with final weight (0.195) ranks third, strategy companies are ranked fourth with final weight (0.172), industry characteristics with final weight (0.123) and complexity with final weight (0.09) are ranked last, as shown in Table 19.

Table 19. Sub-criteria of indicators of external organizational factors

Sub-criteria of indicators of extra-organizational factors	Industry dynamics	Industry characteristics	Complexity	Market Size	Economic infrastructure	The strategy of large companies
Final weight	0.221	0.123	0.09	0.195	0.198	0.172
Rank	1	5	6	3	2	4

In the group of organizational responsiveness, knowledge of the current and future preferences of customers with a final weight (0.352) is in the first place, forecasting future demand with a final weight (0.253) and commitment to exploitation with a final weight (0.253) jointly are in the second place, and the development of programs with the final weight (0.142) are placed last, as described in Table 20.

Table 20. Prioritization of sub-criteria of organizational reactivity index

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Sub-criteria of organizational heterogeneity index	Knowledge of current and future customer preferences	Development of programs	Forecasting future demand	Commitment to exploitation
Final weight	0.352	0.142	0.253	0.253
Rank	1	3	2	2

In the group of criteria of internal organizational factors, working manpower with the final weight (0.227) is in first place, the characteristics of the organization’s top management with the final weight (0.221) is in second place, organizational structure with the final weight (0.185) is ranked third, and the resources of the organization with the final weight (0.183) and the size of the organization with the final weight (0.183) are jointly ranked fourth, which is shown in Table 21.

Table 21. Sub-criteria of internal factors index

Sub-criteria of indicators of extra-organizational factors	Characteristics of excellent management of the organization	Organization size	Organization Structure	Organization resources	Manpower
Final weight	0.221	0.183	0.185	0.183	0.227
Rank	2	4	3	4	1

In alternatives (industries), the food and beverage industry with final weight (0.403) is ranked first, and the production of non-metallic mineral products with final weight (0.989) is ranked last. Meanwhile, the best option is the lowest Qi, which is shown in Table 22.

Table 22. Prioritization of selected industries according to the main indicator

Alter natives (industries)	Production of non-metallic mineral products	Food and beverage production	Textile production	Manufacture of unclassified machinery and equipment
Final weight	0.989	0.403	0.976	0.452
Rank	4	1	3	2

Figure 4 presented the results of fuzzy VIKOR. In Figure 4, the left panel (S-Group Utility), assesses how close each industry is to the group’s ideal performance. The middle panel (R-Individual Regret) reflects the worst-case dissatisfaction per industry. The right panel (Q-Compromise Solution) presents the overall trade-off, in which lower is better.

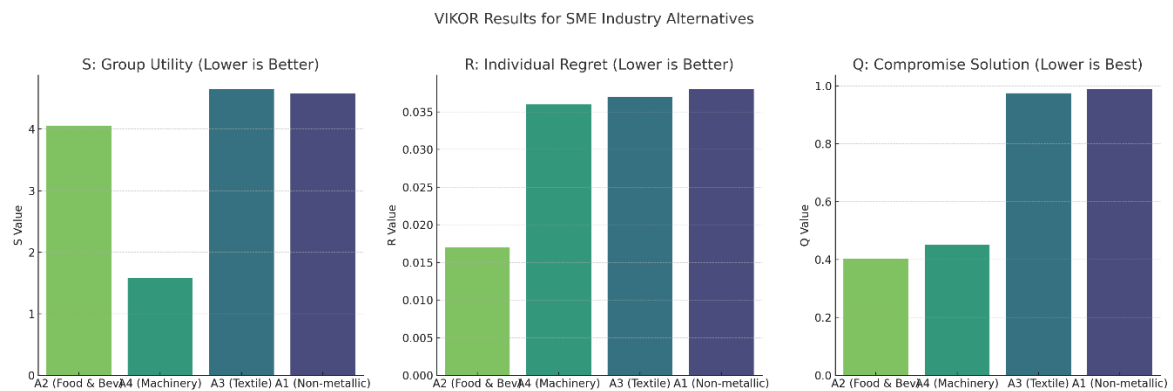


Figure 4. Final results of Fuzzy VIKOR

According to Figure 4, A2 (Food & Beverage) is consistently strong across all metrics, with the lowest Q value, indicating the best compromise. A4 (Machinery) excels in group utility (lowest S), but slightly lags behind A2 in overall Q. A3 (Textile) and A1 (Non-metallic) score poorly across most dimensions, especially A3 in terms of regret and compromise.

## 5 COMPARATIVE STUDY ANALYSIS

To strengthen the comparative dimension of this study, we benchmarked our results against existing literature that applied various MCDM methods such as FAHP, FTOPSIS, and regression-based frameworks. For instance, Kiani Mavi (2014) employed a fuzzy AHP and FTOPSIS hybrid approach to evaluate entrepreneurial university indicators and found “internal support” and “external environment” to be the most critical. Our results, however, highlight “organizational innovation” (0.219) and “risk-taking” (0.217) as dominant entrepreneurship drivers in SMEs, especially in the food and beverage industry, supported by a final performance score of 0.403. Similarly, Bajdor et al. (2021) applied cluster analysis and discovered a focus on social goals within Polish SMEs, unlike our model which emphasizes innovation and competitive tactics. Compared to Pramono et al. (2021), who used stepwise regression to link business progress with education and self-efficacy, our VIKOR-based model integrates a broader set of six hierarchical criteria, offering a more comprehensive lens for evaluating SME entrepreneurship. Figure 5 is the comparative radar chart showing how our proposed fuzzy VIKOR model prioritizes entrepreneurship indicators versus other major studies. From an international policy perspective, the identified priority of organizational innovation and risk-taking is broadly consistent with global entrepreneurship assessment frameworks such as the global entrepreneurship monitor (GEM) and the OECD SME competitiveness indicators. In particular, GEM emphasizes innovation-driven entrepreneurship and opportunity-based risk engagement as key drivers of sustainable SME competitiveness, while OECD frameworks highlight innovation capacity, strategic responsiveness, and market-oriented capabilities as core pillars of SME performance. Accordingly, although the empirical setting of this study is region-specific, the proposed indicator structure and the hybrid fuzzy evaluation framework are transferable to other emerging and developing economies with comparable industrial characteristics.

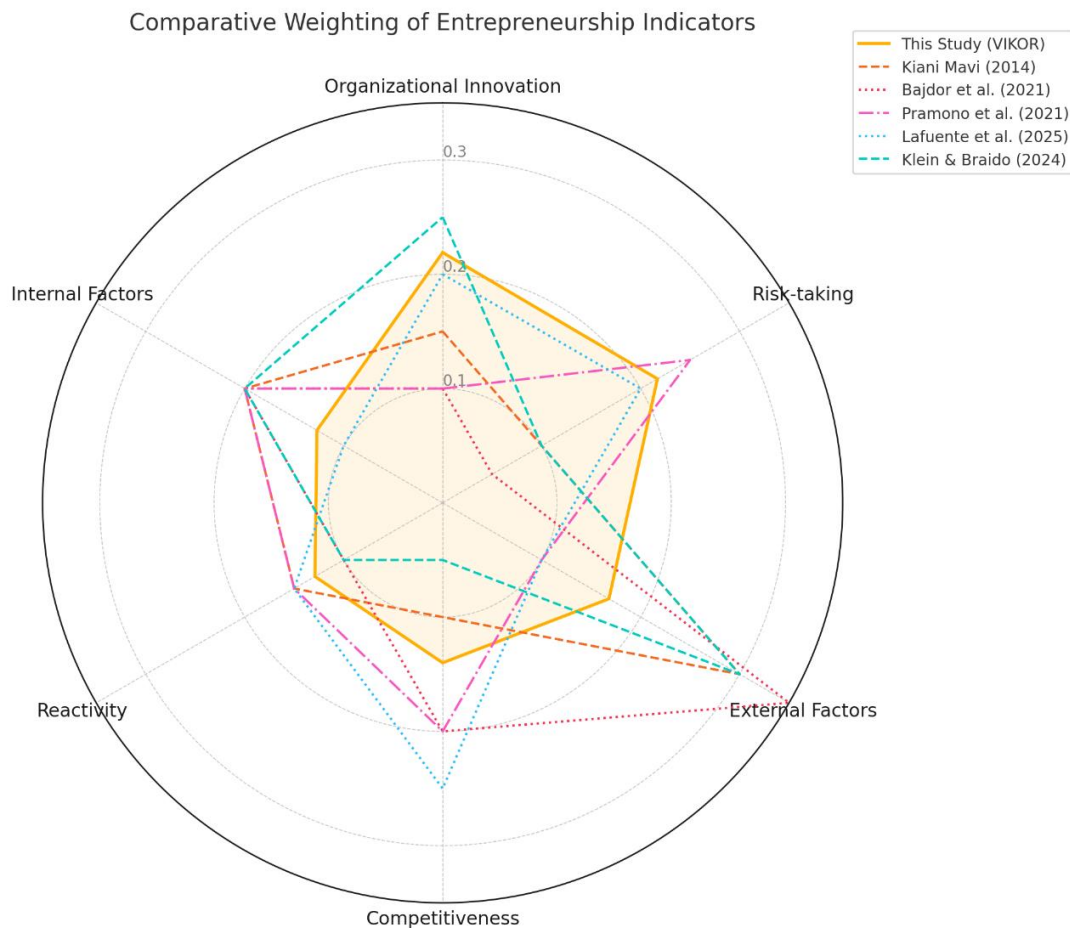


Figure 5. Comparing our results versus other major studies

According to Figure 5, organizational innovation and risk-taking are the highest weighted indicators in our study, showing a strong alignment with dynamic, proactive enterprise behavior. These dimensions receive less emphasis in studies like Kiani Mavi (2014) or Bajdor et al., (2021). External factors were highly rated in both our model and Kiani Mavi (2014) and Klein and Braido (2024), reflecting the importance of environmental and institutional support. Internal factors such as organizational structure and manpower are consistently underweighted across all studies, although our study evaluates them more systematically via fuzzy logic. Pramono et al. (2021) and Lafuente et al. (2025) emphasized competitiveness and learning-oriented behavior but did not integrate fuzzy evaluation or precise weight modeling.

From an international perspective, the findings of this study are broadly consistent with empirical evidence reported for SMEs in both European and Asian contexts, while also reflecting region-specific characteristics. Studies conducted in E.U. countries generally emphasize organizational innovation, strategic orientation, and responsiveness to market dynamics as central drivers of SME competitiveness, particularly in mature institutional environments with strong innovation support systems. Similarly, research from Asian economies, including China and ASEAN countries, highlights the critical role of entrepreneurial risk-taking and innovation capabilities in highly competitive and rapidly evolving markets. The high relative importance of organizational innovation and risk-taking identified in this study aligns well with these international patterns, suggesting that these dimensions constitute universally relevant pillars of SME competitiveness. At the same time, notable territorial differences can be observed in the relative influence of entrepreneurship

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dimensions across regions. In developing and emerging industrial contexts, such as the one examined in this study, external factors and organizational responsiveness play a more pronounced role due to higher levels of environmental uncertainty, institutional volatility, and market imperfections. In contrast, SMEs operating in more developed European environments often rely more heavily on internal organizational capabilities and formalized innovation processes. These differences indicate that, while the proposed hybrid F-BWM–VIKOR framework is transferable across regions, the relative prioritization of entrepreneurship indicators should be interpreted in light of specific institutional, economic, and territorial conditions. This reinforces the importance of context-sensitive policy design when aiming to enhance the international competitiveness of SMEs.

## 6 LIMITATIONS AND FUTURE RESEARCH

Despite the use of a structured hybrid framework that integrates F-BWM and fuzzy VIKOR for evaluating entrepreneurship indicators in SMEs, several limitations should be acknowledged. First, the results are based on expert elicitation within a specific regional and industrial context; therefore, the transferability of findings to other economic, institutional, and cultural environments may be limited. Second, although fuzzy modeling is suitable for representing ambiguity in linguistic judgments, expert-based assessments remain partially subjective. While BWM provides a mechanism to improve judgment consistency, future studies should report and scrutinize consistency more rigorously and explore procedures such as panel calibration and inter-expert agreement analysis to further mitigate elicitation bias. Third, the current study does not conduct a formal sensitivity analysis. Future research should test the robustness of rankings by varying the VIKOR strategy parameter  $v$  and by perturbing criteria weights within plausible ranges to evaluate ranking stability and strengthen inferential rigor. From a methodological benchmarking perspective, additional empirical comparisons with alternative fuzzy MCDM approaches (for example, fuzzy TOPSIS, fuzzy MARCOS, or fuzzy DEMATEL-based hybridizations) would help clarify whether performance differences arise from the weighting scheme, the compromise ranking logic, or the indicator structure. Finally, external validation can be strengthened through cross-country replications, sector-specific case studies, and longitudinal designs that capture dynamic changes in entrepreneurial conditions. Extensions that integrate data-driven components (for example, machine learning models or adaptive neuro-fuzzy inference systems, ANFIS) and, where feasible, digital data streams (for example, IoT-enabled operational indicators) may support more predictive and near real-time assessment of entrepreneurship-related competitiveness in SMEs.

## 7 CONCLUSIONS

Given the critical role that SMEs play in national economic development, supporting the expansion of these enterprises represents a strategic opportunity for both Iran and the East Azerbaijan region. Encouraging the growth of SMEs contributes to poverty reduction, increased household incomes, employment generation particularly for unskilled labor capital formation through improved productivity, and rural development. Moreover, it helps mitigate urban overpopulation and reduce migration pressures. These outcomes collectively foster socio-economic development at both the national and provincial levels and act as catalysts for sustained economic growth. According to the findings of this study, the innovation index emerged as the most significant entrepreneurial indicator. Therefore, it is recommended that a dedicated legal framework for innovation development within SMEs be established. This is particularly relevant as Iran, like many traditional economies, exhibits a low innovation index in its SME sector. In contrast, developed countries have recognized the strategic importance of

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fostering innovation in economic growth by enacting legislation specifically aimed at supporting innovation in small businesses. Such laws typically allow a portion of government agency budgets to be allocated toward financing contracts, providing loans, or engaging in partnership agreements with SMEs, thereby stimulating industrial dynamism and contributing to broader national economic progress. In parallel, it is advised that industrial managers integrate the prioritized entrepreneurial components identified in this study into their strategic planning. Formulating business strategies aligned with these priorities can enhance organizational effectiveness. Additional recommendations include: the development and revision of clear legal and regulatory frameworks to support SME activity; increased managerial attention toward establishing and expanding R&D units within SMEs; the formulation of government policies that promote exports and enhance SME competitiveness in international markets; the provision of expert consultancy services to address operational challenges; and the creation of platforms that nurture creative ideas and harness entrepreneurial potential through talent development. The results are directly relevant to SME managers and industry policymakers by providing a prioritized set of entrepreneurship-related levers that can inform capability-building, innovation support, and competitiveness-oriented interventions. Although the empirical setting is region-specific, the indicator structure and the hybrid fuzzy evaluation logic are transferable and can be adapted to other contexts for cross-sector and cross-country benchmarking. In this sense, the proposed indicator domains can also be conceptually aligned with widely used international entrepreneurship perspectives (for example, GEM- and OECD-related competitiveness pillars), which strengthens the interpretability of the findings beyond the focal region. The economic success of advanced economies clearly demonstrates the essential role of entrepreneurship in fostering growth. Entrepreneurs are key drivers of innovation and economic dynamism, and the promotion of an entrepreneurial culture especially through education and skill development among the educated population is vital for emerging economies such as Iran. Organizational entrepreneurship is indispensable in this context, and the lack of applied research on the topic underlines the urgency for further scholarly inquiry. In conclusion, this study reinforces the predominance of the innovation index over other entrepreneurial indicators, underscoring the necessity for SME owners to prioritize innovation and its related dimensions, such as product and market innovation and understanding customer preferences. This study employed the fuzzy VIKOR method to identify and rank entrepreneurial indicators in SMEs in Tabriz. Future researchers are encouraged to explore entrepreneurial strategies with a focus on marketing-related aspects, including branding, pricing, and product development from an entrepreneurial perspective. Moreover, given the novelty of this subject in the Iranian context and the lack of similar studies in other regions, it is recommended that future investigations extend to other geographical settings. Additionally, the application of alternative or complementary multi-criteria decision-making methods such as AHP, TOPSIS, VIKOR, or DEMATEL particularly in fuzzy environments, is also suggested to further enrich the analysis.

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### Contact information

**Associate Professor Reza Rostamzadeh, Ph.D.**

Department of Management  
Artificial Intelligence, Automation, Big Data Research Center, Ur. C.  
Islamic Azad University, Urmia, Iran  
E-mail: reza.rostamzadeh@iau.ac.ir (corresponding author)  
ORCID: 0000-0002-6161-7173

**Professor Ali Altug Bicer, Ph.D.**

Department of Business Administration  
Faculty of Economics, Administrative and Social Sciences  
Istinye University, Istanbul, Turkey  
Email: alialtug.bicer@istinye.edu.tr  
ORCID: 0000-0002-5515-212X

**Assistant Professor Shahryar Ghorbani, Ph.D.**

Department of Business Administration  
Faculty of Economics, Administrative and Social Sciences  
Istinye University, Istanbul, Turkey  
Email: shahryar.ghorbani@istinye.edu.tr  
ORCID: 0000-0001-6085-1788

**Professor Jonas Šaparauskas, Ph.D.**

Faculty of Civil Engineering  
Department of Construction Management and Real Estate  
Vilnius Gediminas Technical University  
Vilnius, Lithuania  
Email: jonas.saparauskas@vilniustech.lt  
ORCID: 0000-0003-3685-7754

**Professor Zenonas Turskis, Ph.D.**

Institute of Sustainable Construction  
Faculty of Civil Engineering  
Vilnius Gediminas Technical University  
Vilnius, Lithuania  
E-mail: zenonas.turskis@vilniustech.lt  
ORCID: 0000-0002-5835-9388

**Mahdi Abdsharafat, Ph.D student.**

Department of Management, Ur. C.  
Islamic Azad University, Urmia, Iran  
Email: Mahdi.abdsharafat@iau.ac.ir  
ORCID: 0009-0006-0037-5904