

Modelling Fuzzy Analytical Network Process for Sustainability Criteria of Malaysia Higher Education Institutions

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ABSTRACT

Sustainable development (SD) plays greater roles in the advancement of Higher Education Institutions (HEI). Yet, criteria for sustainable criteria must be re-defined, specifically in the context of Malaysian HEI. Accordingly, the aim of this study is to identify the sustainability criteria for HEI in Malaysia using Fuzzy Analytical Network Process (F-ANP). Methods used in this study is equipped with Chang's extent analysis to calculate the local weights for both criteria and sub-criteria based on pairwise comparison evaluations, while the global weights were derived by multiplication operations with the inner dependence weights. Three criteria and nine sub-criteria were identified and analyses thoroughly using six steps of F-ANP for Malaysia HEI sustainability assessment. Based on the numerical results, the sub-criteria "research" scored the highest weights as compared to other sub-criteria, indicating that "research" as the most important contributor to sustain the Malaysia HEI. Meanwhile the total weights score of the overall sub-criteria is 71.60%, which indicates "moderately sustainable" of the entire sustainability range. Overall, the findings suggest that the entire sub-criteria investigated using the extension of AHP are vital in influencing the sustainability of HEI in Malaysia. The study implies that "research" should be given more focus, which in turn leads to greater institutional visibility and reputation.

Keywords: Canonical representation of multiple operations, fuzzy analytical network process (F-ANP), graded mean integration representation, higher education institution (HEI), sustainable development (SD).

INTRODUCTION

Higher education for sustainable development (SD) can be defined as university that emphasize improvement in environmental, through the minimization of negative environmental, economic, societal and health effects to fulfil its functions of teaching, research, outreach and partnership and stewardship in ways to help society make the transition to sustainable lifestyles in regional or global level [1] It also can be demarcated as “enable individuals to reflect through multicultural, global and future oriented perspectives, on their responsibility for the complex effects of decision-making and behavior” [2]. Higher education for sustainable development not only as a ‘subject’ in the education curriculum, but also as a form of ‘transformative learning’ aimed at social change [3]. Moreover, the success of HEI is no longer depending solely on academic perspectives, yet it has been defined broader than that. i.e. energy usage, financial development, human capital development. While, green university is described as university that considering the sustainable development, climate change and adaptation of environmental protection goals to minimize the university’s effect to environment at the same time ensuring the general goal of HEI [4].

In Malaysia, there are many forms of universities that have been established. The main categories of universities are divided to public universities, private higher educational institutions, polytechnics and community college. Public universities are however further divided into three categories, namely research universities (RU), comprehensive universities (CU) and focused universities (FU). Nevertheless, Malaysian universities are relying on the international bodies such as QS ranking and UI Green Index to measure their sustainable development. Globally, the existing indicators in the field of green university, and sustainable university have employed UN Sustainable Development Goal Indicators, World Bank indicators, UI Green Matrix and Sustainability index [4].

Universities are encouraged to incorporate sustainability principles into everyday activities and structures (vision, mission statement, and strategy and sustainability coordinator), management performance, education and research (curriculum, teaching methods), operations, forming networks and reporting to stakeholders. [5] listed 18 barriers for sustainability initiatives. Among others are i) lack of awareness, interest and involvement, ii) organizational structure, iii) lack of funding, iv) lack of data access, v) resistance to change, vi) profit mentality, and vii) lack of policies. Yet, the criteria for sustainability in education are distributed over different aspect of literatures and some are inadequately investigated. Besides that, the level of consensus about policy goals and the institutional setting of the indicators is also the challenge [6]. In addition, [7] highlighted there is a need for real progress in a new methodology for sustainable development. In response to these issues, this study intends to propose sustainable criteria for HEI using fuzzy analytical network process (F-ANP). Accordingly, this study aims to identify the sustainability criteria for HEI specifically in Malaysia. The study is arranged as follows with Section 2 presents the recent literature review of sustainability dimensions. Section 3 explains the research designs and findings, where details procedures with a step-by-step approach using fuzzy analytical network process (ANP) and findings are discussed. Section 4 reviews the conclusions and scope of future research.

LITERATURE REVIEW

Studies on the sustainability among the HEI are quite abundant. However, many of the studies are pioneered based on the western countries, and only a few [8; 9; 10] were based on the Asian countries.

[11] review the UN level treaties/declarations of members of the SDG 4 subcluster in the Higher Education and Research for Sustainable Development (HESD) Global Cluster by the International Association of Universities (IAU). They argue that the involvement of HEI is limited only to the implementation of sustainability, where HEI should be involved in policymaking and become the avenue to practice sustainability. In terms of size, a university is considered as a mid-size town, where they supposedly should be able to handle and monitor their water, energy, and waste flows.

[12] reviewed 1459 Scopus-indexed articles related to higher education for sustainable development. Studies on the HE sustainability has gone through three stages of development, namely, i) emergent growth stage (1998-2004), ii) steady growth stage (2005-2011), and iii) accelerating growth stage (2012-2018). Out of the literature being reviewed, 84 percent of it was studied based on developing countries, while the rest of 16 percent was based on developed countries. Meanwhile, further analysis shows seven emerging countries emerged in sustainability for HE namely China, Malaysia, South Africa, Brazil, India, Mexico, and Turkey.

In addition, it seems that opportunities and constraints in pursuing sustainability are familiar with universities in both industrialised and developing countries [13]. Their findings reveal the causes that hamper local cooperation, namely lack of resources such as financial support and lack of coordination for industrialised countries (Canada, France, Italy, Latvia, Portugal, Serbia, United Kingdom & USA). For developing countries, lack of interest from colleagues, social partner and municipalities, and time are among the main challenges of university. Most universities prefer to have networking with other universities and NGOs. The authors suggested that government involvement, integration of all departments in university, greater strategic leadership and commitment from the top as essential for the success of cooperation. In developed Asian countries, such as Hong Kong where eight universities signed a declaration to incorporate sustainability in teaching and learning. Likewise in China where most universities have employed a phased plan to move towards sustainability agenda. While in Japan, the government is aiming to develop a new educational curriculum with sustainability agenda [14].

In Malaysia context, there are attempts to develop the index locally, yet none of that has been practiced at the national level (e.g. [15]). [16] identified lack of involvement, lack of funding and lack of policy as the challenges in developing the sustainability index in Malaysia.

There are various contexts of sustainability available in the past research. The most frequent topic discussed in the literature was on higher education institutions, curriculum development, students, teaching, learning, planning, environmental education, societies and institutions, the university sector, interdisciplinary education, and sustainability education [12]. Basically, there are three main pillars of sustainable development, namely social development, economic development, and environmental development.

Previous studies are also driven into studies that assessing the impact of existing sustainability index, and there are also studies which attempting to develop a new sustainability index instead of applying the existing one.

Drawbacks of Existing Sustainability Index

Among the sustainability indices for HEI that has been developed are Graphical Assessment of Sustainability in Universities (GASU), Three-Dimensional University Ranking (TUR), Sustainability Tracking and Assessment Rating System (STARS), GreenMetric (GM), Assessment of University Sustainability Policies and their relation to the International Campus of Excellence program (AUSP), Alternative University Appraisal (AUA), Unit-Based Sustainability Assessment Tool (USAT) and the Green Plan. Despite the abundance of index is established, yet it still needs a lot of improvements. The drawbacks of the existing index are mainly due to the suitability of the index itself to the types of the university. For instance, a university established with the aims to develop rural areas should not use the same sustainability index as the university that aiming for internalization and research. The suitability of the index might also relate to the local socioeconomic importance and the size of the university.

One of the issues in developing the sustainability index for HE is the separation of sustainable issue which is secluded from the research component of sustainability and without integration with the components of a sustainable campus [17]. Existing index did not allow for comparison among campuses [18]. This might be the effect of different framework and justification in selecting and aggregating the indicators [19]. More serious is, not all indexes were considering the major concept of sustainability [20].

[21] claims that the widely applied index such as the Sustainability Tracking, Assessment and Rating System (STARS) is still focusing heavily on the internal sustainability development (SD) performance. Not many indexes assess the impact that occurs outside the organization (i.e. Policy making, culture, demographics). In fact, it is only assessed specific activities of the HEIs. There is infrequent to see an index that could assess across both internal and external performance. Nevertheless, drawbacks of the existing index are due to many challenges. Among the challenges of the assessment of the SD impacts are its complexity of data which existing index were not able to capture. Furthermore, data availability is also an issue, where there is a mismatch between the quality of assessment with the additional effort and data required. This is suggesting that it is important to establish an index that is suitable with internal data readily available to HEIs.

Components Used by the Existing Sustainability Index

Numerous components of the SD index criteria have been proposed by the literatures.[22], have wider criteria for SD for the university. There are eight criteria used, namely i) healthy campus environment, ii) prosperous university economy, iii) green campus, iv) public participation, v) community projects, vi) non-curriculum activities, vii) sustainability in courses and curriculum and viii) research and development. The criteria were collected based on questionnaires distributed among the experts from the academia, government, and industry. The analysis reveals that healthy campus environment is the most important criteria, which indicate further that hazardous materials management, waste management strategy; pollution prevention and

municipal solid waste management should be prioritized to strengthen the university sustainability.

On the other hand, [23] suggesting economic, environment, and social as the major components of the sustainability index. These components are similar to the concept of education for sustainable development (ESD) that emphasize economic growth, social development, and environment protection for human development. A key element of sustainable university should include environmental protection, economic performance, and social cohesion as part of sustainable development.

[21] analyzed to what extent sustainability assessment tools (SATs) can measure the impacts that HEI have on the SD. The study examined 1134 indicators which is derived from 19 SATs used by the HEI. The findings of the studies reveal that current SATs were only used internal proxy indicators and neglecting the impacts that HEIs have outside their organizational boundaries. For that, the authors have suggested that the sustainability index among the HEI should include i) outreach, ii) assessment and reporting, iii) education, iv) campus operation and v) research. Similarly, [21] also claims that there are eight important components for HEI sustainability namely i) institutional framework, ii) education, iii) research, iv) outreach, v) campus operations, vi) campus experiences, vii) assessment and reporting, and viii) higher education institution.

Recently, [24] have applied ServQual model comprising five dimensions, namely tangible, reliability, responsiveness, assurance, and empathy to measure sustainable campus services in higher education. These five dimensions are integrated to sustainability and service quality issues in higher education. Essentially, the results show university located in socio-economically more developed region had performed better in overall satisfaction score with four dimensions; services to students, physical means, responsiveness, and natural resources to achieve sustainable campus.

In Malaysia context, there are also few studies available in SD. Among the pioneer in Malaysia is a study by [15] which identified sustainability higher education (SHE) assessment indicators in the community aspect for Malaysia using interview and questionnaire survey. They found that gender issues, command of language and ethnic polarization as specific potential indicators of Malaysian assessment approach. Their findings reveal that the majority of Malaysian HEI reveals that student voluntarism and staff voluntarism would contribute to sustainability of the campus community. Essentially, the main rubrics of community aspect consist of involvement and cohesion, diversity, services, and programs. [25] focused on three sustainability components, namely management, co-curriculum and greening. On the other hand, [9] highlights five important components, namely i) research and publication, ii) administration, iii) campus operation, iv) community engagement and v) assessment and reporting.

Yet, besides focusing on what is required by the UN declaration, the perception of students on what constitutes success in HEI is also equally important. [26] studied five dimensions, namely, smart classroom, user-friendly technology, peers support, partnership, and social governance, as potential determinants for HEI among the undergraduate and postgraduate students. The study reveals that the partnership of the institution, smart classrooms, and social governance

has a positive influence on higher education success. However, user-friendly technology and peer support were not found to be significant.

Methodology used by the Existing Sustainability Index.

Methodology in developing the sustainability index does play important roles, despite the selection of the components and its sub-components. TUR index, which have 3 levels of sustainability hierarchy and 15 indicators used analytical hierarchy process (AHP) in its weighting method [18]. While [22], used fuzzy Delphi method to screen key critical factors. [27] applied explanatory factor analysis (EFA) to validate the instruments, confirmatory factor analysis (CFA) and analyze structural equation modelling (SEM). [8] extended the model to partial least squares-SEM (SEM-PLS) to study the energy management in Malaysian university. [24] introduced new weighting method for the AHP known as Pythagorean Fuzzy sets and adapted new scale such as ServQual using explanatory factor analysis. Since existing researcher rarely explore the HEI sustainability criteria, thus this research was initiated and focus to identify the HEI sustainability criteria using F-ANP. It is believed that the proposed method can assist the policy makers or decision makers (DMs) to identify the most significant criteria and sub-that influenced and contributing to SD. Thus, these inputs can determine the sustainable categories of HEI in Malaysia perspective.

RESEARCH DESIGNS AND FINDINGS

Sustainable HEI Criteria

To develop the sustainability category, three main criteria has been chosen namely institutional commitment (IC), example setting and leadership (ESL) and advancing sustainability (AS). The sub-criteria for IC are statement, strategies, and coordination; sub-criteria for ESL are diversity and equity, resource consumption and experience on campus, while sub-criteria for AS is education, research, and public engagement. These sub-criteria are adopted from [28] after thoroughly reviewed by local research [9]. The criteria are combination of both foreign and local authors, which has tested the suitability of the criteria especially for Preliminaries: For reference purposes, in this section a brief of fuzzy set theory, TFNs, and linguistic variables will be reviewed.

Definition 1: A fuzzy set $\tilde{A}$ in a universe of discourse X is characterized by a membership function $\mu_{\tilde{A}}(x)$ which associates with each element x in X that takes the value in the real number in the interval $[0,1]$. The function value $\mu_{\tilde{A}}(x)$ is termed the grade of membership of x in $\tilde{A}$.

Definition 2: A Triangular Fuzzy Number (TFN) $\tilde{A}$ can be defined by a triplet (l, m, u) , where l , m , and u are left, middle and right foot of TFNs, respectively. The membership function $\mu_{\tilde{A}}(x)$ is defined as:

$$\mu_A(x) = \begin{cases} 0, & x < l, \\ \frac{x-l}{m-l}, & l \leq x \leq m, \\ \frac{x-u}{m-u}, & m < x \leq u, \\ 0, & x > u \end{cases} \quad (1)$$

Definition 3: [29] Let $\tilde{A} = (a^l, a^m, a^u)$ and $\tilde{B} = (b^l, b^m, b^u)$ be two triangular fuzzy numbers. The graded mean integration, representation between $\tilde{A}$ and $\tilde{B}$ as.

$$I_M(\tilde{A}) = \frac{1}{6}(a^l + 4a^m + a^u) \quad \text{and} \quad I_M(\tilde{B}) = \frac{1}{6}(b^l + 4b^m + b^u) \quad (2)$$

Thus, the canonical representation of multiple operation on TFNs between $\tilde{A}$ and $\tilde{B}$ defined as

$$\begin{aligned} I(\tilde{A} \otimes \tilde{B}) &= I(\tilde{A}) \times I(\tilde{B}) \\ &= \frac{1}{6}(a^l + 4a^m + a^u) \times \frac{1}{6}(b^l + 4b^m + b^u) \end{aligned} \quad (3)$$

In this research a mean of fuzzy numbers is used for direct evaluation based on five importance levels of each sub-criteria as shown in Table 1. Meanwhile, the sustainability total score was used to categorise the sustainability [31] of HEI given in Table 2.

Table 1: The Five Importance Levels of Each Sub-Criteria

Linguistic variables	Mean of fuzzy numbers
Very high (VH)	1.0
High (H)	0.75
Medium (M)	0.50
Low (L)	0.25
Very low (VL)	0

Table 2: The Sustainability Category (Rashid, 2015)

Total Score (TS), (%)	Sustainability category
TS ≥ 80	Sustainable
80 > TS ≥ 50	Moderately sustainable
50 > TS	Less sustainable

Fuzzy-Analytic Network Process (F-ANP)

For many decades, there are several methods have applied to solve the decision-making problem in fuzzy environment. One of the popular methods that successfully dealing with the ambiguity and uncertain data is fuzzy ANP. This method has proven and successfully applied in various applications such as in machine selection [31], supplier selection [32 & 33], market value [34], land-use planning [35], outsourcing provider selection [36], etc.

The idea of this method was pioneered from Analytic Hierarchy Process (AHP) which proposed by Saaty in 1980. However, many decision-making problems cannot be analysed efficiently between two different levels of hierarchy, therefore the same researcher has proposed the new method in 1986 which emphasis on the network analysis to overcome this problem known as ANP. Since then, the ANP has been extended by combining with the fuzzy set theory in the evaluation process. The method is able to handle the uncertain information and imprecise data during the judgemental process by decision makers (DMs) with easy and efficient manner. Also, the unique of fuzzy ANP is, it can accommodate with the interrelationships amongst the functional activities [38].

In this paper, all the measurement scores from 0 – 5 were defined and determined prior and the expert's evaluation score is transformed into the TFNs scales as given in Table 3.

Table 3: The Five Degree of Importance and TFNs

Degree of importance	Crisp scale	TFNs	Reciprocal of TFNs
Just equal	0	(1, 1, 1)	(1, 1, 1)
Equally important (EI)	1	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly more important (WMI)	2	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly more important (SMI)	3	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strongly more important (VSMI)	4	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Absolutely more important (AMI)	5	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

A brief procedure to assess the sustainable criteria using Fuzzy ANP [38; 39] is given as follows:

Step 1: Identify the expected sustainable criteria and sub-criteria of HEI in Malaysia context

Step 2: Design and construct the ANP structure in different stages consisting the goal, criteria and sub-criteria, respectively.

Step 3: Calculate the local weights of criteria and sub-criteria, respectively, using the pairwise comparison matrices.

At this step the experts/DMs are requested to evaluate each criteria and sub-criteria using pairwise comparison based on the questionnaire. The general structure of the matrices is given as follows:

$$M = \begin{bmatrix} (1, 1, 1) & (l_{12}, m_{12}, u_{12}) & \dots & (l_{1n}, m_{1n}, u_{1n}) \\ (l_{21}, m_{21}, u_{21}) & (1, 1, 1) & \dots & (l_{2n}, m_{2n}, u_{2n}) \\ \vdots & \vdots & \ddots & \vdots \\ (l_{n1}, m_{n1}, u_{n1}) & (l_{n2}, m_{n2}, u_{n2}) & \dots & (1, 1, 1) \end{bmatrix} \quad (4)$$

where $l_{ij} = \frac{1}{u_{ji}}; \quad m_{ij} = \frac{1}{m_{ji}}; \quad u_{ij} = \frac{1}{l_{ji}}$

For this purpose, the extent analysis, which proposed by [39] was utilised to calculate the local weights and to transform the TFNs into crisp values.

Step 4: Calculate the inner dependence matrix of the criteria.

The inner dependence matrix of the criteria can be determined by multiplying the local weights of the criteria (from Step 3) and the dependence of local weights in the inner matrix. Thus, the inner dependence matrix of criteria is given as

$$W_{\text{criteria}} = \frac{1}{2} \begin{bmatrix} a_{11} & \dots & a_{1n} \\ \dots & \dots & \dots \\ a_{m1} & \dots & a_{mn} \end{bmatrix} \times [d^w(M_1), d^w(M_2), \dots, d^w(M_n)]^T \quad (5)$$

where $d^w(M_i); (i=1,2,3,\dots,n)$ is the local weights of each criteria.

For simplicity, the concept of graded mean integration representation and canonical representation of multiple operations (see Definition 3) were applied to calculate, prior the relative importance weights of each sub-criteria. This concept also can transform the TFNs into crisp values.

Step 5: Calculate the global weights of the sub-criteria.

The global weights ($G_{\text{sub-criteria}}^w$) can be calculated by multiplying local weights of sub-criteria with inner dependence weights that related to the criteria given as

$$G_{\text{sub-criteria}}^w = (L_{\text{sub-criteria}}^w) \times (IN_{\text{dep}}^{wc}) \quad (6)$$

where $L_{\text{sub-criteria}}^w$ and IN_{dep}^{wc} are local weights of sub-criteria and inner dependence weights of criteria, respectively.

Step 6: Determine the total score weights which contributing to the HEI sustainability.

At this stage the global weights ($G_{\text{sub-criteria}}^w$) of the criteria which is obtained from step 5 is multiplied to the scale values (SV) proposed by [40] to derive the total score weights (TS^w) given as

$$TS^w = (G_{\text{sub-criteria}}^w) \times (SV) \times 100\% \quad (7)$$

where SV is scale values.

At this stage, the score weights for each of the sub-criteria can be identified and the highest score weights indicate the biggest contributor to achieve the sustainability. Finally, the level of sustainability category easily can be determined from HEI sustainability total score definition (see Table 2).

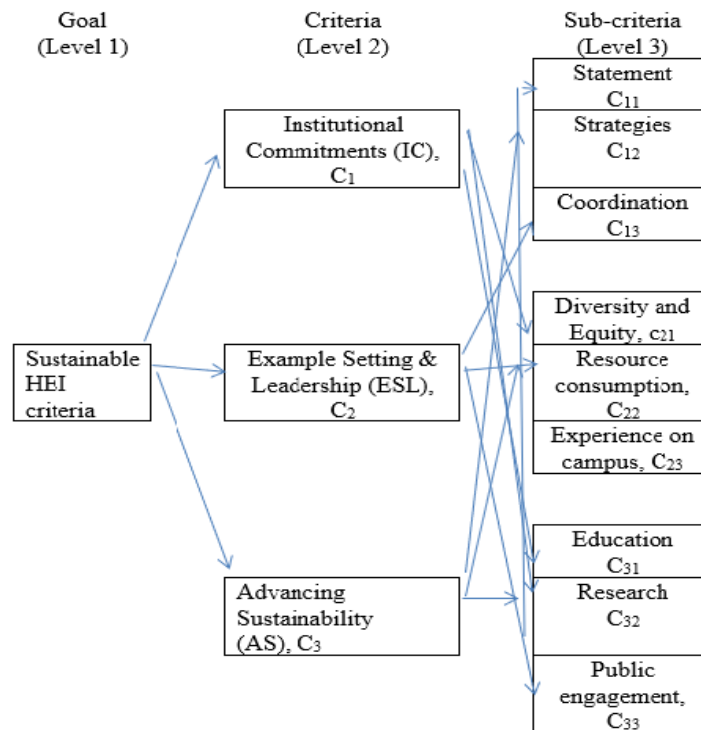


Figure 1: The identified three stages of network structure

A Numerical Example

In this study, we adopted an HEI model which introduced by [28] thoroughly reviewed by local researchers [9], which we believed suitable for the Malaysia HEI environment. For simplicity, suppose that a group of experts or DMs involved with 3 members; (d_i); ($i = 1, 2, 3$) they evaluated the HEI sustainability level, which consisting 3 main criteria (C_i ; $i = 1, 2, 3$) and considered 9 sub-criteria (c_{ij} ; $i = 1, 2, 3$; $j = 1, 2, 3$). Thus, based on 6 steps that we have proposed in the previous section, following is the details procedures:

Step 1 & 2: Identify the expected sustainable criteria and sub-criteria of HEI in Malaysia context. Based on the LRs worldwide and suggested by [9], we have structured the criteria and sub-criteria based on three levels. Also, the different levels consisting of the goal, criteria and sub-criteria were identified completely. The comprehensive structure of the network as shown in Fig. 1.

Step 3: Calculate the local weights of criteria and sub-criteria, respectively, using the pairwise comparison matrices.

In this step, the DMs need to evaluate through pairwise comparison technique between 2 different criteria, respectively using the measurement score which defined in Table 2 and given as follows

Table 4: The Pairwise Comparison Evaluation between Criteria.

Criteria	DMS	C ₁	C ₂	C ₃
C ₁	d ¹		(2/3, 1, 3/2)	(2/3, 1, 3/2)
	d ²	(1,1,1)	(2/5, ½, 2/3)	(1/3, 2/5, ½)
	d ³		(3/2, 2, 5/2)	(1/3, 2/5, ½)
C ₂	d ¹	(2/3, 1, 3/2)		(5/2, 3, 7/2)
	d ²	(3/2, 2, 5/2)	(1,1,1)	(5/2, 3, 7/2)
	d ³	(2/5, 1/2, 3/2)		(1/3, 2/5, ½)
C ₃	d ¹	(2/3, 1, 3/2)	(2/7, 1/3, 2/5)	
	d ²	(2, 5/2, 3)	(2/7, 1/3, 2/5)	(1,1,1)
	d ³	(2, 5/2, 3)	(2, 5/2, 3)	

Table 5: The Average Evaluation Derived From Table 4

Criteria	C ₁	C ₂	C ₃
C ₁	(1,1,1)	(0.856, 1.167, 1.556) (1,1,1)	(0.444, 0.600, 0.833)
C ₂	(0.856, 1.167, 1.833)	(1,1,1)	(1.778, 2.133, 2.500)
C ₃	(1.556, 2.000, 2.500)	(0.857, 1.055, 1.267)	(1,1,1)

By using Chang's extensive analysis [39], the local weights of criteria were calculated and obtained as shown in Table 6.

Table 6: Local Weights of Each Criterion

Criteria	C ₁	C ₂	C ₃
Local weights	0.174	0.431	0.395

Similarly, the local weights of entire 9 sub-criteria with respect to each criterion can also calculate and obtained as shown in Table 7.

Table 7: Local Weights of Each Sub-Criteria With Respect To C1, C2 and C3

Criteria, C _i (i =1,2,3)	Sub-criteria, c _{ij} (i =1,2,3; j =1,2,3)		
IC	0.427	0.354	0.219
ESL	0.387	0.165	0.448
AS	0.277	0.498	0.225

Step 4: Calculate the inner dependence matrix of the criteria

The inner dependence matrix of the criteria can be determined by multiplying the local weights of the criteria (from step 3) and the dependence of local weights in the inner matrix. The concept of graded mean integration representation and canonical representation of multiple operations (see Definition 3) was utilised to derive the relative importance weights (RIW) of each criteria given in Table 8 – 10, respectively.

Table 8: The Relative Importance Weights With Respect To IC (C1)

IC, C ₁	C ₂	C ₃	RIW
C ₂	(1,1,1)	(1.778, 2.133, 2.500)	0.669
C ₃	(0.857, 1.055, 1.267)	(1,1,1)	0.331

Table 9: The Relative Importance Weights With Respect To ESL (C2)

IC, C ₂	C ₁	C ₃	RIW
C ₁	(1,1,1)	(0.444, 0.600, 0.833)	0.339
C ₃	(1.556, 2.000, 2.500)	(1,1,1)	0.661

Table 10: The Relative Importance Weights With Respect To AS (C3)

IC, C ₃	C ₁	C ₂	RIW
C ₁	(1,1,1)	(0.856, 1.167, 1.556)	0.490
C ₂	(0.856, 1.167, 1.833)	(1,1,1)	0.510

Thus, the inner dependence matrix of criteria is calculated given as

$$\begin{aligned}
 W_{\text{criteria}} &= \frac{1}{2} \begin{bmatrix} 1 & 0.339 & 0.490 \\ 0.669 & 1 & 0.510 \\ 0.331 & 0.661 & 1 \end{bmatrix} \times \begin{bmatrix} 0.174 \\ 0.431 \\ 0.395 \end{bmatrix} \\
 &= \frac{1}{2} \begin{bmatrix} 0.514 \\ 0.749 \\ 0.737 \end{bmatrix} = \begin{bmatrix} 0.257 \\ 0.375 \\ 0.369 \end{bmatrix}
 \end{aligned}$$

At this stage, it is clearly seen that criteria 'example setting and leadership' (ESL), C2 is the most important criteria in this sustainability assessment.

Step 5: Calculate the global weights of the sub-criteria.

The global weights can be calculated by multiplying local weights of sub-criteria with inner dependence weights that related to the criteria, obtained as

Table 11: Global Weights of Criteria

Criteria	C ₁			C ₂			C ₃		
Independent weights of criteria	0.257			0.375			0.369		
Local weights of sub-criteria	C ₁₁	C ₁₂	C ₁₃	C ₂₁	C ₂₂	C ₂₃	C ₃₁	C ₃₂	C ₃₃
	0.427	0.354	0.219	0.387	0.165	0.448	0.277	0.498	0.225
Global weights ($G_{\text{sub-criteria}}^w$)	0.110	0.091	0.056	0.145	0.062	0.168	0.102	0.184	0.083

Step 6: Determine the total score weights which contributing to the HEI sustainability.

From Step 5, the global weights of each criteria will be multiplied to the scale values (SV) [40] to derive the total score weights (TSw). The results shown in Table 12.

Table 12: Sustainability Average of Total Scores.

Sub-criteria	Global weights ($G_{\text{sub-criteria}}^w$)	DMs evaluation (d^1, d^2, d^3)	Average SV	Total scores (%), (TS^w)
Statement, c_{11}	0.110	(M, H, L)	0.500	0.055
Strategies, c_{12}	0.091	(VH, H, M)	0.750	0.068
Coordination, c_{13}	0.056	(M, H, VH)	0.750	0.042
Diversity and Equity, c_{21}	0.145	(M, H, H)	0.667	0.097
Resource consumption, c_{22}	0.062	(H, H, H)	0.750	0.047
Experience on campus, c_{23}	0.168	(M, L, VH)	0.583	0.098
Education, c_{31}	0.102	(H, VH, H)	0.833	0.085
Research, c_{32}	0.184	(VH, VH, H)	0.917	0.169
Public engagement, c_{33}	0.083	(H, H, M)	0.667	0.055
Sustainability average of total scores (%)				71.60%

Based on Table 12, it shows that the sub-criteria research (c_{32}) is the most influenced factor that contributing to the HEI sustainability, while the sub-criteria coordination (c_{13}) identified the least influenced factor with total scores are 16.9% and 4.2%, respectively. Overall, the average total score shows 71.60% obtained which means 'moderately sustainable' (see Table 2) achieved for the entire investigated criteria.

CONCLUSION

The paper discussed how the fuzzy method namely, F-ANP was used efficiently to assess the HEI criteria towards achieving the sustainability. F-ANP is used to address the criteria of the sustainability of HEI in Malaysia. Three main criteria namely, institutional commitment (IC), example setting and leadership (ESL) and advancing sustainability (AS) is used. The sub-criteria for IC are statement, strategies, and coordination; sub-criteria for ESL are diversity and equity, resource consumption and experience on campus, while sub-criteria for AS is education, research and public engagement. Among the sub-criteria, research (0.184) has the highest weights, followed by experience on campus (0.168), and diversity and equity (0.145). Coordination recorded as the lowest weights (0.056) among the sub-criteria. Looking into the criteria score, overall, we can see that AS is the most important criteria (0.309), followed by ESL (0.242) and IC (0.165). Overall score for the sustainability index is 71.60%, implying that it is moderately sustainable. The results imply that HEI can be sustained through research and advancing sustainability. This result is consistent to [21] and [9] who emphasized research as one of the components for HE sustainability. It has shed some lights that being a university with concentration on R&D could maintain the university in the long-run and is important for the advancement of the university. Yet, research should be practiced together with education and public engagement. In addition, HEI also needs to focus on the ESL. This indicates that the HEI should be serious in engaging experience on campus. In other words, HEI should put an effort to increase participation related to sustainability, which covers day-to-day activities on campus, internal communications, community training programs and organizing events. Finally, HEI should emphasis on diversity and equity, which means HEI should be aiming to assess the diversity and inclusiveness of the institution, including issues such as salary scheme, equal gender opportunities, and access for students from low socioeconomic backgrounds.

The result also suggests some implications on the methodological applied. Based on the numerical example, the result shows the method offers a comprehensive judgement and extended the certainty elements along with the identification of SD process criteria. The method accommodates the linguistic assessment evaluations using the concept of graded mean integration representation and canonical representation by multiple operations. It also allows the involvement of group DMs to derive more precision attained in terms of evaluations. Although the method applied in this paper was meant specifically to solve the choosing model, other application models are expected to gain benefits and attaining the similar outcome.

As for the practical implication, the findings of the current study may serve as a guideline for Malaysian HEI to look for an initiatives to advance the education and trainings at the tertiary level. This is important as HEI is an avenue to train well-rounded talents, whom will lead and holds important positions, or perhaps become potential employers in the future.

More research needs to be conducted to improve the overall score of the sustainability categories. Going forward, the researchers should consider some other substantial criteria such as graduate employability, entrepreneurship, and human capital. Besides, religious, or ethical perspectives also could be considered in developing the index. Thus, the next phase of this research will focus on how the proposed method can successfully accommodate the diversity of these large substantial criteria from different input of datasets especially for criteria which of naturally uncertain and incomplete information.

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