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CAREER AREA SELECTION AMONG FINAL-YEAR MATHEMATICS STUDENTS AT UITM KELANTAN BRANCH USING THE PYTHAGOREAN FUZZY TOPSIS APPROACH

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Abstract: *Selecting a career path is among the most critical life decisions an individual makes. However, the sheer volume of career options often causes significant ambiguity, while mathematics students specifically face limited awareness of viable professional fields. This study addresses the career path selection problem using a Multi-Criteria Decision-Making (MCDM) approach based on the Pythagorean Fuzzy Technique for Order Preference by Similarity to Ideal Solution (PF-TOPSIS). By integrating Pythagorean Fuzzy Numbers (PFNs) and Pythagorean Fuzzy Weighted Averaging (PFWA) operators alongside a revised closeness index, the model evaluates and ranks potential career alternatives. A panel of final-year mathematics students from UiTM Kelantan Branch served as decision-makers, evaluating four career areas such as Business and Finance, Technology and Innovation, Government, and Industry. The main four key criteria are wage level, job security/stability, job flexibility, and work environment/culture. The analysis demonstrates the significant impact of evaluation criteria on career selection, ultimately identifying Business and Finance as the most preferred career path among the participants. Based on the analysis, Business and Finance ranks first*

Keywords: *Profession Area Selection, Pythagorean Fuzzy TOPSIS, Multi-Criteria Decision-Making, Pythagorean Fuzzy Weighted Averaging, Mathematical Students*

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Introduction

Choosing a career path is a vital milestone for final-year students, particularly those in mathematical sciences, due to the wide array of professional avenues available. This study focuses on final-year mathematics students at Universiti Teknologi MARA (UiTM) Kelantan Branch, aiming to develop a systematic, robust framework to support well-informed career decision-making. Students frequently struggle with this choice due to abundant options, inherent uncertainty, and the need to balance personal interests, market trends, and long-term growth prospects. To address these complexities, this study applies the Pythagorean Fuzzy Technique for Order Preference by Similarity to Ideal Solution (PF-TOPSIS), an approach well-suited for handling vagueness and uncertainty in multi-criteria decisions.

Selecting a profession is often a stressful milestone for students, exacerbated by an overwhelming number of career choices and insufficient exposure to available industries. External influences from family, peers, and society further complicate decision-making, sometimes pushing individuals away from their genuine interests and strengths. This problem is especially pronounced for mathematics students. While their analytical skill set is widely applicable in fields like finance and technology, the specific career pathways into these sectors are rarely straightforward. Many students remain unaware of the high-demand opportunities requiring mathematical expertise, frequently viewing teaching as the sole viable career. Resolving this issue demands both expanding the recognized career options for mathematics graduates and improving the visibility and clarity of these professional pathways.

To address the decision-making complexities faced by graduating students, this study pursues three key objectives: first, to apply Pythagorean Fuzzy Numbers (PFN) and Pythagorean Fuzzy Weighted Average (PFWA) operators within a Multi-Criteria Decision-Making (MCDM) context; second, to adapt the general Fuzzy TOPSIS model for evaluating potential career choices post-graduation; and third, to determine the optimal profession path among the available alternatives.

This research provides valuable insights for students, institutions, and society at large. By understanding crucial evaluation criteria, students can align their personal capabilities with prospective careers, leading to higher job satisfaction and improved employability through targeted skill development. Ultimately, guiding graduates into well-suited roles strengthens the overall workforce, fostering innovation and economic growth.

Literature Review

The world of professions is vast and encompasses a range of fields, including medicine, law, teaching, and engineering, each with its unique demands, responsibilities, and contributions. Every profession's heart lies in knowledge gained through education, training, and experience. Qualification standards for professions are typically associated with university degrees or additional postgraduate requirements (O'Reilly et al., 2020). Moreover, professions establish their identity, social position, and status by asserting claims of authority over other occupational groups to practice in specific fields of expertise (Abbott, 2014). A profession extends beyond mere employment; it represents a dedicated vocation rooted in specialized knowledge, technical competence, and a commitment to standards of excellence. Scholars define a profession as a structured domain requiring specialized education, rigorous training, and recognized qualifications or credentials (O'Reilly et al., 2020).

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Identifying an appropriate career path is a complex process that extends beyond simply matching a candidate's skills to a job opening. In the modern labor market, graduates must evaluate a range of key decision criteria to make well-informed career choices (KILIC & Çevikcan, 2011). Table 1 provides a summary of the primary career selection criteria identified across previous literature.

Table 1: Selection Criteria from the Previous Research

Description and Key Consideration	Key References
Wage level, job security, location of the business, vested benefits, respectability in the society, the difficulty level of the business, flexible working time opportunity.	Selcuk & Ozkan (2015)
Certainty of employment, permanent salary, good relationships in the workplace, the existence of corporate rules, benefits employees (telephone allowance, car, meals, etc.), flexible working hours.	Bejtkovský (2018)
Wage Level, Job Security and Stability, Job Flexibility, Work Environment and Culture	Noorzad (2019)
Family Influence, Personal Interest, Peer Influence, Salary	Najwa et. al (2024)
Learning environment, Job Market Level, Academic Discipline	Ali, et. al (2026)

Based on the framework established by Noorzad (2019) and Horning et al. (2018), this career selection decision-making study considers four criteria: Wage Level, Job Security and Stability, Job Flexibility, and Work Environment and Culture. These criteria are used to evaluate four career paths: Business and Finance, Technology and Innovation, Government, and Industry.

Existing undergraduate career studies rely heavily on qualitative surveys and focus on non-STEM fields, failing to model multi-attribute trade-offs under uncertainty. While Multi-Criteria Decision-Making (MCDM) methods address decision complexities, current models rely on rigid numerical values, ignore criteria interdependencies, and focus on general student populations. Final-year mathematics students face unique "choice overload" due to broad industry options yet lack tailored decision models. To bridge this gap, this study develops an advanced hybrid/fuzzy MCDM framework specifically designed to model career selection for mathematics graduates under conditions of uncertainty.

Developed by Hwang et al., (1981), TOPSIS is a premier MCDM technique that ranks alternatives according to their proximity to an ideal solution to identifying the option closest to the positive ideal and furthest from the negative ideal (Ahmed et al., 2020). Recognized for its capacity to synthesize expert consensus (Shamsuzzoha et al., 2021) and evaluate complex multi-attribute systems such as financial performance (Ahmed et al., 2020), TOPSIS also integrates seamlessly with fuzzy logic to address vague or qualitative data (Kumar et al., 2019). To account for vagueness in human judgment, this study utilizes linguistic variables expressed through Pythagorean Fuzzy Numbers (PFNs) to evaluate both criteria and alternatives.

Fuzzy set theory (Zadeh, 1965) is extensively utilized to address uncertainty and imprecision in decision-making processes, where evaluating qualitative criteria with exact values is difficult for human decision-makers (Rehman & Ali, 2022). By substituting crisp, absolute weights with

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relative attribute preferences, fuzzy sets allow preferences to be naturally expressed via linguistic terms (Fan & Liu, 2010). While classical approaches rely on triangular fuzzy numbers to model information vagueness as demonstrated by Yager and Abbasov (2013) and Xu (2007), this research employs Pythagorean Fuzzy Numbers (PFNs) to better capture complex decision uncertainty.

Intuitionistic Fuzzy Sets (IFSs) were introduced by Atanassov and Stoeva (1986) to incorporate human hesitation by assigning membership μ and non-membership λ degrees under the strict constraint $\mu+\lambda\leq 1$ and the nonzero hesitancy part $\pi=1-\mu-\lambda$. To avoid this structural restriction, Yager and Abbasov (2013) proposed Pythagorean Fuzzy Sets (PFSs), extending the admissible space to $\mu^2+\lambda^2\leq 1$. This expanded boundary enables PFSs to model scenarios that exceed the capacity of IFSs. Because PFSs generalize both classical and intuitionistic fuzzy sets, they offer a more flexible framework for capturing vagueness and ambiguity. As a result, PFS applications have yielded enhanced outcomes across various fields, including pattern recognition (Peng & Garg, 2019), decision sciences (Liu et al., 2020), and medical diagnostics (Xiao & Ding, 2019).

Building on the Pythagorean fuzzy aggregation operators established by Yager and Abbasov (2013), this study employs the Pythagorean Fuzzy Weighted Averaging (PFWA) operator. As a powerful tool for multi-criteria decision-making, the PFWA operator consolidates individual decision matrices from multiple experts into a unified aggregated Pythagorean Fuzzy Decision Matrix (PFDM). Modern MCDM literature reflects the broad applicability of the PFWA operator across engineering, management, and strategic planning. For instance, it has been successfully implemented in material selection (Ye & Chen, 2022), logistics technology evaluation (Mondal et al., 2022), green supply chain management (Hajiaghaei-Keshteli et al., 2023), and site selection and healthcare procurement (Akram et al., 2019). Moreover, Rani et al. (2020) demonstrated its efficacy in solving sustainable recycling partner selection problems with completely unknown criterion weights, while Hussian and Yang (2019) leveraged PFWA to construct novel Harsdorf-based distance and similarity measures.

Demonstrating its versatility across multi-criteria decision-making contexts, Pythagorean fuzzy TOPSIS has been adopted in several domain-specific studies. It has been employed in educational quality evaluation (Li & Zhang, 2025), human resource performance appraisals involving 4 primary criteria and 22 sub-criteria (Ahmad & Wan Azilan, 2021), and environmental assessments for green supplier selection in supply chain management (Zulqarnain et al., 2021).

Preliminaries

Definition of Fuzzy Set (Zadeh, 1965)

Let X be a space consisting of points (objects), with a generic element of X denoted by x. Thus, $X=\{x\}$. A fuzzy set ˜A of discourse X is described by a membership function $f_{\tilde{A}}(x)$ that maps each element x in X to a real number in the interval [0,1]. The function value $f_{\tilde{A}}(x)$ represents the grade of membership of x in $\tilde{A}$. The closer the value of $f_{\tilde{A}}(x)$ to unity, the higher the evaluation of the contribution of x in $\tilde{A}$.

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Definition of Intuitionistic Fuzzy Set (Atanassov & Stoeva, 1986)

Let X be a universe of discourse. The IFS η on X is given by

$$\eta = \left\{ \left\langle x, \mu_\eta(x), \lambda_\eta(x) \middle| x \in X \right\rangle \right\}$$

Where the function $\mu_\eta : X \to [0,1]$ and $\lambda_\eta : X \to [0,1]$ define the degree of membership and the degree of non-membership of the element $x \in X$ to set η with the condition that

$$0 \le \mu_\eta(x) + \lambda_\eta(x) \le 1, \forall x \in X$$

$\pi_\eta(x) = 1 - \mu_\eta(x) - \lambda_\eta(x)$ is define as the degree of indeterminacy of element $x \in X$. For clarity, Xu (2007) denoted $\eta = (\mu_\eta, \lambda_\eta)$ as an IFN.

Definition of Pythagorean Fuzzy Set (Yager & Abbasov, 2013)

Let X be a universe of discourse. The PFSs ξ on X is given by

$$\xi = \left\{ \left\langle x, \mu_\xi(x), \lambda_\xi(x) \middle| x \in X \right\rangle \right\},$$

Where the function $\mu_\xi : X \to [0,1]$ and $\lambda_\xi : X \to [0,1]$ define the degree of membership and the degree of non-membership of the element $x \in X$ to set ξ with the condition that

$$0 \le \left(\mu_\xi(x)\right)^2 + \left(\lambda_\xi(x)\right)^2 \le 1, \forall x \in X.$$

$\pi_\xi(x) = \sqrt{1 - \left(\mu_\xi(x)\right)^2 - \left(\lambda_\xi(x)\right)^2}$ is the degree of indeterminacy of element of $x \in X$. For ease, Zhang & Yu (2014) labelled $\left(\mu_\xi(x), \lambda_\xi(x)\right)$ a PFN denoted by $\xi = \left(\mu_\xi, \lambda_\xi\right)$

Methodology

This section provides a comprehensive description of the Pythagorean Fuzzy TOPSIS (PF-TOPSIS) methodology. It presents the fundamental equations and operational steps involving Pythagorean Fuzzy Numbers (PFNs), including criteria weight determination, decision matrix normalization, distance measure calculations, and relative closeness rankings. Furthermore, the chapter details the data collection, data processing, and analytical procedures used to evaluate and rank career alternatives in this study. The procedure is based on a previous study report by Akram et al. (2019). The hierarchy of evaluated criteria and prospective career alternatives for this study is presented in Figure 1.

Step 1: Data Collection

To collect the data, the decision-makers are from a group of final-year mathematical students in UiTM Kelantan Branch who are to choose their profession preference by questionnaire via Google Form. There are six (6) decision makers chosen to complete the questionnaire.

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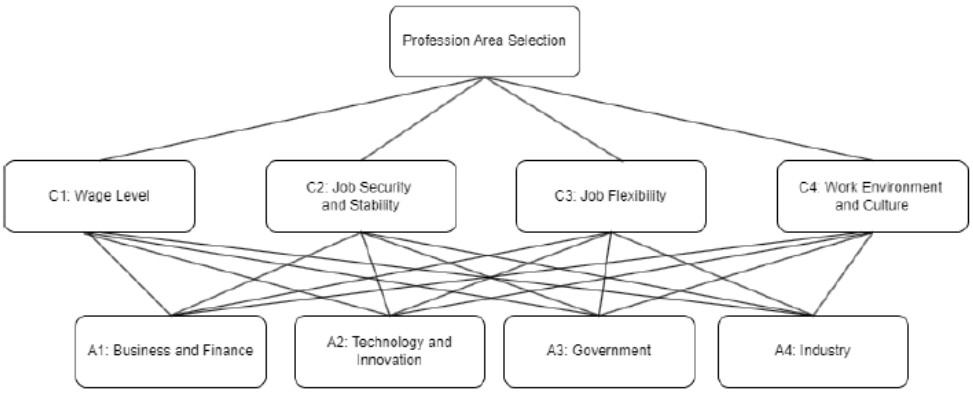


Figure 1: Hierarchy Structure of Career Selection

Step 2: Apply Pythagorean Fuzzy Conversion Number

According to Yager & Abbasov (2013), PFN is used in MCDM techniques to assess options by considering both how closely they align with ideal positive and negative criteria. The linguistic variables within the Pythagorean fuzzy framework, contained by PFNs, act as the basis for evaluating the criteria. A fuzzy version of the common fuzzy scale is presented in Table 2 and Table 3 (Yager & Abbasov, 2013). The result of each comparison is displayed as a Pythagorean Fuzzy Number and its inverse equivalent.

Table 2: Linguistic Variables for the Relative Importance of Criteria

Linguistic Variable	Pythagorean Fuzzy Number (PFNs)
Very Important (VI)	[0.90, 0.20, 0.39]
Important (I)	[0.80, 0.45, 0.40]
Medium (M)	[0.65, 0.50, 0.57]
Unimportant (U)	[0.40, 0.60, 0.69]
Very Unimportant (VU)	[0.20, 0.90, 0.39]

Source: (Yager & Abbasov, 2013)

Table 3: Linguistic Variables for the Relative Importance of Alternative

Linguistic Variable	Pythagorean Fuzzy Number (PFNs)
Extremely Good (EG)	[1.00, 0.00, 0.00]
Very Very Good (VVG)	[0.90, 0.20, 0.39]
Very Good (VG)	[0.80, 0.25, 0.55]
Good (G)	[0.70, 0.35, 0.62]
Medium Good (MG)	[0.60, 0.50, 0.62]
Medium (M)	[0.50, 0.60, 0.62]
Medium Bad (MB)	[0.45, 0.70, 0.55]
Bad (B)	[0.40, 0.75, 0.53]
Very Bad (VB)	[0.20, 0.80, 0.57]
Very Very Bad (VVB)	[0.10, 0.90, 0.42]

Source: (Yager & Abbasovy, 2013)

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Step 3: Construction of Aggregated Pythagorean Fuzzy Decision Matrix, X

To construct the aggregated Pythagorean fuzzy decision matrix (PFDM), $X^{(k)} = \left(x_{ij}^{(k)}\right)_{l\times m}$ is used for decision-maker DM_k with weight $\sigma_k \left(k = 1,2,...,n\right)$. In a group decision-making process, the combination of decision-makers viewpoints is essential to form a collective accord, resulting in the creation of an aggregated PFDM denoted as $X^{(k)} = \left(x_{ij}^{(k)}\right)_{l\times m}$ which can be established through the utilization of the Pythagorean fuzzy aggregated averaging (PFWA) operator (Zhang, 2016) as Equation (1).

$$x_{ij} = PFWA_{\sigma}\left(x_{ij}^{(1)}, x_{ij}^{(2)}, x_{ij}^{(3)}, ..., x_{ij}^{(n)}\right)$$
$$= \sigma_1 x_{ij}^{(1)} \oplus \sigma_2 x_{ij}^{(2)} \oplus \sigma_3 x_{ij}^{(3)}, ..., \sigma_n x_{ij}^{(n)}$$
$$= \left(\sqrt{1-\prod_{k=1}^{n}\left(1-\left(\mu_{ij}^{(k)}\right)^2\right)^{\sigma_k}}, \prod_{k=1}^{n}\left(\lambda_{ij}^{(k)}\right)^{\sigma_k}, \sqrt{\prod_{k=1}^{n}\left(1-\left(\mu_{ij}^{(k)}\right)^2\right)^{\sigma_k} - \left(\prod_{k=1}^{n}\left(\lambda_{ij}^{(k)}\right)^{\sigma_k}\right)^2}\right) \quad (1)$$

where $x_{ij} = \left(\mu_{A_i}\left(C_j\right), \lambda_{A_i}\left(C_j\right), \pi_{A_i}\left(C_j\right)\right), i = 1,2,...,l : j = 1,2,...,m$

Weight consideration:

1. When factoring in the weight of the decision-makers, it can be computed using Equation (2)
2. $$\sigma_k = \frac{\left(\mu_k + \pi_k\left(\mu_k/\left(\mu_k + \lambda_k\right)\right)\right)}{\sum_{k=1}^{n}\left(\mu_k + \pi_k\left(\mu_k/\left(\mu_k + \lambda_k\right)\right)\right)} \quad (2)$$

   satisfying the normalized condition $\sum_{k=1}^{n}\sigma_k$ and $\pi_k = \sqrt{1-\mu_k^2-\lambda_k^2}$
3. Excluding the weight of decision-makers, therefore $\sigma_k = 1$.

Negotiated decision-making where authority is distributed among several participants is divided into two distinct categories:

1. Group: A scenario where all participants share equal authority over the final decision.
2. Organization**:** A scenario where each participant holds a differing level of authority.

In this study, the weight of each decision-maker, σ_k is assumed to be 1 to account for multiple participant involvement in collective decision-making and share equal authority over the final decision.

As noted by Omari et al. (2022), a decision-maker's authority is determined by their assigned degree of importance, or "weight," which reflects their individual contribution to the process.

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Consequently, all students in this study are assumed to have an equal contribution and are thus assigned equivalent weights in decision-making.

Corresponding, $X^{(k)} = \left(x_{ij}^{(k)}\right)_{l\times m}$ is defined as below:

$$X = \begin{pmatrix} (\mu_{A_1}(C_1), \lambda_{A_1}(C_1), & (\mu_{A_1}(C_2), \lambda_{A_1}(C_2), & & (\mu_{A_1}(C_3), \lambda_{A_1}(C_3), \\ \pi_{A_1}(C_1)) & \pi_{A_1}(C_2)) & \cdots & \pi_{A_1}(C_3)) \\ (\mu_{A_2}(C_1), \lambda_{A_2}(C_1), & (\mu_{A_2}(C_2), \lambda_{A_2}(C_2), & & (\mu_{A_2}(C_3), \lambda_{A_2}(C_3), \\ \pi_{A_2}(C_1)) & \pi_{A_2}(C_2)) & \cdots & \pi_{A_2}(C_3)) \\ \vdots & \vdots & \ddots & \vdots \\ (\mu_{A_l}(C_1), \lambda_{A_l}(C_1), & (\mu_{A_l}(C_2), \lambda_{A_l}(C_2), & & (\mu_{A_l}(C_m), \lambda_{A_l}(C_m), \\ \pi_{A_l}(C_1)) & \pi_{A_l}(C_2)) & \cdots & \pi_{A_l}(C_m)) \end{pmatrix}$$

Step 4: Determine the Weights of Criteria, W

Following the construction of the aggregated PFDM, the criteria weights are determined. Here, W represents the matrix of importance degrees for the relevant criteria, formulated by synthesizing all decision-makers' opinions regarding the ranking of each criterion. Let $w_j^{(k)} = \left[\mu_j^{(k)}, \lambda_j^{(k)}, \pi_j^{(k)}\right]$ be the PFN assigned to the criterion by the k-th decision-maker. The viewpoints of decision-makers on the criteria are aggregated using the PFWA operator as shown in Equation (3) to determine the weights of each criterion.

$$\begin{aligned} w_j &= PFWA\sigma\left(w_j^{(1)}, w_j^{(2)}, w_j^{(3)}, \ldots w_j^{(n)}\right) \\ &= \sigma_1 w_j^{(1)} \oplus \sigma_2 w_j^{(2)} \oplus \sigma_3 w_j^{(3)} \oplus \ldots \oplus \sigma_n w_j^{(n)} \\ &= \left(\sqrt{1-\prod_{k=1}^{n}\left(1-\left(\mu_j^{(k)}\right)^2\right)^{\sigma_k}}, \prod_{k=1}^{n}\left(\lambda_j^{(k)}\right)^{\sigma_k}, \sqrt{\prod_{k=1}^{n}\left(1-\left(\mu_j^{(k)}\right)^2\right)^{\sigma_k} - \left(\prod_{k=1}^{n}\left(\lambda_j^{(k)}\right)^{\sigma_k}\right)^2}\right) \end{aligned} \quad (3)$$

and

$W = [w_1\, w_2\, w_3 \ldots w_m]$ where $w_j = \left(\mu_w(C_j), \lambda_w(C_j), \pi_w(C_j)\right), j = 1,2,\ldots,m$

Step 5: Compute Aggregated Weighted Pythagorean Fuzzy Decisions Matrix, X'

Upon calculating the aggregated PFDM X and the criteria weight matrix W, the aggregated weighted PFDM, $X' = \left(x'_{ij}\right)_{l\times m}$ can be constructed using the multiplication operator in Equation (4) (Zhang & Xu, 2014).

$$x'_{ij} = x_{ij} \otimes w_j$$

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$$= \left(\mu_{A_i}(C_j).\mu_B(C_j), \sqrt{\lambda_{A_i}^2(C_j)+\lambda_B^2(C_j)-\lambda_{A_i}^2(C_j).\lambda_B^2(C_j)}, \right.$$
$$\left. \sqrt{1-\mu_{A_i}(C_j).\mu_B(C_j)-\lambda_{A_i}^2(C_j).\lambda_B^2(C_j)+\lambda_B^2(C_j)} \right) \quad (4)$$

where $x'_{ij} = \left(\mu_{A_iw}(C_j), \lambda_{A_iw}(C_j), \pi_{A_iw}(C_j)\right)$

The aggregated weighted PFDM can be formulated as follows:

$$X' = \begin{pmatrix} (\mu_{A_1w}(C_1), \lambda_{A_1w}(C_1), & (\mu_{A_1w}(C_2), \lambda_{A_1w}(C_2), & \cdots & (\mu_{A_1w}(C_3), \lambda_{A_1w}(C_3), \\ \pi_{A_1w}(C_1)) & \pi_{A_1w}(C_2)) & & \pi_{A_1w}(C_3)) \\ (\mu_{A_2w}(C_1), \lambda_{A_2w}(C_1), & (\mu_{A_2w}(C_2), \lambda_{A_2w}(C_2), & \cdots & (\mu_{A_2w}(C_3), \lambda_{A_2w}(C_3), \\ \pi_{A_2w}(C_1)) & \pi_{A_2w}(C_2)) & & \pi_{A_2w}(C_3)) \\ \vdots & \vdots & \ddots & \vdots \\ (\mu_{A_iw}(C_1), \lambda_{A_iw}(C_1), & (\mu_{A_iw}(C_2), \lambda_{A_iw}(C_2), & & (\mu_{A_iw}(C_m), \lambda_{A_iw}(C_m), \\ \pi_{A_iw}(C_1)) & \pi_{A_iw}(C_2)) & \cdots & \pi_{A_iw}(C_m)) \end{pmatrix}$$

Step 6: Identify Pythagorean Fuzzy Positive-Ideal (PFPIS) and Pythagorean Fuzzy Negative- Ideal (PFNIS) Solution

Let J_1 and J_2 denote the sets of benefit-type and cost-type criteria, respectively. The PFPIS, A^+ can be determined using Equations (5) and (7), whereas the PFNIS, A^- is obtained using Equations (6) and (8).

$$A^+ = \left\{ \left\langle C_j, \mu_{A+w}, \lambda_{A+w} \right\rangle \middle| C_j \in C, j = 1,2,\ldots,m \right\} \quad (5)$$

$$A^- = \left\{ \left\langle C_j, \mu_{A-w}, \lambda_{A-w} \right\rangle \middle| C_j \in C, j = 1,2,\ldots,m \right\} \quad (6)$$

$$\mu_{A+w}(C_j) = \begin{cases} \max\limits_{1\le i\le l} \mu_{A_iw}(C_j) & \text{if } C_j \in J_1 \\ \min\limits_{1\le i\le l} \mu_{A_iw}(C_j) & \text{if } C_j \in J_2 \end{cases} \qquad \lambda_{A+w}(C_j) = \begin{cases} \min\limits_{1\le i\le l} \lambda_{A_iw}(C_j) & \text{if } C_j \in J_1 \\ \max\limits_{1\le i\le l} \lambda_{A_iw}(C_j) & \text{if } C_j \in J_2 \end{cases} \quad (7)$$

$$\mu_{A-w}(C_j) = \begin{cases} \min\limits_{1\le i\le l} \mu_{A_iw}(C_j) & \text{if } C_j \in J_1 \\ \max\limits_{1\le i\le l} \mu_{A_iw}(C_j) & \text{if } C_j \in J_2 \end{cases} \qquad \lambda_{A-w}(C_j) = \begin{cases} \max\limits_{1\le i\le l} \lambda_{A_iw}(C_j) & \text{if } C_j \in J_1 \\ \min\limits_{1\le i\le l} \lambda_{A_iw}(C_j) & \text{if } C_j \in J_2 \end{cases} \quad (8)$$

Step 7: Calculate Distance of Each Alternative from PFPIS and PFNIS

In practical decision-making scenarios, the PFPIS, A^+ rarely exists; if it did, it would represent the optimal choice for the multi-criteria decision-making (MCDM) problem. Conversely, the PFNIS, A^- constitutes the least desirable option. Distance measures are therefore established to compute the separation of each alternative from both the A^+ and A^-. To achieve this, the normalized Euclidean distance between Pythagorean fuzzy sets (PFSs) is employed, as defined in Equations (9) and (10) (Peng et al., 2017).

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$$D\left(A_i, A^+\right)=\sqrt{\frac{1}{2m}\sum_{j=1}^{m}\left[\left(\mu_{A_{ij}w}^2\left(C_j\right)-\mu_{A_{i+}w}^2\left(C_j\right)\right)^2+\left(\lambda_{A_{ij}w}^2\left(C_j\right)-\lambda_{A_{i+}w}^2\left(C_j\right)\right)^2+\left(\pi_{A_{ij}w}^2\left(C_j\right)-\pi_{A_{i+}w}^2\left(C_j\right)\right)^2\right]} \tag{9}$$

$$D\left(A_i, A^-\right)=\sqrt{\frac{1}{2m}\sum_{j=1}^{m}\left[\left(\mu_{A_{ij}w}^2\left(C_j\right)-\mu_{A_{i-}w}^2\left(C_j\right)\right)^2+\left(\lambda_{A_{ij}w}^2\left(C_j\right)-\lambda_{A_{i-}w}^2\left(C_j\right)\right)^2+\left(\pi_{A_{ij}w}^2\left(C_j\right)-\pi_{A_{i-}w}^2\left(C_j\right)\right)^2\right]} \tag{10}$$

where $i=1,2,\ldots,I : j=1,2,\ldots,m$

Step 8: Calculate the Revised Closeness Index of Each Alternative

The relative closeness index of an alternative A_i in relation to the PFPIS, A^+ can be computed as Equation (11).

$$C_{i+}=\frac{D\left(A_i, A^-\right)}{D\left(A_i, A^+\right)+D\left(A_i, A^-\right)}, i=1,2,\ldots,I \tag{11}$$

T

he relative closeness index, C_{i+} usually determines alternative rankings and the best overall choice. However, Hadi-Vencheh & Mirjaberi (2014) pointed out that C_{i+} can fail to identify an option that is both closest to the ideal solution (PIS) and furthest from the worst-case scenario (NIS). They developed a revised closeness index shown in Equation (12) to fix this flaw.

$$\zeta\left(A_i\right)=\frac{D\left(A_i, A^-\right)}{D_{\max}\left(A_i, A^-\right)}-\frac{D\left(A_i, A^+\right)}{D_{\min}\left(A_i, A^+\right)}, i=1,2,\ldots,I \tag{12}$$

where it measures the degree to which an alternative A_i closes to PIS and is a far from NIS simultaneously. It is noted that $\zeta\left(A_i\right), i=1,2,\ldots,I$ increases, making the alternative $\zeta\left(A_i\right)$ more preferable.

Step 9: Rank the Alternatives in Descending Order of Revised Closeness Index

After calculating the revised closeness index $\zeta\left(A_i\right), i=1,2,\ldots,I$, the alternatives are ranked in descending order of $\zeta\left(A_i\right)$ and the alternative A^* with the maximum revised closeness index act as the best suitable alternative to the problem, as Equation (13).

$$A^*=\left\{A_i :\left(i:\zeta\left(A_i\right)\right)=\max_{1\le k\le I}\zeta\left(A_k\right)\right\} \tag{13}$$

Implementation

Based on the methodology and implementation in the uploaded document, the numerical implementation follows a nine-step Pythagorean fuzzy TOPSIS procedure. The calculation uses responses from six decision-makers, four profession-selection criteria, and four profession alternatives. The decision-makers are given equal weights because all participants have equal contribution to the group decision. Table 4 shows the information for all six selected decision-makers.

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Table 4: Characteristics of Decision-Makers

Decision-Makers	Gender	Minor Subject Area
1	Male	Accounting
2	Male	Accounting
3	Female	Accounting
4	Female	Big Data Analytics
5	Female	Big Data Analytics
6	Female	Big Data Analytics

Step 1: Data Collection

Data from decision-makers were collected through a questionnaire, which asked them to rate the importance of various criteria, and the alternatives based on these criteria.

Table 5: The Importance of Criteria

	DM1	DM2	DM3	DM4	DM5	DM6
C_1	I	VI	VI	VI	I	I
C_2	M	I	VI	VI	VI	VI
C_3	I	VI	VI	VI	VI	I
C_4	I	I	VI	I	VI	VI

Table 6: Rating for Alternatives for Each Criterion for Six Decision Makers

DM1	C_1	C_2	C_3	C_4	DM2	C_1	C_2	C_3	C_4	DM3	C_1	C_2	C_3	C_4
A_1	G	VG	VG	MG	A_1	EG	G	MG	G	A_1	EG	EG	VVG	VVG
A_2	VG	VVG	G	VVG	A_2	VVG	VG	VG	VG	A_2	VVG	G	EG	EG
A_3	MG	EG	VVG	VG	A_3	VG	EG	VVG	VVG	A_3	VG	VG	VG	VG
A_4	VVG	G	EG	G	A_4	G	VVG	G	EG	A_4	MG	VVG	MG	MG
DM4	**C1**	**C2**	**C3**	**C4**	***DM5***	**C1**	**C2**	**C3**	**C4**	***DM6***	**C1**	**C2**	**C3**	**C4**
A_1	G	VG	VVG	VVG	*A1*	VVG	MG	VVG	VG	*A1*	EG	G	VVG	VVG
A_2	MG	MG	EG	G	*A2*	VG	VG	VG	MG	*A2*	VVG	VG	VG	VG
A_3	VG	VVG	VG	EG	*A3*	MG	VVG	MG	G	*A3*	VG	VVG	G	EG
A_4	VVG	G	G	VG	*A4*	G	G	G	M	*A4*	G	MG	MG	G

Step 2: Apply Pythagorean Fuzzy Conversion Number

Linguistic terms are converted into Pythagorean fuzzy numbers (PFNs) using Pythagorean fuzzy conversion scales, following the transformations in Tables 2 and 3. The evaluation grades for each decision-maker are presented in Tables 7 and 8.

Table 7: The Importance of Criteria with PFNs

	DM1	DM2	DM3	DM4	DM5	DM6
C_1	(0.80,0.45,0.40)	(0.90,0.20,0.39)	(0.90,0.20,0.39)	(0.90,0.20,0.39)	(0.80,0.45,0.40)	(0.80,0.45,0.40)
C_2	(0.65,0.50,0.57)	(0.80,0.45,0.40)	(0.90,0.20,0.39)	(0.90,0.20,0.39)	(0.90,0.20,0.39)	(0.90,0.20,0.39)
C_3	(0.80,0.45,0.40)	(0.90,0.20,0.39)	(0.90,0.20,0.39)	(0.90,0.20,0.39)	(0.90,0.20,0.39)	(0.80,0.45,0.40)
C_4	(0.80,0.45,0.40)	(0.80,0.45,0.40)	(0.90,0.20,0.39)	(0.80,0.45,0.40)	(0.90,0.20,0.39)	(0.90,0.20,0.39)

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Table 8: Ratings for Alternatives for Each Criterion with PFNs from Each Decision Maker

DM1	C_1	C_2	C_3	C_4
A_1	(0.70,0.35,0.62)	(0.80,0.25,0.55)	(0.80,0.25,0.55)	(0.60,0.50,0.62)
A_2	(0.80,0.25,0.55)	(0.90,0.20,0.39)	(0.70,0.35,0.62)	(0.90,0.20,0.39)
A_3	(0.60,0.50,0.62)	(1.00,0.00,0.00)	(0.90,0.20,0.39)	(0.80,0.25,0.55)
A_4	(0.90,0.20,0.39)	(0.70,0.35,0.62)	(1.00,0.00,0.00)	(0.70,0.35,0.62)
DM2	C_1	C_2	C_3	C_4
A_1	(1.00,0.00,0.00)	(0.70,0.35,0.62)	(0.60,0.50,0.62)	(0.70,0.35,0.62)
A_2	(0.90,0.20,0.39)	(0.80,0.25,0.55)	(0.80,0.25,0.55)	(0.80,0.25,0.55)
A_3	(0.80,0.25,0.55)	(1.00,0.00,0.00)	(0.90,0.20,0.39)	(0.90,0.20,0.39)
A_4	(0.70,0.35,0.62)	(0.90,0.20,0.39)	(0.70,0.35,0.62)	(1.00,0.00,0.00)
DM3	C_1	C_2	C_3	C_4
A_1	(1.00,0.00,0.00)	(1.00,0.00,0.00)	(0.90,0.20,0.39)	(0.90,0.20,0.39)
A_2	(0.90,0.20,0.39)	(0.70,0.35,0.62)	(1.00,0.00,0.00)	(1.00,0.00,0.00)
A_3	(0.80,0.25,0.55)	(0.80,0.25,0.55)	(0.80,0.25,0.55)	(0.80,0.25,0.55)
A_4	(0.60,0.50,0.62)	(0.90,0.20,0.39)	(0.60,0.50,0.62)	(0.60,0.50,0.62)
DM4	C_1	C_2	C_3	C_4
A_1	(0.70,0.35,0.62)	(0.80,0.25,0.55)	(0.90,0.20,0.39)	(0.90,0.20,0.39)
A_2	(0.60,0.50,0.62)	(0.60,0.50,0.62)	(1.00,0.00,0.00)	(0.70,0.35,0.62)
A_3	(0.80,0.25,0.55)	(0.90,0.20,0.39)	(0.80,0.25,0.55)	(1.00,0.00,0.00)
A_4	(0.90,0.20,0.39)	(0.70,0.35,0.62)	(0.70,0.35,0.62)	(0.80,0.25,0.55)
DM5	C_1	C_2	C_3	C_4
A_1	(0.90,0.20,0.39)	(0.60,0.50,0.62)	(0.90,0.20,0.39)	(0.80,0.25,0.55)
A_2	(0.80,0.25,0.55)	(0.80,0.25,0.55)	(0.80,0.25,0.55)	(0.60,0.50,0.62)
A_3	(0.60,0.50,0.62)	(0.90,0.20,0.39)	(0.60,0.50,0.62)	(0.70,0.35,0.62)
A_4	(0.70,0.35,0.62)	(0.70,0.35,0.62)	(0.70,0.35,0.62)	(0.50,0.60,0.62)
DM6	C_1	C_2	C_3	C_4
A_1	(1.00,0.00,0.00)	(0.70,0.35,0.62)	(0.90,0.20,0.39)	(0.90,0.20,0.39)
A_2	(0.90,0.20,0.39)	(0.80,0.25,0.55)	(0.80,0.25,0.55)	(0.80,0.25,0.55)
A_3	(0.80,0.25,0.55)	(0.90,0.20,0.39)	(0.70,0.35,0.62)	(1.00,0.00,0.00)
A_4	(0.70,0.35,0.62)	(0.60,0.50,0.62)	(0.60,0.50,0.62)	(0.70,0.35,0.62)

Step 3: Construction of Aggregated Pythagorean Fuzzy Decision Matrix, X

The corresponding Pythagorean fuzzy decision matrix, (PFDM), $X^{(k)} = \left(x_{ij}^{(k)}\right)_{4\times4}$ where $x_{ij}^{(k)}$ indicates the degree assigned by the decision-maker, DM_k to the alternative alternative A_i with respect to the criteria C_{ij} in PFNs are in Table 8. The aggregated PFDM, $X = \left(x_{ij}\right)_{4\times4}$ is obtained by averaging Pythagorean fuzzy opinions of the six decision-makers by using PFWA operator in Equation (1). The Table 9 below shows the result of Aggregated Pythagorean Fuzzy Decision Matrix, X. Calculation for A_1 against C_1:

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$$\mu_{A1}(C_1) = \sqrt{1 - \left[\left(1 - 0.70^2\right)\left(1 - 1.00^2\right)\left(1 - 1.00^2\right)\left(1 - 0.70^2\right)\left(1 - 0.90^2\right)\left(1 - 1.00^2\right)\right]} = 1.0000$$

$$\lambda_{A1}(C_1) = 0.3500 \cdot 0.0000 \cdot 0.0000 \cdot 0.3500 \cdot 0.2000 \cdot 0.0000 = 0.0000$$

$$\pi_{A1}(C_1) = \sqrt{0.0000 - 0.0000} = 0.0000$$

Table 9: Aggregated Pythagorean Fuzzy Decision Matrix, X

X	C_1	C_2	C_3	C_4
A_1	(1.0000, 0.0000, 0.0000)	(1.0000, 0.0000, 0.0000)	(0.9998, 0.0002, 0.0173)	(0.9996, 0.0004, 0.0284)
A_2	(0.9997, 0.0003, 0.0239)	(0.9986, 0.0005, 0.0538)	(1.0000, 0.0000, 0.0000)	(1.0000, 0.0000, 0.0000)
A_3	(0.9966, 0.0010, 0.0829)	(1.0000, 0.0000, 0.0000)	(0.9992, 0.0004, 0.0391)	(1.0000, 0.0000, 0.0000)
A_4	(0.9985, 0.0009, 0.0554)	(0.9985, 0.0009, 0.0554)	(1.0000, 0.0000, 0.0000)	(1.0000, 0.0000, 0.0000)

Step 4: Determine the Weights of Criteria, W

To obtain the criteria weight matrix W, Equation (3) was used to aggregate the six decision-makers' evaluations from Table 7. The matrix of weight of the criteria, W is obtained as below. For C_1:

$$\mu_W(C_1) = \sqrt{1 - \left[\left(1 - 0.80^2\right)\left(1 - 0.90^2\right)\left(1 - 0.90^2\right)\left(1 - 0.90^2\right)\left(1 - 0.80^2\right)\left(1 - 0.80^2\right)\right]} = 0.9998$$

$$\lambda_W(C_1) = 0.4500 \cdot 0.2000 \cdot 0.2000 \cdot 0.2000 \cdot 0.4500 \cdot 0.4500 = 0.0007$$

$$\pi_W(C_1) = \sqrt{0.00032 - 0.0007^2} = 0.0179$$

$$W_{C_1,C_2,C_3,C_4} = \begin{pmatrix} (0.9998, 0.0007, 0.0179) \\ (0.9999, 0.0004, 0.0165) \\ (0.9999, 0.0003, 0.0130) \\ (0.9998, 0.0007, 0.0179) \end{pmatrix}^T$$

Step 5: Compute Aggregated Weighted Pythagorean Fuzzy Decisions Matrix, X'

The Aggregated Weighted Pythagorean Fuzzy Decisions Matrix, X' is obtained using the value in Table 9 and matrix W and applied in Equation (4). The Table 10 below shows the result of Aggregated Weighted Pythagorean Fuzzy Decisions Matrix, X'. Calculation for A_1 against C_1:

$$\mu_{A1W}(C_1) = 1.0000 \cdot 0.9998 = 0.9998$$

$$\lambda_{A1W}(C_1) = \sqrt{0.0000^2 + 0.0007^2 - 0.0000^2 \cdot 0.0007^2} = 0.0007$$

$$\pi_{A1W}(C_1) = \sqrt{1 - 0.9998 - 0.0000^2 - 0.0007^2 + 0.0000^2 \cdot 0.0007^2} = 0.0126$$

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Table 10: Aggregated Weighted Pythagorean Fuzzy Decisions Matrix, X'

X'	C_1	C_2	C_3	C_4
A_1	(0.9998, 0.0007, 0.0126)	(0.9999, 0.0004, 0.0116)	(0.9998, 0.0004, 0.0153)	(0.9994, 0.0008, 0.0237)
A_2	(0.9996, 0.0008, 0.0211)	(0.9984, 0.0007, 0.0398)	(0.9999, 0.0003, 0.0092)	(0.9998, 0.0007, 0.0126)
A_3	(0.9964, 0.0012, 0.0600)	(0.9999, 0.0004, 0.0116)	(0.9992, 0.0005, 0.0291)	(0.9998, 0.0007, 0.0126)
A_4	(0.9983, 0.0011, 0.0411)	(0.9983, 0.0009, 0.0408)	(0.9999, 0.0003, 0.0092)	(0.9998, 0.0007, 0.0126)

Step 6: Identify Pythagorean Fuzzy Positive-Ideal (PFPIS) and Pythagorean Fuzzy Negative- Ideal (PFNIS) Solution

All four (4) criteria in this study are benefit-type criteria. Consequently, the condition for benefit-type criteria J_1 in Equations (7) and (8) was applied to determine the values of A^+ and A^-. Subsequently, the PFPIS and PFNIS were constructed using Equations (5) and (6), based on the values in Table 10. The result for A^+ and A^- are presented in Table 11 below. Calculation for C_1:

For C_1A^+, $\mu_{A^+W}(C_1) = \max_{1<i\pounds l} \mu_{A_i;W}(C_1) = 0.9998$; $\lambda_{A^+W}(C_1) = \min_{1<i\pounds l} \lambda_{A_i;W}(C_1) = 0.0007$

$$C_1A^+ = \left(C_1, \mu_{A^+W}, \lambda_{A^+W}\right) = (0.0126, 0.9998, 0.0007)$$

For C_1A^-, $\mu_{A^-W}(C_1) = \min_{1<i\pounds l} \mu_{A_i;W}(C_1) = 0.9964$; $\lambda_{A^-W}(C_1) = \max_{1<i\pounds l} \lambda_{A_i;W}(C_1) = 0.0012$

$$C_1A^- = \left(C_1, \mu_{A^-W}, \lambda_{A^-W}\right) = (0.0600, 0.9964, 0.0012)$$

Table 11: The result for A^+ and A^-

	A^+	A^-
C_1	(0.0126, 0.9998, 0.0007)	(0.0600, 0.9964, 0.0012)
C_2	(0.0116, 0.9999, 0.0004)	(0.0408, 0.9983, 0.0009)
C_3	(0.0092, 0.9999, 0.0003)	(0.0291, 0.9992, 0.0005)
C_4	(0.0126, 0.9998, 0.0007)	(0.0237, 0.9994, 0.0008)

Step 7: Calculate Distance of Each Alternative from PFPIS and PFNIS

Next, the normalized Euclidean distance formulas in Equations (9) and (10) were used to calculate the distances for each alternative. For illustration, the distance calculations from PFPIS and PFNIS for alternative A_i are detailed below using the values from Tables 10 and 11. The Table 12 and 13 below shows the result of the summation from PFPIS and PFNIS respectively.

Calculation of PFPIS for A_1 against C_1:

$$\left(0.9998^2 - 0.0126^2\right)^2 + \left(0.0007^2 - 0.9998^2\right)^2 + \left(0.0126^2 - 0.0007^2\right)^2 = 1.9982$$

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Table 12: The Summation from PFPIS

	C_1	C_2	C_3	C_4	Total
A_1	1.9982	1.9988	1.9985	1.9966	7.9922
A_2	1.9971	1.9930	1.9991	1.9982	7.9875
A_3	1.9846	1.9988	0.9960	1.9982	7.9776
A_4	1.9921	1.9927	1.9991	1.9982	7.9821

Calculation of PFNIS for A_1 against C_1:

$$\left(0.9998^2 - 0.0600^2\right)^2 + \left(0.0007^2 - 0.9964^2\right)^2 + \left(0.0126^2 - 0.0012^2\right)^2 = 1.9779$$

Table 13: The Summation from PFNIS

	C_1	C_2	C_3	C_4	Total
A_1	1.9779	1.9893	1.9942	1.9942	7.9556
A_2	1.9767	1.9836	1.9948	1.9958	7.9509
A_3	1.9642	1.9893	1.9917	1.9958	7.9411
A_4	1.9718	1.9832	1.9948	1.9958	7.9456

Hence, $D(A_i, A^+)$ and $D(A_i, A^-)$ for all the alternatives were obtained as shown in Table 14. Calculation of the distance for A_1 from PFPIS and PFNIS,

$$D\left(A_1, A^+\right) = \sqrt{\frac{1}{2(4)}\left(7.9922\right)} = 0.9995 \; ; \; D\left(A_1, A^-\right) = \sqrt{\frac{1}{2(4)}\left(7.9556\right)} = 0.9972$$

Table 14: The Distance of Each Alternative from PFPIS and PFNIS

	A_1	A_2	A_3	A_4
$D(A_i, A^+)$	0.9995	0.9992	0.9986	0.9989
$D(A_i, A^-)$	0.9972	0.9969	0.9963	0.9966

Step 8: Calculate the Revised Closeness Index of Each Alternative

To compute the revised closeness index for each alternative, Equation (12) was applied using the values from Table 14. The result of the revised closeness index for each alternative is shown in Table 15. Calculation for A_1:

$$z\left(A_1\right) = \frac{0.9972}{0.9972} - \frac{0.9995}{0.9986} = -0.0009013$$

Table 15: The Revised Closeness Index for Alternatives

	A_1	A_2	A_3	A_4
$D(A_i, A^+)$	0.9995	0.9992	0.9986	0.9989
$D(A_i, A^-)$	0.9972	0.9969	0.9963	0.9966
$z(A_i)$	-0.0009013	-0.0009017	-0.0009025	-0.0009021

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Step 9: Rank the Alternatives in Descending Order of Revised Closeness Index

Lastly, the overall ranking of the alternatives was determined, as shown in Table 16.

Table 16: The Revised Closeness Index and A Final Ranking of Profession Area

Alternatives	$D(A_i,A^+)$	$D(A_i,A^-)$	$z(A_i)$	Rank
Business and Finance (A_1)	0.9995	0.9972	-0.0009013	1
Technology and Innovation (A_2)	0.9992	0.9969	-0.0009017	2
Government (A_3)	0.9986	0.9963	-0.0009025	4
Industry (A_4)	0.9989	0.9966	-0.0009021	3

Result and Discussion

The revised relative closeness indices yield the final preference ranking $A_1 \succ A_2 \succ A_4 \succ A_3$. Business and Finance, A_1 (-0.0009013) emerges as the most preferred career path for mathematical fields, while Government, A_3 (-0.0009025) ranks last due to its lower implementation of key success factors.

These findings indicate that Business and Finance is the most preferred career path among mathematics students, followed by Technology and Innovation, Industry, and Government. The preference for Business and Finance is largely driven by the growth of home-based online ventures such as drop shipping, which minimize overhead costs in marketing, human resources, and utilities (Rosli et al., 2020). Entrepreneurship also offers mathematical graduates' greater autonomy, creative control, and lucrative roles in high-demand positions like financial analysts, quantitative analysts, and data scientists.

Conversely, Government positions are the least preferred, despite offering job stability. This low preference is primarily due to limited vacancies caused by high graduate numbers, a mandatory retirement age of 60 under Malaysian Labor Law, and prudent fiscal recruitment strategies (Tai & Sapuan, 2018). Furthermore, ongoing digital transformation within the public sector has automated traditional tasks, reducing overall demand for manual labor.

Conclusion and Recommendation

This study utilized the Pythagorean fuzzy TOPSIS method to rank career alternatives and identify the most preferred profession among final-year mathematics students at UiTM Kelantan Branch. All three primary objectives were successfully fulfilled: applying Pythagorean fuzzy numbers (PFNs), utilizing Pythagorean fuzzy weighted average (PFWA) operators in a multi-criteria decision-making (MCDM) framework, and implementing a general fuzzy TOPSIS model to derive the final career rankings.

The results indicate that Business and Finance is the most preferred career area, achieving the highest revised closeness index of -0.0009013. Technology and Innovation ranked second with a score of -0.0009017, followed by Industry in third place at -0.0009021. Government occupied the final position with a score of -0.0009025. Consequently, Business and Finance emerges as the primary career choice for graduating mathematics students compared to the other sectors evaluated.

For future work, researchers are encouraged to apply alternative fuzzy extensions such as Spherical or Triangular fuzzy sets to handle linguistic uncertainty. Additionally, integrating

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other MCDM methodologies, such as Fuzzy AHP, Entropy weight methods, or PROMETHEE, could provide deeper comparative insights into career selection preferences.

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