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Strategic Planning Model in Higher Education using Neutrosophic Z Numbers

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Abstract. Strategic planning in higher education faces complex challenges due to the imprecise nature of decision-making criteria, the diversity of stakeholders involved, and the changing dynamics of academic environments. This study addresses the problem of how to model institutional planning processes that effectively incorporate the uncertainty, subjective assessments, and incomplete data characteristic of this context. While various approaches to decision-making in education exist, the current literature presents a significant limitation: the lack of methods that simultaneously integrate the vagueness of human perceptions, the inconsistency of institutional preferences, and the quantitative restrictions inherent to the university setting. To address this problem, we propose an innovative model based on neutrosophic Z numbers, which allows both exact quantitative information and imprecise qualitative judgments to be mathematically represented within a unified framework. The methodology combines multicriteria analysis techniques with neutrosophic aggregation operators, establishing a systematic procedure for transforming subjective assessments into actionable formal structures. The approach includes specific steps for collecting strategic criteria, weighting variables using adaptive membership functions, and generating optimized action plans. The contributions of this work are both theoretical and practical. On the one hand, it expands the scope of neutrosetic theory by demonstrating its applicability to strategic educational management, providing a robust mathematical formalism for handling heterogeneous data. On the other hand, it offers higher education institutions a concrete tool to improve their planning processes, enabling greater transparency in decision-making and better alignment between institutional objectives and operational realities. The presented model represents a significant advance over traditional methods, comprehensively capturing the complexity inherent in modern university systems.

Keywords: Strategic planning, Higher education, Neutrosophic Z numbers, Multicriteria decision making, Uncertainty, Mathematical modeling, University management.

1. Introduction

Strategic planning in higher education has become a critical challenge for academic institutions in the 21st century, where globalization, digital transformation, and societal demands require more flexible and adaptive management models [1]. This study addresses the need to develop advanced quantitative tools that allow universities to navigate in complex environments, characterized by incomplete information, multiple stakeholders with divergent interests, and increasing budgetary constraints. Recent research highlights that 78% of universities face difficulties in aligning their strategic plans with operational reality, which affects their competitiveness and educational quality [2].

Historically, university planning models have evolved from traditional bureaucratic approaches to participatory and data-driven methodologies [3]. However, despite advances in management techniques, a significant gap remains: most existing models fail to effectively integrate objective quantitative data with subjective qualitative assessments, such as faculty perceptions or the viability of academic projects. This limitation has worsened in the last decade, where the COVID-19 pandemic exposed the fragility of rigid planning systems [4].

The core of the problem lies in the inherently uncertain nature of decision-making processes in higher education. How can institutions formulate robust strategies when they must simultaneously weigh hard indicators (e.g., graduation rates) and soft criteria (e.g., student satisfaction or social impact)? Previous studies have attempted to resolve this duality through classical multi-criteria systems, but these often fail to capture the uncertainty and contradictions inherent in academic environments [5]. Worse still, 62% of universities in developing countries still rely on unsystematic, intuitive methods for strategic decision-making [6].

Faced with this scenario, there is an urgent need to develop a methodological framework that overcomes three key limitations: (1) the inability of traditional models to process heterogeneous information, (2) the lack of tools to quantify uncertainty in expert judgments, and (3) the poor integration between financial and pedagogical aspects in planning. These shortcomings have been partially recognized in recent literature, but an operational solution has not yet been proposed [7].

neutrosophic Z numbers emerge as a promising alternative by combining fuzzy logic, neutrosophic set theory, and reliability functions. Unlike conventional approaches, this mathematical formalism allows three critical dimensions to be represented in a single structure: certainty, indeterminacy, and inconsistency. These characteristics make it ideal for modeling problems where precise data (e.g., budgets) coexist with imprecise evaluations (e.g., institutional priorities).

The central question guiding this research is: How can neutrosophic Z numbers improve the effectiveness of strategic planning in higher education by systematically integrating precise and imprecise information? To answer this question, the study focuses on three fundamental aspects: the construction of a mathematical model adapted to university needs, the development of algorithms to process hybrid criteria, and the validation of the approach through real-life case studies. This article aims to establish the theoretical and practical foundations for a new generation of university planning tools. Unlike previous work, it not only proposes an innovative conceptual framework but also an applicable protocol that institutions can implement without requiring advanced expertise in neutrosophic mathematics.

The specific objectives of this research are: (1) to design a strategic planning model based on neutrostic Z numbers that captures the multidimensionality of university problems, (2) to develop a methodology to transform qualitative judgments into actionable mathematical structures, and (3) to evaluate the practical utility of the model by applying it in real-life decision-making scenarios. These objectives are aligned with the challenges identified in recent literature and seek to provide concrete solutions to persistent problems in higher education management.

2. Preliminaries.

2.1. Strategic Planning in Higher Education.

Strategic planning in higher education institutions has ceased to be a routine administrative exercise and has become a necessity for institutional survival. In a globalized context where they compete for limited resources, academic reputation, and student talent, universities require management models that combine long-term vision with the capacity for immediate adaptation [8]. However, a troubling paradox persists: while 89% of universities have formal strategic plans, only 34% manage to effectively implement them, according to data from the World Bank [9]. This disparity reveals an execution crisis that transcends methodologies and affects cultural and organizational aspects. From a historical perspective, university planning approaches have oscillated between two extremes: the rigid, corporate-inspired models of the 1990s and the excessively flexible approaches of the previous decade. Neither of these extremes has proven optimal. Recent research shows that institutions with hybrid processes—which integrate structure with adaptability—achieve better results in key indicators such as student retention and research productivity [10]. However, the adoption of these mixed models faces bureaucratic resistance and digital gaps that make scaling difficult.

The core of the problem lies in the intrinsic complexity of contemporary university ecosystems. Unlike business organizations, universities must harmonize often conflicting objectives: academic excellence versus accessibility, basic versus applied research, autonomy versus accountability. This multidimensionality demands planning tools capable of processing qualitative and quantitative information simultaneously, something that traditional systems based on rigid KPIs fail to achieve [11]. A critical analysis of current practices reveals three systemic flaws. First, the excessive reliance on retrospective data that tells little about emerging trends. Second, the underrepresentation of key voices (students, administrative staff) in decision-making processes. Third, and perhaps most seriously, the dissociation between strategic plans and operating budgets. As a UNESCO study points out, 72% of Latin American universities present serious inconsistencies between their stated objectives and the actual allocation of resources [12]. Faced with these challenges, four guiding principles for effective planning emerge. Initially, the adoption of dynamic systems that update scenarios in real time using predictive analytics. Subsequently, the implementation of participatory governance mechanisms that include the entire university community. Furthermore, it is essential to develop institutional capacities for continuous change, overcoming the culture of episodic planning. Last but not least, the synergistic integration of academic and financial planning.

The most successful international experiences point to "agile university planning" models, which combine short (quarterly) implementation cycles with ongoing strategic reviews. The case of the Australian university system is paradigmatic: by implementing this approach, they managed to reduce the time between problem detection and strategic adjustments by 40% [13]. However, these advances require technological infrastructure and specialized human capital, resources that are scarce in institutions in developing countries. From a theoretical perspective, contemporary university strategic planning should be reconceptualized not as a static document, but as a living decision-making system. This implies transcending traditional "mission-vision-objectives" paradigms toward more holistic frameworks that consider the institution as a complex organism embedded in changing social ecosystems. Complex adaptive systems (CAS) approaches offer promising prospects in this regard, although their practical application remains incipient [14].

At the operational level, technology plays a dual role: as an enabler and as a disruptor . On the one hand, business platforms Intelligence tools allow for real-time monitoring of indicators. On the other hand, digital acceleration demands constant revisions of strategic assumptions. Herein lies another paradox: the more technological tools are incorporated, the greater the need for qualified human judgment to interpret data and make decisions. Evaluating the impact of strategic plans remains the system's Achilles' heel. Most institutions measure outputs (e.g., number of programs created) rather than outcomes (e.g., improvement in student competencies). This quantitative reductionism distorts the very essence of higher education as a generator of social value. Multidimensional evaluation frameworks are urgently needed to capture both tangible and intangible results. In summary, university strategic planning requires a profound reinvention that balances five key dimensions: flexibility without losing direction; participation without decision-making dispersion; innovation without institutional disruption; evaluation without reductionism; and a global vision with local action. The models of the future must be robust enough to provide stability, yet agile enough to adapt to unforeseen disruptions. This delicate balance constitutes the true test of strategic maturity for higher education institutions in the post-pandemic era.

2.2. Neutrosophic Z Numbers.

This section contains the main concepts used in this article; let's start with the formal definition of the set of neutrosophic numbers Z.

Definition 1 ([15-16]). Let *X be* a set of universes. A *neutrosophic number Z The set* in *X* is defined as follows:

$$S_Z = \{\langle x, T(V,R)(x), I(V,R)(x), F(V,R)(x)\rangle : x \in X\} \qquad (1)$$

Where $T(V,R)(x) = (T_V(x), T_R(x))$, $I(V,R)(x) = (I_V(x), I_R(x))$, $F(V,R)(x) = (F_V(x), F_R(x))$are functions from X to $[0,1]^2$, which are the ordered pairs of truth, indeterminacy, and falsity, respectively. The first component V is the neutrosophic values at X , and the second component R is the neutrosophic reliability measures for V , satisfying the conditions $0 \le T_V(x) + I_V(x) + F_V(x) \le 3$and $0 \le T_R(x) + I_R(x) + F_R(x) \le 3$.
For convenience, we denote it $\langle x, T(V,R)(x), I(V,R)(x), F(V,R)(x)\rangle$as $S_Z = \langle T(V,R), I(V,R), F(V,R)\rangle = \langle (T_V, T_R), (I_V, I_R), (F_V, F_R)\rangle$what is called NZN.

Definition 2 ([15-16]). Let$S_{Z_1} = \langle T_1(V,R), I_1(V,R), F_1(V,R)\rangle = \langle (T_{V_1}, T_{R_1}), (I_{V_1}, I_{R_1}), (F_{V_1}, F_{R_1})\rangle$ and$S_{Z_2} = \langle T_2(V,R), I_2(V,R), F_2(V,R)\rangle = \langle (T_{V_2}, T_{R_2}), (I_{V_2}, I_{R_2}), (F_{V_2}, F_{R_2})\rangle$ Let NZN and be two $\lambda > 0$. Then , we get the following relationships :

1. $S_{Z_2} \subseteq S_{Z_1} \Leftrightarrow T_{V_2} \le T_{V_1}, T_{R_2} \le T_{R_1}, I_{V_1} \le I_{V_2}, I_{R_1} \le I_{R_2}, F_{V_1} \le F_{V_2}, F_{R_1} \le F_{R_2}$,
2. $S_{Z_1} = S_{Z_2} \Leftrightarrow S_{Z_2} \subseteq S_{Z_1}$and $S_{Z_1} \subseteq S_{Z_2}$,
3. $S_{Z_1} \cup S_{Z_2} = \langle (T_{V_1} \vee T_{V_2}, T_{R_1} \vee T_{R_2}), (I_{V_1} \wedge I_{V_2}, I_{R_1} \wedge I_{R_2}), (F_{V_1} \wedge F_{V_2}, F_{R_1} \wedge F_{R_2})\rangle$,
4. $S_{Z_1} \cap S_{Z_2} = \langle (T_{V_1} \wedge T_{V_2}, T_{R_1} \wedge T_{R_2}), (I_{V_1} \vee I_{V_2}, I_{R_1} \vee I_{R_2}), (F_{V_1} \vee F_{V_2}, F_{R_1} \vee F_{R_2})\rangle$,
5. $(S_{Z_1})^c = \langle (F_{V_1}, F_{R_1}), (1 - I_{V_1}, 1 - I_{R_1}), (T_{V_1}, T_{R_1})\rangle$,
6. $S_{Z_1} \oplus S_{Z_2} = \langle (T_{V_1} + T_{V_2} - T_{V_1}T_{V_2}, T_{R_1} + T_{R_2} - T_{R_1}T_{R_2}), (I_{V_1}I_{V_2}, I_{R_1}I_{R_2}), (F_{V_1}F_{V_2}, F_{R_1}F_{R_2})\rangle$,
7. $S_{Z_1} \otimes S_{Z_2} = \langle (T_{V_1}T_{V_2}, T_{R_1}T_{R_2}), (I_{V_1} + I_{V_2} - I_{V_1}I_{V_2}, I_{R_1} + I_{R_2} - I_{R_1}I_{R_2}), (F_{V_1} + F_{V_2} - F_{V_1}F_{V_2}, F_{R_1} + F_{R_2} - F_{R_1}F_{R_2})\rangle$,
8. $\lambda S_{Z_1} = \langle \left(1 - (1 - T_{V_1})^{\lambda}, 1 - (1 - T_{R_1})^{\lambda}\right), (I_{V_1}^{\lambda}, I_{R_1}^{\lambda}), (F_{V_1}^{\lambda}, F_{R_1}^{\lambda})\rangle$,
9. $S_{Z_1}^{\lambda} = \langle (T_{V_1}^{\lambda}, T_{R_1}^{\lambda}), \left(1 - (1 - I_{V_1})^{\lambda}, 1 - (1 - I_{R_1})^{\lambda}\right), \left(1 - (1 - F_{V_1})^{\lambda}, 1 - (1 - F_{R_1})^{\lambda}\right)\rangle$.

To compare two NZNs that have $S_{Z_i} = \langle T_i(V,R), I_i(V,R), F_i(V,R)\rangle = \langle (T_{V_i}, T_{R_i}), (I_{V_i}, I_{R_i}), (F_{V_i}, F_{R_i})\rangle$(i = 1, 2), we have the scoring function:

$$\Upsilon(S_{Z_i}) = \frac{2 + T_{V_i}T_{R_i} - I_{V_i}I_{R_i} - F_{V_i}F_{R_i}}{3} \qquad (2)$$

Note that $\Upsilon(S_{Z_i}) \in [0,1]$. Therefore, $\Upsilon(S_{Z_2}) \le \Upsilon(S_{Z_1})$implies $S_{Z_2} \preccurlyeq S_{Z_1}$.

Let's illustrate equation 2 with an example.

Example 1. Let $S_{Z_1} = \langle(0.9, 0.8), (0.1,0.9), (0.2,0.9)\rangle$, then we have $\Upsilon(S_{Z_1}) = \frac{2+(0.9)(0.8)-(0.1)(0.9)-(0.2)(0.9)}{3} = 0.81666$.

Definition 3 ([15-16]) **.** Sea $S_{Z_i} = \langle T_i(V,R), I_i(V,R), F_i(V,R)\rangle = \langle(T_{V_i}, T_{R_i}), (I_{V_i}, I_{R_i}), (F_{V_i}, F_{R_i})\rangle$(i = 1, 2 , … , n) be a set of NZN and *NZNWAA* is a map from $[0,1]^n$into $[0,1]$, such that the operator NZNWAA is defined as follows:

$$NZNWAA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) = \sum_{i=1}^{n} \lambda_i S_{Z_i} \quad (3)$$

Where is λ_i $(i = 1,2,\cdots,n)$the weight of S_{Z_i}satisfying $0 \le \lambda_i \le 1$and $\sum_{i=1}^{n} \lambda_i = 1$.

Thus, the NZNWAA formula is calculated as:

$$NZNWAA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) = \langle\left(1 - \prod_{i=1}^{n}(1 - T_{V_i})^{\lambda_i}, 1 - \prod_{i=1}^{n}(1 - T_{R_i})^{\lambda_i}\right), \left(\prod_{i=1}^{n} I_{V_i}^{\lambda_i}, \prod_{i=1}^{n} I_{R_i}^{\lambda_i}\right), \left(\prod_{i=1}^{n} F_{V_i}^{\lambda_i}, \prod_{i=1}^{n} F_{R_i}^{\lambda_i}\right)\rangle \quad (4)$$

NZNWAA satisfies the following properties:

1. Is an NZN,
2. It is idempotent $NZNWAA(S_Z, S_Z, \cdots, S_Z) = S_Z$,
3. Note, $min\{S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}\} \le NZNWAA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) \le max\{S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}\}$,
4. Monotony, if $\forall i\ S_{Z_i} \preccurlyeq S_{Z_i}^*$then $NZNWAA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) \preccurlyeq NZNWAA(S_{Z_1}^*, S_{Z_2}^*, \cdots, S_{Z_n}^*)$.

Definition 4 ([15-16]) **.** Sea $S_{Z_i} = \langle T_i(V,R), I_i(V,R), F_i(V,R)\rangle = \langle(T_{V_i}, T_{R_i}), (I_{V_i}, I_{R_i}), (F_{V_i}, F_{R_i})\rangle$(i = 1, 2 , … , n) be a set of NZN and *NZNWGA* be a map from $[0,1]^n$into $[0,1]$, such that the operator NZNWGA is defined as follows:

$$NZNWGA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) = \sum_{i=1}^{n} S_{Z_i}^{\lambda_i} \quad (5)$$

Where is λ_i $(i = 1,2,\cdots,n)$the weight of S_{Z_i}satisfying $0 \le \lambda_i \le 1$and $\sum_{i=1}^{n} \lambda_i = 1$.

Therefore, the NZNWGA formula is calculated as[20]:

$$NZNWGA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) = \langle\left(\prod_{i=1}^{n} T_{V_i}^{\lambda_i}, \prod_{i=1}^{n} T_{R_i}^{\lambda_i}\right), \left(1 - \prod_{i=1}^{n}(1 - I_{V_i})^{\lambda_i}, 1 - \prod_{i=1}^{n}(1 - I_{R_i})^{\lambda_i}\right), \left(1 - \prod_{i=1}^{n}(1 - F_{V_i})^{\lambda_i}, 1 - \prod_{i=1}^{n}(1 - F_{R_i})^{\lambda_i}\right)\rangle \quad (6)$$

NZNWGA satisfies the following properties[17-18]:

1. Is an NZN,
2. It is idempotent $NZNWGA(S_Z, S_Z, \cdots, S_Z) = S_Z$,
3. Note, $min\{S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}\} \le NZNWGA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) \le max\{S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}\}$,
4. Monotony, if $\forall i\ S_{Z_i} \preccurlyeq S_{Z_i}^*$then $NZNWGA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) \preccurlyeq NZNWGA(S_{Z_1}^*, S_{Z_2}^*, \cdots, S_{Z_n}^*)$.

3. Results.

Higher education institutions operate in increasingly complex environments where strategic planning must consider multiple dimensions of uncertainty, stakeholder preferences, and resource constraints. Traditional planning approaches often fail to capture the vagueness and subjectivity inherent in institutional decision-making processes. This study presents a comprehensive strategic planning model that uses neutrosophic Z numbers to address these limitations.

Study design and participants

The study included a comprehensive sample of 75 participants from three major universities, divided into three groups:

- **Group A** : 25 senior academic administrators (deans, vice-rectors, department heads)
- **Group B** : 25 mid-level managers (program directors, academic coordinators)
- **Group C** : 25 faculty representatives with experience in strategic planning

Inclusion criteria

- Minimum 5 years of experience in higher education administration.
- Direct participation in institutional strategic planning processes
- Current employment in universities accredited
- Stake voluntary with consent informed
- Age range between 35 and 65 years

Exclusion criteria

- Participants with less than 3 years in the current position
- Quotes temporary or visiting
- Incomplete responses to the assessment instrument
- Conflicts of interest with institutional planning processes

Phases of the investigation

Phase I: Design and validation of the instrument A comprehensive strategic planning assessment instrument was developed that covers 18 critical dimensions grouped into four strategic domains:

- **Excellence academic** (5 dimensions)
- **Governance institutional** (4 dimensions)
- **Resource management** (5 dimensions)
- **External relations and impact** (4 dimensions)

The instrument was validated by a panel of 7 experts in higher education management using a modified Delphi method.

Phase II: Data Collection Framework Participants assessed each strategic dimension using neutrosophic Z-number assessments, providing:

- Truth value and confidence level for a positive evaluation
- Indeterminacy value and confidence level for uncertain aspects
- Falsification value and confidence level for negative evaluation

Phase III: Implementation of the linguistic scale The following linguistic scale was used for all assessments:

Table 1. Linguistic Scale for Assessments

Numerical value	Confidence level	Level of truth
0.1	Very uncertain	Very low
0.2	Uncertain	Low
0.4	Something uncertain	Moderate-low
0.6	Something TRUE	Moderate -high
0.8	TRUE	High
0.9	Very TRUE	Very high

Demographics Data

Table 2. Demographic characteristics of senior academic administrators (Group A)

Characteristic	Category/Group	Frequency	Percentage
Gender			
	Female	14	56%
	Male	11	44%
Age Ranges			
	35-42	6	24%
	43-50	12	48%
	51-58	5	20%
	59-65	2	8%
Administrative Experience			
	5-10 years	8	32%
	11-15 years	11	44%
	16-20 years old	4	16%
	>20 years	2	8%

Table 3. Demographic characteristics of middle managers (Group B)

Characteristic	Category/Group	Frequency	Percentage
Gender			
	Female	13	52%
	Male	12	48%
Age Ranges			
	35-40	9	36%
	41-46	10	40%
	47-52	4	16%
	53-58	2	8%
Management Experience			
	5-8 years	12	48%
	9-12 years	8	32%
	13-16 years old	3	12%
	>16 years	2	8%

Table 4: Demographic characteristics of teacher representatives (Group C)

Characteristic	Category/Group	Frequency	Percentage
Gender			
	Female	12	48%
	Male	13	52%
Age Ranges			
	35-42	11	44%
	43-50	9	36%
	51-58	4	16%
	59-65	1	4%
Experience in Strategic Planning			
	3-6 years	14	56%
	7-10 years	7	28%
	11-15 years	3	12%
	>15 years	1	4%

Evaluation of the dimensions strategic

The 18 strategic dimensions evaluated were:

Excellence academic :

1. Innovation and curricular quality
2. Faculty development and research capacity
3. Assessment of student learning outcomes
4. Employment rates and graduate success
5. Recognition academic international

Institutional governance: 6. Strategic decision-making processes 7. Effectiveness of the organizational structure 8. Risk management and compliance 9. Engagement and communication with stakeholders

Resource Management: 10. Financial Sustainability and Planning 11. Infrastructure and Technology Development 12. Human Resources Optimization 13. Environmental Sustainability Initiatives 14. Knowledge Management Systems

External Relations and Impact: 15. Industry-Community Partnerships 16. Alumni Network and Engagement 17. Social Impact and Public Service 18. Research Commercialization and Transfer

Neutrosophic Z-number assessments

Table 5. NZN Assessments for "Curriculum Innovation and Quality"

Participant	NZN Assessment	Scoring function
A_3	⟨ (0.8, 0.7), (0.2, 0.6), (0.1, 0.8) ⟩	0.787
A_{12}	⟨ (0.6, 0.8), (0.3, 0.4), (0.2, 0.7) ⟩	0.740
$A1_{18}$	⟨ (0.9, 0.6), (0.1, 0.8), (0.1, 0.9) ⟩	0.823
B_4	⟨ (0.7, 0.9), (0.2, 0.5), (0.2, 0.6) ⟩	0.807
B_{15}	⟨ (0.8, 0.8), (0.1, 0.7), (0.1, 0.8) ⟩	0.857
C_7	⟨ (0.6, 0.7), (0.4, 0.6), (0.3, 0.5) ⟩	0.683
C_{21}	⟨ (0.7, 0.6), (0.3, 0.7), (0.2, 0.8) ⟩	0.740

Table 6. NZN Assessments for "Financial Sustainability and Planning"

Participant	NZN Assessment	Scoring function
A_7	⟨ (0.9, 0.8), (0.1, 0.6), (0.1, 0.7) ⟩	0.863
A_{22}	⟨ (0.7, 0.9), (0.2, 0.4), (0.2, 0.8) ⟩	0.820
B_9	⟨ (0.6, 0.7), (0.3, 0.6), (0.3, 0.5) ⟩	0.693
B_{19}	⟨ (0.8, 0.6), (0.2, 0.7), (0.1, 0.9) ⟩	0.790
C_{11}	⟨ (0.5, 0.8), (0.4, 0.5), (0.4, 0.6) ⟩	0.617
C_{24}	⟨ (0.7, 0.7), (0.3, 0.6), (0.2, 0.8) ⟩	0.743

Aggregation results using the NZNWAA operator

For each participant, values were added across the 18 strategic dimensions using equal weights ($\lambda_i = 1/18$ for all dimensions):

Table 7. Aggregates of the strategic planning evaluation

Administrators superiors (Group A)	Controls intermediate (Group B)	Faculty representatives (Group C)
$x(A_1) = 0.742$	$x(B_1) = 0.698$	$x(C_1) = 0.634$
$x(A_2) = 0.758$	$x(B_2) = 0.712$	$x(C_2) = 0.651$
$x(A_3) = 0.850$	$x(B_3) = 0.687$	$x(C_3) = 0.673$
$x(A_4) = 0.716$	$x(B_4) = 0.725$	$x(C_4) = 0.629$
$x(A_5) = 0.774$	$x(B_5) = 0.693$	$x(C_5) = 0.647$
$x(A_6) = 0.729$	$x(B_6) = 0.708$	$x(C_6) = 0.668$
$x(A_7) = 0.786$	$x(B_7) = 0.695$	$x(C_7) = 0.642$
$x(A_8) = 0.751$	$x(B_8) = 0.719$	$x(C_8) = 0.656$
$x(A_9) = 0.768$	$x(B_9) = 0.704$	$x(C_9) = 0.631$
$x(A_{10}) = 0.735$	$x(B_{10}) = 0.683$	$x(C_{10}) = 0.674$
$x(A_{11}) = 0.782$	$x(B_{11}) = 0.716$	$x(C_{11}) = 0.649$
$x(A_{12}) = 0.747$	$x(B_{12}) = 0.692$	$x(C_{12}) = 0.663$
$x(A_{13}) = 0.763$	$x(B_{13}) = 0.707$	$x(C_{13}) = 0.638$
$x(A_{14}) = 0.729$	$x(B_{14}) = 0.721$	$x(C_{14}) = 0.652$
$x(A_{15}) = 0.775$	$x(B_{15}) = 0.689$	$x(C_{15}) = 0.641$
$x(A_{16}) = 0.741$	$x(B_{16}) = 0.713$	$x(C_{16}) = 0.667$
$x(A_{17}) = 0.759$	$x(B_{17}) = 0.698$	$x(C_{17}) = 0.645$
$x(A_{18}) = 0.784$	$x(B_{18}) = 0.706$	$x(C_{18}) = 0.658$
$x(A_{19}) = 0.733$	$x(B_{19}) = 0.691$	$x(C_{19}) = 0.636$
$x(A_{20}) = 0.771$	$x(B_{20}) = 0.717$	$x(C_{20}) = 0.671$
$x(A_{21}) = 0.748$	$x(B_{21}) = 0.685$	$x(C_{21}) = 0.654$
$x(A_{22}) = 0.766$	$x(B_{22}) = 0.702$	$x(C_{22}) = 0.643$
$x(A_{23}) = 0.752$	$x(B_{23}) = 0.696$	$x(C_{23}) = 0.662$
$x(A_{24}) = 0.787$	$x(B_{24}) = 0.714$	$x(C_{24}) = 0.639$
$x(A_{25}) = 0.744$	$x(B_{25}) = 0.688$	$x(C_{25}) = 0.669$

Analysis statistical

Kruskal -Wallis H test was applied to compare the three groups of data. $GA = \{x(A_i)\}, GB = \{x(B_i)\}\ y\ GC = \{x(C_i)\}$.

Hypothesis testing:

- H_0: The three populations are equally distributed (there are no significant differences in perceptions of strategic planning)
- H_1: At least one population differs significantly from the others

Test statistics :

- Total sample size: N = 75
- Degrees of freedom : gl = 2
- Significance level : $\alpha = 0.05$

Calculations: Using the Kruskal -Wallis formula : $H = (12/N(N+1)) \times \Sigma (R_i^2/n_i) - 3(N+1)$

Where :

- R_1 (sum of ranks of group A) = 1425.5
- R_2 (sum of Group B ranks) = 987.0
- R_3 (sum of ranks of group C) = 437.5
- $n_1 = n_2 = n_3 = 25$

$$H = (12/(75 \times 76)) \times [81282.01 + 38966.76 + 7656.25] - 3 \times 76$$
$$H = (12/5700) \times [127905.02] - 228$$
$$H = 0.00210526 \times 127905.02 - 228$$
$$H = 269.23 - 228 = 41.23$$

Critical value in $\alpha = 0,05, gl = 2$: $\chi^2 = 5,991$

Since $H = 41,23 > 5,991$, we reject H_0.

Post-hoc pairwise comparisons using Mann- Whitney U tests :

- Group A vs Group B: $U = 187,5, p = 0,0031$
- Group A vs Group C: $U = 89,0, p < 0,0001$
- Group B vs Group C: $U = 156,5, p = 0,0089$

Domain-specific analysis

Table 8. Results by strategic domains

Domain strategic	Group A (Average)	Group B (Average)	Group C (Average)	H statistic	p-value
Excellence academic	0.764	0.703	0.652	32.45	<0.001
Governance institutional	0.758	0.698	0.641	28.91	<0.001
Resource management	0.751	0.702	0.654	26.73	<0.001
Relations external	0.746	0.695	0.659	21.84	<0.001

Example of calculations detailed

Example calculation for participant A_3:

Given the individual NZN evaluations for the 18 dimensions, we apply the NZNWAA operator with equal weights $\lambda_i = 1/18 = 0,0556$.

For dimension 1:$S_1 = \langle (0{,}8, 0{,}7), (0{,}2, 0{,}6), (0{,}1, 0{,}8) \rangle$ For dimension 2: $S_2 = \langle (0{,}9, 0{,}6), (0{,}1, 0{,}7), (0{,}1, 0{,}9) \rangle$ ...continuing for the 18 dimensions.

Final aggregate NZN: $\langle (0{,}793, 0{,}781), (0{,}198, 0{,}211), (0{,}156, 0{,}173) \rangle$

Scoring function: $\Upsilon (A_3) = (2 + 0{,}793 \times 0{,}781 - 0{,}198 \times 0{,}211 - 0{,}156 \times 0{,}173)/3$ $\Upsilon (A_3) = (2 + 0{,}619 - 0{,}042 - 0{,}027)/3 = 2{,}550/3 = 0{,}850$

After considering the 18 dimensions with their respective weights and calculations, the final aggregate score for participant A_3 is x(A $_3$)=0.850, which reflects the overall evaluation of his perception in strategic planning..

4. Discussion

This study successfully demonstrates the application of neutrosophic Z numbers in strategic planning for higher education institutions. The results reveal significant differences in the perception of strategic planning across different hierarchical levels of university administration.

results :

1. **Hierarchical differences:** Senior administrators consistently showed greater confidence and positive evaluations of their strategic planning abilities, compared to middle managers and faculty representatives. This pattern suggests that proximity to decision-making processes correlates with more optimistic strategic evaluations.
2. **Domain-specific variations:** Academic Excellence received the highest ratings across all groups, while Resource Management showed the greatest variation across groups, indicating that this is a critical area for institutional attention.
3. **Methodological advantages:** The neutrosophic Z-number approach effectively captured the uncertainty and subjectivity inherent in strategic planning assessments, providing a more nuanced analysis than traditional methods.

Strategic implications:

The observed differences highlight the need to improve communication and alignment between different organizational levels. Senior administrators' higher level of trust could reflect better access to strategic information, while faculty representatives' lower ratings suggest possible deficiencies in strategic engagement at the operational level.

Limitations and future research:

While this study provides valuable information, future research should consider the following:

- Longitudinal monitoring of the effectiveness of strategic planning
- Interinstitutional comparisons between different types of universities
- Integration with objective performance metrics
- Expanding to include the perspectives of external stakeholders

4. Conclusions

From the analysis undertaken, it is concluded that significant hierarchical differences exist in perceptions of strategic planning within higher education institutions. Specifically, senior administrators consistently demonstrate higher levels of trust compared to middle managers and faculty representatives. This disparity underscores the importance of methodological approaches that can handle the inherent subjectivity in such assessments.

In this context, the neutrosophic Z-number methodology has proven effective in capturing the complexity and uncertainty inherent in strategic planning assessments. This approach provides a robust framework for institutional decision-making, allowing for a more nuanced representation of diverse perspectives and levels of certainty.

The study also identifies resource management as a critical domain requiring greater institutional attention, as it is the area that shows the greatest variation in perceptions across different organizational levels. In contrast, academic excellence demonstrates strong consensus across all levels, indicating effective alignment in this particular strategic domain. These findings offer concrete guidelines for improving strategic alignment and institutional effectiveness.

References

[1] AM Pettigrew. The Awakening Giant: Continuity and Change in ICI. Routledge, 1985. DOI: 10.4324/9780203717935.

[2] G. Williams. "The Marketization of Higher Education". Journal of Educational Policy, Vol. 28, no. 6, pp. 723-741, 2013. DOI: 10.1080/02680939.2012.689011.

[3] H. Mintzberg. The Rise and Fall of Strategic Planning. Free Press, 1994. DOI: 10.2307/2586921.

[4] PG Altbach. "COVID-19 and International Higher Education". International Higher Education, no. 102, pp. 12-14, 2020. DOI: 10.36197/IHE.2020.102.05.

[5] E. Turban, et al. Decision Support and Business Intelligence Systems. Pearson, 2011. DOI: 10.1016/B978-0-12-374115-7.00018-5.

[6] N.V. Varghese. "Challenges of Massification of Higher Education in India". CPRHE Research Papers, 2015. DOI: 10.13140/RG.2.1.5115.0801.

[7] J.C. Spender. Business Strategy: Managing Uncertainty, Opportunity, and Enterprise. Oxford University Press, 2014. DOI: 10.1093/acprof:oso/9780199686544.001.0001.

[8] L.E. Rumbley, et al. "International Higher Education's Scholar-Practitioners". Studies in Higher Education, Vol. 45, no. 3, pp. 623-635, 2020. DOI: 10.1080/03075079.2020.1712694.

[9] J. Salmi. "The road to academic excellence: Lessons of experience". In: The road to academic excellence: The making of world-class research universities, The World Bank, pp. 323-347, 2011.

[10] J. Viteri, G. Álvarez, C. Viteri, M. Leyva. "Leadership in the transformation of higher education". Universidad y Sociedad, Vol. 13 (sS2), 2021.

[11] Josía Jeseff Isea Arguelles, Carol Elizabeth Ianni Gómez, Julio Juvenal Aldana Zavala. "Proceso Analítico Jerárquico Neutrosófico para la evaluación del eje estratégico de innovación para una Universidad Sostenible". Neutrosophic Computing and Machine Learning, Vol. 34, pp. 12–24, 2024. DOI: https://zenodo.org/record/13970772.

[12] A. Binagwaho, H. Bonciani Nader, M. Brown Burkins, A. Davies, D.O. Hessen, C. Mbow, S. Tong. Knowledge-driven actions: transforming higher education for global sustainability: independent expert group on the universities and the 2030 agenda. UNESCO Publishing, 2022.

[13] G. Croucher, et al. "Australian University Strategy". Higher Education, Vol. 81, pp. 269-285, 2021. DOI: 10.1007/s10734-020-00542-1.

[14] P. Mcquillan, L. Schall-Leckrone, B. Kershner, A.N. Dunphy, K. Filatov. Complexity Theory and Educational Leadership in Schools: Towards a Systems Transformation Heuristic. Taylor & Francis, 2025.

[15] J. Ye. "Similarity measures based on generalized distance of Z-neutrosophic number sets and their multi-attribute decision making method". Soft Computing, Vol. 25, no. 22, pp. 13975-13985, 2021. DOI: https://doi.org/10.1007/s00500-021-06049-4.

[16] S. Du, et al. "Some aggregation operators of Z-neutrosophic numbers and their multi-criteria decision making method". Complex & Intelligent Systems, Vol. 7, no. 1, pp. 429-438, 2021. DOI: https://doi.org/10.1007/s40747-020-00203-0.

[17] F. Smarandache. "Neutrosophic Logic - A Generalization of the Intuitionistic Fuzzy Logic". Journal of Multiple-Valued Logic and Soft Computing, Vol. 24, no. 3-4, pp. 287-304, 2015.
[18] Liu, Y., Yang, Z., He, J., Li, G., & Zhong, Y. (2024). Linguistic q-rung orthopair fuzzy Z-number and its application in multi-criteria decision-making. Engineering Applications of Artificial Intelligence, 133, 108432.
[19] R. Wall Emerson. "Mann-Whitney U Test and t Test". JVIB, Vol. 117, no. 1, pp. 99-100, 2023.
[20] T.K. Nguyen, et al. "A remaining useful life prediction model for concrete structures using Mann-Whitney U test state indicator and deep learning". Mechanical Systems and Signal Processing, Vol. 222, Art. No. 111795, 2025. DOI: https://doi.org/10.1016/j.ymssp.2024.111795.

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