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An application of FAHP-TOPSIS integrated method for selecting a university by first-year students in Zimbabwe

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Abstract

The purpose of this study is to apply a novel hybrid multi-criteria decision method that combines the fuzzy analytical hierarchical process and the technique for order preference by similarity to ideal solution (FAHP-TOPSIS) to rank Zimbabwe's state universities. This is because the selection of a university by first-year students is a complex decision-making process that requires interrogation of often conflicting goals such as academic reputation, cost of tuition, epistemic value, and employability after graduating. The diversity of universities and students becomes an impediment to the proper decision-making process, especially when the ability and knowledge of prospective students to analyze various disciplines on offer and the quality of tuition is minimal. Quantitative data on predetermined multi-criteria were collected from ten academic experts who were selected using the purposive sampling technique. Our findings demonstrate that the University of Zimbabwe, Midlands State University, and the National University of Science and Technology are the most preferred institutions of higher learning on the basis of cost of tuition, academic reputation, epistemic value, and degree variety. Universities must ensure a wider menu of competitive degrees to attract more students and improve brand equity and, in turn, their ranking. The contribution of the study is creating a more robust and balanced methodology for ranking universities in Zimbabwe by incorporating carefully selected criteria that are often overlooked in conventional rankings.

Keywords: FAHP, Ranking, Students, TOPSIS, Universities, Zimbabwe.

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1. Introduction and Background

Times without number, many prospective first-year university students are confronted with complex decision-making situations where they have to make the right call in selecting a university after finishing high school education. After the publication in 1983 of America's Best Colleges, university rankings have become very popular worldwide in student recruitment and assessing the performance of a university. In recent years, a number of university rankings have been developed, including the Times Higher Education (THE) Rankings, the QS World University Rankings, the Webometrics Ranking of World Universities, and the Centre for Science and Technology Studies (CWTS) Leiden Ranking. Depending on the methodology, most university rankings often employ multi-criteria metrics such as research environment, quality of teaching, industry collaboration [1-3] academic reputation, research quality, international outlook, research output, international collaboration, proportion of international students [4] scientific publications, online visibility, research funding, graduate employability [5, 6] number of citations received and Ph.D. holders, university infrastructure, academic influence, and scientific productivity [7, 8] cost of tuition, teaching quality, emotional and social value [9-11] infrastructure, extracurricular facilities [12] and availability of scholarships as well as a wide choice of degrees [2, 13].

Zimbabwe has 14 state universities, namely the University of Zimbabwe (UZ), Midlands State University (MSU), Marondera University of Agricultural Sciences and Technology (MUAST), Manicaland State University of Applied Sciences (MSUAS), Chinhoyi University of Technology (CUT), Great Zimbabwe University (GZU), National University of Science and Technology (NUST), Bindura University of Science Education (BUSE), Lupane State University (LSU), Zimbabwe Open University (ZOU), Gwanda State University (GSU), among others. These universities recruit first-year students according to certain predetermined criteria, in particular, the number of Advanced Level points and the type of degree sought. The 2024 Webometrics World University ranking reported that the top-ranked universities in Zimbabwe are UZ (2178), MSU (3753), CUT (5009), GZU (5205), and NUST (5730), whilst the least ranked are MUAST (18920), MSUAS (21589), and GSU (22526). Due to the closeness of rankings, especially among the top-ranked and worst-ranked universities in Zimbabwe, it is often difficult for most first-year students to make accurate choices given the predetermined criteria. In addition, most state universities in Zimbabwe offer course content that is almost 80% similar, hence posing significant challenges for first-year students in selecting an appropriate university. Against this background, the main purpose of this study is to apply a hybrid FAHP-TOPSIS method to rank some purposively chosen universities in Zimbabwe. We incorporate carefully selected eight predetermined multiple criteria that are often excluded in conventional rankings by considering their similarities to the ideal solution. In particular, the study seeks to answer the following questions: Which is the best-ranked university in Zimbabwe and why? What factors are considered by first-year students in Zimbabwe to select a university? The study is significant for several reasons. First, Zimbabwe's education ecosystem is confronted with idiosyncratic challenges that well-established university rankings cannot address adequately. For instance, the country has been under economic sanctions for the better part of the last two decades. Hence, it is frequently impossible for local universities to attract qualified lecturers or seek win-win collaboration with other established universities, key attributes that are often used in international rankings. In addition, most Zimbabwean universities are relatively young when compared to their regional peers that are top-ranked. As a consequence, despite having at least one million graduates employed in almost every country in the world, local universities do not feature even in the top 5000 world university rankings. This is because some of the criteria used in various rankings, such as scientific productivity, patents and innovation, international outlook, infrastructure, and funding, are adversely skewed against local universities.

Second, in most countries irrespective of their level of development, academia, potential students, public and private companies, governments and other stakeholders are showing growing concern and interest in the performance of universities as depicted by their ranking [14, 15]. Therefore, developing a ranking framework for local universities may help first year students to select the most appropriate university that align with career aspiration. Third, a university ranking is a signal to the student that the university has prestige, qualified staff, necessary infrastructure, and is able to provide the requisite knowledge to the student. It is also an indicator for academic reputation, brand visibility, epistemic value of the institution, and hence, a potential avenue for creating fecund international collaborations. Fourth, in more recent years government funding of universities are increasingly being informed by regional and world rankings [16, 17].

Fifth, university education in Zimbabwe has increasingly become more expensive since the government removed subsidies and grants in the late 1990s. Given the number and similarities of some state universities in Zimbabwe, the decision-making process for first-year students has become more complex, with an extended and costly information search. Indeed, the selection of an undergraduate degree is probably one of the major decisions a first-year student makes in the journey of life. This decision has extensive spillover consequences in the future, such as delineating success from failure in the job market, employability, and even self-actualization. If universities in Zimbabwe understand and appreciate the importance of rankings, they may be able to attract international students, form collaborations, and provide effective career advice to potential students. They are also able to tailor their educational degrees and course content to meet the aspirations of potential students as well as exceed employers' expectations.

Prior studies show that international students and qualified lecturers are attracted by many push-pull factors, especially foreign university rankings [8, 17, 18]. Sixth, most world and regional rankings ignore social-economic, culture and political differences among countries hence the possibility of generating controversy. Recent studies have started incorporating hybrid MCDM methods in many areas including environmental decision making, business management, public policy and health care management [19-21] To the best of our knowledge, no studies have employed hybrid MCDM methods to identify criteria and evaluate universities in developing countries.

Finally, the emergence in Zimbabwe of private universities such as Africa University, which is well-funded by international donors, has amplified competition for high-level performance students. Private universities are offering value-for-money education in terms of recruiting international lecturers, creating collaborations with international universities, the number of degrees offered, and quality infrastructure; hence, they are providing switching opportunities to first-year students. If state-funded universities lag behind further, they will find themselves with poor-quality students, risking even lower rankings in the future. The rest of the paper is organized as follows. The second section covers the literature review, where various multi-criteria decision models and factors motivating students to select certain universities are reviewed. In section three, a detailed methodology of the FAHP-TOPSIS method is ventilated. The fourth and fifth sections cover findings, discussions, and recommendations.

2. Literature Review

The use of MCDM techniques has gained popularity in the higher educational sector, allowing decision makers to interrogate conflicting objectives simultaneously [22-24] Some of the popular MCDM methods that have been used in the higher education system include the fuzzy analytical hierarchical process method (FAHP) [25-27] Decision-Making Trial and Evaluation Laboratory (DEMATEL) [28-30] Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) ([31-33] Weighted Sum Model (WPM) [34, 35] the Weighted Sum Model (WSM) [36] the elimination et Choix Traduisant la REalité (ELECTRE) [37] data envelopment analysis (DEA), simple additive weighting (SAW) [38] the VlseKriterijuska Optimizacija Komoromisno Resenje (VIKOR) [39] Method based on the removal effects of criteria (MEREC) [40] and the Criteria Importance through inter-criteria correlation (CRITIC). The popularity of MCDM methods have seen them being widely used in diverse disciplines such as project analysis, supplier selection, environment management, disaster management, chemical analyses, and strategic decision making, educational sectors, global suppliers network development and logistics, water management, supply chain management [35, 41-43]. In recent years, MCDM methods have also gained traction in the educational sector, where they have been utilized to rank the performance of universities and to predict factors that motivate first-year students to select certain universities [31, 44, 45].

Prior studies argue that university rankings reflect scientific rigor, academic performance and also foster competition among universities [46]. Other studies also observe that ranking universities improves the quality of university education [1]. Nevertheless, most criteria used in ranking universities have also received significant criticism in many developing economies. The major argument being that university rankings developed in advanced economies neglect idiosyncratic contexts of developing economies and tend to favor foreign universities. Unlike many universities in developing countries, universities in developed economies are well-funded and hence, the ability to attract higher quality students [47, 48]. These universities are also able to create long-term collaboration with industry and commerce [49]. In recent years, most studies have migrated towards integrating various MCDM methods and, this strategy have proven their efficacy in providing solutions to complex decision problems [40, 50].

3. Methodology

Although most MCDM methods have been successfully applied singularly to rank complex factors in various knowledge disciplines, the extant study integrates the FAHP and TOPSIS methods to rank Zimbabwean universities. The integration of MCDMs with data-driven approaches such as neural networks, decision trees, machine learning algorithms, support vector machines, and even with other MCDM methods has improved their reliability, accuracy, and prediction capabilities. While most prior studies have used either the FAHP or TOPSIS method in ranking universities, we depart from this approach by integrating the two methods for the following reasons. By integrating FAHP-TOPSIS, we reduce the complexities and ambiguities inherent in human language, including the thought process during decision-making.

Furthermore, we argue that integrating the FHAP-TOPSIS approach may enhance decision support by addressing the limitations of the individual methods. For instance, the FAHP is, to a larger extent, intuitive, consistent, user-friendly, and not difficult to manage, particularly when dealing with multiple-criteria factors that are both quantitative and qualitative. On the other hand, the TOPSIS is suitable for evaluating alternative methods by assuming that each criterion has a monotonically increasing or decreasing utility. For these reasons, developing a hybrid approach may assist researchers in identifying Pareto-optimal evaluations that represent trade-offs between conflicting objectives. Lastly, we aver that the FAHP-TOPSIS integration enables the handling of decision problems with linguistic assessments and fuzzy criteria, thereby providing more realistic and practical decision support in university ranking.

3.1. The FAHP Method

In line with Saaty [51] the initial step is decomposing the decision problem into a three-level hierarchy as shown in Figure 1. The first level of the hierarchy represented the overall goal of the decision problem that is evaluating and identifying factors that influence the selection of universities by first year students. The second hierarchy is the intermediate level representing the criterial affecting the decision whilst the third hierarchy depicts the bottom level and represents the possible alternatives. The second step is using pair-wise comparisons to compute the relative important weights of decision criteria in each level. In this stage, the decision maker is allowed to employ the fundamental scale or weights. The weights ranged from 1 depicting equal importance, and 9 indicating extreme importance as was proposed by Saaty [52] (Table 1). This allows the researchers to come with a pair-wise comparison matrix where elements a^{ij} inside the matrix is interpreted as the degree of the precedence of the *ith* criterion over the *jth* criterion.

The last step of FAHP method involves evaluating the decision alternatives by taking into account the weights of decision alternative. The alternative scores were combined with criterion weights to come up with the overall score for each alternative. To convert linguistic judgements into triangular fuzzy numbers we adopted the following procedures. Let $S \in F(Z)$ be a fuzzy number if it exists $y_0 \in Z$ such that $\theta_S(y_0) = 1. B_\alpha = \langle y. \emptyset_{B\alpha}(y) \geq a \rangle$ is a closed interval for any $a \in \{0.1\}. F(Z)$ is representing all fuzzy number sets. S is the set of real numbers. A triangular fuzzy number is then represented as $Z = (l, c, u)$ if its membership function $\emptyset_S(y): Z \rightarrow [0.1]$ is equal to;

$$\emptyset_S y = \begin{cases} \frac{y}{c-1} - \frac{l}{c-1}, y \in [l, c] \\ \frac{y}{c-u} - \frac{u}{c-u}, y \in [c, u] \\ 0 \quad \text{Otherwise} \end{cases} \tag{1}$$

Where $l \leq s \leq y, l, y$ and s are lower, upper and middle-values of the support of S respectively. The support of S is the set of all elements $\{y \in ZIl < \emptyset < y\}$

The geometric mean is calculated using equation

$$X_{ij} = \sqrt[k]{X_{ij}^1 x X_{ij}^2 x X_{ij}^3, \dots \dots \dots X_{ij}^k} \tag{2}$$

Let triangular fuzzy numbers $Z_1, Z_3, Z_{5,} Z_7$ and Z_9 represent the assessment from equally to extremely important and $Z_2, Z_4, Z_{6,}$ and Z_8 are the middle values. From Saaty [53], the following triangular fuzzy score conversion is adopted.

Table 1.
Triangular Fuzzy Score Conversion.

Linguistic Scale	TFN	Reciprocal TFN
Equally important	(1, 1, 1)	(1, 1, 1)
Weakly more important	(2/3, 1, 3/2)	(2/3. 1, 3/2)
Strong more important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strong more important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)
Absolutely more important	(7/2, 4, 9/2)	(2/9, ¼, 2/7)

Source: Saaty [53].

Let Y=$\{y_1, y_2, y_3 \dots \dots \dots \dots \dots \dots \dots \dots y_n\}$ be an object set and Y=$\{u_1, u_2, u_3 \dots \dots \dots \dots \dots \dots \dots \dots u_n\}$ be an objective set. Each of the objects is taken to execute an extent analysis for each goal, respectively. Then the *s* extent analysis values for each object can be discovered with the following signs.

$S_{g_i}^1, S_{g_i}^2, \dots \dots \dots \dots, S_{g_i}^s, where\ i = 1,2,3 \dots \dots n;$

Where $s_{g_i}^j = \{l_{g_i}^j, n_{g_i}^j, u_{g_i}^j\}, j = 1,2, \dots \dots \dots \dots \dots . s$ are a set of triangular fuzzy numbers. The value of the fuzzy synthetic extent with respect to the i[th] object is expressed as;

$$R_i = \sum_{j=1}^n S_{g_i}^j \times \left\{\sum_{i=1}^n \sum_{j=1}^n S_{g_i}^j\right\}^{-1} \tag{3}$$

$$\tilde{A} = \begin{bmatrix} 1 & \dot{\alpha}_{12} \dots & \dot{\alpha}_{1n} \\ \dot{\alpha}_{21} & 1 \dots & \dot{\alpha}_{2n} \\ \dot{\alpha}_{n1} & \dot{\alpha}_{n2} \dots & 1 \end{bmatrix} \tag{4}$$

Where$\dot{\alpha}_{ij}$ is a fuzzy triangular number (FTN) and $\dot{\alpha}_{ij} = (l_{ij}, m_{ij}, u_{ij}$ ãij) and that, $\dot{\alpha}_{ij} = \frac{1}{\dot{\alpha}_{ij}}$. For every TFN $\dot{\alpha}_{ij}$ or M=(1,m,u), its membership function µâ 9x or µ M9X) is a continuous mapping from real numbers -∞ ≤ x ≤r ∞ to the closed interval (1.0) and can be defined by the equation

$$d_L \sum_{s=1}^r x_{ls}, d_m = \sum_{s=1}^r x_{ms}, d_u = \sum_{s=1}^r x_{us} \tag{5}$$

$$\mu 0\ (x) = \begin{cases} (x-l)(m-l), & l \leq x \leq m \\ (u-x) / (u-m), & m \leq x \leq u \\ 0, & \text{otherwise} \end{cases} \tag{6}$$

The operations on TFNs can be multiplication, addition and inverse. For example if M_1 and M_2 are TFNs where M1= (M1=(l_1, m_1, u_1) and M_2=(l_2, m_2, u_2), then

Multiplication $\quad m_1 x m_2 = (l_1 x l_2, m_1 x m_2, u_1 x u_2) \quad (7)$

Addition $m_1 + m_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$ (8)

Inverse $m_1^{-1} = (l_1 x m_1 x u_1)^{-1} = (\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1})$ (9)

The third stage was aggregating the group decisions, where after collecting matrices from all decision makers there are aggregated using the fuzzy geometric method proposed by Buckley [32]. In a certain case $\hat{u}_{ij} = (l_{ij}, m_{ij}, u_{ij})$, the aggregated TFN of *n* judgements made by decision makers is given by

$$\hat{u}_{ij} = (\prod_{i=1}^{n} \hat{a}_{ijk})^{1/n} \quad (10)$$

$\hat{a}_{ijk}$, represents the relative importance in the form of TFN of the kth decision maker's perception and, n is the total number of decision makers. The weight values are determined by taking the average of each row of the normalised decision matrix 4a

$$X_m = (X_1 + X_2 + X_3 + \cdots X_n)/n \quad (11)$$

On the basis of the aggregated pairwise comparison matrix, $\tilde{U}=(\tilde{u}_{ij})$, the value of fuzzy synthetic extent S_i with respect to the ith criterion can be computed by making use of the algebraic operations on TFNs described above.

$$S_i = \sum_{j=1}^{n} \tilde{u}_{ij}\, x(\sum_{i=j}^{n} \sum_{j=1}^{m} \tilde{u}_g)^{-1} \quad (12)$$

Where $\sum_{j=1}^{m} \tilde{u}_{ij} = (\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j \sum_{j=1}^{m} u_j\ and$

$\sum_{i=1}^{n} \sum_{j=1}^{m} \tilde{u}_{ij} = \sum_{l=1}^{n} \tilde{u}_{ij} \sum_{l=1}^{n} m_j \sum_{l=1}^{n} u_i$

Relying on the fuzzy synthetic extent values, the non-fuzzy values that represent the relative weight or preference of one criterion over others are required. Adopting [33] to find the degree of possibility that $S_b > S_a$ is given as follows.

$$V(S_b > S_a) = \begin{cases} 1 & , if M_b \geq M_a \\ 0 & , if\ L_b \geq U_a \\ \frac{L_a - L_b}{(m_b - m_a) - (m_a - l_a)} & , otherwise \end{cases} \quad (13)$$

Where *b* is the ordinate of the highest intersection between u S_a and uS_b for the degree of possibility for a TFN Si to be greater than the number of n TFNs Kk can be shown by the operation min as proposed by Dubois and Prade [54]

The degree of possibility of $S_1 \geq S_2$ is expressed as in the equation:

$$V\{S_1 \geq S_2\} = (sup|min)\{u_{S_1(x)}\}, u_{S_2}(y)), \quad (14)$$

Where $y \geq p$

When a pair (x, y) exists such that $x \geq y$ and $u_{M_1}(x) = u_{M_2}(y) = 1$, then $V(R_1 \geq R) = 1, iff\ c_1 \geq c_2$ If $c_1 \geq c_2, V(S_1 \geq S_2) = hgt\{S_1 \cap S_2\}$, then

$$V(S_1 \geq S_2) = \left\{\frac{l_2 - u_1}{(c_1 - u_2) = (c_2 - l_2)}\right\}^{\prime l_2} \leq u_2, otherwise \quad (15)$$

The degree of possibility for a triangular fuzzy number that is greater than K triangular fuzzy number $S_1(i = 1,2,3 \dots \dots \dots \dots \dots \dots \dots \dots k)$ can be expressed as $V(S \geq S_1, S_2, \dots \dots .S_k) = min\ V(S \geq S_1$ Assume that $d'(A_t) = minV(S_t \geq S_k)$ where d' is the abscissa of the highest intersection point between B_1 and B_2 and At is the i[th] element of the k[th] level for $k = 1,2, \dots .n; k \neq i$. The weight vector of the k[th] level is $W' = (d'(B_1), d'(B_2), d'(B_n))^T$. The normalised weight vector is then obtained by normalization as;

$$W = (d(B_1), d(B_2), \dots .d(B_n))^T \quad (16)$$

Where *W* is not a fuzzy number

For consistency testing of the weights, the first step is to multiply the initial decision matrix with the weighted values as in Equation 14. The outcome is divided by the weighted values as in Equation 15.

$$D = \begin{pmatrix} X_{1J}, X_{2J} \dots .X_{IN} \\ X_{m1}, X_{2m} \dots .X_{MN} \end{pmatrix} * \begin{pmatrix} W_1 \\ W_M \end{pmatrix} = \frac{Z_1}{Z_m} \quad (17)$$

$$T_m = \frac{Z_M}{W_M} \quad (18)$$

From 15, the ʎmx is calculated with Equation 19 and CR with Equation 21

$$\lambda_{max} = (Z_1 + Z_2 + Z_3)/m \quad (19)$$

$$CI = \frac{\lambda_{max} - M}{m-1} \quad (20)$$

$$CR = \frac{CI}{RI} \quad (21)$$

3.2. TOPSIS Method

Among many MSCDM methods, the TOPSIS has witnessed significant development and is suitable in many business and scientific areas. The TOPSIS method is based on a mathematical distance of relative similarity, closest to the ideal solution and furthest from the anti-ideal solution [50]. The methodology adopted for this section is in accordance with Hwang et al. [55] and is as follows:

Step 1: With the data taken from experts, who are the decision makers, the decision matrix for each expert is constructed as in Equation 22 (this data was taken from FHAP)

$$Yk= \begin{bmatrix} Y_{11} & Y_{12} & Y_{1j} \\ Y_{21} & Y_{22} & Y_{2}j \\ \ldots & \ldots & \ldots \\ Y_{I1} & Y_{I2}\ldots & Y_{Ij)} \end{bmatrix} \qquad (22)$$

Step 2: The geometric mean of TFN for each element from the k number of decision matrices is obtained using Equation 23

$$X_{ij} = \sqrt[k]{X_{ij}^{1} x X_{ij}^{2} x X_{ij}^{3}, \ldots \ldots \ldots X_{ij}^{k}} \qquad (23)$$

Step 3: According to the geometric mean obtained using Equation 22, the beginning decision matrix is shown in Equation 24

$$D = \begin{cases} V_{11} & V_{12} & V_{1j} \\ V_{21} & V_{22} & V_{2j} \\ V_{i1} & V_{12} & V_{ij} \end{cases} \qquad (24)$$

Step 4: After the matrix is created, the decision matrix is normalized with Equation 25

$$y_{ij} = {x_{ij}} \Big/ \sqrt{\textstyle\sum_{i=1}^{I} {x_{ij}}^{2}} \qquad (25)$$

Where, $y_{ij}(i = 1{,}2{,}3 \ldots \text{I are number of criteria and j} = 1{,}2{,}3 \ldots, \text{J represent alternatives})$

Step 5: The fifth stage is integrating weights with ratings using Equations 1 and 5 to form a weighted normalized decision matrix as in Equation 26.

$$v_{ij} = W_j * y_{ij}; (i = 1{,}2{,}3 \ldots, I; j = 1.2.3 \ldots., J) \qquad (26)$$

Step 6: Is finding a negative solution denoted by A^n and a positive ideal solution represented by A^p as per Equations 27 and 29.

$$A^{n} = (v_1^n, v_{2,}^n v_3^n) \qquad (27)$$

$$A^{p} = (v_1^*, v_{2,}^* v_3^*) \qquad (28)$$

Where

$$v_j^p = \begin{pmatrix} maxv_{ij}, if\ j\ is\ a\ benefit\ attribute \\ maxv_{ij},\ \ if\ j\ is\ a\ cost\ attribute \end{pmatrix} \qquad (29)$$

$$v_j^n = \begin{pmatrix} maxv_{ij}, if\ j\ is\ a\ benefit\ attribute \\ maxv_{ij},\ \ if\ j\ is\ a\ cost\ attribute \end{pmatrix} \qquad (30)$$

The decision on the order of options was made according to the order of numbers using Equation 31

$$D^* = \frac{d(A_i, A^{\circ})}{d(A_i, A^*) + d(A_i, A^{\circ})} = \frac{1}{\frac{d(A_i, A^*)}{d(A_i, A^{\circ}) + 1}} \qquad (31)$$

The option A_{i1} is the best solution if $\max(D_{1,}^* D_{2,}^* D_3^* \ldots.. D_m^*) = D_{i_1}^*$ and the option Ai_2 is the worst solution if $\max(D_{1,}^* D_{2,}^* D_3^* \ldots.. D_m^*) = D_{i_2}^*$ and the other options are within these two extremes.

The maximum distance given by $D^* = maximum_{i=1} \ldots.. mD_i^*$ is also known as the TOPSIS metric calculated from each row by adding the square of the difference from the positive ideal solution and the negative ideal solution as shown in Equations 32 and 33.

$$D^{+} = \sqrt{\mathrm{I}\frac{1}{3}((\sum_{j=1}^{3}(V_{ij} - A^{+})^{2})\mathbf{I}} \quad (32)$$

$$D^{-} = \sqrt{\mathbf{I}\frac{1}{3}((\sum_{j=1}^{3}(V_{ij} - A^{-})^{2})\mathbf{I}} \quad (33)$$

Step 6: The Euclidean distance theory is applied to obtain the separation of values, which is the distance of each alternative rating from both the negative and positive ideal solutions, Equations 34 and 36.

$$S_i^p = \sqrt{\sum_{j=1}^{J}(v_{ij} - v_j^*)} \quad (34)$$

$$S_J^n = \sqrt{\sum_{j=1}^{J}(v_{ij} - v_j^n)} \quad (35)$$

Step 7: The last stage is getting the overall preference score V_i for each alternative A_i using Equation 36

$$V_{ij} = {S^n}/{S^P} \ OR \ \frac{S^P}{S_i^n + S_J^P} \quad 0 \le V_{ij} \le 1 \quad (36)$$

3.3. Conceptual Framework 3.0.2

The following hierarchical conceptual framework for FAHP-TOPSIS integration is proposed for this study.

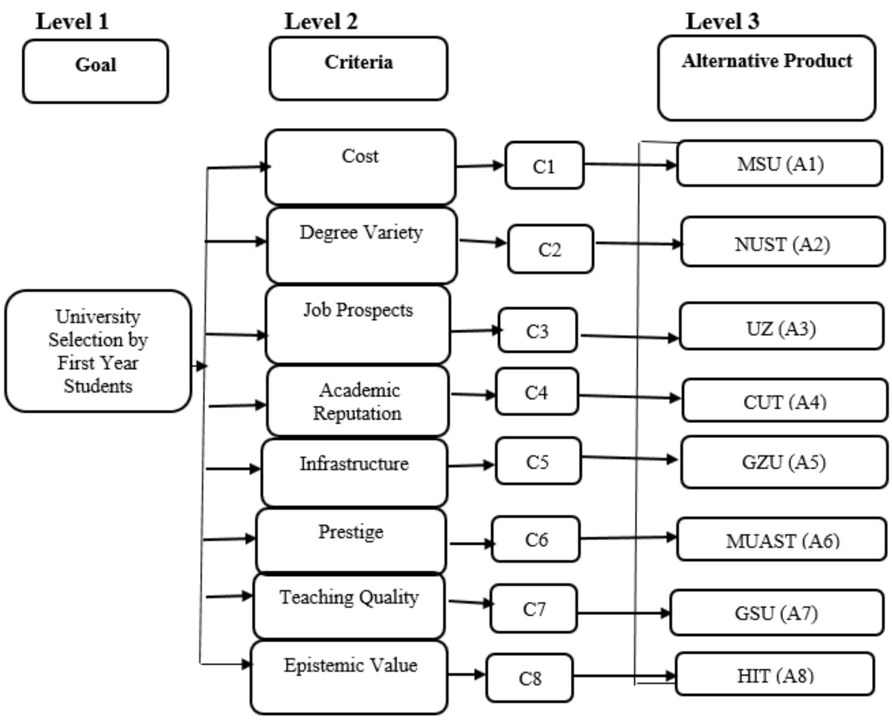

Figure 1.
Conceptual Framework: Own source.

Table 2. Explains the variables shown in the conceptual framework.

Table 2.
Variable Explanation.

Criteria	Explanation
Epistemic value	The institution's ability to generate knowledge and create technologies.
Degree Choices	Number of degrees offered by the university.
Job Prospects	How effectively the university prepares the students for prosperous careers, and the knowledge demanded by the job market.
Academic Reputation	How well is the university known and praised by former and current students?
Infrastructure	Availability of lecture rooms, sports, accommodation and other facilities.
Teaching Quality	Number of experienced professors, Ph.D, and senior lecturers.
Prestige	The general image of the university in society in terms of producing the most capable, innovative and accomplished graduates.
Cost of Tuition	Total cost needed before and after admission, including other costs.

3.4. Data Collection and Validity

A structured questionnaire was administered to a purposively chosen ten academic experts who are all senior lecturers at different universities in Zimbabwe. The questionnaire allowed the ten experts to rate the universities shown in Figure 1. UZ (A2), NUST(A2), GZU(A3), CUT (A4), HIT (A5), GSU (A6), MUAST (A7) and MSU (A8) using predetermined multiple criteria that is, Cost of tuition (C1), Degree Variety (C2), Job prospects (C3), Academic Reputation (C4), Infrastructure (C5), Prestige (C6), teaching quality (C7) and epistemic value (C8). To ensure a certain quality level of a decision or the value of consistency, consistency rate (CR) defined as the ratio between the consistency of a consistency index (CI) and the consistency of a random consistency index (RI) was calculated A reasonable evaluation is less than 0.1 whilst an acceptable evaluation is less than 0.2 [56]. The threshold for this ratio is 0.1 for a matrix larger than four by four [38].

4. Findings and Discussions

The presentation of findings are done according to the steps proposed by [52] starting with the comparison of matrix.

4.1. Step 1: Comparison of Criteria

The FAHP was used to compare criteria and evaluate the criteria against each other using a [53] 1 to 9 scale. The evaluations were converted into triangular fuzzy numbers (TFN) as in the equation.

Table 3.
Comparison of Criteria (FAHP).

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1.00	3.06	4.15	2.70	3.63	3.82	4.88	6.35
C2	0.35	1.00	1.98	0.88	1.41	1.25	3.18	4.30
C3	0.26	0.53	1.00	0.58	0.82	0.87	2.98	4.70
C4	0.40	1.07	1.88	1.00	2.50	2.26	5.40	6.28
C5	0.29	0.74	1.30	0.42	1.00	1.00	2.73	4.054
C6	0.28	0.83	0.10	0.45	1.00	1.00	3.83	5.10
C7	0.21	0.31	0.19	0.38	0.17	0.37	1.00	2.25
C8	0.18	0.23	0.20	0.18	0.26	0.21	0.46	1.00

4.2. Step 2: Normalized Criteria Comparison

A normalized decision-making comparison was calculated using Equations 4 and 8, and the results are presented in Table 4.

Table 4.
Normalized Criteria Comparison.

	C1	C2	C3	C4	C5	C6	C7	C8
C1	0.35	3.06	4.15	2.70	3.63	3.82	4.88	6.35
C2	0.14	0.13	0.18	0.15	0.14	0.13	0.12	0.14
C3	0.05	0.07	0.08	0.09	0.06	0.08	0.13	0.14
C4	0.15	0.13	0.14	0.16	0.23	0.20	0.21	0.16
C5	0.07	0.08	0.08	0.11	0.07	0.08	0.09	0.12
C6	0.08	0.12	0.08	0.07	0.09	0.10	0.14	0.16
C7	0.06	0.04	0.03	0.03	0.04	0.12	0.04	0.07
C8	0.05	0.03	0.02	0.03	0.02	0.01	0.02	0.03

4.3. Step 3: Comparison of Criteria

Step 1: The FAHP was used to compare and evaluate each criterion against the other. The criterion chosen for the comparison of alternatives are defined using codes as follows: epistemic value (C1), Degree (C2), Job Prospects (C3), Academic value (C4), Facilities (C5), Teaching Quality (C6), Prestige (C7), and Cost of Tuition C8. The experts who are the decision makers evaluated criteria using the Saaty scale (Table 1) and transformed using Equation 4. The geometric mean of the pairwise comparison value of each expert was obtained using Equation 23. The results of the comparison of criteria are presented in Table 2.

Table 5.
Comparison of Criteria using FAHP.

	C1	C2	C3	C4	C5	C6	C7	C8
C1	(1.85, 2.45, 4.22)	(2.15, 2.88, 4.00)	(2.18, 3.23, 3.98)	(2.42, 3.60, 4.05)	(2.51, 3.63, 4.65)	(2.80, 3.78, 4.83)	(3.76, 4.91, 5.98)	(5.41, 6.39, 7.33)
C2	(0.75, 1.13, 3.10)	(0.85, 0.23, 0.78)	(0.65, 1,13, 1.76)	(0.44, 0.56, 0.87)	(0,93, 1.35, 1.89)	(0.85, 1.22, 1.69)	(3.78, 4.92, 5.99)	(3.20, 4.32, 5.41)
C3	(1.00, 1.00, 1.00)	(1,24, 2.13, 3.01)	(1.23, 1.36, 2.00)	(1.33, 1.02, 1,20)	(0.57, 0.80, 1.12)	(0.66, 086, 1.15)	(2.08, 3.22, 4.30)	(3.71, 4.74, 5.80)
C4	(0.33, 0.45, 0.65)	(1.00, 1.00, 1.00)	(1.55, 1.66, 1.89)	(0.55, 0.35, 1.03)	(1.63, 2.46, 3.22)	(1.37, 2.25, 3.05)	(4.36, 5.36, 6.41)	(5.21, 6.23, 7.25)
C5	(0.98, 1.00, 2.23)	(0.87, 1.00, 0.88)	(1.00, 1.00, 1.00)	(0.24, 0.74, 0.32),	(1.00, 1.00, 1.00)	(0.89, 1.10, 1.23)	(1.66, 2.74, 3.77)	(2.91, 4.02, 5.08)
C6	(0.15, 1.12, 1.78)	(1.12, 0.23, 0.34)	(0.27, 0.45, 077)	(0.33, 0.52, 1.11)	(0.83, 1.00, 1.15)	(1.00, 1.00, 1.00)	(2,74, 3.84, 4.82)	(3.00, 5.09, 6.16)
C7	(1.14, 1.26, 2.14	(0.38, 1.13, 2.14)	(2.86, 2.99, 3.05)	(1.11, 1.48, 0.31)	(0.27, 0.37, 0.59)	(0.22, 0.27, 0.38)	(1.00, 1.00, 1.00)	(1.44, 2.28, 3.23)
C8	(0.25, 0.35, 0.48)	(0.98, 0.24, 1.13)	(0.65, 0.88, 1.12)	(0.00, 0.56, 0.92)	(0.11, 0.25, 0.34)	(0.12, 0.21, 0.26)	(0.32, 0.50, 0.72)	(1.00, 1.00, 1.00)

4.4. Step 4: Geometric Mean

The decision matrix on the comparison of the geometric mean of each lower boundary (l), middle limit (m), and upper limit (u) on a row basis was found using Equation 10. Using Equation 11, the total values at the end of the column were calculated, and the results are shown in Table 6.

Table 6.
Mean boundary values of triangular fuzzy numbers.

Criteria	Lower boundary (l)	middle limit (m)	upper limit (u)
C1	2.49	3.33	4.04
C2	1.05	1.41	1.88
C3	0.76	0.94	1.12
C4	1.41	1.86	2.37
C5	0.78	1.05	1.35
C6	0.88	1.1	1.4
C7	0.36	0.42	0.54
C8	0.25	0.25	0.35
TOTAL	7.98	10.36	13.05

4.5. Step 5: Triangular Fuzzy Number of Weights

Applying Equation 6, the triangular limit values of the criteria were weighted, and the weights were computed and are shown in Table 7.

Table 7.
Triangular Fuzzy Number Weights of Criteria.

	Lower boundary (L)	Middle limit (m)	Upper boundary (u)
C1	0.22	0.33	0.5
C2	0.09	0.15	0.23
C3	0.06	0.1	0.14
C4	0.13	0.16	0.29
C5	0.06	0.1	0.18
C6	0.07	0.13	0.19
C7	0.03	0.03	0.08
C8	0.01	0.02	0.05

4.6. Step 6: Calculating Consistency Test of the Weights

For the consistency test of the weighting ʎ Equation 19 was employed and the confidence Interval (CI) was found from the table as 1.40. The CR value of the model is consistent as CR is 0.03> 0.01 using Equation 21. The RI was calculated using Equation 20. The parameters of the consistency test of the model are presented in Tables 8 and 9.

Table 8.
Random Consistency Value.

	RI value
1	0.00
2	0.00
3	0.48
4	0.80
4	1.08
5	1.10
6	1.11
7	1.25
8	1.43
9	1.48
10	1.50

Table 9.
Test of Consistency.

ʎ	CI	RI	CR
8.25	0.04	1.43	0.03

4.7. Step 7: Calculating Weighted Criteria Using FAHP

The weighted values of the rows' average of the normalized criteria comparison shown in Table 3 were found using Equation 19. The results are presented in Table 10 and Figure 2.

Table 10.
Weights of the Criterion using FAHP.

Criteria	(C1) Cost	(C2) Degree Choices	(C3) Job Prospects	(C4) Academic Reputation	(C5) Infrastructure	(C6) Prestige	(C7) Teaching Quality	(C8) Epistemic Value
Weight	0.35	0.14	0.10	0.19	0.11	0.13	0.04	0.13

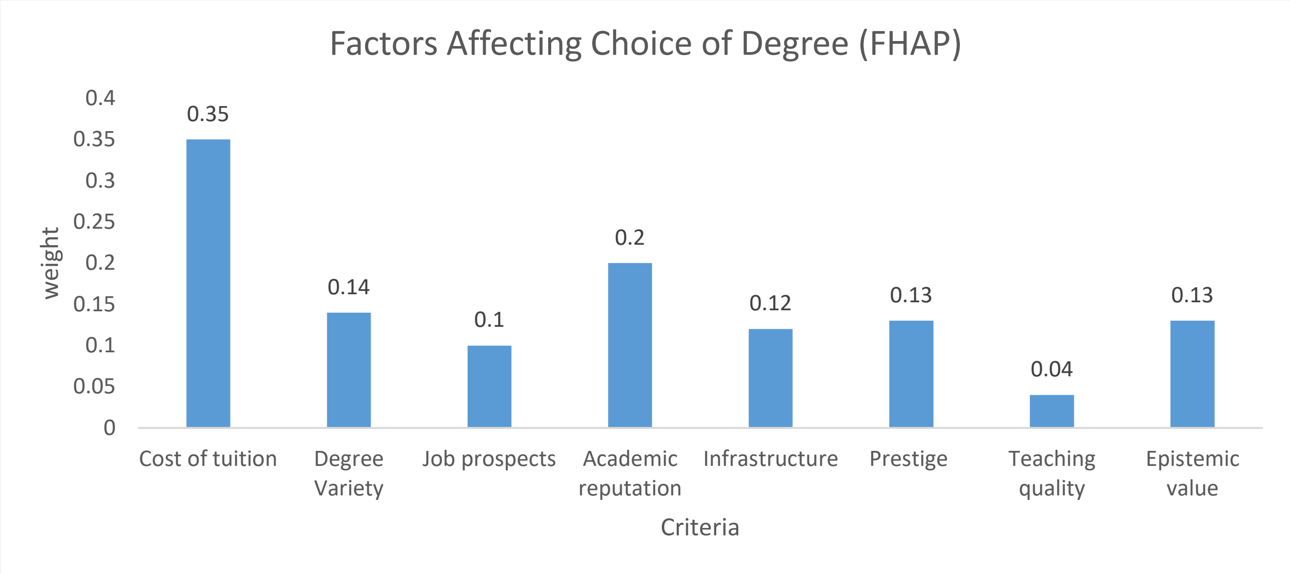

Figure 2.
Factors affecting Choice of Degree by first year Students.

Figure 2 shows that the decision to select a university by first-year students in Zimbabwe is motivated by a number of factors, key among them are cost of tuition, followed by academic reputation. They also consider epistemic value, prestige and infrastructure. Criteria such as teaching quality and future job prospects receive less consideration. These findings have confirmation in the literature for example cost of tuition [43, 57], academic reputation [58], and infrastructure [59]. Teaching quality was found the least important criterion in Zimbabwe, however, this result is hardly surprising as many first-year students may not have the capacity to assess this criterion.

4.8. Step 8: Integrating FAHP and TOPSIS

Step 4: The fuzzy analytical hierarchical-TOPSIS method was used to estimate the alternatives. To obtain the decision matrix the information from academic experts and prospective students was used. Universities were coded as per FAHP method. Each decision maker evaluated the alternative for all criteria using the formula seen in Table 1. This information was converted to TFNs using Equation 23, and the geometric mean was calculated using Equations 24 and 25. The findings are shown in Table 11.

Table 11.
Decision Matrix for Fuzzy-TOPSIS.

	C1	C2	C3	C4	C5	C6	C7	C8
A1	(3.44, 4.46, 5.47)	(6.35, 7.28, 8.20)	(6.88. 7.70, 8.45)	(8.05, 8.50, 8.55)	(5.72, 6.77, 7.18)	(4.23, 5.30, 6.33)	(6.33, 7.20, 8.10)	(4.34, 5.37, 6.43)
A2	(2.33, 3.40, 6.44)	(2.51, 3.33, 4.09)	(2.86, 4.09, 5.18)	(3.33, 4.88, 5.91)	(5.72, 6.77, 7.18)	(4.23, 5.30, 6.33)	(3.28, 4.30, 5.32)	(6.92, 7.08, 8.88)
A3	(3.75, 4.81, 5.81)	(1.00, 1.00, 1.00)	(1.00, 1.55, 1.20)	(2.60, 3.63, 4.63)	(5.72, 6.77, 7.18)	(4.23, 5.30, 6.33)	(4.99, 5.98, 6.70)	(7.55, 8.25, 8.88)
A4	(5.49, 6.50, 7.61)	(9.01, 9.01, 9.01)	(8.74, 8.88, 9.01)	(2.11, 3.20, 4.11)	(3.16, 4.75, 5.20)	(6.50, 7.45, 8.33)	(1.95, 2.76, 3.50)	(5.65, 6.45, 7.64)
A5	(3.81, 4.86, 5.89)	(1.00, 1.57, 1.99)	(2.50, 3.30, 4.11)	(5.31, 6.32, 4,25)	(3.68, 4.70, 5.74)	(4.23, 5.30, 6.33)	(4.55, 5.57, 6.59)	(5.69, 6.61, 7.63)
A6	(2.06, 3.07, 4.10)	(7.60, 8.20, 8.70)	(8.05, 8.48, 8.90)	(8.05, 8.50, 7.35	(8.33, 8.66, 8.78	(8.33, 8.66, 8.88	(7.95, 8.50, 9.01)	(1.10, 1.65, 2.08)
A7	(1,81, 2.85, 3.86)	(1.40, 2.45, 3.53)	(6.41, 7.20, 7.90)	(8.05, 8.50, 8.87)	(5.72, 6.77, 7.18)	(4.23, 5.30, 6.33)	(6.68, 7.60, 8.48)	(1.99, 3.10, 4.15)
A8	(1.73, 2.43, 2.52)	(4.86, 5.88, 6.90)	(3.40, 4.44, 5.48)	(3,20, 4.95, 5.20)	(5.72, 6.77, 7.18)	(4.23, 5.30, 6.33)	(5.09, 6.10, 7.23)	(3.23, 4.20, 5.23)

4.9. Step 9: Normalized Decision Matrix (FHAP-TOPSIS)

This stage involved normalization of the decision matrix and this was done using Equation 25, and the results are presented in Table 12.

Table 12.
Normalized Decision Matrix FHAP-TOPSIS.

	C1	C2	C3	C4	C5	C6	C7	C8
A1	(0.24, 0.39, 0.62)	(0.40, 0.46, 0.58)	(0.39, 0.45, 0.54)	(0.39, 0.47, 0.55)	(0.28, 0.37, 0.49)	(0.22, 032, 0.43)	(0.30, 0.41, 0.55)	(0.23, 0.32, 0.45)
A2	(0.17, 0.29, 0.48)	(0.15, 0.21, 0.29)	(0.15, 0.20, 0.30)	(0.20, 0.29, 0.38)	(0.28, 0.37, 0.49)	(0.22, 0.32, 0.43)	(0.17, 0.25, 0.36)	(0.37, 0.45, 0.55)
A3	(0.27, 0.42, 0.65)	(0.05, 0.07, 0.08)	(0.05, 0.09, 0.13)	(0.13, 0.20, 0.30)	(0.28, 0.37, 0.49)	(0.22, 0.32, 0.43)	(0.25, 0.35, 0.46)	(0.45, 0.50, 0.60)
A4	(0.38, 0.55, 0.83)	(0.55, 0.57, 0.63)	(0.46, 0.51, 0.56)	(0.11, 0.17, 0.30)	(0.55, 024, 033)	(0.35, 0.40, 0.57)	(0.96, 0.17, 0.24)	(0.39, 0.47, 0.54)
A5	(0.27, 0.42, 0.67)	(0.04, 0.10, 0.14)	(0.30, 0.20, 0.27)	(0.27, 0.35, 0.46)	(0.18, 0.26, 0.38)	(0.22, 0.32, 0.43)	(0.25, 0.34 , 0.45)	(0.29, 0.38, 0.49)
A6	(0.15, 0,30, 0.50)	(0.45, 0.53, 0.60)	(0.42, 0.49, 0.56)	(0.41, 0.47, 0.55)	(0.40, 0.48, 0.56)	(0.40, 0.97, 0.60)	(0.41, 0.49, 0.60)	(0.04, 0.10, 0.14)
A7	(0.13, 0.27, 0.43)	(0.06, 0.18, 0.26)	(0.30, 0.41, 0.50)	(0.41, 0.47, 0.55)	(0.28, 0.37, 0.50)	(0.20, 0.32, 0.43)	(0.35, 0.44, 0.57)	(0.11, 0.21, 0.26)
A8	(0.18, 0.20, 0.32)	(0.28, 0.42, 0.47)	(0.18, 0.26, 0.34)	(0.21, 0.30, 0.41)	(0.28, 0.38, 0.50)	(0.20, 0.32, 0.43)	(0.55, 0.35, 0.46)	(0.45, 0.18, 0.34)

4.10. Step 10: Weighted Decision Matrix (FHAP-TOPSIS)

The calculation of the weighted decision matrix was done using Equation 26 and the findings are presented in Table 13.

Table 13.
Weighted Decision Matrix FHAP-TOPSIS.

	C1	C2	C3	C4	C5	C6	C7	C8
A1	(0.48, 0.15, 0.31)	(0.04, 0.07, 0.15)	(0.03, 0.05, 0.10)	(0.05, 0.09, 0.17)	(0.01, 0.34, 0.08)	(0.15, 0.04, 0.08)	(0.06, 0.13, 0.05)	(0.05, 0.08, 0.12)
A2	(0.04, 0.10, 0.27)	(0.01, 0.03, 0.07)	(0.02, 0.04, 0.07)	(0.02, 0.05, 0.12)	(0.01, 0.34, 0.08)	(0.15, 0.04, 0.08)	(0.05, 0.01, 0.02)	(0.06, 0.02, 0.04)
A3	(0.06, 0.15, 0.35)	(0.05, 0.14, 0.33)	(0.04, 0.08, 0.15)	(0.01, 0.04, 0.09)	(0.01, 0.34, 0.08)	(0.15, 0.04, 0.08)	(0.05, 0.10, 0.03)	(0.06, 0.01, 0.03)
A4	(0.08, 0.16, 0.41)	(0.04, 0.08, 0.16)	(0.03, 0.05, 0.09)	(0.03, 0.06, 0.14)	(0.08, 0.03, 0.06)	(0.03, 0.05, 0.10)	(0.02, 0.03, 0.04)	(0.01, 0.05, 0.03)
A5	(0.01, 0.03, 0.05)	(0.05, 0.13, 0.33)	(0.02, 0.03, 0.04)	(0.04, 0.07, 0.18)	(0.01, 0.03, 0.06)	(0.01, 0.03, 0.08)	(0.01, 0.03, 0.08)	(0.05, 0.02, 0.06)
A6	(0.03, 0.05, 0.10)	(0.02, 0.07, 0.15)	(0.02, 0.05, 0.09)	(0.05, 0.09, 0.17)	(0.02, 0.05, 0.10)	(0.02, 0.05, 0.10)	(0.03, 0.05, 0.04)	(0.01, 0.02, 0.06)
A7	(0.02, 0.04, 0.08)	(0.01, 0.03, 0.07)	(0.02, 0.04. 0.08)	(0.05, 0.09, 0.17)	(0.02, 0.04; 0.08)	(0.02, 0.04, 0.09)	(0.08, 0.07, 0.03)	0.01, 0.03, 0.04)
A8	(0.01, 0.04, 0.11)	(0.01, 0.03, 0.07)	(0.01, 0.02, 0.04)	(0.02, 0.05, 0.12)	(0.01, 0.04, 0.01)	(0.01, 0.04, 0.11)	(0.05, 0.02, 0.03)	(0.02, 0.06, 0.02)

4.11. Step 11: Positive ideal A^p and negative ideal A^n

A^p represents the best performance values, whereas A^n depicts the worst performance outcomes. The A^p was calculated using Equation 28 and A^n by applying Equation 27. The findings are presented in Table 14.

Table 14.
Positive and Negative Ideal Solutions FTOPSIS.

	C1	C2	C3	C4	C5	C6	C7	C8
A^p	0.43	0.16	0.09	0.17	0.11	0.05	0.03	0.03
A^n	0.021	0.004	0.003	0.008	0.012	0.012	0.002	0.001

4.12. Step 12: Discrimination Measurement-FAHP-TOPSIS

The weighted values are clarified with Equations 31 and 33. Equations 35 and 36 were used to calculate the distance from the positive ideal solutions S^p and the distance from the negative ideal solutions (S^n). The results of discrimination measurements are presented in Table 15.

Table 15.
Discrimination Measurement (FAHP-TOPSIS).

Criteria	S^p	S^n
A1	0.06	0.53
A2	0.77	0.38
A3	0.78	0.36
A4	0.65	0.55
A5	0.75	0.42
A6	0.69	0.52
A7	0.74	0.42
A8	0.79	0.35

4.13. Step 13: Universities Ranking in Zimbabwe

Using Equation 36, the closeness to the ideal solution K* was calculated and the findings are presented in Table 16.

Table 16.
Ranking of Universities in Zimbabwe.

Rank	University	Result (K*)
1	University of Zimbabwe	0.47
2	Midlands State University	0.44
3	National University of Science and Technology	0.40
4	Great Zimbabwe University	0.36
5	Chinhoyi University of Science and Technology	0.35
6	Harare Institute of Technology	0.32
7	Marondera State university of Agriculture, Science and technology	0.31
8	Gwanda State University	0.30

Table 16 shows that the University of Zimbabwe (0.47) is the most preferred institution of higher learning in Zimbabwe, followed by Midlands State University (0.44) and the National University of Science and Technology 0.40) respectively. The least preferred universities by first-year students are Gwanda State University (0.31), closely followed by Marondera State University of Agriculture Science and Technology (0.31) and Harare Institute of Technology (0.32). The findings are not surprising given that the University of Zimbabwe is the oldest educational institution in Zimbabwe and many students are likely to make it their first choice. The findings are confirmed by literature where most students look at academic reputation, prestige and epistemic value when selecting a university [46, 57]. These findings are confirmed by the literature, where the University of Zimbabwe and Midlands State University were ranked as two top state universities in the global world ranking of universities [60].

5. Recommendations/ Implications

The implications arising from the findings are very clear to various stakeholders. Policymakers should ensure that universities are ranked regularly using multiple relevant criteria in order to understand the current education ecosystem. The ranking of universities must not be seen as a means to an end but must help universities identify areas that need to be strengthened to maintain competitiveness in an increasingly globalized educational environment. This can also inform not only strategies to improve local university performance but also to promote dialogue and more effective decision-making by first-year university students. The study has obvious limitations. For instance, most university rankings are temporary in nature and hence, the findings of this study may not hold in different periods. Instead of relying on rankings, it may be important to consider other assessment tools that promote innovation, research, and holistic student development after admission. The second limitation is that the findings might change if other MCDM methods like VIKOR, PROMETHEE, and ELECTRE are combined with either TOPSIS or FAHP.

6. Conclusions

Given the number and similarities of some state universities in Zimbabwe, the decision-making process for first-year students has become more complex, with an extended information search. The purpose of the study was to apply a hybrid MACDM method, specifically the FAHP-TOPSIS, to determine criteria and evaluate eight state universities in Zimbabwe. Our findings show that the University of Zimbabwe is the most preferred institution, followed by Midlands State University, based on the cost of tuition, academic reputation, epistemic value, and degree variety.

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