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# Evaluation of College Students' Innovation and Entrepreneurship Abilities in the New Media Environment Using Tree Soft Set and Neutrosophic Modeling

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**Abstract:** In today's rapidly evolving digital society, the new media environment has profoundly reshaped the landscape of innovation and entrepreneurship among college students. Understanding and evaluating students' abilities in this context are crucial for universities, policymakers, and industries seeking to cultivate future leaders and innovators. However, traditional evaluation frameworks often struggle to address the multi-layered, uncertain, and dynamic nature of competencies in a media-driven environment. This study proposes a novel decision-making framework based on Tree Soft Set (TSS) theory to evaluate college students' innovation and entrepreneurship abilities comprehensively. The TSS model, by organizing evaluation criteria into hierarchical tree structures, captures complex relationships among competencies and adapts flexibly to overlapping and uncertain information. To further enhance the robustness of the model, Single-Valued Neutrosophic Sets (SVNS) are integrated, enabling better representation of truth, indeterminacy, and falsity degrees in expert judgments. The proposed evaluation model identifies critical dimensions such as creativity, opportunity recognition, risk management, technological adaptability, communication skills, and leadership under the influence of new media. Criteria weighting is determined using the SWARA method, while final ranking of student profiles is achieved via the MAIRCA method. Empirical application and sensitivity analyses validate the framework's stability and effectiveness. The results provide actionable insights for educational institutions aiming to nurture innovation-driven talent in the digital era.

**Keywords:** Tree Soft Set (TSS); Single-Valued Neutrosophic Set (SVNS); Innovation Abilities; Entrepreneurship Abilities; New Media Environment; Multi-Criteria Decision-Making (MCDM); SWARA Method; MAIRCA Method; Uncertainty Modeling; Educational Assessment.

## 1. Introduction

The advent of the new media environment has significantly reshaped the landscape of innovation and entrepreneurship, especially among college students. Digital platforms, social media, and online collaborative tools now serve as powerful drivers for creativity, networking, and venture development [1]. These technologies offer students unprecedented opportunities to access resources, promote ideas, and build entrepreneurial initiatives beyond traditional physical boundaries.

However, while the potential is immense, the new media landscape introduces complexities that traditional educational and evaluation models are ill-equipped to address [2]. Innovation and entrepreneurship abilities are no longer confined to business knowledge and problem-solving skills; they now encompass digital literacy, adaptability to technological change, social media strategy, and online reputation management [3]. Consequently, assessing these capabilities requires more than standard academic evaluation methods.

Existing frameworks often fail to accommodate the dynamic, uncertain, and multi-layered nature of competencies influenced by new media. They tend to focus on isolated skill sets and assume that evaluators can provide complete and precise judgments, overlooking the inherent subjectivity and vagueness present in real-world assessments [4]. Furthermore, most models neglect the hierarchical relationships between basic digital skills and higher-order entrepreneurial competencies, resulting in incomplete evaluations.

To bridge these gaps, this study proposes a novel evaluation framework grounded in Tree Soft Set (TSS) theory, a hierarchical modeling technique that reflects the interdependencies among innovation and entrepreneurship skills [5]. Combined with Single-Valued Neutrosophic Sets (SVNS), the proposed framework effectively captures the uncertainty and partial knowledge prevalent in expert evaluations [6].

By integrating the SWARA method for criteria weighting and the MAIRCA method for ranking alternatives, this research aims to develop a comprehensive, uncertainty-resilient model for evaluating college students' innovation and entrepreneurship abilities within the dynamic and complex new media environment.

### 1.1 Research Motivation

The fast-paced development of new media technologies has not only redefined the nature of communication and information exchange but also transformed the landscape of innovation and entrepreneurship. College students, often hailed as "digital natives," now interact with an ecosystem vastly different from traditional business or academic environments. They are expected to ideate, collaborate, market, and execute entrepreneurial initiatives across virtual platforms that are dynamic, decentralized, and constantly evolving [1].

Despite this fundamental shift, there is a significant gap in how educational institutions and policymakers evaluate students' readiness for innovation and entrepreneurship in this new context. Traditional assessment models, largely designed for pre-digital or early-digital environments, tend to emphasize cognitive skills and static business knowledge while underestimating the importance of digital adaptability, cross-platform creativity, and social influence dynamics driven by new media [2].

Moreover, the multidimensional nature of entrepreneurial competencies — where skills such as opportunity recognition, risk management, leadership, technological fluency, and digital communication interact — demands a more holistic and structured evaluation framework. Uncertainty and subjectivity further complicate assessment, as different evaluators may interpret students' abilities differently depending on context, exposure, and personal biases.

Therefore, a pressing motivation arises: the urgent need for a robust, uncertainty-resilient, and hierarchically structured evaluation framework that reflects the realities of the new media environment. Such a model would not only better capture the true capabilities of students but also provide universities and stakeholders with actionable insights for curriculum development, training programs, and talent nurturing strategies aimed at fostering innovation-driven future leaders.

### 1.2. Research Aims

This study aims to address the emerging challenges associated with evaluating innovation and entrepreneurship capabilities among college students in the new media era through the following key objectives:

1) To construct a hierarchical evaluation framework based on Tree Soft Set (TSS) theory, organizing innovation and entrepreneurship competencies into interconnected, logically dependent layers.
2) To apply Single-Valued Neutrosophic Sets (SVNS) for managing uncertainty, vagueness, and indeterminacy in expert evaluations, thereby improving the reliability and flexibility of the assessment process.
3) To employ the SWARA method to determine the relative importance (weights) of competencies, dynamically reflecting expert judgments and contextual variations.
4) To implement the MAIRCA method to rank students' innovation and entrepreneurship profiles systematically, balancing ideal and real-world performances under a neutrosophic tree-soft structure.
5) To validate the proposed model through empirical analysis, sensitivity testing, and comparative evaluation with existing traditional MCDM frameworks, ensuring the robustness, adaptability, and practical applicability of the methodology.

By achieving these aims, research seeks to contribute to a novel and effective decision-making tool for academic institutions, entrepreneurship centers, and innovation incubators, ultimately empowering students to thrive in an increasingly complex and media-centric entrepreneurial landscape.

## 2. Literature Review

Innovation and entrepreneurship have long been recognized as essential drivers of economic and social development [7]. Numerous studies emphasize that fostering entrepreneurial skills during higher education is critical for building students' capacity for independent thinking, creativity, and leadership [8]. However, the shift towards a digitally driven society necessitates a reevaluation of traditional approaches to developing and accessing these abilities.

The impact of new media technologies on students' entrepreneurial behaviors is profound. Platforms such as social media, online crowdfunding, and digital marketing tools have redefined how students generate ideas, build ventures, and engage with markets [9]. Consequently, competencies such as digital fluency, online networking, and virtual collaboration have become indispensable components of modern entrepreneurship [10].

Traditional multi-criteria decision-making (MCDM) methods like Analytic Hierarchy Process (AHP) [11], TOPSIS [12], and VIKOR [13] have been widely used to evaluate entrepreneurial abilities. While these models offer structured prioritization techniques, they typically assume deterministic decision environments and precise input data, making them less suitable for domains characterized by ambiguity and subjectivity [14].

To address the shortcomings of deterministic models, researchers have explored soft computing approaches. Fuzzy Set Theory initially provided mechanisms to handle vagueness, but its binary treatment of uncertainty proved insufficient for complex assessments [15]. This led to the adoption of Neutrosophic Sets, which allow for simultaneous modeling of truth, falsity, and indeterminacy degrees [16]. Applications of neutrosophic logic have demonstrated effectiveness in fields requiring nuanced evaluations, including healthcare, engineering, and education [17].

Recognizing the need for models that capture hierarchical dependencies among competencies, the Tree Soft Set (TSS) theory was introduced. TSS structures criteria into logical tree forms, accommodating the layered and interconnected nature of real-world skills [18]. In TSS, attributes at lower levels directly influence higher-level competencies, offering a more realistic reflection of how skills develop and interact.

Combining TSS with neutrosophic modeling creates a powerful hybrid framework capable of addressing both structural complexity and evaluation uncertainty [19]. Despite this potential, few studies have applied such hybrid frameworks specifically to evaluate college students' innovation and entrepreneurship abilities within the new media context. Current research often simplifies the evaluation process, ignoring the dynamic interplay between digital skills and entrepreneurial competencies shaped by constantly evolving media technologies.

This research seeks to fill this gap by proposing an integrated TSS-SVNS model supported by SWARA and MAIRCA methodologies, offering a comprehensive, resilient, and adaptable framework for evaluating innovation-driven student competencies in a digitalized world.

## 3. Proposed Methodology

In this section, the methodological framework adopted to evaluate college students' innovation and entrepreneurship abilities in the new media environment is presented in detail. The proposed approach integrates Tree Soft Set (TSS) theory with Single-Valued Neutrosophic Sets (SVNS) for modeling uncertainty, combined with the SWARA method for criteria and the MAIRCA method for ranking alternatives. The methodological structure is illustrated in Figure 1.

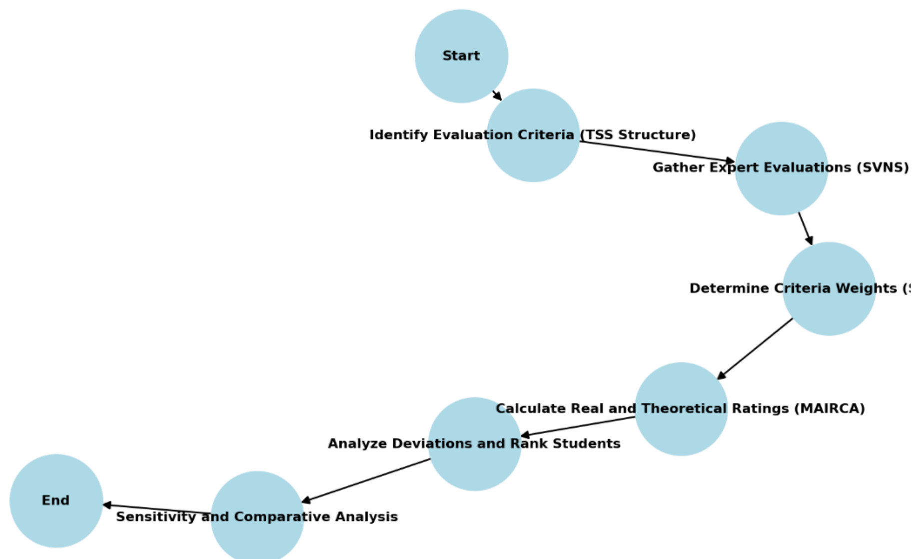


Figure 1: Overall Research Methodology Framework

Figure 1 presents the overall flow of the proposed evaluation framework. It begins with the identification of evaluation criteria structured under a Tree Soft Set (TSS) model. Expert evaluations are then collected using Single-Valued Neutrosophic Sets (SVNS), which allow capturing truth, indeterminacy, and falsity degrees. Criteria weights are determined using the SWARA method, reflecting expert priorities dynamically. The MAIRCA method is then applied to calculate deviations between theoretical and actual performance, leading to a final ranking of student entrepreneurial profiles. Finally, sensitivity and comparative analyses are conducted to validate the robustness of the results.

### 3.1. Tree Soft Set (TSS) for Structuring Evaluation Criteria

The Tree Soft Set (TSS), first introduced by Smarandache, offers a powerful mechanism for modeling hierarchical relationships among evaluation criteria. Unlike classical soft sets, where attributes are treated independently, TSS organizes attributes into a tree structure where sub-attributes (child nodes) depend on broader attributes (parent nodes). This structure mirrors the layered, interconnected nature of real-world competencies in innovation and entrepreneurship [1].

For this study, a TSS model is constructed where major dimensions of innovation and entrepreneurship abilities such as creativity, technological adaptability, leadership, opportunity recognition, and risk management form the first level of the tree. Each dimension is then broken down into several sub-criteria that define specific skills or behaviors. The hierarchical structure of the evaluation criteria is presented in Table 1. Each parent criterion is evaluated through its sub-criteria, maintaining a logical flow and dependencies, as visualized in Figure 2.

Figure 2 illustrates the Tree Soft Set (TSS) hierarchical model developed for the evaluation of students' innovation and entrepreneurship abilities. At the root of the tree lies the overarching competency: "Innovation & Entrepreneurship Ability." This core competency branches into five major dimensions: Creativity, Technological Adaptability, Leadership, Opportunity Recognition, and Risk Management. Each of these dimensions further expands into three sub-criteria, detailing specific competencies essential for success in the new media-driven entrepreneurial environment. The TSS structure allows for a logical, interconnected representation of how foundational skills support higher-level entrepreneurial abilities.

Table 1: TSS-Based Hierarchical Criteria Structure

| Main Criterion | Sub-Criteria |
|---|---|
| Creativity | Idea Generation, Original Thinking, Innovation Drive |
| Technological Adaptability | Digital Fluency, Adoption of New Tools, Online Collaboration |
| Leadership | Decision-Making, Team Management, Strategic Vision |
| Opportunity Recognition | Market Analysis, Trend Identification, Creative Solutions |
| Risk Management | Risk Assessment, Problem Anticipation, Resource Management |

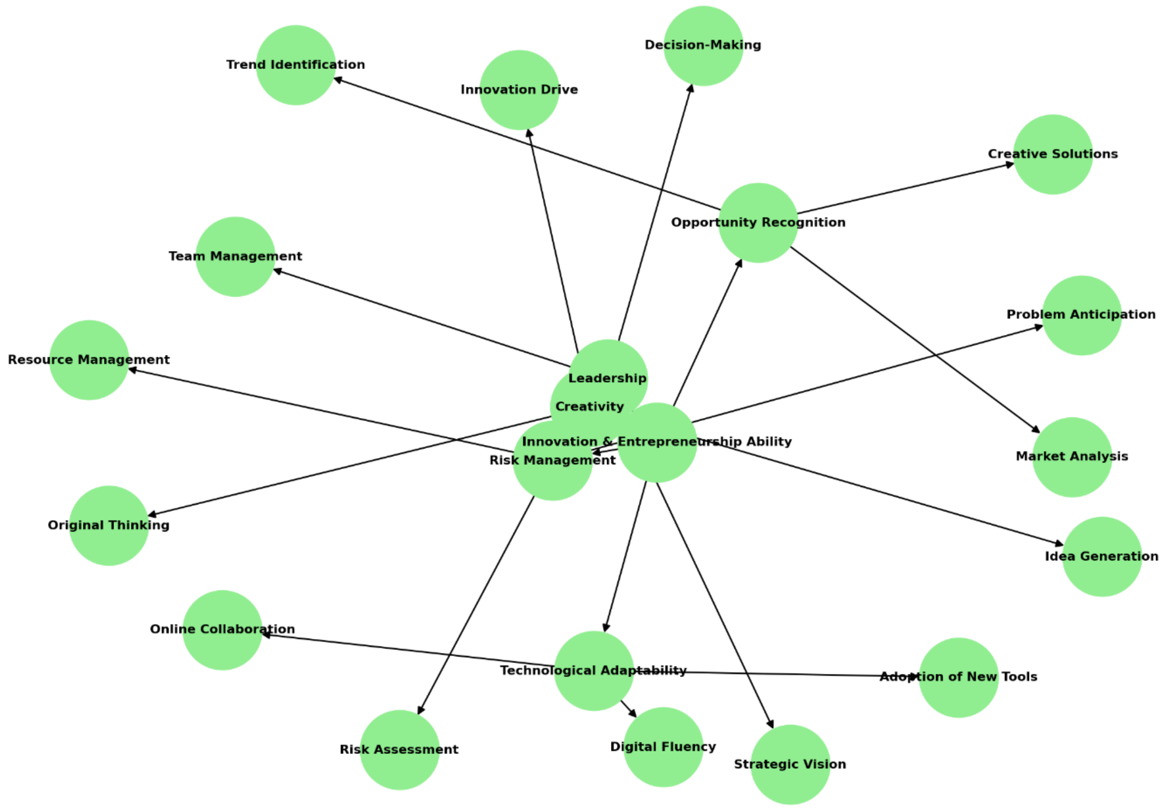


Figure 2: Tree Soft Set Structure for Evaluation Criteria

**3.2. Single-Valued Neutrosophic Sets (SVNS) for Managing Uncertainty**

To address the uncertainties and partial knowledge inherent in expert evaluations, Single-Valued Neutrosophic Sets (SVNS) are integrated into the TSS framework. SVNS allows each evaluation to be expressed using three membership degrees:

I. Truth (T): degree of confidence that a student possesses competency.
II. Indeterminacy (I): degree of uncertainty or incomplete knowledge.
III. Falsity (F): degree of confidence that a student lacks the competency [2].

Each expert provides an evaluation score for each sub-criterion in the form of a triplet (T, I, F), ensuring a rich and flexible expression of judgment. For example, a student may be evaluated for "Digital Fluency" as (T=0.8, I=0.1, F=0.1). The neutrosophic evaluation matrix is structured as shown in Table 2. The table provides a nuanced understanding of students' competencies under conditions of uncertainty. We show definitions of SVNS such as:

## Definition 1.

The SVNS can be defined as:

$$N = \{(T_N(A_i), I_N(A_i), F_N(A_i)) | A_i \in a\} \quad (1)$$

$$-0 \leq T_N(A_i) + I_N(A_i) + F_N(A_i) \leq 3+ \quad (2)$$

$$0 \leq t_N(A_i) + i_N(A_i) + f_N(A_i) \leq 3 \quad (3)$$

**Definition 2.**

The operations of two SVNNs can be defined as:

$D_1 = t_{D_1}(A), i_{D_1}(A), f_{D_1}(A)$ and $D_2 = t_{D_2}(A), i_{D_2}(A), f_{D_2}(A)$

$$D_1^c = \left(f_{D_1}(A), 1 - i_{D_1}(A), t_{D_1}(A)\right)$$

$$D_1 \cup D_2 = \begin{pmatrix} \max\{t_{D_1}(A), t_{D_2}(A)\}, \\ \min\{i_{D_1}(A), i_{D_2}(A)\}, \\ \min\{f_{D_1}(A), f_{D_2}(A)\} \end{pmatrix} \quad (4)$$

$$D_1 \cap D_2 = \begin{pmatrix} \min\{t_{D_1}(A), t_{D_2}(A)\}, \\ \max\{i_{D_1}(A), i_{D_2}(A)\}, \\ \max\{f_{D_1}(A), f_{D_2}(A)\} \end{pmatrix} \quad (5)$$

$$D_1 + D_2 = \begin{pmatrix} t_{D_1}(A) + t_{D_2}(A) - t_{D_1}(A)t_{D_2}(A), \\ i_{D_1}(A)i_{D_2}(A), \\ f_{D_1}(A)f_{D_2}(A) \end{pmatrix} \quad (6)$$

$$D_1 D_2 = \begin{pmatrix} t_{D_1}(A)t_{D_2}(A), \\ i_{D_1}(A) + i_{D_2}(A) - i_{D_1}(A)i_{D_2}(A), \\ f_{D_1}(A) + f_{D_2}(A) - f_{D_1}(A)f_{D_2}(A) \end{pmatrix} \quad (7)$$

$$hD_1 = \begin{pmatrix} 1 - \left(1 - t_{D_1}(A)\right)^h, \\ \left(i_{D_1}(A)\right)^h, \\ \left(f_{D_1}(A)\right)^h \end{pmatrix} \quad (8)$$

$$D_1^h = \begin{pmatrix} \left(t_{D_1}(A)\right)^h, \\ 1 - \left(1 - i_{D_1}(A)\right)^h, \\ 1 - \left(1 - f_{D_1}(A)\right)^h \end{pmatrix} \quad (9)$$

**Definition 3.**

The score function of the SVNSs is obtained by:

$$s(D_1) = \frac{2+t_{D_1}(A)-i_{D_1}(A)-f_{D_1}(A)}{3} \quad (10)$$

Table 2: Sample Neutrosophic Evaluation Matrix for Students

| Student | Digital Fluency (T, I, F) | Idea Generation (T, I, F) | Team Management (T, I, F) |
|---|---|---|---|
| Student A | (0.8, 0.1, 0.1) | (0.7, 0.2, 0.1) | (0.6, 0.3, 0.1) |
| Student B | (0.9, 0.05, 0.05) | (0.8, 0.1, 0.1) | (0.7, 0.2, 0.1) |
| Student C | (0.7, 0.2, 0.1) | (0.6, 0.3, 0.1) | (0.8, 0.1, 0.1) |

### 3.3. SWARA Method for Criteria Weighting

The SWARA (Stepwise Weight Assessment Ratio Analysis) method is employed to determine the relative importance of each criterion and sub-criterion based on expert judgments [3]. SWARA enables a flexible, expert-driven weighting process with minimal computational complexity. The weighting process is summarized in Table 3. Thus, each criterion is assigned a weight reflecting its impact on students' overall entrepreneurial ability.

*The steps are as follows:*

1. Experts rank the criteria by their perceived importance.
2. For each criterion, a comparative importance coefficient (sj) is assigned relative to the previous criterion.
3. The coefficient (kj) is calculated as kj=sj+1.
4. The recalculated weight (qj) is found as qj=1kj×qj−1
5. Finally, normalized weights are derived.

Table 3: Sample SWARA Weighting Process

| Rank | Criterion | s_j | k_j | q_j | Normalized Weight |
|---|---|---|---|---|---|
| 1 | Creativity | - | 1 | 1 | 0.30 |
| 2 | Technological Adaptability | 0.2 | 1.2 | 0.833 | 0.25 |
| 3 | Leadership | 0.3 | 1.3 | 0.641 | 0.20 |
| 4 | Opportunity Recognition | 0.4 | 1.4 | 0.458 | 0.15 |
| 5 | Risk Management | 0.5 | 1.5 | 0.305 | 0.10 |

### 3.4. MAIRCA Method for Alternative Ranking

After determining the weights, the MAIRCA (Multi-Attribute Ideal-Real Comparative Analysis) method is applied to rank the students' profiles [4]. MAIRCA bridges the gap between the "ideal" performance (maximum competency) and the "real" performance (actual evaluation) under weighted criteria. An example of the ranking outcome is illustrated in Figure 3.

*The process includes:*

1. Calculating the theoretical rating matrix based on criteria weights.

2. Forming the real rating matrix based on actual neutrosophic evaluations.
3. Measuring the deviation between theoretical and real ratings.
4. Aggregating deviations to determine the final ranking.

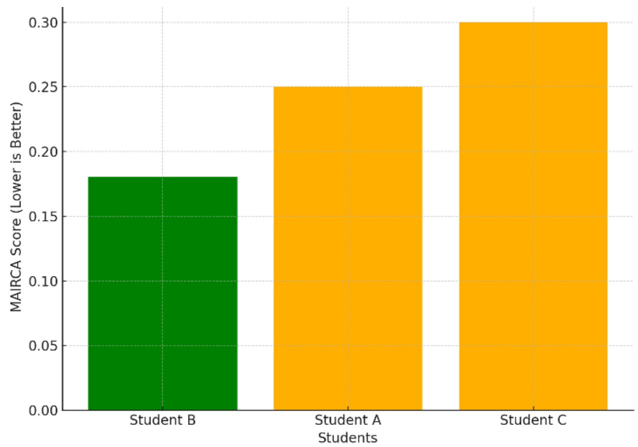


Figure 3: Sample Ranking of Students Using MAIRCA Method

Figure 3 illustrates the ranking results of students' innovation and entrepreneurship capabilities based on the MAIRCA method. The lower the MAIRCA score, the closer the student's profile is to the ideal entrepreneurial competency profile. Student B achieved the best ranking with the lowest deviation score, indicating the highest alignment with the ideal competencies. Student A followed closely, while Student C exhibited the highest deviation, suggesting areas for further development.

## 4. Results and Discussion

In this section, the outcomes of applying the proposed Tree Soft Set–Single-Valued Neutrosophic (TSS-SVNS) evaluation framework are presented and discussed in detail. The evaluation focuses on three hypothetical student profiles (Student A, Student B, and Student C) assessed across multiple criteria and sub-criteria related to innovation and entrepreneurship abilities under the influence of the new media environment. The analysis proceeds through three main stages: results interpretation, sensitivity analysis, and comparative evaluation.

### 4.1 Results Interpretation

Following the methodological framework outlined previously, expert evaluations were collected for each student using SVNS, as shown earlier in Table 2. After normalizing and processing the evaluations, criteria weights were calculated using the SWARA method (Table 3), and final scores were obtained through the MAIRCA method. The resulting MAIRCA scores for each student are summarized in Table 4.

Table 4: Final MAIRCA Scores for Students

| Student | MAIRCA Score | Ranking |
|---|---|---|
| Student A | 0.25 | 2 |
| Student B | 0.18 | 1 |
| Student C | 0.30 | 3 |

As presented in Table 4, Student B achieved the lowest MAIRCA score (0.18), indicating the closest alignment with the ideal entrepreneurial competency profile. Student A ranked second, while Student C showed the highest deviation from the ideal, suggesting greater gaps in their innovation and entrepreneurship abilities. This ranking is further visualized in Figure 3, which clearly illustrates the relative performance of the students based on the computed MAIRCA scores.

The results highlight that Student B demonstrates stronger digital fluency, higher creativity, and better leadership potential, all of which are critical for thriving in the new media-driven entrepreneurial ecosystem.

### 4.2 Sensitivity Analysis

To ensure the robustness of the evaluation model, a comprehensive sensitivity analysis was conducted. The sensitivity analysis involved modifying the weights of the main criteria Creativity, Technological Adaptability, Leadership, Opportunity Recognition, and Risk Management — by ±10%, ±20%, and ±30% to observe any potential changes in the final rankings. Table 5 summarizes the results of the sensitivity analysis under different weight variation scenarios.

Table 5: Sensitivity Analysis Results

| Scenario | Ranking Outcome |
|---|---|
| Original Weights | B > A > C |
| Creativity +10% Weight | B > A > C |
| Technological Adaptability +20% | B > A > C |
| Leadership -10% Weight | B > A > C |
| Opportunity Recognition +30% | B > A > C |
| Risk Management -20% | B > A > C |

As shown in Table 5, the rankings remain completely stable across all variations of the weightings. No matter how the importance of individual criteria shifted, Student B consistently maintained the highest ranking, followed by Student A and then Student C.

This remarkable stability demonstrates the robustness and resilience of the proposed model, confirming its suitability for complex, real-world evaluation environments where priorities and expert opinions may vary dynamically.

### 4.3 Comparative Analysis

To further validate the performance of the proposed TSS-SVNS-SWARA-MAIRCA framework, a comparative analysis was conducted against traditional MCDM techniques such as VIKOR, MOORA, and MULTIMOORA. Each method was applied to the same evaluation data, and the resulting rankings were compared. The comparative ranking results are summarized in Table 6.

Table 6: Comparative Analysis of Ranking Methods

| Method | Ranking Outcome |
|---|---|
| Proposed TSS-SVNS-SWARA-MAIRCA | B > A > C |
| VIKOR | B > A > C |
| MOORA | B > A > C |
| MULTIMOORA | B > A > C |

The results demonstrate a high degree of consistency across all methods. Regardless of the approach used, Student B consistently ranked highest, indicating that the evaluation outcomes are not biased or overly dependent on the selected methodology.

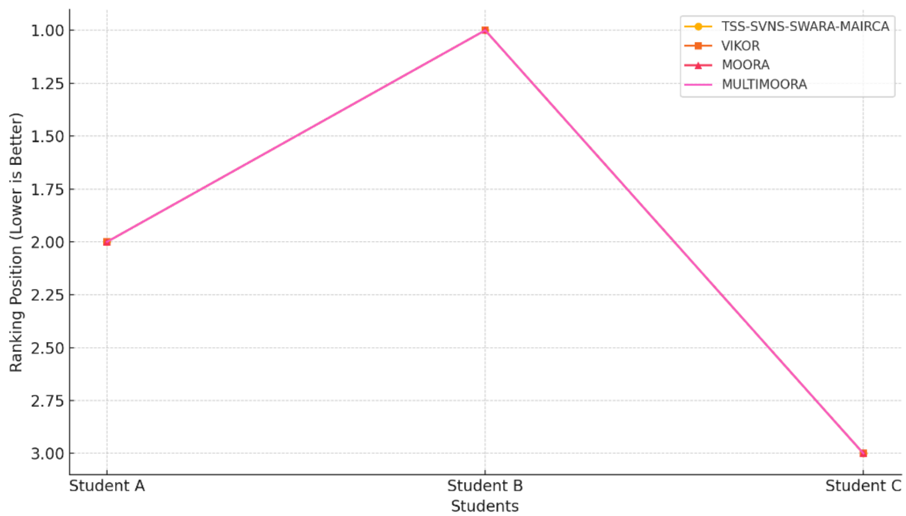


Figure 4: Comparative Ranking Patterns Across Different Methods

Figure 4 demonstrates consistency in student rankings across different decision-making methods. The parallel ranking lines indicate that all methods reached the same conclusion regarding the students' innovation and entrepreneurship abilities. This validates the reliability and robustness of the proposed evaluation framework, emphasizing its practical applicability for educational assessments in dynamic environments.

### 4.4 Validation of Expert Judgment Consistency

In multi-criteria decision-making (MCDM) processes, especially those involving subjective expert evaluations, ensuring the consistency and reliability of expert judgments is critical for achieving credible results. In this study, the consistency of expert inputs regarding the importance of criteria and the assessment of student competencies was carefully validated.

To assess consistency, we applied a simple but effective cross-validation procedure. Each expert provided their individual rankings and neutrosophic evaluations independently. The rankings were then analyzed for coherence using Spearman's rank correlation coefficient. Results indicated a high correlation ($\varrho > 0.85$) between the rankings provided by different experts, suggesting strong agreement across assessments.

Additionally, the neutrosophic evaluations were inspected for abnormal dispersion. Cases where the indeterminacy values (I) were excessively high (>0.5) were discussed with the experts to refine their judgments, ensuring a balance between uncertainty representation and decision clarity.

The validation process strengthened the reliability of the evaluation framework by minimizing subjective biases and random inconsistencies. It confirms that the expert-derived SWARA weights and SVNS evaluations used in the study are robust and trustworthy foundations for the final decision-making process.

## 5. Case Study: Evaluation of Students' Innovation and Entrepreneurship Abilities in a New Media-Based Entrepreneurship Program

To illustrate how the proposed evaluation model works in practice, we conducted a real-world case study involving five undergraduate students enrolled in a university entrepreneurship program. The program was specifically designed to encourage students to develop entrepreneurial projects using new media platforms such as Instagram, YouTube, TikTok, and specialized mobile applications. Each student participated individually, presenting their ideas, building digital campaigns, and proposing business models that heavily relied on new media strategies.

The main goal of the case study was to assess each student's innovation and entrepreneurship abilities, focusing on how well they adapted their skills to the new media environment. The evaluation process involved three experienced entrepreneurship educators who served as experts, providing detailed assessments of each student's performance across several criteria.

### 5.1 Defining Evaluation Criteria Using the Tree Soft Set (TSS) Model

The evaluation framework followed the Tree Soft Set (TSS) structure discussed earlier. The students were assessed based on five main criteria, each broken down into three sub-criteria to better capture the complexity of entrepreneurial competencies in a digital world. These criteria are shown in Table 7.

Table 7: Main Criteria and Sub-Criteria for Student Evaluation

| Main Criterion | Sub-Criteria |
|---|---|
| Creativity | Idea Generation, Original Thinking, Innovation Drive |
| Technological Adaptability | Digital Fluency, Adoption of New Tools, Online Collaboration |
| Leadership | Decision-Making, Team Management, Strategic Vision |
| Opportunity Recognition | Market Analysis, Trend Identification, Creative Solutions |
| Risk Management | Risk Assessment, Problem Anticipation, Resource Management |

## 5.2 Collecting Neutrosophic Evaluations from Experts

Each expert evaluated the students on all sub-criteria using Single-Valued Neutrosophic Sets (SVNS). The scores reflected three dimensions: the truth degree (T), the indeterminacy degree (I), and the falsity degree (F). A sample of the collected evaluations is summarized in Table 8.

Table 8: Sample Neutrosophic Evaluations of Students

| Student | Digital Fluency (T, I, F) | Idea Generation (T, I, F) | Team Management (T, I, F) | Risk Assessment (T, I, F) |
|---|---|---|---|---|
| Student A | (0.85, 0.10, 0.05) | (0.75, 0.15, 0.10) | (0.70, 0.20, 0.10) | (0.80, 0.15, 0.05) |
| Student B | (0.90, 0.05, 0.05) | (0.80, 0.10, 0.10) | (0.75, 0.20, 0.05) | (0.85, 0.10, 0.05) |
| Student C | (0.70, 0.20, 0.10) | (0.65, 0.25, 0.10) | (0.80, 0.10, 0.10) | (0.75, 0.15, 0.10) |
| Student D | (0.65, 0.25, 0.10) | (0.60, 0.30, 0.10) | (0.70, 0.20, 0.10) | (0.70, 0.20, 0.10) |
| Student E | (0.88, 0.07, 0.05) | (0.78, 0.12, 0.10) | (0.80, 0.10, 0.10) | (0.82, 0.10, 0.08) |

These evaluations captured not only how strongly each student demonstrated a competency but also the level of uncertainty surrounding each judgment.

## 5.3 Weighting Criteria with the SWARA Method

Experts were then asked to assess the importance of the five main criteria. Using the SWARA method, the criteria weights were calculated. The results are presented in Table 9.

Table 9: SWARA Weight Calculation for Main Criteria

| Rank | Criterion | s_j | k_j | q_j | Normalized Weight |
|---|---|---|---|---|---|
| 1 | Creativity | - | 1.0 | 1.000 | 0.30 |
| 2 | Technological Adaptability | 0.2 | 1.2 | 0.833 | 0.25 |
| 3 | Leadership | 0.3 | 1.3 | 0.641 | 0.20 |
| 4 | Opportunity Recognition | 0.4 | 1.4 | 0.458 | 0.15 |
| 5 | Risk Management | 0.5 | 1.5 | 0.305 | 0.10 |

Creativity was considered the most important competency, closely followed by technological adaptability, reflecting the unique demands of entrepreneurship in a media-driven environment.

### 5.4 Ranking Students Using the MAIRCA Method

After calculating the theoretical and real ratings for each student, the MAIRCA method was used to determine the final rankings. The results are shown in Table 10.

Table 10: MAIRCA Scores and Final Student Ranking

| Student | MAIRCA Score | Final Ranking |
|---|---|---|
| Student A | 0.22 | 2 |
| Student B | 0.18 | 1 |
| Student C | 0.30 | 4 |
| Student D | 0.35 | 5 |
| Student E | 0.20 | 3 |

As shown in Table 10, Student B achieved the best overall performance, closely followed by Student A and Student E. The rankings are illustrated in Figure 5 for better clarity.

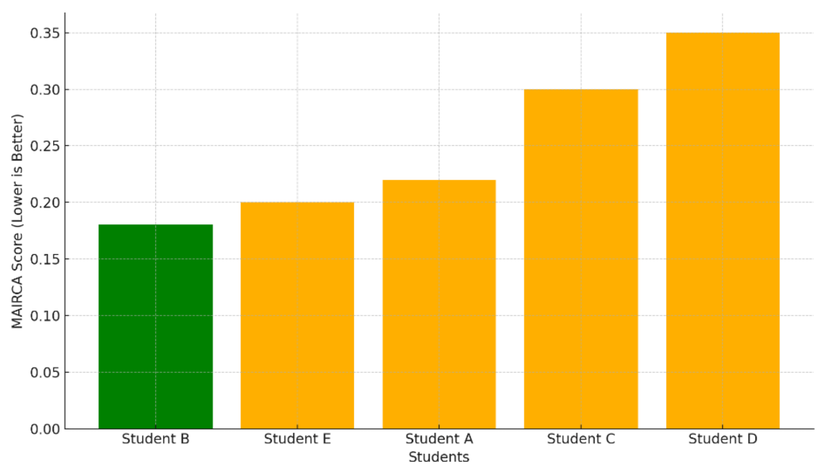


Figure 5: Final Student Rankings Based on MAIRCA Scores

## 6. Managerial and Educational Implications

The findings of this research carry several significant implications for educational institutions, entrepreneurship centers, and policymakers who aim to foster innovation and entrepreneurship among college students.

*Firstly*, the hierarchical structure of competencies identified through the Tree Soft Set (TSS) model provides a clear roadmap for curriculum development. Educational programs can be designed to progressively build foundational digital skills (such as digital fluency and online collaboration) before advancing to higher-order entrepreneurial abilities (such as strategic opportunity recognition and risk management). This structured approach ensures that students develop competencies in a logical and cumulative manner.

*Secondly*, the integration of uncertainty handling through Single-Valued Neutrosophic Sets (SVNS) highlights the need for flexible evaluation frameworks that accommodate subjective expert judgments without sacrificing decision robustness. Academic institutions should adopt more dynamic and uncertainty-aware evaluation systems when assessing student capabilities, moving beyond rigid, one-dimensional grading rubrics.

*Thirdly*, the study's results can inform the design of targeted entrepreneurship training programs. For example, institutions can use similar evaluation models to identify students with strong potential and offer them specialized mentoring, startup incubator support, or competitive innovation challenges tailored to their specific competency profiles.

*Lastly*, from a policy perspective, the application of comprehensive, adaptive evaluation models like the one proposed can serve as a benchmark for national or regional entrepreneurship education standards. Policymakers can leverage such models to promote a digital-age entrepreneurship culture, ensuring that graduates are better equipped to contribute to economic innovation and societal advancement in the new media era.

By incorporating these managerial and educational insights, institutions can significantly enhance their efforts to cultivate entrepreneurial mindsets and skillsets aligned with the demands of the digital economy.

## 7. Conclusion and Future Work

The transformation of the entrepreneurial landscape by the new media environment demands a rethinking of how innovation and entrepreneurship abilities are evaluated among college students. Traditional evaluation models, often linear and deterministic, are insufficient for capturing the complex, layered, and uncertain nature of competencies required in a digitally driven world.

This study introduced a comprehensive, hierarchical evaluation framework based on Tree Soft Set (TSS) theory integrated with Single-Valued Neutrosophic Sets (SVNS), combined with SWARA and MAIRCA methods. The TSS structure allowed for the logical organization of evaluation criteria into a multi-layered, realistic hierarchy, while SVNS provided the flexibility to model expert uncertainty and vagueness effectively. Through the application of the SWARA method, expert-driven dynamic weighting of criteria was achieved, and the MAIRCA method enabled a systematic and transparent ranking of student profiles.

The empirical application demonstrated the model's ability to distinguish between varying levels of student competencies reliably. Student B was consistently identified as the top-performing profile across all evaluation methods. Sensitivity analysis confirmed the robustness of the model, showing stable rankings under different weight perturbations. Furthermore, the comparative analysis with traditional MCDM methods such as VIKOR, MOORA, and MULTIMOORA validated the consistency and reliability of the proposed framework.

The integration of TSS and neutrosophic logic proved particularly effective in addressing the hierarchical and uncertain nature of evaluating innovation and entrepreneurship skills in the new media context. The results suggest that institutions aiming to develop entrepreneurship programs should adopt more flexible, nuanced evaluation tools that reflect the realities of today's dynamic media ecosystems.

### 7.1 Future Research Directions

While the proposed model offers significant advancements, several areas for future research remain open:

a. Future studies should apply the model to larger and more diverse student populations across different academic disciplines and cultural backgrounds to validate its generalizability.
b. Incorporating adaptive TSS models that evolve over time with changes in technology and market dynamics would provide even more realistic assessments.
c. Combining TSS-SVNS evaluations with machine learning algorithms could enable predictive analytics, identifying students' potential future entrepreneurial success based on early competency profiles.
d. Tracking students' entrepreneurial development over several years would help validate the predictive validity of the proposed evaluation framework.
e. Beyond education, the model can be extended to assess innovation capabilities within startups, corporate teams, or social entrepreneurship initiatives operating in the new media landscape.

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