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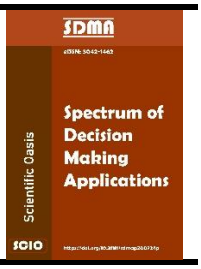

Prioritizing Strategies for the Development and Sustainability of Higher Education in Developing Countries: A FullEX MCDM Approach

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ABSTRACT

This study examines strategies for advancing and sustaining Nigeria's higher education system, which plays a vital role in achieving the Sustainable Development Goals. Despite its importance, higher education in Nigeria faces numerous challenges. Through a combination of literature review and expert insights, nine strategies were identified to address these challenges. The FullEX method is employed to prioritize these strategies, with experts' experience and educational backgrounds used to weigh the significance of each strategy in the decision-making process. To validate the robustness of the method, comparative and sensitivity analyses were conducted. The findings underscore increased funding, recruiting additional lecturers, enhancing infrastructure, and ensuring a stable academic calendar as the most effective strategies to support the development and sustainability of Nigeria's higher education sector.

1. Introduction

Higher education plays a crucial role in enhancing a country's research capacity and producing skilled professionals necessary for the labor market. According to Obanya [1], it encompasses all formal learning and training at the tertiary level, which includes not only traditional universities but also specialized institutions. In addition, higher education extends to post-secondary establishments like teacher training colleges and polytechnics, as well as various professional institutions that attract individuals with diverse secondary education backgrounds. Moreover, the scope of higher education also covers non-formal learning, offering mature learners the opportunity to participate in structured programs that enhance their knowledge and skills, equipping them to address practical life challenges. Higher education aims to instill values for personal and societal growth, develop intellectual and practical skills, and foster a broad understanding of local and global contexts [2].

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Orunbon and Isaac-Philips [3] stated that tertiary institutions aim to unlock human potential by developing social, intellectual, and psychomotor skills, fostering positive values, and instilling a lifelong drive for learning.

Nigeria's higher education system, the largest in Africa, serves millions of students across diverse institutions. To maintain quality, the Federal government has established oversight bodies like the National Commission for Colleges of Education and the National Board for Technical Education, aimed at upholding educational standards. However, challenges persist in advancing and sustaining the development of this sector. According to Egwa [4], while these agencies strive to ensure quality, concerns about declining educational standards remain. Rao and Ediger [5] highlighted that universities, colleges of education, and polytechnics are producing graduates who often lack the competencies required by the labor market. Similarly, Mohammed and Gbenu [6] noted a significant decline in the overall quality of higher education in recent years. Babalola *et al.,* [7] described this issue as "institutional failure," attributing it to a skills mismatch in which graduates are not equipped with the skills demanded by employers. The National Universities Commission [8] attributed this gap to outdated curricula, limited industry collaboration, lack of practical training, and a shortage of qualified instructors in vocational and job-specific areas. Further compounding these issues, Ogunode and Musa [9] identified additional barriers, such as insufficient staff development programs, brain drain, academic instability, limited research capacity, poor infrastructure among others.

The studies above identify numerous challenges affecting the development and sustainability of higher education in Nigeria. Ogunode and Musa [9], among others, have suggested strategies to address these challenges and promote sustainable growth in the sector. However, these strategies lack prioritization by importance. To bridge this gap, a comprehensive managerial approach is needed to develop a robust strategy for sustainable higher education development. This approach should incorporate Multi-criteria decision-making (MCDM) techniques to enhance decision-making [10].

In the higher education sector, experts from varied backgrounds contribute essential insights. This study applies a newly developed FullEX method by Bošković *et al.*, [11] to evaluate and rank strategies aimed at addressing sustainable development challenges in Nigerian higher education. The FullEX method offers several advantages over traditional subjective approaches. Firstly, unlike methods like the Best Worst Method (BWM), Stepwise Weight Assessment Ratio Analysis (SWARA), Full Consistency Method (FUCOM), and Analytic Hierarchy Process (AHP), which typically rely on pairwise comparisons (PCs) of criteria, the FullEX method incorporates an expert's reputation—factoring in their experience and educational background. This approach strengthens decision-making, as it allows experts to prioritize criteria based on their experience and academic expertise, enhancing decision accuracy. Greater experience contributes to more reliable assessments, while higher education levels signify the theoretical knowledge needed for precise evaluations. In addition, methods like AHP depend on expert input to conduct PCs, converting judgments into numerical values (one-to-nine scale) to determine each criterion's importance [12]. SWARA, however, streamlines the process by excluding less significant criteria, focusing only on those deemed most critical [13]. BWM is particularly useful when objective data is scarce, employing PCs between the Best and Worst criteria to reduce anchoring bias [14]. Meanwhile, FUCOM utilizes n-1 PCs on integer or decimal scales to assess criteria [15,16]. In the FullEX method, PCs follow Fuller's triangle approach, based on expert judgments, but uniquely incorporate the experts' education and experience. The method also distinguishes itself with a specialized consistency ratio (CR) calculation. In a second round of interviews, experts are asked to rate each criterion's importance without knowing the first-round outcomes, assigning percentages between 0 and 100% to each criterion. This final step enables experts to allocate significance percentages, refining the ranking accuracy across the criteria.

This paper makes several key contributions:

i. It applies the FullEX method to assess strategies for addressing challenges to the sustainable development of Nigeria's higher education system.
ii. It identifies the most effective strategies for fostering sustainable growth within Nigeria's higher education sector.
iii. Following the introduction, Section 2 Literature review, 3 Methodology, 4 Case study application, 5 Sensitivity analysis 6 Comparative analysis, and 7 Conclusion.

2. Literature review

2.1 Approaches related to studies in the higher education sector

Research on the higher education sector has been carried out in various countries worldwide. For instance, Sonn *et al.,* [17] highlighted the realizations and issues of higher education institutions (HEIs) during the pandemic. While HEIs worked to offer equal access to education, mental health support, and devices, issues like student anxiety and unequal educational quality due to contextual factors worsened social inequalities in Africa. Hungwe and Ndofirepi [18] explored four key paradigms in the decolonization of African higher education: Africanisation, indigeneity, racial perspectives, and Ubuntu. They concluded that while decolonization is vital, misinterpreting these paradigms can obstruct the goals of true educational decolonization in Africa. Yeboah and Nyagorme [19] used the unified theory of acceptance and use of technology (UTAUT) model to identify factors influencing distance students' acceptance of WhatsApp for learning. They found that facilitating conditions, performance expectancy, social influence, and effort expectancy significantly predicted students' intentions to use WhatsApp, while mobile phone self-efficacy alone did not. Olatokun *et al.,* [20] surveyed 85 library and information science educators in Nigerian universities, finding that while many had a moderate understanding of Massive Open Online Courses (MOOCs), few had practical experience integrating them into teaching. Shafait and Huang [21] studied how knowledge-oriented leadership fosters emotional intelligence (EI) in Chinese higher education and its link to academic creative performance. They also analyzed the mediating roles of trust in leaders and organizational climate in the EI-creative performance relationship. Moshtari and Safarpour [22] explored the challenges of higher education internationalization in low-income East African countries and proposed strategies to address these challenges, considering both internal and external factors within institutions.

2.2 Studies related to the application of MCDM in the higher education sector

MCDM methods are effective decision-making approaches widely utilized across diverse domains [23, 24]. For instance, Makki *et al.*, [25] proposed a strategy to enable universities to meet international ranking standards alongside their own strategic objectives, guiding them in creating effective performance metrics and allocating resources to enhance educational quality. Kazancoglu and Ozkan-Ozen [26] developed a multi-stage model to identify and analyze the eight wastes of lean philosophy in higher education. Ekinci *et al.*, [27] developed a framework to help universities and governments choose strategies based on strategic interactions. Their findings revealed that both parties, in various scenarios, favored encouraging high-quality academic research. Chen and Chen [28] developed an innovation support system (ISS) to assess innovation performance in Taiwanese higher education institutions. Ayyildiz *et al.,* [29] introduced a university evaluation process using MCDM methods, clustering universities based on teaching and research criteria.

3. Methodology

The FullEX method enhances decision accuracy by factoring in experts' experience and education. Key features include weighting expert reputation, using a unique Fuller's triangle comparison with a novel consistency ratio, and a two-round interview process where experts assign significance percentages. Despite being new, FullEX has been applied in areas like propulsion technology [30], sustainable mining [31], and net-zero emissions [32]. The flowchart of our study is shown in Figure 1.

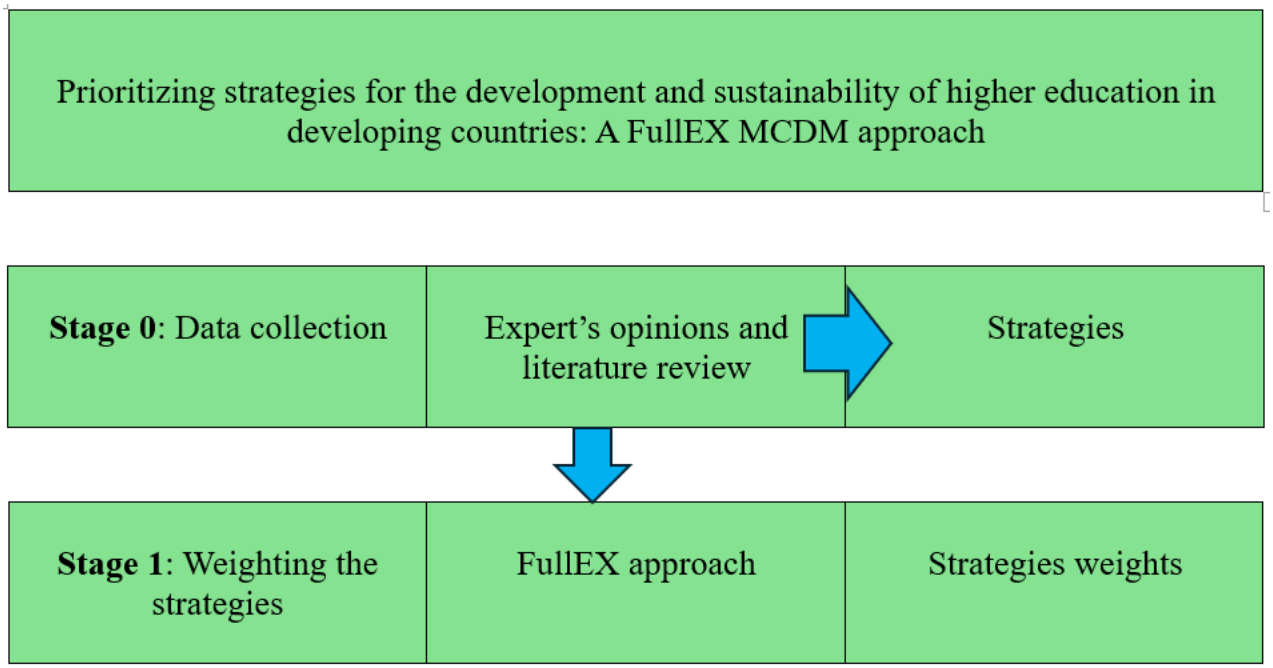

Fig. 1. Flowchart of our study approach

The FullEX approach operates within 11 steps as shown bellows.

Step 1. Expert identification.

In this step, key experts are selected based on their extensive knowledge and experience, such as those with years of expertise in Nigerian higher education system.

Step 2. Experts' reputations obtention.

Experts' reputations are assessed based on their years of experience (YE) and education (ED), with more experienced and educated experts having greater influence or weight (W^{Ei}). The reputation of each expert, denoted as L_i, is the average of their YE and ED

$$L_i = \frac{YE_i + ED_i}{2}, i = 1, 2, \dots, q, \quad (1)$$

Step 3. Criteria identification.

In decision-making, conflicting and interdependent criteria are identified using expert input or literature. This study combines both sources, with further details provided in the case study section.

Step 4. Experts' criteria evaluation.

At this stage, the selected experts assess the criteria using Fuller's triangle comparison scale [11].

Step 5. Input-data matrix formulation.

The experts' evaluations of the criteria form an input data matrix, as shown in Table A1 in the appendix. In this matrix, *q* experts assess *p* criteria using Fuller's triangle scale.

Step 6. Input-data matrix normalization.

In this step, the data undergoes normalization according to Eq. (2):

$$v_{ij} = \frac{z_{ij}}{\sum_{i=1}^{q} z_{ij}}, i = 1, 2, \dots, q, j = 1, 2, \dots, p. \quad (2)$$

Step 7. Normalized matrix by the experts' reputations multiplication.

The normalized matrix is multiplied by experts' reputations to form the expert-weighted matrix (Eq. (3)):

$$r_{ij} = v_{ij} \cdot W^{Ei}, i = 1, 2, \dots, q, j = 1, 2, \dots, p. \quad (3)$$

Step 8. Optimal value for each criterion identification.

This step seeks to determine the optimal value for each criterion ($V_{j\,max}$) using Eq. (4):

$$V_{j\,max} = \max_{i=1,2,\dots,q} r_{ij}, j = 1, 2, \dots, p. \quad (4)$$

Step 9. Optimal decision-making matrix obtention.

This step involves dividing each element of the expert-weighted normalized matrix by the optimal value ($V_{j\,max}$) via Eq. (5):

$$y_{ij} = \frac{r_{ij}}{V_{j\,max}}, i = 1, 2, \dots, q, j = 1, 2, \dots, p. \quad (5)$$

Step 10. Sum for each criterion calculation.

At this stage, the sum for each criterion (K_j) is derived from the optimal decision-making matrix (Eq. (6)):

$$K_j = \sum_{i=1}^{q} y_{ij}, i = 1, 2, \dots q, j = 1, 2, \dots, p. \quad (6)$$

Step 11. Final criteria ranking equation calculation.

The criteria weights (F_j) are determined based on the final ranking using Eq. (7).

$$F_j = \frac{K_j}{\sum_{j=1}^{p} K_j}, j = 1, 2, \dots, p. \quad (7)$$

4. Application

A study was conducted to assess the effectiveness of the FullEX technique in evaluating and prioritizing strategies for sustainable development in Nigeria's higher education sector. An expert panel of three individuals with extensive sector experience was formed to provide insights into the significance of nine identified strategies, validated through a literature review and expert opinions (see background of experts in Table 1). The strategies, prevalent in Nigeria's higher education sector (see Table 2), were evaluated based on two key parameters: expert experience and educational level (Ph.D., Master's, Bachelor's).

Table 1
Background information on experts

Experts	Gender	Professional role	Education level	Experience
E_1	Female	Associate professor	3	22
E_2	Male	Assistant professor	2	10
E_3	Female	Full professor	3	7

Table 2
Sustainable higher education development related strategies

Strategies	References
Employment of more lecturers (S1)	[9]
Stable academic calendar (S2)	[9]
Adequate funding (S3)	Expert opinion
Provide adequate ICT in schools for online education (S4)	Expert opinion
Provision of more adequate infrastructural facilities (S5)	[9]
Appointment of qualified school administrator (S6)	[9]
Adequate security in higher institutions (S7)	Expert opinion
Motivation of lecturers (S8)	Expert opinion
Fight institutional corruption (S9)	[9]

Steps 1-5. Using Fuller's triangle principle, experts compared two criteria and selected the more important one based on their assessments. This led to the formation of the input data matrix, which serves as the foundation for evaluating the significance of the criteria. The finalized matrix is presented in Table 3.

Table 3
Input-data matrix

Experts/strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9
E_1	4	0	3	5	1	2	7	6	8
E_2	3	4	6	3	1	0	5	6	8
E_3	8	4	5	2	1	0	6	3	7
Sum (E_1 to E_3)	15	8	14	10	3	2	18	15	23

Steps 6-7. After the initial input data matrix is created, the expert evaluation process begins. Then, the input data is normalized using the expert weighted matrix, with results displayed in Tables 4 and 5.

Table 4
Normalized input-data matrix

Experts/strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9
E_1	0.266	0.000	0.214	0.500	0.333	1.000	0.388	0.400	0.347
E_2	0.200	0.500	0.428	0.300	0.333	0.000	0.277	0.400	0.347
E_3	0.533	0.500	0.357	0.200	0.333	0.000	0.333	0.200	0.304

Table 5
Expert-weighted normalized input-data matrix

Experts/strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9
E_1	0.141	0.000	0.114	0.266	0.177	0.531	0.206	0.212	0.185
E_2	0.051	0.127	0.109	0.076	0.085	0.000	0.070	0.102	0.088
E_3	0.113	0.106	0.076	0.042	0.070	0.000	0.070	0.042	0.064
V_{jmax}	0.141	0.127	0.114	0.266	0.177	0.531	0.206	0.212	0.185

Steps 8-9. To obtain the optimal decision-making matrix (Table 6), each element in the expert-weighted normalized input data matrix is divided by its corresponding optimal value (V_{jmax}).

Table 6
Optimal decision-making matrix

Experts/strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9
E_1	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
E_2	0.360	1.000	0.960	0.288	0.480	0.000	0.342	0.480	0.480
E_3	0.800	0.833	0.666	0.160	0.400	0.000	0.342	0.200	0.350

Steps 10-11. The optimal decision-making matrix aggregates all values to determine the final criteria weights (F_j), displayed in Figure 2.

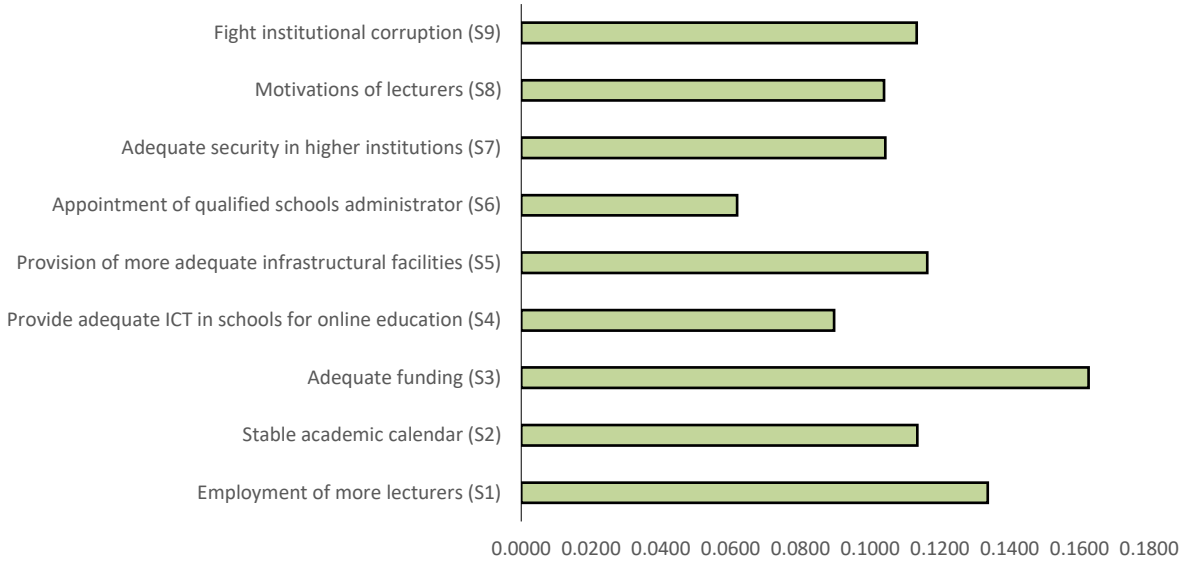

Fig. 2. Final rank of strategies related to sustainable development of higher education sector

According to Figure 1, the top four appropriate strategies for the development and sustainability of higher education sector in Nigeria are: adequate funding (S3), employment of more lecturers (S1), provision of more adequate infrastructural facilities (S5), and stable academic calendar (S2).

5. Sensitivity Analysis

Sensitivity analysis evaluates the robustness of the approach via the strategy weights assessment by considering variations in expert reputations under three scenarios: the first (YE&ED) scenario includes both years of experience (YE) and educational degree (ED), the second considers only YE, and the third focuses solely on ED. The results are illustrated in Figure 3.

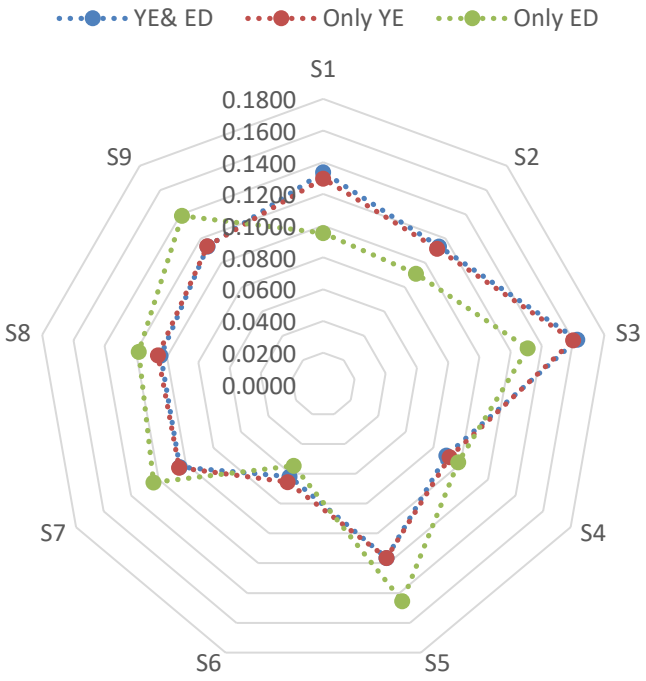

Fig. 3. First sensitivity analysis outcomes

As shown in Figure 3, incorporating both variables in calculating experts' reputations improves model stability (represented by the blue line), whereas using a single variable leads to notable shifts in the final criteria ranking. This highlights the importance of considering both variables and reinforces the value of applying the FullEX approach, a modern criterion weighting technique.

6. Comparative analysis

A comparative analysis was carried out to assess the strategy weights derived from the FullEX method in comparison with two other techniques, analytical hierarchy process (AHP) and the best worst method (BWM). AHP uses expert pairwise comparisons to assign numerical values to strategy importance, while BWM relies on Best-Worst comparisons without objective metrics. FullEX stands out by incorporating experts' education and experience and introducing a novel consistency ratio calculation. The strategy rankings from each method are summarized in Figure 4.

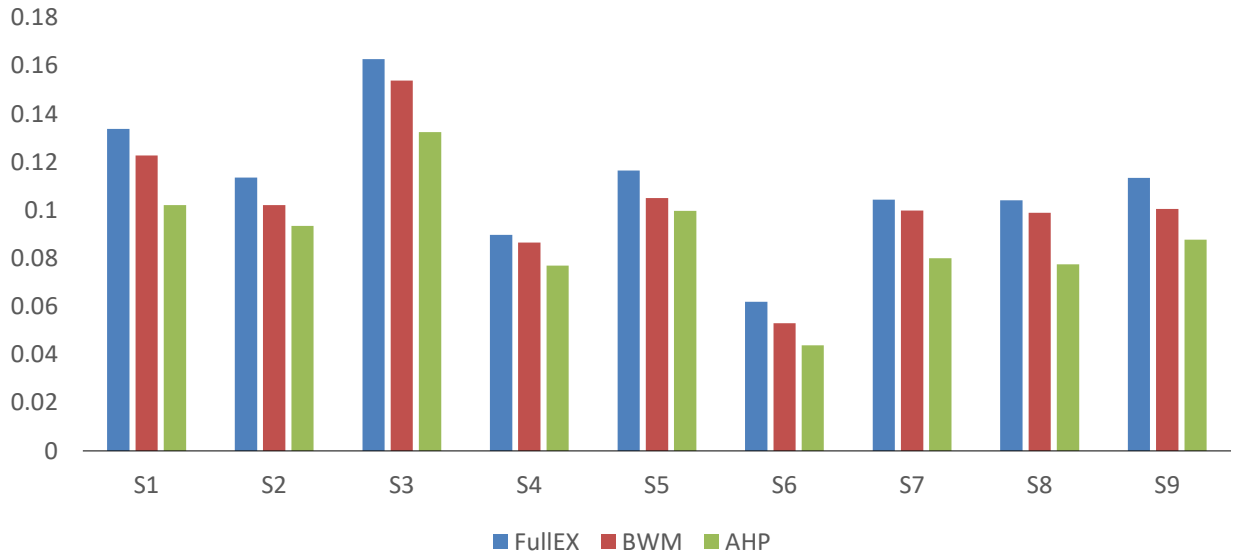

Fig. 4. Comparative analysis outcomes

The results indicate that the criteria weight outcomes derived from the FullEX method were fully consistent with those obtained using the BWM and AHP methods. As a result, the comparative analysis confirms the compatibility of the FullEX method with these alternative strategies weighting approaches.

7. Conclusions

This study applies the FullEX technique to prioritize strategies for advancing and sustaining Nigeria's higher education sector, providing valuable insights for policymakers. The approach emphasizes the importance of experts' years of experience and educational backgrounds, forming a critical basis for strategic decision-making. To validate the robustness of the method, a comparative and sensitivity analyses were conducted. Using Nigeria as a case study, the research highlights the technique's effectiveness in identifying key strategies. Our study highlights several key impacts and insights, including the role of adequate funding in providing resources for modern infrastructure, advancing research, and building faculty and staff capacity, thereby enhancing educational quality. Additionally, the employment of more lecturers reduces the student-to-lecturer ratio, improving the quality of teaching and personalized attention for students. Furthermore, the provision of adequate infrastructural facilities supports effective teaching, learning, and research through modern classrooms, laboratories, and technology-driven resources. Lastly, a stable academic calendar

ensures the timely completion of academic programs, improving students' learning outcomes and institutional efficiency. As its primary contribution, our study offers the most appropriate strategies that both federal and state governments can implement to develop and sustain higher education; however, it also acknowledges certain limitations. Firstly, the exclusive focus on Nigeria may limit the broader applicability of the results, suggesting the need for future research in other contexts. Secondly, the FullEX technique is currently limited to utilizing crisp values; expanding this method to incorporate uncertainty frameworks, such as fuzzy sets, Neutrosophic sets, or spherical fuzzy sets, would significantly improve its adaptability. Lastly, the evaluation involved a limited number of experts, indicating that future studies would benefit from including a larger pool of expert participants.

Appendix

Table A1
Input data matrix

Experts/Criteria	C_1	C_1	…	C_j	…	C_p
E_1	z_{11}	z_{12}	…	z_{1j}	…	z_{1p}
E_1	z_{21}	z_{22}	…	z_{2j}	…	z_{2p}
…	…	…	…	…	…	…
E_i	z_{i1}	z_{i2}	…	z_{ij}	…	z_{ip}
…	…	…	…	…	…	…
E_q	z_{q1}	z_{q2}	…	z_{qj}	…	z_{qp}

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Conflicts of Interest
The authors declare no conflicts of interest.

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