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Research Article

Priority Roles of Stakeholders for Overcoming the Barriers to Implementing Education 4.0: An Integrated Fermatean Fuzzy Entropy-Based CRITIC-CODAS-SORT Approach

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This work defines various stakeholder roles (or strategies) to overcome the barriers to implementing Education 4.0 (EDUC4), which were recently identified in the domain literature. The stakeholder roles are evaluated against these barriers, and such evaluation is structured as a multicriteria sorting problem. To this end, an integrated entropy-based CRITIC-CODAS-SORT under a Fermatean fuzzy (FF) environment addresses epistemic uncertainties inherent in decision-making. The FF CRITIC assigns the priority weights of the barriers, while the FF CODAS-SORT determines the high-priority stakeholder roles. A case of an HEI evaluating 57 possible roles of 5 stakeholders is demonstrated here. Findings suggest the lack of collaboration, apprehensive stakeholders, cybersecurity threats, health issues, and cost as crucial barriers to the HEI. The sorting process yields 13 high-priority roles, encompassing those within the influence of the government (i.e., cybersecurity awareness, allocation of necessary funds, designing more aligned curricula, and streamlining the basic education agenda), university management (i.e., investing in efficient technologies and forging extensive stakeholder collaboration), human resource function (i.e., implementing periodic skills training for educators), and educators (i.e., engaging in continuous learning about cybersecurity threats, integrating awareness of applicable laws against cyberbullying, devising alternative cost-efficient teaching strategies, taking part in initiatives to improve curricula, efficient preparation of learning materials, and participating in skills development initiatives). Various managerial insights are offered as inputs to the design of initiatives in EDUC4 implementation.

1. Introduction

In recent years, Education 4.0 (EDUC4) has been recognized as a framework for learning institutions so that teaching and learning will be aligned with the fourth industrial revolution (4IR). EDUC4 characterizes a learning process highly associated with technologies such as virtual learning environments [1], adaptive internet of things (IoT) [2], and artificial intelligence (AI) [3]. These technologies have a curriculum design that reflects technology-based environments [4]. Despite these advances in the teaching-learning process linked to EDUC4, developing economies encounter barriers in its implementation due to resource scarcity, educational politics, and cultural aspects. For instance, the response of Malaysia in EDUC4 faces challenges ranging from limited and inefficient educational resources, outdated

teaching styles, and inadequate infrastructure, to a lack of close linkages among educational institutions [5]. In Pakistan, they found no framework that provides the base for EDUC4 with the lack of resources, improper implementation of relevant policies, and inexperienced human resources [6]. A recent review by Costan et al. [7], with an empirical work of Gonzales et al. [8], comprehensively identified these EDUC4 implementation barriers, with a particular focus on developing economies.

Current literature (e.g., [3, 9]) highlighted some essential roles of stakeholders in overcoming the barriers of implementing EDUC4 and putting such an initiative into action. Although Costan et al. [7] established the barriers through a systematic literature review, there is no existing literature about identifying specific functions of the stakeholders that can better address the barriers to EDUC4 implementation, especially in a developing economy. Mourtzis [10] reported the relevance of the teaching factory concept for successful EDUC4 implementation, but the degree of participation of the stakeholders so that a university could dynamically execute the teaching factory direction is not clear. This implies that stakeholders' roles in taking the EDUC4 initiative are not straightforward. For instance, we expect to improve government investments in social and human capital [11] and prepare for the costly challenges of rapid technological advancements and developing ICT competencies. Thus, overcoming the barriers to EDUC4 implementation needs a thorough understanding of stakeholder roles so that educational managers, human resources, educators, ICT function, and other relevant stakeholders can function systematically in any policy direction toward EDUC4.

In this work, evaluating stakeholder roles in overcoming different barriers to implementing EDUC4 is structured as multiple-attribute decision-making (MADM) problem, where barriers are treated as "evaluation criteria" and stakeholder roles as "evaluation alternatives." In addressing this problem, we proposed the integration of the CRiteria Importance through Intercriteria Correlation (CRITIC) and multiple criteria sorting (MCS) method based on the COmbinative Distance-based ASsessment (CODAS) approach (i.e., CODAS-SORT) under Fermatean fuzzy set (FFS) environment to account for epistemic uncertainties in expert decision-making. The Fermatean fuzzy (FF) CRITIC assigns priority weights of implementation barriers, while the FF CODAS-SORT sorts the stakeholder roles by identifying those high roles for strategic implementation of EDUC4. Unlike other priority weight allocation methods (e.g., analytic hierarchy process, best-worst method, and full consistency method), the CRITIC developed by Diakoulaki et al. [12] provides an efficient technique for generating priority weights of criteria or attributes from a decision matrix. The mental workload required from decision-makers in eliciting judgments is significantly minimized, particularly in a huge number of attributes (e.g., 50 attributes). Recent applications of the CRITIC method were reported in the MADM literature (e.g., [13–15]). On the other hand, the CODAS method, proposed by Ghorabaee et al. [16], offers an efficient yet powerful MADM platform based on Euclidean distance, similarly conceptualized with the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). Such applications of the CODAS and its extensions have been increasing in the literature (e.g., [17–19]). The CODAS-SORT, with a variant offered by Ouhibi and Frikha [20], is part of the family of MCS methods that assigns a set of elements (e.g., alternatives) to predefined classes under an evaluation based on multiple criteria. A brief discussion of the background of MCS is found elsewhere (e.g., [21]), and the performance of the CODAS-SORT is found to be comparable with TOPSIS-SORT and VIKORSORT [21, 22], but with a more efficient computational framework.

Due to the presence of vagueness and uncertainty inherent in both CRITIC and CODAS-SORT, the use of the FFS addresses these conditions by overcoming the limitations of the classical fuzzy set [23] and the intuitionistic fuzzy set [24] or the Pythagorean fuzzy set [25]. This particular argument on epistemic uncertainties has been repeatedly mentioned in several other works in the field of management [26–28]. Proposed by Senapati and Yager [29], the FFS is deemed more capable of handling higher uncertainties than the previously developed fuzzy environments. Although the FF CRITIC has been recently offered in the literature [30, 31], the integration of FFS within CODAS-SORT is not yet explored, so is the application of an integrated FF CRITIC-CODAS-SORT in an MADM problem. This forms the methodological contribution of this work. A case study in a publicly funded HEI in the central Philippines demonstrates the application of the proposed approach. Ultimately, the main contributions of this work advance both the literature on EDUC4 and MCS by developing an integrated approach based on FF CRITIC-CODAS-SORT in systematically identifying high-priority stakeholder roles in overcoming the barriers to EDUC4 implementation. Determining these important roles would inform the design of initiatives and policy directions of different stakeholders in advancing the implementation of EDUC4 in an HEI.

The remainder of this paper is arranged as follows. Section 2 reviews the relevant literature. Section 3 presents some background of FFS, the CRITIC, and CODAS methods. Section 4 details the methodology by illustrating the case study environment and demonstrates the application of the proposed FF CRITIC-CODAS-SORT in identifying the high-priority stakeholder roles. The findings and some key policy insights are discussed in Section 5. It ends with concluding remarks and a discussion of future works in Section 6.

2. Literature Review

Previous works have investigated the barriers to EDUC4 implementation in various aspects: human resources [2, 3], change management [32], technological infrastructure [33, 34], and financial [35], among others. A systematic literature review by Costan et al. [7] reported a comprehensive identification of the barriers to EDUC4 in developing economies. In their work, 12 barriers were identified. These barriers include cybersecurity threats, costly, skill gap of the human capital, apprehensive stakeholders, lack of

training resources, lack of collaboration, knowledge gap for the customization of curriculum design, insufficient available technologies, health issues, time constraint for material preparation, the complexity of learning platforms, and insufficient foundation in basic foundation. The initiatives in addressing these barriers are complex, and the policy directions are ideally dependent on economic characteristics and the willpower of the stakeholders. Notably, the implementation strategies are contextually unique, and there is a need to capture the evidence of changes among the key players, such as the policy-makers, educators (enablers), and learners (receivers) [4]. For example, a study on the design framework for Indonesian higher education using blockchain technology (i.e., an EDUC4 component) concentrates on investing in human resources and social capital [11].

As part of the clusters of barriers identified by Costan et al. [7], managing human resources requires the need for a sustainable program that enhances labor market demands, such as upskilling and reskilling of university graduates aligned with the requirements of the industries [36] to increase productivity [6] and harmonize human and artificial intellectual capital [3]. The policies and practices necessary for upgrading human resources are imperative in EDUC4 implementation. On the other hand, as a technology-based environment, EDUC4 requires ICTs to be integrated into the teaching-learning process. In Malaysian Schools, Ghavifekr and Wong [37] suggest that the utilization of ICTs and the digital revolution have been the focal points in this direction. They demonstrated that the ICT leadership of school principals impacts teachers' effective ICT utilization. Finally, as front liners in the implementation process, the role of educators in exercising the strategic initiatives of the HEI managers is equivalent to the quality of the target competencies. Hamilton [34] postulated teachers' human side efforts while working with AI and other technologies in a university experience. Customized adaptive learning, redefined assessment, and intelligent and smart approaches are some initiatives for enhanced delivery of learning outcomes under an EDUC4 environment.

Previous studies revealed that stakeholders, that is, government, university management, human resource function, ICT function, and educators, play crucial roles in implementing EDUC4 [3, 9, 34]. The macro-level role of the government goes beyond policy-making and funding sources. For instance, in the Philippines, the government and its faculties are committed to the following functions: (1) provide training to educators for lesson delivery, curriculum design, and instructional materials development, (2) align and device initiatives that will complement basic education and EDUC4, (3) craft protocols to safeguard from cybersecurity attacks and to promote healthy use of technologies, (4) strengthen collaboration efforts from internationally recognized higher education institutions (HEIs) and intragovernment agencies, (5) benchmark technologies used by successful implementers of EDUC4, and (6) ensure and evaluate that EDUC4 responds to the sustainable development goals. Moreover, the government's massive role in EDUC4 translates to the seamless coordination between delivering agencies and the HEIs. As a decision-making body, the role of HEI managers is to carry out strategic initiatives to achieve target goals, including pedagogical and evaluation assessments, relevant approaches to promote cybersecurity awareness, applicable measures in learning material preparation, and essential and cost-efficient technologies for content delivery.

Different findings emerged in the literature on EDUC4 implementation. For example, Ramírez-Montoya et al. [38] identified that decision-makers and the social and academic communities play important roles in developing reasoning for complexity. Critical thinking competency has been given importance in the EDUC4 framework in their work. Thus, HEIs must understand that training in complex reasoning is necessary for the academe. Gonzales et al. [8] identified that the financial aspect and lack of training resources are the most prominent barriers among developing economies. HEIs shall take the primary responsibility for overcoming these barriers. As supported by González-Pérez and Ramírez-Montoya [39], the need to incorporate educational practices into the core components of EDUC4 becomes imperative. They added that schools and teachers do not possess the twenty-first-century skill frameworks with the EDUC4 components to develop future skills. The school leadership towards ICT utilization impacts teachers' active ICT utilization, leading to an increase in students' academic performance [37]. The IT integration in schools towards the EDUC4 system has been a great challenge among administrators. López et al. [40] highlighted that leadership in EDUC4 can lead to students' success in attaining the skills and competencies to become IT leaders in modern industries. Due to the university's decentralized design, instructors might use whatever other technology they consider appropriate for their classes at the risk of losing official backing [41]. The ongoing training for using digital educational resources and their integration into traditional practices is important to ease the transition process, with the COVID-19 crisis emphasizing such importance.

Likewise, the need to fully align the practices of various academic disciplines into the EDUC4 framework is discussed in the literature. For example, Bilotta et al. [42] revealed that methods and technologies introduced by big data, automation, virtual and augmented reality, robotics, and ICT will fit with EDUC4, with a case in the tourism industry. Still, the students are not yet trained on techniques, issues, and methods related to the emerging framework. Goldin et al. [43] proposed an architecture to help users recognize how to digitalize education and create a better plan on how EDUC4 can be implemented into the IT landscape of the universities. Another stream emphasizes that professors must possess competencies for innovation, complex problem-solving, entrepreneurship, collaboration, international perspective, leadership, and connection with the needs of society [33]. Emerging literature also focuses on the alignment to engineering education, emphasizing that the education sector mainly benefits from the recent technological progress [9]. They proposed the four core components of EDUC4 in higher education: (1) competencies, (2) learning methods, (3) ICTs, and (4) infrastructure. The 4IR requires that the education system do everything in time

to support the transformation of the curriculum with the requirements of EDUC4 [44]. Thus, it is evident in the literature that the roles of stakeholders are always linked to the EDUC4 transition, either implicitly or explicitly. However, despite the need to systematically understand these roles, the current literature offers limited insights.

3. Preliminaries

3.1. Fermatean Fuzzy Set. The fuzzy set theory has been well-regarded for dealing with imprecise information and uncertainties. It was developed primarily by Zadeh [23] as an application for the numerous valued logic to illustrate the behavior of complex electrical systems. An extension of the fuzzy set theory was introduced by Atanassov [24], which is the intuitionistic fuzzy set (IFS). It is characterized by a membership function, a non-membership function, and a hesitancy degree that expresses support, opposition, and neutrality in eliciting information [24], extending the concept of membership functions of Zadeh's fuzzy set theory. It is defined as follows:

Definition 1 (see [24]). Let Δ be a non-empty universe of discourse. The IFS F has the general form

$$F = \{(x, \mu_F(x), \nu_F(x)) : x \in \Delta\}, \tag{1}$$

where $\mu_F(x) : \Delta \longrightarrow [0,1]$ and $\nu_F(x) : \Delta \longrightarrow [0,1]$ such that $0 \le (\mu_F(x) + \nu_F(x)) \le 1$ for all $x \in \Delta$. Furthermore, $\mu_F(x)$ and $\nu_F(x)$ refer to the degree of membership and degree of non-membership of the element $x \in \Delta$ in the set F, respectively.

However, in practical application, decision-makers may elicit their judgment fulfilling a set condition either to an assisting or opposing degree greater than 1. Thus, Yager [25] introduced the notion of Pythagorean fuzzy sets (PFS) to address this possible condition, whose illustration is given as follows:

Definition 2 (see [25]). Let Δ be a non-empty universe of discourse, and the PFS $\mathscr{P}$ can be presented as follows:

$$\mathscr{P} = \{(x, \mu_{\mathscr{P}}(x), \nu_{\mathscr{P}}(x)) : x \in \Delta\}, \tag{2}$$

where $\mu_{\mathscr{P}}(x) : \Delta \longrightarrow [0,1]$ and $\nu_{\mathscr{P}}(x) : \Delta \longrightarrow [0,1]$ such that $0 \le (\mu_{\mathscr{P}}(x))^2 + (\nu_{\mathscr{P}}(x))^2 \le 1$ for all $x \in \Delta$. Furthermore, $\mu_{\mathscr{P}}$ and $\nu_{\mathscr{P}}(x)$ refer to the degree of membership and degree of non-membership of the element $x \in \Delta$ in the set $\mathscr{P}$, respectively. For any $\mathscr{P}$ and $x \in \Delta$, the degree of indeterminacy, $\pi_{\mathscr{P}}(x)$, can be calculated by

$$\pi_{\mathscr{P}}(x) = \sqrt{1 - (\mu_{\mathscr{P}}(x))^2 - (\nu_{\mathscr{P}}(x))^2}. \tag{3}$$

However, the PFS could not handle certain conditions. For instance, $\mu_{\mathscr{P}} = 0.9$ and $\nu_{\mathscr{P}} = 0.6$ suggest that $0.9^2 + 0.6^2 \le 1$. Thus, Senapati and Yager [29] proposed the notion of the FFS to provide a tool for handling uncertain information more efficiently and is more flexible in capturing uncertain information than IFS and PFS. The features and operators of FFS are defined as follows:

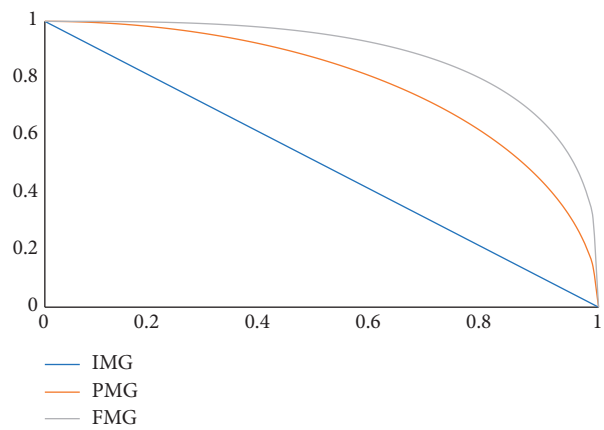

Figure 1: Comparison of space of FMGs, PMGs, and IMGs.

Definition 3 (see [29]). Let Δ be a non-empty universe of discourse. The Fermatean fuzzy set T in Δ can be presented as follows:

$$T = \{(x, \mu_T(x), \nu_T(x)) : x \in \Delta\}, \tag{4}$$

where $\mu_T(x) : \Delta \longrightarrow [0,1]$ and $\nu_T(x) : \Delta \longrightarrow [0,1]$ such that $0 \le (\mu_T(x))^3 + (\nu_T(x))^3 \le 1$ for all $x \in \Delta$. Furthermore, $\mu_T(x)$ and $\nu_T(x)$ refer to the degree of membership and degree of non-membership of the element x in the set T, respectively. Meanwhile, the degree of indeterminacy, $\pi_T(x)$, is identified through

$$\pi_T(x) = \sqrt[3]{1 - (\mu_T(x))^3 - (\nu_T(x))^3}. \tag{5}$$

Figure 1 shows the difference among the spaces related to intuitionistic membership grades (IMG), Pythagorean membership grades (PMG), and Fermatean membership grades (FMG). In general, these fuzzy sets are part of a class of q-rung orthopair fuzzy sets in which the sum of the qth power of the membership function and the qth power of the non-membership function is bounded by 1 [45]. For instance, $q = 1$ implies IFS; $q = 2$ implies PFS.

Definition 4 (see [29]). Suppose that $T = (\mu_T, \nu_T)$, $T_1 = (\mu_{T_1}, \nu_{T_1})$, and $T_2 = (\mu_{T_2}, \nu_{T_2})$ are three distinct FFS and $\alpha > 0$, then the following are the operators for the FFS:

$$\begin{aligned}
T_1 \cap T_2 &= \left(\min\{\mu_{T_1}, \mu_{T_2}\}, \max\{\nu_{T_1}, \nu_{T_2}\}\right),\\
T_1 \cup T_2 &= \left(\max\{\mu_{T_1}, \mu_{T_2}\}, \min\{\nu_{T_1}, \nu_{T_2}\}\right),\\
T^c &= (\nu_T, \mu_T),\\
T_1 \oplus T_2 &= \left(\sqrt[3]{\mu_{T_1}^3 + \mu_{T_2}^3 - \mu_{T_1}^3 \mu_{T_2}^3}, \nu_{T_1}\nu_{T_2}\right),\\
T_1 \otimes T_2 &= \left(\mu_{T_1}\mu_{T_2}, \sqrt[3]{\nu_{T_1}^3 + \nu_{T_2}^3 - \nu_{T_1}^3 \nu_{T_2}^3}\right),\\
\alpha T &= \left(\sqrt[3]{1 - \left(1 - \mu_T^3\right)^\alpha}, (\nu_T)^\alpha\right),\\
T^\alpha &= \left((\mu_T)^\alpha, \sqrt[3]{1 - \left(1 - \nu_T^3\right)^\alpha}\right).
\end{aligned} \tag{6}$$

Additional operations on subtraction and division of FFS were introduced by Senapati and Yager [46].

Definition 5 (see [46]). Assume $T_1 = (\mu_{T_1}, \nu_{T_1})$, and $T_2 = (\mu_{T_2}, \nu_{T_2})$ are two distinct FFS, then

$$T_1 \boxminus T_2 = \left(\sqrt[3]{\frac{\mu_{T_1}^3 - \mu_{T_2}^3}{1-\mu_{T_2}^3}}, \frac{\nu_{T_1}^3}{\nu_{T_2}^3} \right) \text{if } \mu_{T_1} \geq \mu_{T_2}, \nu_{T_1} \leq \min\left\{ \nu_{T_2}, \frac{\nu_{T_2}\pi_{T_1}}{\pi_{T_2}} \right\}. \tag{7}$$

$$T_1 \boxminus T_2 = \left(\frac{\mu_{T_1}}{\mu_{T_2}}, \sqrt[3]{\frac{\nu_{T_1}^3 - \nu_{T_2}^3}{1-\nu_{T_2}^3}} \right) \text{if } \mu_{T_1} \leq \min\left\{ \mu_{T_2}, \frac{\mu_{T_2}\pi_1}{\pi_2} \right\}, \nu_{T_1} \geq \nu_{T_2}. \tag{8}$$

Definition 6 (see [29]). Assume $T_i = (\mu_{T_i}, \nu_{T_i})$ $(i = 1, 2, \ldots, n)$ be a set of FFS and $w = (w_1, w_2, \ldots, w_n)^K$ be the corresponding weight vector for $\sum_i w_i = 1$. Then, the FF weighted average *FFW* aggregation operator is defined by

$$FFWA(T_1, T_2, \ldots T_n) = \left(\sum_{i=1}^{n} w_i \mu_{T_i}, \sum_{i=1}^{n} w_i \nu_{T_i} \right). \tag{9}$$

Senapati and Yager [29] provided the concept of a score function score: $T \longrightarrow \mathbb{R}$, where T is an FFS and is the basis for ranking FFS alongside the accuracy function. However, the score function cannot rank the FFS in some special cases precisely. Thus, Mishra and Rani [47] proposed a novel FF score function to provide the shortcomings of the existing score function. The features of this score function are defined as follows:

Definition 7 (see [47]). Suppose that $T = (\mu_T, \nu_T)$ is an FFS, the score function for T is defined as follows:

$$S(T) = \frac{1}{2}\left[\left(\mu_T^3 - \nu_T^3 - ln\left(1 + \pi_T^3\right)\right) + 1\right], \tag{10}$$

where π_T is the corresponding indeterminacy degree. For all μ_T and ν_T, provided that $\mu_T^3 + \nu_T^3 \leq 1$, $S(T) \in [0, 1]$.

Mishra and Rani [47] show that S is increasing monotonically with respect to μ_T and decreasing monotonically with respect to ν_T. The following provides the basis for ranking FFS according to S.

Theorem 1 [47]. *For any two FFS $T_1 = (\mu_{T_1}, \nu_{T_1})$ and $T_2 = (\mu_{T_2}, \nu_{T_2})$, if $\mu_{T_1} > \mu_{T_2}$ and $\nu_{T_1} < \nu_{T_2}$, then $S(T_1) > S(T_2)$.*

The Euclidean distance is also defined in FFS.

Definition 8 (see [29]). Let $T_1 = (\mu_{T_1}, \nu_{T_1})$ and $T_2 = (\mu_{T_2}, \nu_{T_2})$ be two distinct FFS. Then, the Euclidean distance between T_1 and T_2 is

$$d(T_1, T_2) = \sqrt{\frac{1}{2}\left[\left(\mu_{T_1}^3 - \mu_{T_2}^3\right)^2 + \left(\nu_{T_1}^3 - \nu_{T_2}^3\right)^2 + \left(\pi_{T_1}^3 - \pi_{T_2}^3\right)^2\right]}. \tag{11}$$

3.2. The CRITIC Method. Diakoulaki et al. [12] initially proposed the CRITIC method, which determines the priority weights of elements of a given set through an aggregation process. Accordingly, the underlying notion of the CRITIC method is the significant information that can be drawn from the criteria set that contains the contrast and conflict concentration between criteria [12, 48, 49]. The contrast intensity and degree of variability among scores within the criterion are captured through computing the standard deviation. Additionally, the CRITIC method obtains the pairwise linear correlation coefficients among criteria in evaluating their conflicting relationships. Thus, CRITIC collectively analyses sufficient information contained in the set of evaluation criteria and, in general, the set of homogeneous decision elements.

Definition 9 (see [12]). Let U be a finite set of m alternatives. Then, given a system of n evaluation criteria c_j $(j = 1, \ldots, n)$, the MADM problem in its general form is presented as follows:

$$\max\{c_1(u), c_2(u), \ldots, c_n(u) | a \in U\}. \tag{12}$$

In this case, for every criterion c_j, a membership function x_j is defined that maps the values of c_j to the interval $[0, 1]$. This transformation is based on the concept of the ideal point. Thus, a value close to the ideal c_j^* is the best performance in criterion j and close to the anti-ideal value c_{j^*} is the worst performance in criterion j. The steps in determining the criteria weights using the CRITIC method are as follows. Note that, in general, the criteria set can be a set of any homogeneous decision elements.

Step 1: Determine the set of n criteria and m alternatives constructed as a hierarchical MADM problem.

Step 2: Evaluate the performance score a_{ij} of the ith $(i = 1, \ldots, m)$ alternative with respect to the jth $(j = 1, \ldots, n)$ criterion.

Step 3: Compute the normalized matrix $X = (x_{ij})_{m \times n}$ where the normalized score x_{ij} describes a linear normalization of a_{ij} scores and represents

$$x_{ij} = \frac{a_{ij} - a_{j^*}}{a_j^* - a_{j^*}}, \tag{13}$$

where $a_j^* = \max_i a_{ij}$ and $a_{j^*} = \min_i a_{ij}$ for $j = 1, \ldots, n$.

Step 4: Generate a vector x_j denoting the normalized scores of all m alternatives. Vector x_j is calculated using the following equation:

$$x_j = \left(x_{1j}, x_{2j}, \ldots, x_{mj}\right). \tag{14}$$

Step 5: Compute the standard deviation of each x_j by the following formula:

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}\left(x_{ij} - \overline{x}_j\right)^2}{m}}, \tag{15}$$

where $\overline{x}_j = \sum_{i=1}^{m} x_{ij}/m$. Aside from standard deviation, Diakoulaki et al. [12] suggest that the use of entropy or variance is also possible.

Step 6: Construct a symmetric matrix $R = (r_{jk})_{n\times n}$ where r_{jk} denotes the linear correlation coefficient of two vectors x_j and x_k, $j, k \in \{1, \ldots, n\}$, using the following formula:

$$r_{jk} = \frac{\sum_{i=1}^{m}\left(x_{ij} - \overline{x}_j\right)\left(x_{ik} - \overline{x}_k\right)}{\sqrt{\sum_{i=1}^{m}\left(x_{ij} - \overline{x}_j\right)^2 \sum_{i=1}^{m}\left(x_{ik} - \overline{x}_k\right)^2}}, \tag{16}$$

where $r_{jk} \in [-1, 1]$. Obviously, when $j = k$, then $r_{jk} = 1$.

Step 7: Compute the amount of information z_j as follows:

$$z_j = \sigma_j \sum_{k=1}^{n}\left(1 - r_{jk}\right), \tag{17}$$

where the higher value of z_j implies that the criterion j contains more information.

Step 8: Determine the criteria weights according to the following formula:

$$w_j = \frac{z_j}{\sum_{k=1}^{n} z_k}. \tag{18}$$

3.3. The CODAS Method. The CODAS method was initially proposed by Ghorabaee et al. [16], wherein the desirability of the alternatives is determined based on l^1-norm and l^2-norm indifference spaces for criteria. In this method, a combinative form of the Euclidean distance and the secondary measure, Taxicab distance, is used to calculate the assessment score of alternatives wherein the alternative has a greater distance from the negative ideal solution is more desirable. The steps of the CODAS method for MADM problems are presented as follows:

Step 1. Construct the decision matrix A that is represented as follows:

$$A = \left(a_{ij}\right)_{m\times n} = \begin{pmatrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} & \ldots & a_{mn} \end{pmatrix}, \tag{19}$$

where $a_{ij} \geq 0$ denotes the performance value of ith ($i \in \{1, 2, \ldots, m\}$) alternative with respect to the jth ($j \in \{1, 2, \ldots, n\}$) criterion (or attribute).

Step 2. Determine normalized decision matrix $N = (n_{ij})_{m\times n}$ according to the type of each criterion using the linear normalization of performance values as follows:

$$n_{ij} = \begin{cases} \dfrac{a_{ij}}{\max\limits_i a_{ij}}, & \text{if } j \in P, \\[2ex] \dfrac{\min\limits_i a_{ij}}{a_{ij}}, & \text{if } j \in C, \end{cases} \tag{20}$$

where P and C represent the sets of benefit and cost criteria (or attributes), respectively, and n_{ij} denotes the normalized performance values.

Step 3. Calculate the weighted normalized decision matrix $B = (b_{ij})_{m\times n}$ as follows:

$$b_{ij} = w_j n_{ij}, \tag{21}$$

wherein $\sum_{j=1}^{n} w_j = 1$, w_j denotes the weight of the jth criterion, and $0 < w_j < 1$. w_j can be determined through any priority weight generation method (e.g., CRITIC).

Step 4. Determine the negative ideal solution as follows:

$$b_* = \left(b_{j*}\right)_{1\times n}. \tag{22}$$

$$b_{j*} = \min_i b_{ij}. \tag{23}$$

Step 5. Calculate the Euclidean d_i and Taxicab t_i distances of alternatives from the negative ideal solution using the following equation:

$$d_i = \sqrt{\sum_{j=1}^{m}\left(b_{ij} - b_{j*}\right)^2}, \quad \forall i = 1, \ldots, n. \tag{24}$$

$$t_i = \sum_{j=1}^{m}\left|b_{ij} - b_{j*}\right|, \quad \forall i = 1, \ldots, n. \tag{25}$$

Step 6. Construct the relative assessment matrix $H = (h_{ik})_{m\times m}$ presented as follows:

$$h_{ik} = \left(d_i - d_k\right) + \left(\beta\left(d_i - d_k\right) \times \left(t_i - t_k\right)\right), \tag{26}$$

where $k \in \{1, 2, \ldots, m\}$ and β is a threshold function that can be set by the decision-maker and defined as follows:

$$\beta = \begin{cases} 1, & \text{if } d_i - d_k \geq \rho, \\ 0, & \text{if } d_i - d_k < \rho. \end{cases} \tag{27}$$

If the difference between the Euclidean distances of the two alternatives is less than ρ, then these two alternatives are also compared by the Taxicab distance.

Step 7. Calculate the assessment score (S_i) of each alternative as follows:

$$S_i = \sum_{k=1}^{m} h_{ik}, \tag{28}$$

wherein the alternative with the highest S_i value is the most desirable. Given the simplicity of the CODAS for the decision-makers and its success, a sorting method was developed by Ouhibi and Frikha [20] called CODAS-SORT. In an MCS problem, the decision-maker aims to assign alternatives to predefined classes. For brevity, the steps of the CODAS-SORT are not repeated here. Despite the introduction of the CODAS-SORT, some technical issues in the sorting process proposed by Ouhibi and Frikha [20] are evident, which prompted an introduction of a modified CODAS-SORT variant, along with the integration of FFS.

4. Methodology

4.1. Case Study Background. To keep up with the consequential dynamics that continue to reshape life, economies, industries, and jobs in developing economies, HEIs should embrace the emerging trends of EDUC4, including personalized learning, remote learning opportunities, an abundance of educational tools, project-based learning, and innovation-based education. In this context, the curriculum and learning outcomes require twenty-first-century skills to address the urgency of essential modernization. Current reports predict that AI will transform the hiring behavior of tech-driven companies. Calibrating to the industry requirements propels the HEIs to remodel their curriculum to integrate life skills into the programs through immersion with real-world stakeholders such as the industry, society, and entrepreneurial networks. Government investments with industry and local society across all aspects of the education value chain, from curricula and faculty to infrastructure, research, study experience, and placements, should expand partnerships. The collaborative models with global experts from academia and industry should also advance in-site research opportunities for small and medium enterprises with limited research groundwork. The faculty may be able to develop a group of champion faculty members coming from different departments who are leading the way in developing digital skills or new innovative teaching techniques utilizing various technologies.

Cebu Technological University (CTU) Danao Campus is a component campus of the CTU, a state university in the central Philippines. Following existing guidelines in Philippine institutions, the operating expenditures among state universities and colleges for personnel services, maintenance, and other operating expenses and the capital outlays are coming from government subsidies allocated through the General Appropriations Act (GAA)—the annual national expenditure budget of the government. Aside from the GAA funds, incomes are also generated from various fees and grants provided by international and local institutions. With the recent rise of the university in various rankings and its expanded role in the national development agenda, CTU is pushing for innovation efforts in its different functions, including instruction and research. Among these efforts is directed towards attaining an environment fostering EDUC4. Since CTU Danao Campus is positioning itself as a globally competitive campus of the university and alignment to EDUC4 is inevitable, efforts are becoming grounded for its realization. Although efforts and activities are evident, an integrative framework, particularly on the design of these initiatives, is missing.

The government resources remained significantly deficient to support the massive task to consolidate the efforts to address barriers related to financial resources and to recalibrate CTU to stay relevant in the age of EDUC4, resulting in struggling levels of university-industry collaboration, insufficient industry-relevant research consortiums, and underdeveloped research infrastructure and cutting-edge laboratories and equipment. The initiatives of CTU 4.0 transformation, coined by the university through EDUC4, are underway; however, government funding priorities should be enforced not only for the operating expenditures but also for the innovation disbursements targeting the significant deficiencies in attaining the inevitable EDUC4 transformation to become a globally competitive educational institution. Although the Philippine government's spending on public higher education exhibited an upward trend, the corresponding increase in government appropriation to state universities means that these universities shall prioritize expenses to expedite solutions for the implementation barriers to enhance research funding, talent, infrastructure, and links with the industry. However, there are inadequate policies, mechanisms, and understanding of how these barriers will be directed. One possible direction is that the constrained allocation of public funding should move toward a performance-based approach for campus research and capital expenditures to concentrate on attaining EDUC4.

In this regard, following a series of strong evidence in the literature, stakeholders play a substantial role in guiding the university for the design, planning, and implementation of any initiative, which includes the direction leaning toward EDUC4. In the current setting, the following stakeholders are relevant for CTU Danao: (1) the Philippine government (i.e., represented by the trifocal agencies Commission on Higher Education (CHED), Department of Education (DepEd), and Technical Education and Skills Development Authority (TESDA)), (2) university management (i.e., from the top management down to academic departments), (3) human resource, (4) ICT function, and (5) educators. Identifying the crucial roles of these stakeholders in systematically overcoming the barriers of EDUC4 implementation is an essential agenda for CTU Danao in its efforts for EDUC4. This agenda would help establish institutional-level policies to describe the impacts, show findings, and provide recommendations for a conceptual-analytical framework for implementing EDUC4. Furthermore, although idiosyncrasies exist, the insights would yield comparative results with other developing economies' strategic priorities and policy actions addressing implementation barriers.

4.2. Proposed Procedure. Figure 2 shows the methodological framework of the Fermatean fuzzy CRITIC-CODAS-SORT approach in establishing the degree to which the stakeholder roles overcome the barriers of EDUC4 implementation.

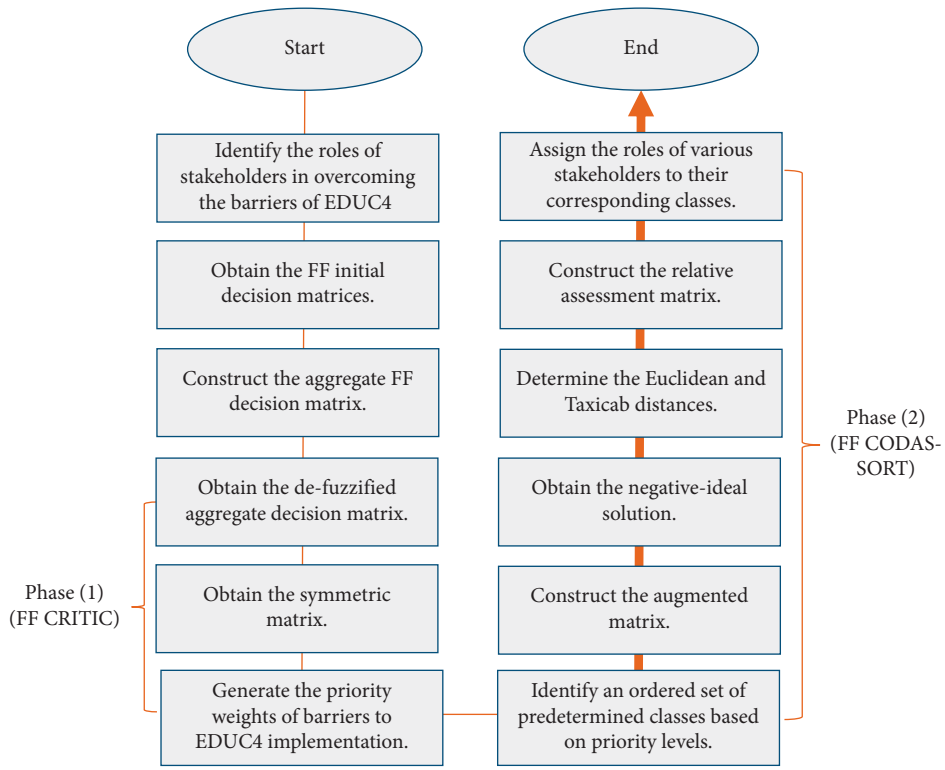

Figure 2: The methodological framework.

Note that due to idiosyncrasies, the implementation of the proposed framework is intended for a single case (e.g., an HEI).

The proposed methodological framework consists of two main phases: (1) obtaining the priority weights of the barriers to EDUC4 implementation through FF CRITIC and (2) sorting the stakeholder roles in addressing these barriers via FF CODAS-SORT. In this framework, the weights generated from phase (1) are integrated into phase (2). The application of the proposed approach is discussed as follows:

Step 1. Identify the roles of stakeholders. This study identified the roles of stakeholders in overcoming the barriers to EDUC4 implementation of a case university (i.e., CTU) through a focus group discussion of domain expert decision-makers. They were chosen in such a way that satisfies the following qualifications: (1) must be affiliated with the HEI in the case environment, (2) must have a PhD degree, (3) must have at least five years of experience in a supervisory or administrative function, and (4) must have at least five years of experience working with the HEI in the case environment. As shown in Table 1, five stakeholders, that is, government, university management, human resource function, ICT function, and educators, were identified along with their corresponding roles in overcoming the barriers identified by Costan et al. [7] (see Table 2). In the case study, the government comprises frontline institutions consisting of the CHED, DepEd, and TESDA. They are the trifocal institutions associated with the educational system in the Philippines. The university management consists of those in the organizational hierarchy ranging from the chairs of the academic departments, deans of colleges, campus directors, vice presidents, and president, to the board of regents. The human resource function oversees the functional areas of human resource management, including staffing, development, compensation, safety and health, human resource information system, and employee and labor relations. On the other hand, the ICT function manages communication, data management, cybersecurity, and technology development. Lastly, the educators represent the teaching staff of the university.

Step 2. Obtain the FF initial decision matrices. Initial decision matrices $\widetilde{A}^k = (\widetilde{a}_{ij}^k)_{m\times n}$, for $k = 1, \ldots, K$, where $\widetilde{a}_{ij}^k = (\mu_{\widetilde{a}_{ij}^k}, \nu_{\widetilde{a}_{ij}^k})$ represents the degree of relevance of stakeholder role i in overcoming a barrier to EDUC4 implementation j elicited by the kth decision-maker in linguistic terms, were constructed. These matrices were transformed into FF decision matrices using the linguistic scale shown in Table 3.

Phase 1. Implementation of the FF CRITIC.

The processes in steps 3 to 5 discuss the integration of FF CRITIC in assigning priority weights to barriers to EDUC4 implementation.

Step 3. Construct the aggregate FF decision matrix. The aggregate FF decision matrix $\widetilde{A} = (\widetilde{a}_{ij})_{m\times n}$ is

Table 1: Stakeholder roles in overcoming the barriers of EDUC4 implementation.

Stakeholders	Codes	Roles
Government (i.e., CHED, DepEd, and TESDA)	G1	Investing in endpoint protection against cybersecurity attacks (e.g., malware, phishing, and trojans, among others)
	G2	Delivering up-to-date training of human resources (e.g., educators) about cybersecurity threats
	G3	Inclusion of cybersecurity awareness in the basic education curriculum
	G4	Allocating more funds to support the necessary inclusive activities in the implementation of EDUC4
	G5	Implementing initiatives to direct linkages among stakeholders in different areas of cooperation (e.g., industry-CHED and international organizations)
	G6	Updating of curricular offerings based on the labor market signals posed by I4.0
	G7	Forging heightened information dissemination drives about EDUC4 to all stakeholders
	G8	Designing an overall policy agenda, including road mapping, in the implementation of EDUC4
	G9	Positioning the EDUC4 implementation within the UN Sustainable Development Goals
	G10	Promoting cross-functional collaboration that involves different functional expertise in various relevant government offices
	G11	Designing the curricula in line with the implementation and sustainment of EDUC4
	G12	Designing appropriate measures for the emergence of new technologies that affect learning (e.g., addiction to gaming and social media)
	G13	Promotion and creation of initiatives that yield social and psychological benefits to foster healthy behaviors
	G14	Creation of network infrastructure to lessen the complexity of learning platforms
	G15	Fostering opportunities for the emergence of self-organization, dynamic activities with AIs
	G16	Streamlining alignment initiatives of the basic education agenda (e.g., human resources and curricula) to EDUC4
University management (from the top management down to academic departments)	U17	Engaging in initiatives in promoting cybersecurity awareness among university members (i.e., educators, learners, and staff)
	U18	Designing measures that are security-cognizant (e.g., centralized IT governance, uniform control, segregation of networks, enhanced strategic alignment, and accountability), including stringent access regulators to shield sensitive data and information
	U19	Investing in efficient technologies (e.g., virtual classrooms, enablement or process audit, analytic tools for strategic planning, and the hybrid or fully automated process of project management), which are known to reduce overall costs and improve the experience of the university stakeholders
	U20	Constant training and capability upgrading of educators in terms of technical competencies and behavioral stamina for supporting adaptability, reliability, productivity, and total well-being as they align with the demands of EDUC4
	U21	Fostering transformational support and environmental and institutional framework for university educators, learners, and staff for adapting to the EDUC4 atmosphere
	U22	Engaging stakeholders in dialogues that emphasize the alignment of EDUC4 with global inclusive agenda (e.g., UN-SDGs)
	U23	Exploring the translation of the EDUC4 framework into pedagogy, assessment, and the design of an instructional system
	U24	Forging extensive collaboration with various stakeholders (e.g., policy-makers, academic experts, university networks, educators, education leaders, learners, and industry partners) to provide space and training resources for implementing EDUC4
	U25	Benchmarking of established and favorable practices for EDUC4 implementation
	U26	Establishing measures that would allow more time for the educators in preparing learning materials, conducting research and development projects, and attending to continuous learning opportunities inclined to EDUC4

Table 1: Continued.

Stakeholders	Codes	Roles
	U27	Established intensified policies of college entry requirements, particularly in evaluating the readiness of candidate learners in an EDUC4 environment
Human resource function	H28	Incorporating data privacy and protection orientation during personnel hiring
	H29	Restricting access of any information and sites only to its trusted users or known parties
	H30	Designing non-ambiguous measures for the protection of the human resource from insider threats, which may expose potentially damaging contents
	H31	Implementing information drives for personnel and other stakeholders on how to protect themselves against phishing, social engineering (e.g., acquiring login credentials), and other cybersecurity attacks
	H32	Designing initiatives that would encourage cybersecurity culture among university educators
	H33	Participating actively in university-wide efforts for cost-efficient initiatives in building human capabilities required in EDUC4 implementation
	H34	Periodic training of the human resources on the skills (i.e., especially digital readiness and customization of curriculum design) fitting to the current demands of EDUC4
	H35	Designing policies for personnel hiring, merit, and promotions system (i.e., including collaboration as an indicator) relevant to EDUC4 to ensure that the most competent and qualified employees are hired and retained
	H36	Initiating forums among stakeholders (e.g., educators, parents, and local governments) to discuss the pressing need for EDUC4 adoption
	H37	Establishing programs to coach or support employees who seek to acquire external training grants and collaboration
	H38	Designing a recognition system that recognizes and acknowledges the collaborative endeavors of the educators and staff
	H39	Integrating health issues as an integral part of the personnel development efforts (e.g., periodic health monitoring and health benefits) of the university
ICT function	I40	Investing in collaboration efforts with IT experts capable of addressing cybersecurity threats
	I41	Designing robust infrastructure against cybersecurity threats
	I42	Initiating inclusive programs (e.g., information dissemination, training, workshops, and continuous learning) that would encourage an IT culture among university stakeholders
	I43	Directing the IT infrastructure needs of the university, including maintenance of equipment, that would support the implementation of EDUC4
	I44	Forging constant collaboration with IT experts to seek efficient and effective IT solutions for EDUC4 needs
Educators	E45	Engaging in continuous learning initiatives about relevant cybersecurity threats at the university (i.e., data breaches on student information, denial of service attacks, and phishing)
	E46	Integrating awareness of applicable laws to cyberbullying in (virtual) classroom teaching
	E47	Devising alternative cost-efficient teaching strategies in the delivery of required learning outcomes while upholding the implementation of EDUC4
	E48	Initiating collaboration efforts with other educators (i.e., inside or outside the university) in the delivery of cost-efficient methods in EDUC4 implementation
	E49	Participating in inclusive efforts (e.g., training, workshops, formal education, focus group discussions, symposiums, and industry immersion) for upgrading and aligning necessary skills (including an emphasis on handling complex learning platforms) for implementing EDUC4
	E50	Taking part in efforts to demonstrate the need and relevance of EDUC4 to stakeholders (i.e., parents, investors, local governments, and immediate community)
	E51	Involvement in the planning, selection, and maintenance efforts of technologies to support teaching-learning under an EDUC4 environment
	E52	Establishing holistic initiatives for linkage and collaboration with foreign universities, industry, non-government organizations, government offices, and international organizations, among others, in the delivery of intended

Table 1: Continued.

Stakeholders	Codes	Roles
		learning outcomes, along with their support infrastructure, within the context of EDUC4
	E53	Participation in efforts for increased visibility in online forums and platforms to possibly establish collaboration
	E54	Taking part in the design, development, and improvement of innovative curricula aligned to EDUC4
	E55	Integrating health standards, including the mental health of learners, in designing their intended learning outcomes consistent with EDUC4
	E56	Promoting ways to efficiently prepare learning materials, including the use of advanced ICTs
	E57	Participating in skills development initiatives aimed at equipping educators with the capabilities in handling different complex learning platforms

Table 2: Barriers to EDUC4 implementation [7].

Code	Barrier	Brief description
B1	Cybersecurity threat	The threat of information leakage, security attacks, and misusage of technology
B2	Costly	Implementation of EDUC4 requires high costs (e.g., acquisition of equipment and maintenance)
B3	Skills gap of the human capital	Insufficient knowledge and experience of the human capital in using digital technology for education and lack of specific skills (i.e., critical thinking and emotional intelligence)
B4	Apprehensive stakeholders	Apprehension of some stakeholders (i.e., learners, educators, and administrators) to EDUC4
B5	Lack of training resources	The lack of training resources (i.e., facility and materials) for professional development
B6	Lack of collaboration	Lack of collaboration with other sectors (i.e., community, government, other HEIs, and industry) that is essential in successfully implementing EDUC4
B7	Knowledge gap for the customization of curriculum design	Current lack of knowledge to create a customized curriculum design to enhance learner's skills (i.e., creativity and critical thinking) and promote skills-based training
B8	Insufficient available technologies	Due to the rapid advancement of technology, developing countries cannot catch up with developed countries; some technology might already be available in some countries but not in others
B9	Health issues	Prolonged exposure to the technology that may cause health issues in the physical and mental well-being of the learners and educators
B10	Time constraint for material preparation	The time needed to prepare and teach in a virtual learning platform that requires more time than the traditional one
B11	Complexity of learning platforms	The challenge that the users (i.e., learners and educators) face in utilizing the virtual learning platform
B12	Insufficient foundation in basic foundation	Students with proper primary education, an essential component in implementing EDUC4, are rare

Table 3: Linguistic evaluation scale.

Linguistic term	Non-FFS scores	FFS
Extremely low	1	(0.1, 0.9)
Low	2	(0.25, 0.6)
Moderately low	3	(0.4, 0.5)
Medium	4	(0.5, 0.4)
Moderately high	5	(0.6, 0.3)
High	6	(0.7, 0.2)
Extremely high	7	(0.9, 0.1)

constructed, where $\tilde{a}_{ij}$ is obtained using equation (9) and w_i is the corresponding weight of kth decision-maker. In this study, the length of service holding a supervisory or managerial position and level of administrative function were used to assign weights to decision-makers. Following the agreement of the decision-makers, the following are used to generate their importance weights to the decision-making problem. To give more credit to their current administrative functions, the scores of 5, 4, 3, and 2 are assigned to Campus Director, Assistant Campus Director, Dean, and Program Chair, respectively. For instance, the importance weight of DM3 is computed as: $0.2022 = 14/87 * 4/3.1839$, where 14 is the number of years holding a supervisory or managerial position, 87 is the sum of column (2) of Table 4, and 3.1839 is the sum of all products of normalized column (2) and the scores associated with their current administrative functions of all decision-makers. Analogous to equation (9), $\tilde{A}$ is shown in Table 5, where

$$\tilde{a}_{ij} = FFWA\left(\tilde{a}_{ij}^1, \tilde{a}_{ij}^2, \ldots, \tilde{a}_{ij}^K\right) = \left(\sum_{k=1}^{K} w_k \mu_{\tilde{a}_{ij}^k}, \sum_{k=1}^{K} w_k \nu_{\tilde{a}_{ij}^k}\right), \quad (29)$$

Table 4: Assignment of weights of decision-makers.

Decision-maker	No. of years holding a supervisory or managerial position	Current administrative function	Importance weight
DM1	5	Program chair	0.0361
DM2	13	Program chair	0.0939
DM3	14	Assistant campus director	0.2022
DM4	10	Dean	0.1083
DM5	12	Program chair	0.0866
DM6	17	Dean	0.1841
DM7	16	Campus director	0.2888

where w_k is the importance weight of kth decision-maker.

Step 4. Obtain the defuzzified aggregate decision matrix A. The defuzzified aggregate decision matrix $A = (a_{ij})_{m\times n}$ was obtained using equation (10) to transform the aggregate evaluation scores in FFS to their corresponding crisp (non-FFS) values. The resulting matrix is shown in Table 6. Instead of equation (15), the entropy e_j method was used in this work as presented in the following equation:

$$e_j = \frac{1}{\ln(m)} \sum_{i=1}^{m} a_{ij} \ln\left(a_{ij}\right) \text{ for } j = 1, \ldots, n. \tag{30}$$

Step 5. Obtain the symmetric matrix R. The symmetric matrix R was constructed using equation (16) and is shown in Table 7.

Step 6. Generate the priority weights w_j, $j = 1, \ldots, m$, of barriers to EDUC4 implementation. The information value z_j is calculated using equation (17). Furthermore, the two values, e_j and z_j, are used to obtain the priority weights w_j using equation (18). The w_j values are presented in Table 8.

Phase 2. Implementation of the FF CODAS-SORT

Here, steps 6 to 10 discuss the application of FF CODAS-SORT in sorting the roles of various stakeholders in overcoming the different barriers to EDUC4 implementation.

Step 6. Identify an ordered set of predetermined classes based on priority levels. In general, L $(e = 1, \ldots, L)$ classes can be predefined for the MCS process. These classes generate $L-1$ limit profiles. Each e class contains lower and upper boundaries, denoted by l_e^a and l_e^b, where $l_e^b = l_{e+1}^a$. In this work, $L = 3$ classes (i.e., low relevance, moderate relevance, and high relevance) and two limit profiles are introduced.

Step 7. Construct the augmented matrix $\overline{A}$. The aggregate FF decision matrix in step 3 with the $L-1$ limit profiles identified in step 6 is used to construct the augmented matrix $\overline{A} = (\overline{a}_{ij})_{m\times n}$. The resulting matrix is presented in Table 9.

Step 8. Obtain the negative ideal solution b_*. $\overline{A}$ was used to obtain the negative ideal solution $\widetilde{b}_* = (\widetilde{b}_{j*})_{1\times n}$ using equation (23). Considering that the elements in $\overline{A}$ are FFS, then Definition 7 and Theorem 1 discussed in Section 3.1 were used to obtain $\widetilde{b}_*$. The resulting vector is illustrated in Table 10.

Step 9. Determine the Euclidean and Taxicab distances. The Euclidean distance $D_i(\overline{a}_{ij}, \widetilde{b}_{j*})$ between each stakeholder role i (including the limit profiles) and the ideal negative solution b_{j*} obtained in step 8 is calculated using the following equation:

$$D_i\left(\overline{a}_{ij}, \widetilde{b}_{j*}\right) = \sum_{j=1}^{m} w_j d\left(\overline{a}_{ij}, b_{j*}\right), \tag{31}$$

where w_j represents the priority weights of barriers to EDUC4 implementation obtained from FF CRITIC in step 5 in Section 3.2 and $d(\overline{a}_{ij}, b_{j*})$ is calculated using equation (11).

On the other hand, the Taxicab distance $\widetilde{t}_i(\overline{a}_{ij}, \widetilde{b}_{j*})$ between each stakeholder role i (including the limit profiles) and the ideal negative solution b_{j*} obtained in step 8 in Section 3.2. is calculated analogously using equation (25). Considering that both elements are FFS, equation (7) was used to obtain their difference. Then, equation (10) was used to transform the obtained Taxicab distance $\widetilde{t}_i(\overline{a}_{ij}, \widetilde{b}_{j*})$ to their corresponding crisp value $t_i(\overline{a}_{ij}, \widetilde{b}_{j*})$. Both the Euclidean and Taxicab distances are shown in Table 11.

Step 10. Construct the relative assessment matrix. Following step 6 in Section 3.2, the relative assessment matrix $H = (h_{i\kappa})_{m\times L-1}$ is calculated, where $h_{i\kappa}$ is shown in equation (32), and the resulting matrix is featured in Table 12. The threshold parameter is set to be $\rho = 0.02$.

$$\begin{aligned} h_{i\kappa} = &\left(D_i\left(\overline{a}_{ij}, \widetilde{b}_{j*}\right) - D_\kappa\left(\overline{a}_{\kappa j}, \widetilde{b}_{j*}\right)\right) \\ &+ \left(\beta\left(D_i\left(\overline{a}_{ij}, \widetilde{b}_{j*}\right) - D_\kappa\left(\overline{a}_{\kappa j}, \widetilde{b}_{j*}\right)\right)\right. \\ &\times\left(t_i\left(\overline{a}_{ij}, \widetilde{b}_{j*}\right) - t_\kappa\left(\overline{a}_{\kappa j}, \widetilde{b}_{j*}\right)\right). \end{aligned} \tag{32}$$

where $\kappa = 1, \ldots, L-1$ and β is a threshold function defined in equation (27).

Step 11. Assign the roles of various stakeholders to the predefined classes.

Suppose that $h_{i\kappa}(L2)$ is the highest limiting profile, then the stakeholder role i can be classified as follows:

class L_{high} if $h_{ik}(L2) \geq 0$.

class L_{mod} if $h_{ik}(L2) < 0$ and $h_{ik}(L1) \geq 0$.

Table 5: Aggregate FF decision matrix.

Codes	B1	B2	B3	B4	B5	B6
G1	(0.8675, 0.1217)	(0.5798, 0.3238)	(0.6184, 0.3036)	(0.5498, 0.3502)	(0.6069, 0.2913)	(0.6404, 0.2921)
G2	(0.7989, 0.1614)	(0.6960, 0.2365)	(0.7036, 0.2184)	(0.6014, 0.2986)	(0.7542, 0.1783)	(0.6773, 0.2516)
G3	(0.8495, 0.1361)	(0.5621, 0.3448)	(0.6487, 0.2549)	(0.6350, 0.2650)	(0.6708, 0.2292)	(0.7412, 0.2155)
G4	(0.6545, 0.2819)	(0.8567, 0.1325)	(0.6437, 0.2870)	(0.7253, 0.2036)	(0.7354, 0.1866)	(0.6051, 0.2949)
G5	(0.5838, 0.3238)	(0.6231, 0.2769)	(0.6271, 0.2729)	(0.8783, 0.1108)	(0.6047, 0.2953)	(0.8675, 0.1217)
G6	(0.5960, 0.3256)	(0.5534, 0.3502)	(0.8502, 0.1303)	(0.6032, 0.2968)	(0.6220, 0.2780)	(0.5823, 0.3177)
G7	(0.5119, 0.4011)	(0.6112, 0.2924)	(0.6274, 0.3014)	(0.8783, 0.1108)	(0.4946, 0.4054)	(0.8675, 0.1217)
G8	(0.5599, 0.3495)	(0.5112, 0.3870)	(0.7527, 0.2014)	(0.7942, 0.1729)	(0.6076, 0.2924)	(0.6957, 0.2130)
G9	(0.5227, 0.3773)	(0.5968, 0.3014)	(0.6783, 0.2217)	(0.5755, 0.3245)	(0.5361, 0.3621)	(0.6686, 0.2383)
G10	(0.5469, 0.3617)	(0.5274, 0.3848)	(0.6112, 0.2888)	(0.8061, 0.1523)	(0.5859, 0.3325)	(0.8567, 0.1325)
G11	(0.5412, 0.3682)	(0.5401, 0.3635)	(0.7729, 0.1787)	(0.6415, 0.2585)	(0.7116, 0.2069)	(0.4989, 0.3993)
G12	(0.7166, 0.2087)	(0.7332, 0.2087)	(0.6119, 0.3152)	(0.5635, 0.3365)	(0.6906, 0.2383)	(0.5906, 0.3130)
G13	(0.5809, 0.3227)	(0.5329, 0.3708)	(0.6166, 0.2816)	(0.6856, 0.2390)	(0.5300, 0.3682)	(0.6292, 0.2744)
G14	(0.5729, 0.3347)	(0.7801, 0.1906)	(0.6588, 0.2498)	(0.4986, 0.4014)	(0.5325, 0.3632)	(0.4585, 0.4415)
G15	(0.6574, 0.2646)	(0.7729, 0.1780)	(0.6783, 0.2401)	(0.5816, 0.3184)	(0.7245, 0.1939)	(0.5491, 0.3509)
G16	(0.5408, 0.3722)	(0.5599, 0.3437)	(0.8343, 0.1426)	(0.5560, 0.3440)	(0.7011, 0.2155)	(0.4986, 0.4014)
U17	(0.8487, 0.1274)	(0.6567, 0.2653)	(0.7318, 0.2155)	(0.5224, 0.3769)	(0.6112, 0.2924)	(0.6199, 0.2838)
U18	(0.8134, 0.1433)	(0.8126, 0.1581)	(0.6318, 0.2751)	(0.6029, 0.2971)	(0.6058, 0.2924)	(0.6235, 0.2765)
U19	(0.8144, 0.1599)	(0.8458, 0.1433)	(0.6047, 0.3224)	(0.6444, 0.2740)	(0.6209, 0.2957)	(0.7130, 0.2379)
U20	(0.6155, 0.2968)	(0.7209, 0.2202)	(0.8502, 0.1303)	(0.6040, 0.2960)	(0.8025, 0.1542)	(0.5549, 0.3451)
U21	(0.6278, 0.3000)	(0.5729, 0.3307)	(0.6740, 0.2260)	(0.6892, 0.2108)	(0.6625, 0.2560)	(0.7542, 0.1729)
U22	(0.5448, 0.3552)	(0.5310, 0.3671)	(0.5238, 0.3762)	(0.8415, 0.1292)	(0.5498, 0.3502)	(0.8235, 0.1437)
U23	(0.5249, 0.3827)	(0.6090, 0.2946)	(0.8321, 0.1448)	(0.5599, 0.3401)	(0.8235, 0.1437)	(0.6040, 0.2960)
U24	(0.5394, 0.3588)	(0.6014, 0.3022)	(0.6271, 0.2949)	(0.8675, 0.1181)	(0.8307, 0.1365)	(0.9000, 0.1000)
U25	(0.5480, 0.3606)	(0.5718, 0.3318)	(0.6148, 0.3159)	(0.6292, 0.2708)	(0.5671, 0.3329)	(0.7245, 0.1939)
U26	(0.5675, 0.3455)	(0.5036, 0.4000)	(0.5274, 0.3910)	(0.4693, 0.4307)	(0.5599, 0.3401)	(0.5307, 0.3693)
U27	(0.5664, 0.3458)	(0.4960, 0.4076)	(0.6588, 0.2596)	(0.6108, 0.2892)	(0.4715, 0.4267)	(0.4946, 0.4162)
H28	(0.8343, 0.1419)	(0.6199, 0.2838)	(0.6365, 0.2819)	(0.5329, 0.3671)	(0.6256, 0.2744)	(0.5982, 0.3000)
H29	(0.8134, 0.1433)	(0.6632, 0.2368)	(0.5527, 0.3509)	(0.5343, 0.3657)	(0.6935, 0.2336)	(0.5386, 0.3758)
H30	(0.8487, 0.1274)	(0.6199, 0.2838)	(0.6072, 0.2928)	(0.5473, 0.3527)	(0.5650, 0.3350)	(0.6036, 0.2964)
H31	(0.7722, 0.1787)	(0.5599, 0.3437)	(0.6812, 0.2458)	(0.6307, 0.2693)	(0.6271, 0.2729)	(0.6513, 0.2487)
H32	(0.8408, 0.1390)	(0.6112, 0.2924)	(0.6783, 0.2401)	(0.6617, 0.2383)	(0.6668, 0.2332)	(0.7072, 0.1964)
H33	(0.5253, 0.3747)	(0.6184, 0.2852)	(0.6740, 0.2531)	(0.6220, 0.2780)	(0.6097, 0.3123)	(0.7578, 0.1711)
H34	(0.5635, 0.3549)	(0.6957, 0.2166)	(0.8783, 0.1108)	(0.5570, 0.3430)	(0.8783, 0.1108)	(0.6325, 0.2783)
H35	(0.4982, 0.4018)	(0.5520, 0.3516)	(0.6199, 0.2986)	(0.6899, 0.2390)	(0.6458, 0.2726)	(0.7245, 0.2032)
H36	(0.4700, 0.4242)	(0.5148, 0.3888)	(0.4455, 0.4502)	(0.8675, 0.1217)	(0.4823, 0.4159)	(0.6769, 0.2451)
H37	(0.4184, 0.4845)	(0.7043, 0.2177)	(0.8502, 0.1303)	(0.5466, 0.3534)	(0.7245, 0.1975)	(0.5776, 0.3390)
H38	(0.4119, 0.4769)	(0.5819, 0.3217)	(0.6076, 0.3108)	(0.5397, 0.3585)	(0.6184, 0.3036)	(0.7473, 0.1910)
H39	(0.5458, 0.3578)	(0.6227, 0.2809)	(0.5982, 0.3000)	(0.6097, 0.2859)	(0.5928, 0.3108)	(0.6069, 0.2913)
I40	(0.8675, 0.1217)	(0.7686, 0.1910)	(0.6675, 0.2509)	(0.6307, 0.2693)	(0.6516, 0.2668)	(0.7101, 0.2083)
I41	(0.8596, 0.1202)	(0.5895, 0.3141)	(0.6177, 0.2823)	(0.5224, 0.3733)	(0.6924, 0.2347)	(0.6870, 0.2455)
I42	(0.5632, 0.3491)	(0.6935, 0.2285)	(0.6639, 0.2581)	(0.8126, 0.1545)	(0.5794, 0.3390)	(0.8502, 0.1267)
I43	(0.6307, 0.2877)	(0.8018, 0.1690)	(0.5238, 0.3848)	(0.6708, 0.2292)	(0.6841, 0.2159)	(0.6166, 0.2816)
I44	(0.6783, 0.2401)	(0.6783, 0.2253)	(0.6415, 0.2585)	(0.6617, 0.2383)	(0.5874, 0.3126)	(0.8206, 0.1397)
E45	(0.9000, 0.1000)	(0.6567, 0.2653)	(0.7469, 0.1827)	(0.6415, 0.2585)	(0.8603, 0.1253)	(0.6343, 0.2657)
E46	(0.8451, 0.1310)	(0.6004, 0.3227)	(0.5440, 0.3596)	(0.8271, 0.1401)	(0.5787, 0.3433)	(0.8126, 0.1581)
E47	(0.5231, 0.3805)	(0.6292, 0.2794)	(0.7195, 0.1989)	(0.6040, 0.2960)	(0.8892, 0.1072)	(0.7191, 0.2206)
E48	(0.5036, 0.4000)	(0.5744, 0.3256)	(0.6242, 0.2758)	(0.6448, 0.2661)	(0.6661, 0.2632)	(0.8783, 0.1108)
E49	(0.4473, 0.4379)	(0.6957, 0.2166)	(0.8206, 0.1397)	(0.6217, 0.2819)	(0.8603, 0.1253)	(0.6379, 0.2621)
E50	(0.4314, 0.4574)	(0.5946, 0.3199)	(0.4910, 0.4072)	(0.7989, 0.1686)	(0.5484, 0.3498)	(0.7650, 0.1823)
E51	(0.4217, 0.4671)	(0.6675, 0.2361)	(0.7332, 0.1852)	(0.5437, 0.3563)	(0.5903, 0.3097)	(0.5545, 0.3491)
E52	(0.4260, 0.4733)	(0.5209, 0.4011)	(0.6776, 0.2444)	(0.6087, 0.2913)	(0.6588, 0.2596)	(0.7224, 0.1996)
E53	(0.6195, 0.2841)	(0.6014, 0.3022)	(0.6162, 0.2838)	(0.6108, 0.2892)	(0.5061, 0.3939)	(0.7643, 0.1830)
E54	(0.4401, 0.4451)	(0.5347, 0.3690)	(0.8278, 0.1491)	(0.7545, 0.1838)	(0.8567, 0.1289)	(0.6108, 0.2928)
E55	(0.5646, 0.3390)	(0.7152, 0.2069)	(0.6159, 0.2841)	(0.6964, 0.2036)	(0.5235, 0.3801)	(0.5278, 0.3722)
E56	(0.7787, 0.1704)	(0.8126, 0.1581)	(0.7924, 0.1556)	(0.7458, 0.1917)	(0.8271, 0.1401)	(0.5653, 0.3347)

Table 5: Continued.

Codes	B1	B2	B3	B4	B5	B6
E57	(0.6047, 0.2953)	(0.7513, 0.1996)	(0.8415, 0.1390)	(0.6596, 0.2440)	(0.8603, 0.1253)	(0.6866, 0.2422)
Codes	B7	B8	B9	B10	B11	B12
G1	(0.5202, 0.3791)	(0.7422, 0.2144)	(0.5061, 0.3931)	(0.4545, 0.4412)	(0.5152, 0.3848)	(0.4567, 0.4462)
G2	(0.5123, 0.3733)	(0.7069, 0.2220)	(0.4480, 0.4314)	(0.4491, 0.4448)	(0.4736, 0.4220)	(0.6018, 0.3112)
G3	(0.6679, 0.2523)	(0.7542, 0.1949)	(0.6162, 0.3072)	(0.4560, 0.4397)	(0.5437, 0.3520)	(0.5708, 0.3513)
G4	(0.5606, 0.3394)	(0.8134, 0.1487)	(0.5134, 0.3776)	(0.5260, 0.3740)	(0.4939, 0.4061)	(0.6578, 0.2404)
G5	(0.4238, 0.4455)	(0.5700, 0.3282)	(0.3957, 0.4798)	(0.4116, 0.4722)	(0.3870, 0.4823)	(0.5199, 0.3787)
G6	(0.7513, 0.1996)	(0.7397, 0.1892)	(0.6162, 0.3072)	(0.3859, 0.4996)	(0.5166, 0.3773)	(0.6949, 0.2321)
G7	(0.5614, 0.3426)	(0.6426, 0.2668)	(0.4588, 0.4256)	(0.4116, 0.4722)	(0.4108, 0.4603)	(0.4736, 0.4256)
G8	(0.7087, 0.2300)	(0.6625, 0.2375)	(0.6466, 0.2780)	(0.3556, 0.5137)	(0.4736, 0.4119)	(0.7152, 0.2094)
G9	(0.6480, 0.2704)	(0.6076, 0.2906)	(0.6870, 0.2538)	(0.4116, 0.4722)	(0.4538, 0.4354)	(0.7224, 0.2224)
G10	(0.5866, 0.3173)	(0.6191, 0.2903)	(0.4899, 0.3939)	(0.4227, 0.4664)	(0.6841, 0.2404)	(0.8112, 0.1614)
G11	(0.7845, 0.1578)	(0.7946, 0.1545)	(0.6581, 0.2697)	(0.7805, 0.1755)	(0.7816, 0.1675)	(0.8523, 0.1238)
G12	(0.6675, 0.2325)	(0.6646, 0.2574)	(0.6188, 0.2812)	(0.4282, 0.4556)	(0.4076, 0.4671)	(0.7007, 0.2238)
G13	(0.6794, 0.2531)	(0.5780, 0.3296)	(0.7235, 0.2191)	(0.5722, 0.3314)	(0.5892, 0.3144)	(0.6513, 0.2487)
G14	(0.5025, 0.3931)	(0.6209, 0.2884)	(0.4722, 0.4260)	(0.7440, 0.2173)	(0.8285, 0.1513)	(0.7144, 0.2072)
G15	(0.6025, 0.2975)	(0.7448, 0.1830)	(0.5354, 0.3581)	(0.4949, 0.4087)	(0.5303, 0.3697)	(0.6632, 0.2368)
G16	(0.6697, 0.2505)	(0.7722, 0.1892)	(0.6292, 0.2986)	(0.7321, 0.2152)	(0.7509, 0.1964)	(0.8227, 0.1386)
U17	(0.5617, 0.3314)	(0.6487, 0.2549)	(0.4628, 0.4220)	(0.5029, 0.4007)	(0.5881, 0.3119)	(0.5231, 0.3805)
U18	(0.4542, 0.4314)	(0.6989, 0.2300)	(0.3773, 0.5029)	(0.3574, 0.5119)	(0.5498, 0.3495)	(0.4906, 0.3986)
U19	(0.5888, 0.3242)	(0.8097, 0.1700)	(0.5235, 0.3700)	(0.5599, 0.3621)	(0.7061, 0.2412)	(0.7498, 0.2029)
U20	(0.6249, 0.2874)	(0.6206, 0.2794)	(0.5321, 0.3715)	(0.4841, 0.4116)	(0.5917, 0.3166)	(0.5036, 0.3899)
U21	(0.6762, 0.2552)	(0.7563, 0.1928)	(0.5462, 0.3473)	(0.5101, 0.3791)	(0.4502, 0.4354)	(0.6047, 0.2910)
U22	(0.5455, 0.3671)	(0.4585, 0.4271)	(0.4195, 0.4650)	(0.4245, 0.4646)	(0.4206, 0.4632)	(0.4339, 0.4516)
U23	(0.6502, 0.2755)	(0.7823, 0.1755)	(0.5040, 0.3895)	(0.6148, 0.2852)	(0.5253, 0.3747)	(0.6314, 0.2686)
U24	(0.5852, 0.3224)	(0.5491, 0.3509)	(0.5043, 0.3791)	(0.4704, 0.4152)	(0.4444, 0.4412)	(0.5094, 0.3946)
U25	(0.6004, 0.3383)	(0.5477, 0.3523)	(0.4823, 0.4130)	(0.4556, 0.4300)	(0.4354, 0.4502)	(0.4632, 0.4224)
U26	(0.6856, 0.2469)	(0.6177, 0.2805)	(0.6635, 0.2653)	(0.8191, 0.1606)	(0.7473, 0.2105)	(0.7809, 0.1751)
U27	(0.5433, 0.3498)	(0.4653, 0.4303)	(0.4877, 0.3957)	(0.3939, 0.4953)	(0.4639, 0.4260)	(0.5181, 0.3895)
H28	(0.4072, 0.4639)	(0.3993, 0.4845)	(0.3758, 0.4935)	(0.3791, 0.4921)	(0.4664, 0.4271)	(0.4617, 0.4274)
H29	(0.5603, 0.3390)	(0.6996, 0.2329)	(0.5466, 0.3534)	(0.4152, 0.4729)	(0.7004, 0.2480)	(0.5848, 0.3188)
H30	(0.5076, 0.3863)	(0.6126, 0.2910)	(0.5137, 0.3845)	(0.3556, 0.5235)	(0.4585, 0.4372)	(0.4000, 0.4747)
H31	(0.5116, 0.3884)	(0.5058, 0.3942)	(0.7458, 0.2014)	(0.4744, 0.4249)	(0.5949, 0.3087)	(0.6715, 0.2610)
H32	(0.5336, 0.3664)	(0.5715, 0.3285)	(0.7087, 0.2238)	(0.4401, 0.4635)	(0.3379, 0.5801)	(0.4747, 0.4188)
H33	(0.7715, 0.1794)	(0.5661, 0.3321)	(0.5256, 0.3780)	(0.5094, 0.3906)	(0.4928, 0.4155)	(0.6083, 0.2910)
H34	(0.8379, 0.1419)	(0.7415, 0.2076)	(0.5513, 0.3480)	(0.5581, 0.3419)	(0.7542, 0.1931)	(0.6480, 0.2740)
H35	(0.5794, 0.3347)	(0.5148, 0.3888)	(0.5256, 0.3780)	(0.4928, 0.4054)	(0.4740, 0.4159)	(0.4747, 0.4188)
H36	(0.5159, 0.3841)	(0.4394, 0.4444)	(0.4733, 0.4260)	(0.4585, 0.4451)	(0.4560, 0.4375)	(0.4653, 0.4282)
H37	(0.5888, 0.3332)	(0.5188, 0.3794)	(0.5437, 0.3599)	(0.5307, 0.3693)	(0.4704, 0.4195)	(0.5116, 0.4004)
H38	(0.6209, 0.2827)	(0.6000, 0.3036)	(0.6386, 0.2834)	(0.4271, 0.4722)	(0.3509, 0.5715)	(0.4653, 0.4282)
H39	(0.5025, 0.3968)	(0.4513, 0.4426)	(0.7975, 0.1736)	(0.5087, 0.3852)	(0.3758, 0.5032)	(0.4379, 0.4556)
I40	(0.5188, 0.3769)	(0.6206, 0.2996)	(0.5863, 0.3119)	(0.4664, 0.4372)	(0.4032, 0.4819)	(0.4563, 0.4372)
I41	(0.4877, 0.4061)	(0.6025, 0.3213)	(0.6278, 0.2899)	(0.4845, 0.4191)	(0.3675, 0.5069)	(0.4531, 0.4404)
I42	(0.5881, 0.3339)	(0.5480, 0.3502)	(0.5235, 0.3758)	(0.5108, 0.3931)	(0.5032, 0.3960)	(0.4877, 0.4199)
I43	(0.4700, 0.4300)	(0.5700, 0.3484)	(0.4924, 0.4032)	(0.5520, 0.3480)	(0.5682, 0.3271)	(0.4928, 0.4007)
I44	(0.4881, 0.4119)	(0.5412, 0.3809)	(0.4455, 0.4538)	(0.5527, 0.3473)	(0.5278, 0.3675)	(0.4401, 0.4390)
E45	(0.4484, 0.4354)	(0.5755, 0.3285)	(0.5971, 0.2975)	(0.4300, 0.4538)	(0.5563, 0.3394)	(0.5809, 0.3184)
E46	(0.6083, 0.3137)	(0.5621, 0.3415)	(0.7119, 0.2123)	(0.6141, 0.2895)	(0.6498, 0.2827)	(0.6004, 0.3032)
E47	(0.8018, 0.1693)	(0.7137, 0.2152)	(0.5278, 0.3657)	(0.7011, 0.2278)	(0.5812, 0.3188)	(0.6202, 0.2834)
E48	(0.5722, 0.3462)	(0.5690, 0.3310)	(0.5426, 0.3563)	(0.4978, 0.4061)	(0.5090, 0.3910)	(0.6245, 0.2791)
E49	(0.7881, 0.1715)	(0.6303, 0.2697)	(0.5426, 0.3563)	(0.5534, 0.3466)	(0.5477, 0.3523)	(0.5350, 0.3686)
E50	(0.6224, 0.2942)	(0.5534, 0.3502)	(0.5235, 0.3718)	(0.3899, 0.4949)	(0.4173, 0.4726)	(0.3819, 0.4971)
E51	(0.7004, 0.2162)	(0.6433, 0.2549)	(0.5079, 0.3874)	(0.4495, 0.4444)	(0.4531, 0.4451)	(0.5462, 0.3574)
E52	(0.7729, 0.1780)	(0.6126, 0.2874)	(0.5740, 0.3195)	(0.4798, 0.4159)	(0.4029, 0.4726)	(0.4574, 0.4361)
E53	(0.5224, 0.3733)	(0.5386, 0.3596)	(0.5123, 0.3975)	(0.4570, 0.4466)	(0.4097, 0.4801)	(0.3744, 0.5047)
E54	(0.7708, 0.1801)	(0.6729, 0.2560)	(0.5379, 0.3610)	(0.7267, 0.2058)	(0.6747, 0.2339)	(0.6224, 0.2812)
E55	(0.6097, 0.3123)	(0.5715, 0.3267)	(0.8101, 0.1614)	(0.5256, 0.3780)	(0.5303, 0.3679)	(0.5043, 0.3993)
E56	(0.6097, 0.3087)	(0.7181, 0.2292)	(0.6931, 0.2531)	(0.7563, 0.1910)	(0.6426, 0.2574)	(0.7072, 0.2253)
E57	(0.7881, 0.1715)	(0.6433, 0.2549)	(0.5513, 0.3477)	(0.7751, 0.1827)	(0.8134, 0.1628)	(0.7552, 0.2061)

Table 6: Defuzzified aggregate decision matrix.

Codes	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
G1	0.6772	0.2947	0.3286	0.2703	0.3191	0.3499	0.2479	0.4704	0.2379	0.2045	0.2442	0.2049
G2	0.5549	0.4117	0.4212	0.3140	0.4876	0.3899	0.2436	0.4250	0.2027	0.2015	0.2165	0.3136
G3	0.6425	0.2796	0.3599	0.3460	0.3836	0.4689	0.3797	0.4872	0.3264	0.2054	0.2659	0.2856
G4	0.3645	0.6562	0.3534	0.4484	0.4619	0.3173	0.2790	0.5786	0.2438	0.2521	0.2294	0.3696
G5	0.2978	0.3343	0.3382	0.6989	0.3170	0.6772	0.1902	0.2868	0.1742	0.1814	0.1708	0.2478
G6	0.3077	0.2729	0.6439	0.3157	0.3333	0.2971	0.4831	0.4676	0.3264	0.1676	0.2459	0.4106
G7	0.2406	0.3228	0.3370	0.6989	0.2299	0.6772	0.2792	0.3533	0.2086	0.1814	0.1829	0.2161
G8	0.2776	0.2416	0.4851	0.5472	0.3196	0.4120	0.4270	0.3746	0.3567	0.1554	0.2177	0.4355
G9	0.2497	0.3099	0.3921	0.2912	0.2598	0.3810	0.3585	0.3197	0.4007	0.1814	0.2049	0.4442
G10	0.2673	0.2520	0.3230	0.5667	0.2989	0.6562	0.3006	0.3300	0.2285	0.1868	0.3979	0.5749
G11	0.2627	0.2624	0.5146	0.3526	0.4311	0.2330	0.5323	0.5481	0.3688	0.5260	0.5277	0.6480
G12	0.4373	0.4586	0.3221	0.2813	0.4054	0.3041	0.3801	0.3761	0.3302	0.1906	0.1806	0.4176
G13	0.2956	0.2569	0.3282	0.3996	0.2552	0.3401	0.3923	0.2928	0.4457	0.2882	0.3028	0.3626
G14	0.2885	0.5252	0.3703	0.2326	0.2573	0.2064	0.2358	0.3317	0.2153	0.4728	0.6046	0.4347
G15	0.3683	0.5146	0.3915	0.2964	0.4477	0.2697	0.3150	0.4745	0.2597	0.2297	0.2553	0.3753
G16	0.2621	0.2781	0.6149	0.2752	0.4183	0.2326	0.3817	0.5133	0.3389	0.4570	0.4827	0.5947
U17	0.6413	0.3675	0.4565	0.2495	0.3228	0.3310	0.2803	0.3599	0.2110	0.2352	0.3021	0.2496
U18	0.5787	0.5773	0.3425	0.3153	0.3181	0.3347	0.2056	0.4153	0.1641	0.1563	0.2703	0.2284
U19	0.5803	0.6358	0.3153	0.3547	0.3314	0.4320	0.3019	0.5724	0.2509	0.2766	0.4236	0.4810
U20	0.3264	0.4425	0.6439	0.3163	0.5608	0.2743	0.3354	0.3319	0.2564	0.2233	0.3047	0.2367
U21	0.3374	0.2888	0.3873	0.4046	0.3739	0.4876	0.3886	0.4903	0.2680	0.2417	0.2032	0.3172
U22	0.2663	0.2560	0.2505	0.6280	0.2703	0.5959	0.2658	0.2083	0.1857	0.1878	0.1864	0.1937
U23	0.2506	0.3208	0.6110	0.2784	0.5959	0.3163	0.3604	0.5287	0.2370	0.3264	0.2516	0.3424
U24	0.2623	0.3138	0.3370	0.6772	0.6085	0.7445	0.2991	0.2697	0.2382	0.2157	0.1998	0.2397
U25	0.2681	0.2879	0.3246	0.3403	0.2843	0.4477	0.3105	0.2686	0.2222	0.2065	0.1945	0.2111
U26	0.2836	0.2357	0.2514	0.2132	0.2784	0.2556	0.3993	0.3292	0.3746	0.5883	0.4774	0.5265
U27	0.2827	0.2304	0.3700	0.3227	0.2148	0.2286	0.2658	0.2112	0.2271	0.1711	0.2111	0.2456
H28	0.6149	0.3310	0.3466	0.2572	0.3368	0.3112	0.1810	0.1748	0.1652	0.1665	0.2122	0.2098
H29	0.5787	0.3753	0.2723	0.2583	0.4089	0.2603	0.2787	0.4161	0.2677	0.1827	0.4164	0.2990
H30	0.6413	0.3310	0.3193	0.2683	0.2825	0.3160	0.2395	0.3241	0.2434	0.1537	0.2070	0.1766
H31	0.5135	0.2781	0.3945	0.3417	0.3382	0.3626	0.2416	0.2376	0.4756	0.2165	0.3079	0.3833
H32	0.6266	0.3228	0.3915	0.3738	0.3793	0.4261	0.2578	0.2879	0.4272	0.1947	0.1373	0.2175
H33	0.2516	0.3296	0.3863	0.3333	0.3204	0.4927	0.5124	0.2835	0.2515	0.2401	0.2277	0.3203
H34	0.2799	0.4119	0.6989	0.2760	0.6989	0.3430	0.6213	0.4696	0.2715	0.2769	0.4873	0.3583
H35	0.2323	0.2717	0.3302	0.4045	0.3562	0.4475	0.2936	0.2436	0.2515	0.2288	0.2174	0.2175
H36	0.2144	0.2436	0.1991	0.6772	0.2218	0.3898	0.2447	0.1971	0.2158	0.2059	0.2057	0.2115
H37	0.1823	0.4221	0.6439	0.2677	0.4476	0.2919	0.3012	0.2470	0.2652	0.2556	0.2151	0.2404
H38	0.1808	0.2965	0.3186	0.2626	0.3286	0.4778	0.3320	0.3125	0.3486	0.1878	0.1428	0.2115
H39	0.2669	0.3338	0.3112	0.3219	0.3060	0.3191	0.2354	0.2028	0.5524	0.2402	0.1635	0.1949
I40	0.6772	0.5080	0.3794	0.3417	0.3623	0.4293	0.2472	0.3308	0.3006	0.2109	0.1767	0.2059
I41	0.6618	0.3031	0.3291	0.2499	0.4076	0.4010	0.2259	0.3135	0.3380	0.2226	0.1603	0.2039
I42	0.2801	0.4090	0.3753	0.5774	0.2933	0.6440	0.3006	0.2690	0.2503	0.2407	0.2359	0.2243
I43	0.3408	0.5594	0.2497	0.3836	0.3987	0.3282	0.2137	0.2853	0.2289	0.2720	0.2855	0.2293
I44	0.3915	0.3920	0.3526	0.3738	0.3015	0.5909	0.2255	0.2615	0.1986	0.2726	0.2539	0.1981
E45	0.7445	0.3675	0.4775	0.3526	0.6631	0.3453	0.2024	0.2909	0.3104	0.1917	0.2758	0.2959
E46	0.6346	0.3116	0.2655	0.6022	0.2924	0.5773	0.3190	0.2799	0.4314	0.3255	0.3597	0.3128
E47	0.2496	0.3399	0.4412	0.3163	0.7213	0.4402	0.5594	0.4336	0.2540	0.4179	0.2961	0.3314
E48	0.2357	0.2903	0.3354	0.3554	0.3774	0.6989	0.2871	0.2858	0.2647	0.2316	0.2399	0.3355
E49	0.2015	0.4119	0.5909	0.3327	0.6631	0.3489	0.5377	0.3414	0.2647	0.2731	0.2686	0.2585
E50	0.1918	0.3069	0.2276	0.5548	0.2693	0.5029	0.3328	0.2729	0.2507	0.1697	0.1837	0.1666
E51	0.1862	0.3799	0.4591	0.2655	0.3040	0.2737	0.4174	0.3545	0.2396	0.2017	0.2033	0.2672
E52	0.1871	0.2462	0.3906	0.3206	0.3700	0.4448	0.5146	0.3243	0.2904	0.2205	0.1780	0.2066
E53	0.3307	0.3138	0.3277	0.3227	0.2378	0.5018	0.2499	0.2618	0.2412	0.2050	0.1795	0.1628
E54	0.1973	0.2583	0.6033	0.4880	0.6562	0.3225	0.5113	0.3850	0.2611	0.4502	0.3878	0.3334
E55	0.2819	0.4356	0.3274	0.4131	0.2499	0.2534	0.3204	0.2880	0.5731	0.2515	0.2555	0.2362
E56	0.5233	0.5773	0.5446	0.4758	0.6022	0.2828	0.3206	0.4386	0.4078	0.4904	0.3537	0.4254
E57	0.3170	0.4831	0.6279	0.3713	0.6631	0.4007	0.5377	0.3545	0.2715	0.5177	0.5785	0.4885

Table 7: Symmetric matrix.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
B1	1.0000	0.2590	−0.1662	−0.2301	0.0126	−0.1239	−0.4585	0.1409	0.0449	−0.1913	−0.0171	−0.1273
B2	0.2590	1.0000	0.1005	−0.1488	0.2557	−0.2422	−0.1695	0.3351	−0.1374	0.1141	0.1984	0.0497
B3	−0.1662	0.1005	1.0000	−0.2748	0.6608	−0.3537	0.5629	0.3920	0.0216	0.3315	0.3429	0.3388
B4	−0.2301	−0.1488	−0.2748	1.0000	−0.1245	0.6632	−0.1297	−0.2358	−0.1066	−0.1425	−0.1851	−0.1200
B5	0.0126	0.2557	0.6608	−0.1245	1.0000	−0.1449	0.4607	0.3755	−0.0618	0.3727	0.2944	0.1982
B6	−0.1239	−0.2422	−0.3537	0.6632	−0.1449	1.0000	−0.1466	−0.2892	−0.2537	−0.3072	−0.3409	−0.2640
B7	−0.4585	−0.1695	0.5629	−0.1297	0.4607	−0.1466	1.0000	0.3878	0.1485	0.4291	0.3640	0.4303
B8	0.1409	0.3351	0.3920	−0.2358	0.3755	−0.2892	0.3878	1.0000	−0.0462	0.3072	0.3869	0.5385
B9	0.0449	−0.1374	0.0216	−0.1066	−0.0618	−0.2537	0.1485	−0.0462	1.0000	0.1987	0.0515	0.2311
B10	−0.1913	0.1141	0.3315	−0.1425	0.3727	−0.3072	0.4291	0.3072	0.1987	1.0000	0.7582	0.5991
B11	−0.0171	0.1984	0.3429	−0.1851	0.2944	−0.3409	0.3640	0.3869	0.0515	0.7582	1.0000	0.7171
B12	−0.1273	0.0497	0.3388	−0.1200	0.1982	−0.2640	0.4303	0.5385	0.2311	0.5991	0.7171	1.0000

Table 8: Priority weights of the barriers to EDUC4 implementation.

Barriers	e_j	z_j	w_j
B1	0.9769	11.5827	0.0988
B2	0.9901	10.2825	0.0877
B3	0.9894	8.9476	0.0763
B4	0.9871	11.8796	0.1013
B5	0.9862	8.5806	0.0732
B6	0.9872	12.6392	0.1078
B7	0.9882	9.0134	0.0769
B8	0.9901	8.6214	0.0735
B9	0.9893	10.7923	0.0920
B10	0.9827	8.3830	0.0715
B11	0.9822	8.2799	0.0706
B12	0.9842	8.2754	0.0706

class L_{low} if $h_{ik}(L2) < 0$ and $h_{ik}(L1) < 0$.

The final classification of the roles of various stakeholders to overcome barriers to EDUC4 implementation is illustrated in Figure 3.

5. Results and Discussion

In promoting a workable EDUC4 implementation roadmap, this work offers the application of the proposed FF entropy-based CRITIC-CODAS-SORT in evaluating the stakeholder roles for overcoming the barriers to implementing EDUC4. The applicability of the proposed framework is positioned to analyze the conditions describing an HEI. In the proposed approach, the FF CRITIC determines the priority barriers, while FF CODAS-SORT identifies the high-priority stakeholder roles that could guide the case HEI in formulating policy directions appropriate for its implementation of EDUC4. Identifying the relevant and priority barriers is essential for an HEI at different managerial levels to accomplish activities attuned to addressing these barriers. A set of expert decision-makers at the university level elicited judgments on the relevance of various stakeholder roles in overcoming the barriers to implementing EDUC4 in developing economies recently identified in the literature. Consequently, the insights generated strategic views to design appropriate approaches for the implementation agenda. Results show that the top five most relevant barriers associated with the case HEI in developing initiatives for EDUC4 implementation are the lack of collaboration (B6; i.e., external fund sourcing and industry linkages), apprehensive stakeholders (B4; i.e., low motivation, fear of the unknown and limited technical know-how), cybersecurity threats (B1; i.e., no infrastructure against cybersecurity attracts), health issues (B9; i.e., concerns on-screen time and cyber stress), and costly (B2; i.e., ICT infrastructure and fast-changing upgrades). These findings draw parallel insights with recent studies concerning the readiness of the HEIs in developing economies. For example, Jamaludin et al. [4] raised concerns about the managerial and financial readiness of HEIs in the ASEAN countries. Thus, aside from the costs associated with EDUC4 implementation, the administrative aspect is essential in ensuring effective collaboration and dealing with apprehensive stakeholders. Another emerging literature emphasized that curriculum design for EDUC4 implementation must include teaching industrial cybersecurity to accelerate the next-generation programmers and cybersecurity researchers [50]. Lastly, Hariharasudan and Kot [51] emphasized the relevance of health issues following their observation that one of IoT's most critical industrial applications in the EDUC4 era includes medical, health, and elderly care. These works in the literature justify the priority judgments of educational decision-makers at a university level from a developing economy perspective.

In addition, the decision-makers of the case HEI positioned insufficient foundation in basic education (B12; i.e., lack of learner's proper primary education), the complexity of learning platforms (B11; i.e., difficulty in utilizing virtual learning platforms), and time constraint for material preparation (B10; i.e., time constraint in preparation for virtual learning platform) among the minor priority barriers in achieving EDUC4. Unlike the other top priority barriers (i.e., B2, B9, B1, B6, and B4), the least three priorities barriers (i.e., B10, B11, and B10) are construed along with case-specific conditions of the HEI wherein limited or no control is available due to the trifocal education system [52] with each has own mandates and budgetary directions.

Table 9: Augmented FF decision matrix.

Codes	B1	B2	B3	B4	B5	B6
G1	(0.8675, 0.1217)	(0.5798, 0.3238)	(0.6184, 0.3036)	(0.5498, 0.3502)	(0.6069, 0.2913)	(0.6404, 0.2921)
G2	(0.7989, 0.1614)	(0.6960, 0.2365)	(0.7036, 0.2184)	(0.6014, 0.2986)	(0.7542, 0.1783)	(0.6773, 0.2516)
G3	(0.8495, 0.1361)	(0.5621, 0.3448)	(0.6487, 0.2549)	(0.6350, 0.2650)	(0.6708, 0.2292)	(0.7412, 0.2155)
G4	(0.6545, 0.2819)	(0.8567, 0.1325)	(0.6437, 0.2870)	(0.7253, 0.2036)	(0.7354, 0.1866)	(0.6051, 0.2949)
G5	(0.5838, 0.3238)	(0.6231, 0.2769)	(0.6271, 0.2729)	(0.8783, 0.1108)	(0.6047, 0.2953)	(0.8675, 0.1217)
G6	(0.5960, 0.3256)	(0.5534, 0.3502)	(0.8502, 0.1303)	(0.6032, 0.2968)	(0.6220, 0.2780)	(0.5823, 0.3177)
G7	(0.5119, 0.4011)	(0.6112, 0.2924)	(0.6274, 0.3014)	(0.8783, 0.1108)	(0.4946, 0.4054)	(0.8675, 0.1217)
G8	(0.5599, 0.3495)	(0.5112, 0.3870)	(0.7527, 0.2014)	(0.7942, 0.1729)	(0.6076, 0.2924)	(0.6957, 0.2130)
G9	(0.5227, 0.3773)	(0.5968, 0.3014)	(0.6783, 0.2217)	(0.5755, 0.3245)	(0.5361, 0.3621)	(0.6686, 0.2383)
G10	(0.5469, 0.3617)	(0.5274, 0.3848)	(0.6112, 0.2888)	(0.8061, 0.1523)	(0.5859, 0.3325)	(0.8567, 0.1325)
G11	(0.5412, 0.3682)	(0.5401, 0.3635)	(0.7729, 0.1787)	(0.6415, 0.2585)	(0.7116, 0.2069)	(0.4989, 0.3993)
G12	(0.7166, 0.2087)	(0.7332, 0.2087)	(0.6119, 0.3152)	(0.5635, 0.3365)	(0.6906, 0.2383)	(0.5906, 0.3130)
G13	(0.5809, 0.3227)	(0.5329, 0.3708)	(0.6166, 0.2816)	(0.6856, 0.2390)	(0.5300, 0.3682)	(0.6292, 0.2744)
G14	(0.5729, 0.3347)	(0.7801, 0.1906)	(0.6588, 0.2498)	(0.4986, 0.4014)	(0.5325, 0.3632)	(0.4585, 0.4415)
G15	(0.6574, 0.2646)	(0.7729, 0.1780)	(0.6783, 0.2401)	(0.5816, 0.3184)	(0.7245, 0.1939)	(0.5491, 0.3509)
G16	(0.5408, 0.3722)	(0.5599, 0.3437)	(0.8343, 0.1426)	(0.5560, 0.3440)	(0.7011, 0.2155)	(0.4986, 0.4014)
U17	(0.8487, 0.1274)	(0.6567, 0.2653)	(0.7318, 0.2155)	(0.5224, 0.3769)	(0.6112, 0.2924)	(0.6199, 0.2838)
U18	(0.8134, 0.1433)	(0.8126, 0.1581)	(0.6318, 0.2751)	(0.6029, 0.2971)	(0.6058, 0.2924)	(0.6235, 0.2765)
U19	(0.8144, 0.1599)	(0.8458, 0.1433)	(0.6047, 0.3224)	(0.6444, 0.2740)	(0.6209, 0.2957)	(0.7130, 0.2379)
U20	(0.6155, 0.2968)	(0.7209, 0.2202)	(0.8502, 0.1303)	(0.6040, 0.2960)	(0.8025, 0.1542)	(0.5549, 0.3451)
U21	(0.6278, 0.3000)	(0.5729, 0.3307)	(0.6740, 0.2260)	(0.6892, 0.2108)	(0.6625, 0.2560)	(0.7542, 0.1729)
U22	(0.5448, 0.3552)	(0.5310, 0.3671)	(0.5238, 0.3762)	(0.8415, 0.1292)	(0.5498, 0.3502)	(0.8235, 0.1437)
U23	(0.5249, 0.3827)	(0.6090, 0.2946)	(0.8321, 0.1448)	(0.5599, 0.3401)	(0.8235, 0.1437)	(0.6040, 0.2960)
U24	(0.5394, 0.3588)	(0.6014, 0.3022)	(0.6271, 0.2949)	(0.8675, 0.1181)	(0.8307, 0.1365)	(0.9000, 0.1000)
U25	(0.5480, 0.3606)	(0.5718, 0.3318)	(0.6148, 0.3159)	(0.6292, 0.2708)	(0.5671, 0.3329)	(0.7245, 0.1939)
U26	(0.5675, 0.3455)	(0.5036, 0.4000)	(0.5274, 0.3910)	(0.4693, 0.4307)	(0.5599, 0.3401)	(0.5307, 0.3693)
U27	(0.5664, 0.3458)	(0.4960, 0.4076)	(0.6588, 0.2596)	(0.6108, 0.2892)	(0.4715, 0.4267)	(0.4946, 0.4162)
H28	(0.8343, 0.1419)	(0.6199, 0.2838)	(0.6365, 0.2819)	(0.5329, 0.3671)	(0.6256, 0.2744)	(0.5982, 0.3000)
H29	(0.8134, 0.1433)	(0.6632, 0.2368)	(0.5527, 0.3509)	(0.5343, 0.3657)	(0.6935, 0.2336)	(0.5386, 0.3758)
H30	(0.8487, 0.1274)	(0.6199, 0.2838)	(0.6072, 0.2928)	(0.5473, 0.3527)	(0.5650, 0.3350)	(0.6036, 0.2964)
H31	(0.7722, 0.1787)	(0.5599, 0.3437)	(0.6812, 0.2458)	(0.6307, 0.2693)	(0.6271, 0.2729)	(0.6513, 0.2487)
H32	(0.8408, 0.1390)	(0.6112, 0.2924)	(0.6783, 0.2401)	(0.6617, 0.2383)	(0.6668, 0.2332)	(0.7072, 0.1964)
H33	(0.5253, 0.3747)	(0.6184, 0.2852)	(0.6740, 0.2531)	(0.6220, 0.2780)	(0.6097, 0.3123)	(0.7578, 0.1711)
H34	(0.5635, 0.3549)	(0.6957, 0.2166)	(0.8783, 0.1108)	(0.5570, 0.3430)	(0.8783, 0.1108)	(0.6325, 0.2783)
H35	(0.4982, 0.4018)	(0.5520, 0.3516)	(0.6199, 0.2986)	(0.6899, 0.2390)	(0.6458, 0.2726)	(0.7245, 0.2032)
H36	(0.4700, 0.4242)	(0.5148, 0.3888)	(0.4455, 0.4502)	(0.8675, 0.1217)	(0.4823, 0.4159)	(0.6769, 0.2451)
H37	(0.4184, 0.4845)	(0.7043, 0.2177)	(0.8502, 0.1303)	(0.5466, 0.3534)	(0.7245, 0.1975)	(0.5776, 0.3390)
H38	(0.4119, 0.4769)	(0.5819, 0.3217)	(0.6076, 0.3108)	(0.5397, 0.3585)	(0.6184, 0.3036)	(0.7473, 0.1910)
H39	(0.5458, 0.3578)	(0.6227, 0.2809)	(0.5982, 0.3000)	(0.6097, 0.2859)	(0.5928, 0.3108)	(0.6069, 0.2913)
I40	(0.8675, 0.1217)	(0.7686, 0.1910)	(0.6675, 0.2509)	(0.6307, 0.2693)	(0.6516, 0.2668)	(0.7101, 0.2083)
I41	(0.8596, 0.1202)	(0.5895, 0.3141)	(0.6177, 0.2823)	(0.5224, 0.3733)	(0.6924, 0.2347)	(0.6870, 0.2455)
I42	(0.5632, 0.3491)	(0.6935, 0.2285)	(0.6639, 0.2581)	(0.8126, 0.1545)	(0.5794, 0.3390)	(0.8502, 0.1267)
I43	(0.6307, 0.2877)	(0.8018, 0.1690)	(0.5238, 0.3848)	(0.6708, 0.2292)	(0.6841, 0.2159)	(0.6166, 0.2816)
I44	(0.6783, 0.2401)	(0.6783, 0.2253)	(0.6415, 0.2585)	(0.6617, 0.2383)	(0.5874, 0.3126)	(0.8206, 0.1397)
E45	(0.9000, 0.1000)	(0.6567, 0.2653)	(0.7469, 0.1827)	(0.6415, 0.2585)	(0.8603, 0.1253)	(0.6343, 0.2657)
E46	(0.8451, 0.1310)	(0.6004, 0.3227)	(0.5440, 0.3596)	(0.8271, 0.1401)	(0.5787, 0.3433)	(0.8126, 0.1581)
E47	(0.5231, 0.3805)	(0.6292, 0.2794)	(0.7195, 0.1989)	(0.6040, 0.2960)	(0.8892, 0.1072)	(0.7191, 0.2206)
E48	(0.5036, 0.4000)	(0.5744, 0.3256)	(0.6242, 0.2758)	(0.6448, 0.2661)	(0.6661, 0.2632)	(0.8783, 0.1108)
E49	(0.4473, 0.4379)	(0.6957, 0.2166)	(0.8206, 0.1397)	(0.6217, 0.2819)	(0.8603, 0.1253)	(0.6379, 0.2621)
E50	(0.4314, 0.4574)	(0.5946, 0.3199)	(0.4910, 0.4072)	(0.7989, 0.1686)	(0.5484, 0.3498)	(0.7650, 0.1823)
E51	(0.4217, 0.4671)	(0.6675, 0.2361)	(0.7332, 0.1852)	(0.5437, 0.3563)	(0.5903, 0.3097)	(0.5545, 0.3491)
E52	(0.4260, 0.4733)	(0.5209, 0.4011)	(0.6776, 0.2444)	(0.6087, 0.2913)	(0.6588, 0.2596)	(0.7224, 0.1996)
E53	(0.6195, 0.2841)	(0.6014, 0.3022)	(0.6162, 0.2838)	(0.6108, 0.2892)	(0.5061, 0.3939)	(0.7643, 0.1830)
E54	(0.4401, 0.4451)	(0.5347, 0.3690)	(0.8278, 0.1491)	(0.7545, 0.1838)	(0.8567, 0.1289)	(0.6108, 0.2928)
E55	(0.5646, 0.3390)	(0.7152, 0.2069)	(0.6159, 0.2841)	(0.6964, 0.2036)	(0.5235, 0.3801)	(0.5278, 0.3722)
E56	(0.7787, 0.1704)	(0.8126, 0.1581)	(0.7924, 0.1556)	(0.7458, 0.1917)	(0.8271, 0.1401)	(0.5653, 0.3347)
E57	(0.6047, 0.2953)	(0.7513, 0.1996)	(0.8415, 0.1390)	(0.6596, 0.2440)	(0.8603, 0.1253)	(0.6866, 0.2422)
L2	(0.7020, 0.2665)	(0.6682, 0.2242)	(0.6851, 0.2476)	(0.6851, 0.2369)	(0.6936, 0.2347)	(0.7020, 0.2428)

Table 9: Continued.

Codes	B1	B2	B3	B4	B5	B6
L1	(0.4950, 0.3779)	(0.4712, 0.3179)	(0.4831, 0.3511)	(0.4831, 0.3359)	(0.4890, 0.3328)	(0.4950, 0.3444)
Codes	B7	B8	B9	B10	B11	B12
G1	(0.5202, 0.3791)	(0.7422, 0.2144)	(0.5061, 0.3931)	(0.4545, 0.4412)	(0.5152, 0.3848)	(0.4567, 0.4462)
G2	(0.5123, 0.3733)	(0.7069, 0.2220)	(0.4480, 0.4314)	(0.4491, 0.4448)	(0.4736, 0.4220)	(0.6018, 0.3112)
G3	(0.6679, 0.2523)	(0.7542, 0.1949)	(0.6162, 0.3072)	(0.4560, 0.4397)	(0.5437, 0.3520)	(0.5708, 0.3513)
G4	(0.5606, 0.3394)	(0.8134, 0.1487)	(0.5134, 0.3776)	(0.5260, 0.3740)	(0.4939, 0.4061)	(0.6578, 0.2404)
G5	(0.4238, 0.4455)	(0.5700, 0.3282)	(0.3957, 0.4798)	(0.4116, 0.4722)	(0.3870, 0.4823)	(0.5199, 0.3787)
G6	(0.7513, 0.1996)	(0.7397, 0.1892)	(0.6162, 0.3072)	(0.3859, 0.4996)	(0.5166, 0.3773)	(0.6949, 0.2321)
G7	(0.5614, 0.3426)	(0.6426, 0.2668)	(0.4588, 0.4256)	(0.4116, 0.4722)	(0.4108, 0.4603)	(0.4736, 0.4256)
G8	(0.7087, 0.2300)	(0.6625, 0.2375)	(0.6466, 0.2780)	(0.3556, 0.5137)	(0.4736, 0.4119)	(0.7152, 0.2094)
G9	(0.6480, 0.2704)	(0.6076, 0.2906)	(0.6870, 0.2538)	(0.4116, 0.4722)	(0.4538, 0.4354)	(0.7224, 0.2224)
G10	(0.5866, 0.3173)	(0.6191, 0.2903)	(0.4899, 0.3939)	(0.4227, 0.4664)	(0.6841, 0.2404)	(0.8112, 0.1614)
G11	(0.7845, 0.1578)	(0.7946, 0.1545)	(0.6581, 0.2697)	(0.7805, 0.1755)	(0.7816, 0.1675)	(0.8523, 0.1238)
G12	(0.6675, 0.2325)	(0.6646, 0.2574)	(0.6188, 0.2812)	(0.4282, 0.4556)	(0.4076, 0.4671)	(0.7007, 0.2238)
G13	(0.6794, 0.2531)	(0.5780, 0.3296)	(0.7235, 0.2191)	(0.5722, 0.3314)	(0.5892, 0.3144)	(0.6513, 0.2487)
G14	(0.5025, 0.3931)	(0.6209, 0.2884)	(0.4722, 0.4260)	(0.7440, 0.2173)	(0.8285, 0.1513)	(0.7144, 0.2072)
G15	(0.6025, 0.2975)	(0.7448, 0.1830)	(0.5354, 0.3581)	(0.4949, 0.4087)	(0.5303, 0.3697)	(0.6632, 0.2368)
G16	(0.6697, 0.2505)	(0.7722, 0.1892)	(0.6292, 0.2986)	(0.7321, 0.2152)	(0.7509, 0.1964)	(0.8227, 0.1386)
U17	(0.5617, 0.3314)	(0.6487, 0.2549)	(0.4628, 0.4220)	(0.5029, 0.4007)	(0.5881, 0.3119)	(0.5231, 0.3805)
U18	(0.4542, 0.4314)	(0.6989, 0.2300)	(0.3773, 0.5029)	(0.3574, 0.5119)	(0.5498, 0.3495)	(0.4906, 0.3986)
U19	(0.5888, 0.3242)	(0.8097, 0.1700)	(0.5235, 0.3700)	(0.5599, 0.3621)	(0.7061, 0.2412)	(0.7498, 0.2029)
U20	(0.6249, 0.2874)	(0.6206, 0.2794)	(0.5321, 0.3715)	(0.4841, 0.4116)	(0.5917, 0.3166)	(0.5036, 0.3899)
U21	(0.6762, 0.2552)	(0.7563, 0.1928)	(0.5462, 0.3473)	(0.5101, 0.3791)	(0.4502, 0.4354)	(0.6047, 0.2910)
U22	(0.5455, 0.3671)	(0.4585, 0.4271)	(0.4195, 0.4650)	(0.4245, 0.4646)	(0.4206, 0.4632)	(0.4339, 0.4516)
U23	(0.6502, 0.2755)	(0.7823, 0.1755)	(0.5040, 0.3895)	(0.6148, 0.2852)	(0.5253, 0.3747)	(0.6314, 0.2686)
U24	(0.5852, 0.3224)	(0.5491, 0.3509)	(0.5043, 0.3791)	(0.4704, 0.4152)	(0.4444, 0.4412)	(0.5094, 0.3946)
U25	(0.6004, 0.3383)	(0.5477, 0.3523)	(0.4823, 0.4130)	(0.4556, 0.4300)	(0.4354, 0.4502)	(0.4632, 0.4224)
U26	(0.6856, 0.2469)	(0.6177, 0.2805)	(0.6635, 0.2653)	(0.8191, 0.1606)	(0.7473, 0.2105)	(0.7809, 0.1751)
U27	(0.5433, 0.3498)	(0.4653, 0.4303)	(0.4877, 0.3957)	(0.3939, 0.4953)	(0.4639, 0.4260)	(0.5181, 0.3895)
H28	(0.4072, 0.4639)	(0.3993, 0.4845)	(0.3758, 0.4935)	(0.3791, 0.4921)	(0.4664, 0.4271)	(0.4617, 0.4274)
H29	(0.5603, 0.3390)	(0.6996, 0.2329)	(0.5466, 0.3534)	(0.4152, 0.4729)	(0.7004, 0.2480)	(0.5848, 0.3188)
H30	(0.5076, 0.3863)	(0.6126, 0.2910)	(0.5137, 0.3845)	(0.3556, 0.5235)	(0.4585, 0.4372)	(0.4000, 0.4747)
H31	(0.5116, 0.3884)	(0.5058, 0.3942)	(0.7458, 0.2014)	(0.4744, 0.4249)	(0.5949, 0.3087)	(0.6715, 0.2610)
H32	(0.5336, 0.3664)	(0.5715, 0.3285)	(0.7087, 0.2238)	(0.4401, 0.4635)	(0.3379, 0.5801)	(0.4747, 0.4188)
H33	(0.7715, 0.1794)	(0.5661, 0.3321)	(0.5256, 0.3780)	(0.5094, 0.3906)	(0.4928, 0.4155)	(0.6083, 0.2910)
H34	(0.8379, 0.1419)	(0.7415, 0.2076)	(0.5513, 0.3480)	(0.5581, 0.3419)	(0.7542, 0.1931)	(0.6480, 0.2740)
H35	(0.5794, 0.3347)	(0.5148, 0.3888)	(0.5256, 0.3780)	(0.4928, 0.4054)	(0.4740, 0.4159)	(0.4747, 0.4188)
H36	(0.5159, 0.3841)	(0.4394, 0.4444)	(0.4733, 0.4260)	(0.4585, 0.4451)	(0.4560, 0.4375)	(0.4653, 0.4282)
H37	(0.5888, 0.3332)	(0.5188, 0.3794)	(0.5437, 0.3599)	(0.5307, 0.3693)	(0.4704, 0.4195)	(0.5116, 0.4004)
H38	(0.6209, 0.2827)	(0.6000, 0.3036)	(0.6386, 0.2834)	(0.4271, 0.4722)	(0.3509, 0.5715)	(0.4653, 0.4282)
H39	(0.5025, 0.3968)	(0.4513, 0.4426)	(0.7975, 0.1736)	(0.5087, 0.3852)	(0.3758, 0.5032)	(0.4379, 0.4556)
I40	(0.5188, 0.3769)	(0.6206, 0.2996)	(0.5863, 0.3119)	(0.4664, 0.4372)	(0.4032, 0.4819)	(0.4563, 0.4372)
I41	(0.4877, 0.4061)	(0.6025, 0.3213)	(0.6278, 0.2899)	(0.4845, 0.4191)	(0.3675, 0.5069)	(0.4531, 0.4404)
I42	(0.5881, 0.3339)	(0.5480, 0.3502)	(0.5235, 0.3758)	(0.5108, 0.3931)	(0.5032, 0.3960)	(0.4877, 0.4199)
I43	(0.4700, 0.4300)	(0.5700, 0.3484)	(0.4924, 0.4032)	(0.5520, 0.3480)	(0.5682, 0.3271)	(0.4928, 0.4007)
I44	(0.4881, 0.4119)	(0.5412, 0.3809)	(0.4455, 0.4538)	(0.5527, 0.3473)	(0.5278, 0.3675)	(0.4401, 0.4390)
E45	(0.4484, 0.4354)	(0.5755, 0.3285)	(0.5971, 0.2975)	(0.4300, 0.4538)	(0.5563, 0.3394)	(0.5809, 0.3184)
E46	(0.6083, 0.3137)	(0.5621, 0.3415)	(0.7119, 0.2123)	(0.6141, 0.2895)	(0.6498, 0.2827)	(0.6004, 0.3032)
E47	(0.8018, 0.1693)	(0.7137, 0.2152)	(0.5278, 0.3657)	(0.7011, 0.2278)	(0.5812, 0.3188)	(0.6202, 0.2834)
E48	(0.5722, 0.3462)	(0.5690, 0.3310)	(0.5426, 0.3563)	(0.4978, 0.4061)	(0.5090, 0.3910)	(0.6245, 0.2791)
E49	(0.7881, 0.1715)	(0.6303, 0.2697)	(0.5426, 0.3563)	(0.5534, 0.3466)	(0.5477, 0.3523)	(0.5350, 0.3686)
E50	(0.6224, 0.2942)	(0.5534, 0.3502)	(0.5235, 0.3718)	(0.3899, 0.4949)	(0.4173, 0.4726)	(0.3819, 0.4971)
E51	(0.7004, 0.2162)	(0.6433, 0.2549)	(0.5079, 0.3874)	(0.4495, 0.4444)	(0.4531, 0.4451)	(0.5462, 0.3574)
E52	(0.7729, 0.1780)	(0.6126, 0.2874)	(0.5740, 0.3195)	(0.4798, 0.4159)	(0.4029, 0.4726)	(0.4574, 0.4361)
E53	(0.5224, 0.3733)	(0.5386, 0.3596)	(0.5123, 0.3975)	(0.4570, 0.4466)	(0.4097, 0.4801)	(0.3744, 0.5047)
E54	(0.7708, 0.1801)	(0.6729, 0.2560)	(0.5379, 0.3610)	(0.7267, 0.2058)	(0.6747, 0.2339)	(0.6224, 0.2812)
E55	(0.6097, 0.3123)	(0.5715, 0.3267)	(0.8101, 0.1614)	(0.5256, 0.3780)	(0.5303, 0.3679)	(0.5043, 0.3993)
E56	(0.6097, 0.3087)	(0.7181, 0.2292)	(0.6931, 0.2531)	(0.7563, 0.1910)	(0.6426, 0.2574)	(0.7072, 0.2253)
E57	(0.7881, 0.1715)	(0.6433, 0.2549)	(0.5513, 0.3477)	(0.7751, 0.1827)	(0.8134, 0.1628)	(0.7552, 0.2061)
L2	(0.6536, 0.2551)	(0.6344, 0.2664)	(0.6319, 0.2766)	(0.6389, 0.2879)	(0.6463, 0.3191)	(0.6648, 0.2776)
L1	(0.4608, 0.3619)	(0.4474, 0.3779)	(0.4456, 0.3922)	(0.4505, 0.4083)	(0.4557, 0.4525)	(0.4688, 0.3937)

Table 10: The negative ideal solution.

Barriers	b_{j*}
B1	(0.4119, 0.4769)
B2	(0.4712, 0.3179)
B3	(0.4455, 0.4502)
B4	(0.4693, 0.4307)
B5	(0.4715, 0.4267)
B6	(0.4585, 0.4415)
B7	(0.4072, 0.4639)
B8	(0.3993, 0.4845)
B9	(0.3773, 0.5029)
B10	(0.3556, 0.5235)
B11	(0.3379, 0.5801)
B12	(0.3744, 0.5047)

Table 11: Euclidean d_i and Taxicab distances t_i.

	d_i	t_i		d_i	t_i		d_i	t_i
G1	0.0746	0.5108	U21	0.0875	0.5700	I41	0.0754	0.4995
G2	0.0885	0.5561	U22	0.0676	0.4410	I42	0.0912	0.5483
G3	0.1003	0.5871	U23	0.0905	0.5795	I43	0.0691	0.5177
G4	0.1031	0.5979	U24	0.1075	0.5575	I44	0.0754	0.5154
G5	0.0873	0.4811	U25	0.0531	0.4699	E45	0.1043	0.5741
G6	0.0863	0.5578	U26	0.0783	0.5136	E46	0.1176	0.6093
G7	0.0875	0.4920	U27	0.0346	0.3747	E47	0.1081	0.6203
G8	0.0916	0.5378	H28	0.0528	0.3532	E48	0.0794	0.5339
G9	0.0679	0.5162	H29	0.0763	0.5350	E49	0.0964	0.5813
G10	0.0990	0.5612	H30	0.0606	0.4408	E50	0.0611	0.4313
G11	0.1198	0.6391	H31	0.0828	0.5533	E51	0.0558	0.4770
G12	0.0815	0.5515	H32	0.0857	0.5161	E52	0.0665	0.4879
G13	0.0741	0.5449	H33	0.0762	0.5430	E53	0.0537	0.4320
G14	0.0773	0.5078	H34	0.1228	0.6449	E54	0.1097	0.6101
G15	0.0835	0.5693	H35	0.0585	0.4879	E55	0.0743	0.5265
G16	0.1040	0.6095	H36	0.0530	0.3793	E56	0.1396	0.6846
U17	0.0790	0.5363	H37	0.0669	0.4968	E57	0.1415	0.6918
U18	0.0779	0.4736	H38	0.0529	0.4341	L2	0.0997	0.6226
U19	0.1206	0.6351	H39	0.0568	0.4625	L1	0.0235	0.2935
U20	0.0861	0.5664	I40	0.0932	0.5476			

Consequently, the authorities of each of these systems are emanated from decision- and policy-makers at the national to the classroom level. Decision-makers formulate policies, structures, implementation strategies, and evaluation procedures based on various legislations, public opinion, education studies, technological advances, societal demands, industry demands, research findings, national testing, new leadership, accreditation, cross-country evaluation, and available funds. The barrier B12 (i.e., insufficient foundation in basic education) is the least among the preidentified 12 barriers. Nevertheless, B12 is associated with the top five priority barriers when addressed accordingly. For instance, B6 (i.e., lack of collaboration) components may be managed by identifying the gaps between CHED preservice teacher training and DepEd recommended curriculum's Most Important Learning Competencies. The actions to bridge the gap through collaboration should stress the importance of DepEd working closely with CHED for the curriculum of general education courses and the close supervision of TESDA for the national competency training under the senior high school curriculum of DepEd. With this coordination, the connection between these government educational agencies shall see these gaps closed. On the other hand, B10 and B11 are deemed low-bearing barriers. For example, learning platforms are as common as social network sites (e.g., Google, LinkedIn, and Facebook). Educators have already integrated these sites as educational delivery tools in the learning environment. These platforms are coined as an "alternative to the institutions' current Learning Management Systems (LMS)" in the delivery of asynchronous and synchronous learning [53]. LMS in HEIs is becoming responsive for organizing and distributing course materials. Since 2014, the case HEI has embarked on faculty development programs for the online LMS training and invested in the curriculum development and material preparation aligned with the LMS to make learning flexible and attuned to the requirements of EDUC4. Thus, the experts view these barriers with less priority.

The use of the FF CODAS-SORT reveals the high-priority stakeholder roles in overcoming EDUC4 implementation barriers. For the government, these roles include the inclusion of cybersecurity awareness in the basic education curriculum (G3), allocating more funds to support the necessary inclusive activities in the implementation of EDUC4 (G4), designing the curricula in line with the implementation and sustainment of EDUC4 (G11), and streamlining alignment initiatives of the basic education agenda (e.g., human resources and curricula) to EDUC4 (G16). As pointed out in the domain literature, governments play a vital role in designing, implementing, and monitoring EDUC4. With regard to cybersecurity threats, the Philippine government, through its arms (i.e., CHED, DepEd, and TESDA), may promote the inclusion of cybersecurity awareness in the basic education curriculum to cater to such concerns. The CHED may organize a pool of experts to roam around the universities for such an agenda. On the other hand, allocating more funds to support the necessary inclusive activities in the implementation of EDUC4 is also encouraged by the government to cater to the skills gap of human capital, to add training resources, and also for the Philippines to catch up with the developed countries in terms of technological gaps. The Philippine government may also encourage its arms to design curricula that align with the implementation and sustainment of EDUC4. CHED shall strengthen the collaboration among its agencies to address the knowledge gap for the customization of curriculum design and insufficient foundation of basic education. This initiative may include retooling human resources (e.g., educators, educational managers, and ICT personnel) to bridge the complexity of learning platforms.

For the university managers, the high-priority roles include investing in efficient technologies (e.g., virtual classrooms, enablement or process audit, analytic tools for strategic planning, and the hybrid or fully automated process of project management), which are known to reduce overall costs and improve the experience of the university stakeholders (U19) and forging extensive collaboration with various stakeholders (e.g., policy-makers, academic experts, university networks, educators, education leaders, learners, and industry partners) to provide space and training

Table 12: The relative assessment matrix.

	h_j (L2)	h_j (L1)		h_j (L2)	h_j (L1)		h_j (L2)	h_j (L1)
G1	−0.0251	0.0569	U20	−0.0137	0.0735	H39	−0.0429	0.0358
G2	−0.0113	0.0757	U21	−0.0122	0.0755	I40	−0.0066	0.0805
G3	0.0006	0.0918	U22	−0.0322	0.0465	I41	−0.0243	0.0575
G4	0.0033	0.0963	U23	−0.0093	0.0796	I42	−0.0085	0.0780
G5	−0.0124	0.0700	U24	0.0078	0.0978	I43	−0.0306	0.0514
G6	−0.0134	0.0732	U25	−0.0466	0.0319	I44	−0.0243	0.0584
G7	−0.0122	0.0705	U26	−0.0214	0.0616	E45	0.0046	0.0958
G8	−0.0081	0.0784	U27	−0.0652	0.0110	E46	0.0179	0.1147
G9	−0.0319	0.0499	H28	−0.0469	0.0298	E47	0.0084	0.1045
G10	−0.0007	0.0881	H29	−0.0235	0.0603	E48	−0.0203	0.0637
G11	0.0205	0.1210	H30	−0.0392	0.0394	E49	−0.0033	0.0870
G12	−0.0183	0.0674	H31	−0.0169	0.0688	E50	−0.0387	0.0395
G13	−0.0256	0.0582	H32	−0.0141	0.0703	E51	−0.0439	0.0353
G14	−0.0224	0.0604	H33	−0.0236	0.0606	E52	−0.0332	0.0472
G15	−0.0162	0.0709	H34	0.0237	0.1254	E53	−0.0460	0.0319
G16	0.0043	0.0983	H35	−0.0412	0.0383	E54	0.0100	0.1055
U17	−0.0207	0.0635	H36	−0.0468	0.0299	E55	−0.0254	0.0577
U18	−0.0218	0.0598	H37	−0.0328	0.0480	E56	0.0430	0.1526
U19	0.0211	0.1212	H38	−0.0468	0.0310	E57	0.0455	0.1562

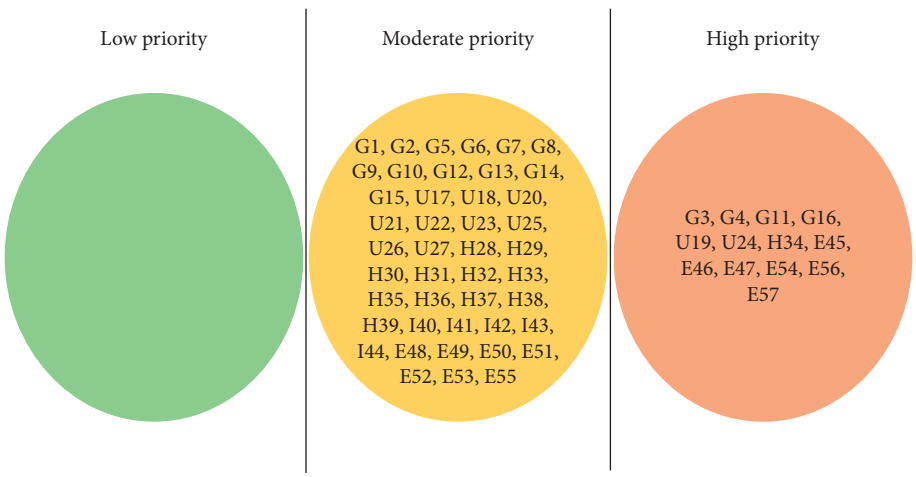

Figure 3: Sorting of the roles of various stakeholders.

resources for implementing EDUC4 (U24). Investments in efficient technologies would generally address the barriers related to cost (B2), lack of available technologies (B8), and complexity of learning platforms (B11). This role may be straightforward as EDUC4 implementation is associated with technology-intensive environments. Investing in those efficient technologies may integrate necessary activities for fully automated teaching and learning, resulting in increased productivity for educators. HEI managers may source these technologies from extensive collaborations with various stakeholders, providing inputs and learning experiences using such technologies. Forging partnerships require necessary diplomatic skills that HEI managers must possess. One efficient approach that is more applicable to the case HEI is to engage government institutions in finding collaborators as they can organize various stakeholders for an identified collaborative agenda. Nevertheless, the triple helix approach (i.e., government, industry, and academia) in initiating collaborations is rich in the literature (see [54]).

For the human resource function, periodic training of the human resources on the skills (i.e., especially digital readiness and customization of curriculum design) fitting to the current demands of EDUC4 emerges as a high-priority role (H34). The HEI managers and their governing boards may work together to examine existing policies and guidelines in hiring teaching and non-teaching personnel to include the skills relevant to EDUC4 as part of the selection criteria. On the other hand, incumbent personnel could be submitted to rigorous training and seminars to transform the workforce into becoming EDUC4 ready. In this manner, the HEIs could effectively address the skill gap of the human capital barrier, particularly those related to the lack of skills

(B3) and training resources (B5). To make the training and seminars relevant and need-based, periodic inventories on personnel training needs and the timely response of the human resource personnel to the identified needs could help the HEIs retain the best and most qualified personnel while addressing the demands of EDUC4.

Due to the danger primarily posed by online threats at the university level, educators can engage in continuous learning initiatives about relevant cybersecurity threats (i.e., data breaches on student information, denial of service attacks, and phishing; E45). This initiative will equip them with the necessary skills to help safeguard crucial information of learners and other members of the university. This may be achieved by integrating awareness of applicable laws to cyberbullying in (virtual) classroom teaching (E46). On the other hand, they can also devise alternative cost-efficient teaching strategies to deliver required learning outcomes geared to EDUC4 while upholding the implementation of EDUC4 (E47) and taking part in the design, development and improvement of innovative curricula aligned to EDUC4 (E54). Educators can also promote ways to efficiently prepare learning materials, including advanced ICTs (E56). They can also participate in skills development initiatives to equip them with the capabilities in handling different complex learning platforms (E57).

6. Conclusion and Future Work

While the recent literature has identified barriers to implementing EDUC4 in developing economies, holistic insights into overcoming these barriers remain largely unknown. This gap poses the relevance of the roles of various stakeholders in generating insights for the design of strategies and initiatives in the implementation of EDUC4. In this work, designed for HEIs, an analytic evaluation tool based on integrating Fermatean fuzzy sets into a hybrid entropy-based CRITIC-CODAS-SORT for evaluating various stakeholder roles is proposed. With the entropy-based CRITIC assigning priority weights to the recently reported 12 barriers and the CODAS-SORT identifying those roles with high priority, the incorporation of FFS into the integrated methodology addresses epistemic uncertainties inherent in decision-making. Through a focus group discussion of experts on a case HEI in a developing economy, the roles of various stakeholders, including the government, university management, human resource, ICT function, and educators, were identified. The application of FF CRITIC yields the following most relevant barriers to EDUC4 implementation in developing economies: lack of collaboration, apprehensive stakeholders, cybersecurity threats, health issues, and costs.

To overcome these barriers, the proposed methodology finds the following high-priority stakeholder roles. The government must consider the inclusion of cybersecurity awareness in the basic education curriculum, allocating more funds to support the necessary inclusive activities in the implementation, designing the curricula in line with the implementation and sustainment of EDUC4, and streamlining alignment initiatives of the basic education agenda (e.g., human resources and curricula) to EDUC4 in its priority agenda. On the other hand, HEIs must invest in efficient technologies to reduce the overall costs of implementing EDUC4 and enhance the experience of university stakeholders. Also, they need to forge extensive collaboration with various stakeholders to provide the necessary resources for EDUC4 implementation. The human resource management function of HEIs must implement periodic training of educators on the skills required of EDUC4. Finally, educators have the highest number of critical roles, including engaging in continuous learning initiatives about relevant cybersecurity threats at the university; integrating awareness of applicable laws to cyberbullying in (virtual) classroom teaching; devising alternative cost-efficient teaching strategies in the delivery of required learning outcomes while upholding the implementation of EDUC4; taking part in the design, development, and improvement of innovative curricula aligned to EDUC4; promoting ways to efficiently prepare learning materials; including the use of advanced ICTs; and participating in skills development initiatives aimed at equipping educators with the capabilities in handling different complex learning platforms.

The high-priority roles offer some insights into the design of specific initiatives in implementing EDUC4 in HEIs, not just in the case of university but in comparable HEIs, particularly in developing economies. Although idiosyncrasies exist, these insights may be relevant in other HEIs with similar conditions. Investigating how these roles or strategies may work out in practice is an interesting future endeavor and is highly suggested as a follow-up to this work. Furthermore, if available, the utilization of statistical data and analysis may be opted to cross-reference the findings of this study empirically. For instance, gathering data on the increase of utilization of digital technologies and other compositions of EDUC4 in different settings where some of these strategies are implemented may provide some idea on the actual effectiveness of the strategies, which can validate the results of this work based on expert decisions.

Data Availability

The perception data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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