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A Fuzzy Analytic Hierarchy Process (FAHP) Approaches for Investment Decision-Making in Malaysia

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ABSTRACT

Investment decisions are essential for achieving financial growth and stability. Young Malaysians, however, often face challenges such as limited financial resources, rising living costs, and low financial literacy. Common investment options in Malaysia include gold, stocks, property, and cryptocurrency. Each option differs in capital requirements, profitability, risk level, and long-term viability. Selecting the most appropriate investment is difficult because decision making is often subjective and influenced by uncertainty. Conventional multi criteria decision making (MCDM) methods such as Simple Additive Weighting (SAW), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and Analytic Hierarchy Process (AHP) have been widely used, but they are less effective in dealing with this challenge. To overcome this limitation, this study applies the Fuzzy Analytic Hierarchy Process (FAHP), which integrates fuzzy logic with AHP to capture expert evaluations more realistically. Four investment alternatives are assessed based on capital, profit, risk, and sustainability. The results indicate that gold is the most preferred investment option, followed by property, stocks, and cryptocurrency. By applying FAHP to investment decision-making in Malaysia, this study introduces a novel framework that not only supports young investors in making strategic choices but also offers insights that may inform financial literacy programs and policy initiatives under uncertain market conditions.

1. INTRODUCTION

Investment is a fundamental component of personal financial management. It enables individuals to grow wealth, reduce the effects of inflation, and achieve long-term financial security. In Malaysia, popular investment options include gold, stocks, property, and cryptocurrency. Each alternative presents different levels of risk, return potential, capital requirement, and sustainability (Mushaddik & Nori, 2023; Hassan et al., 2022; Eaw et al., 2024). Despite this availability, many Malaysians — especially young adults and fresh graduates — find it difficult to make informed decisions. Limited financial resources, rising living costs,

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and insufficient financial literacy continue to restrict their ability to participate in suitable investment opportunities (Idris et al., 2013; Anuwar et al., 2024).

The urgency of enhancing investment literacy is underscored by concerning statistics. According to the Employees Provident Fund (EPF), as of 2021, only 3% of Malaysians are financially prepared for retirement, highlighting a critical gap in personal financial planning and investment practices (Malay Mail, 2021). This issue is exacerbated by the tendency of individuals to engage in high-risk or unsuitable investment schemes due to a lack of understanding regarding essential factors such as capital, profit, risk, and sustainability (Raut, 2020). Consequently, there is a pressing need for structured decision-making frameworks that can guide individuals, especially the younger generation, in selecting suitable investment options aligned with their financial goals and risk tolerance.

To address this gap, numerous multi-criteria decision-making (MCDM) methods have been utilized in previous studies to evaluate and rank investment alternatives. Techniques such as Simple Additive Weighting (SAW), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and the Analytic Hierarchy Process (AHP) have been widely applied in investment decision-making (Aliyeva, 2024; Dweiri & Al-Oqla, 2006; Purwita & Subriadi, 2019; Sahore, 2017). While these methods offer structured evaluation mechanisms, they often fall short in handling the vagueness and subjectivity inherent in human judgments, especially when dealing with qualitative criteria (Hodosi et al., 2023).

To overcome these limitations, the Fuzzy Analytic Hierarchy Process (FAHP) integrates fuzzy set theory with AHP, allowing decision-makers to express preferences using linguistic variables and accommodate the inherent ambiguity of human assessments (Sachdeva et al., 2023; Singh, 2016). FAHP has been successfully applied in various domains where subjective expert opinions are crucial, offering a more realistic and flexible decision-making framework compared to traditional methods.

Given the limited application of FAHP in the context of investment decision-making in Malaysia, this study aims to bridge this gap by applying FAHP to evaluate four major investment options, namely gold, stocks, property, and cryptocurrency, based on the criteria of capital, profit, risk, and sustainability. The difficulty of investment decision-making in Malaysia is compounded by several factors, including limited financial literacy among young adults, rising living costs, and the tendency to rely on subjective or uncertain judgments when assessing alternatives. Conventional MCDM approaches, while widely used, often fail to adequately address this ambiguity. By incorporating fuzzy logic into AHP, the FAHP method allows expert judgments to be expressed more realistically and reduces the effects of vagueness in evaluation. In this way, the study not only fills a methodological gap but also provides practical insights that can help young Malaysian investors make informed, strategic, and resilient investment decisions aligned with their financial capacity and long-term goals.

2. METHODOLOGY

2.1 Overview of FAHP applications

The Fuzzy Analytic Hierarchy Process (FAHP) has been widely applied across various fields to support complex decision-making, particularly when subjective judgments and qualitative factors are involved. Recent studies have demonstrated the effectiveness of FAHP in addressing problems that require multi-criteria evaluation. For instance, Mohd Idris et al. (2019) applied FAHP to determine the underlying causes of divorce in Perlis, showcasing the method's ability to prioritize qualitative social factors. Similarly, Abd Aziz et al. (2024a) employed FAHP to analyze factors influencing career choices among graduate students, providing insights into personal and economic considerations in academic decision-making. In the public health domain, Idris et al. (2023) utilized FAHP to select the most effective measures for preventing the spread of COVID-19, emphasizing its applicability in crisis management scenarios.

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Furthermore, Idris et al. (2024) applied FAHP to evaluate courier service preferences among Malaysian users, while Zahrin et al. (2022) used the method to identify criteria for choosing tour packages in Langkawi Island. In the context of consumer behavior, Abd Aziz et al. (2024b) examined factors affecting online shopping platform selection, and Abd Aziz et al. (2023) utilized FAHP to select recipients of the Best Student Award. These diverse applications highlight FAHP's versatility and robustness in handling decision-making problems that involve ambiguity and subjective human judgments, thereby justifying its suitability for investment decision-making in this study.

2.2 Research framework and FAHP process

The research framework in this study serves as a systematic guideline for evaluating investment alternatives using the Fuzzy Analytic Hierarchy Process (FAHP). By integrating multi-criteria decision-making (MCDM) principles with fuzzy logic, the framework effectively addresses the ambiguity and subjectivity inherent in human judgments. This is particularly important when dealing with qualitative factors that influence investment decisions, where traditional crisp values may not capture expert preferences accurately.

The primary objective of this study is to assess and rank four common investment options in Malaysia, which are gold, stocks, property, and cryptocurrency. These alternatives are evaluated based on four key criteria, namely capital, profit, risk, and sustainability. The relationships between the overall goal, evaluation criteria, and investment alternatives are illustrated in the following Fig. 1.

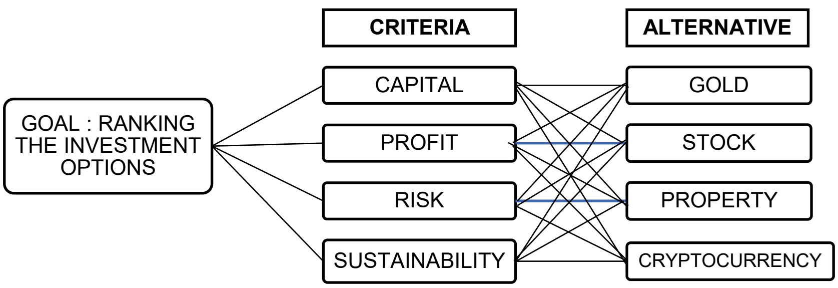

Fig. 1. Investment decision hierarchy tree

To operationalize this evaluation, the research framework adopts a structured sequence of steps guided by the FAHP methodology. This step-by-step process ensures that expert judgments are systematically collected, processed, and analyzed, while also accommodating the inherent uncertainty of subjective assessments. The general flow of the FAHP implementation in this study is illustrated in the following Fig. 2.

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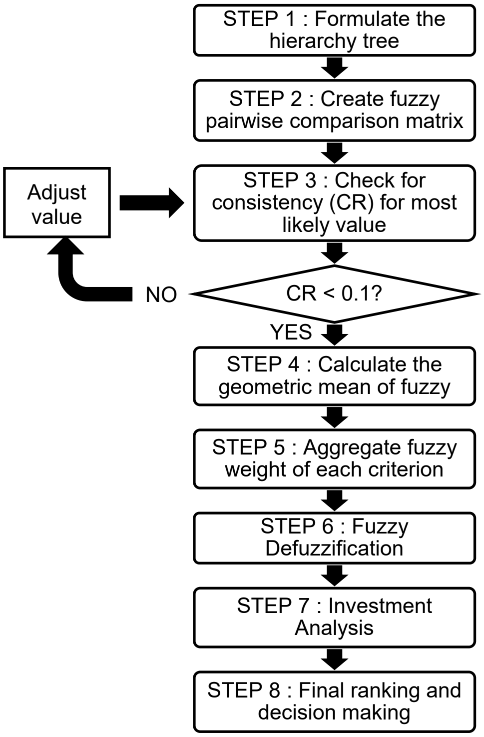

Fig. 2. FAHP process flowchart

The process begins with formulating the hierarchy tree, where the decision problem is structured into three levels: the overall goal, evaluation criteria, and available investment alternatives, as illustrated in Fig. 1. Following this, a fuzzy pairwise comparison matrix is constructed by gathering expert judgments through linguistic variables, which are represented as triangular fuzzy numbers (TFNs) to accommodate the inherent uncertainty and subjectivity in human assessments.

Triangular Fuzzy Numbers (TFNs) are a type of fuzzy number commonly used in decision-making to represent uncertain or imprecise judgments. A TFN is defined by three values: the lower (*l*), middle (*m*), and upper (*u*) bounds, written as (*l, m, u*). These values form a triangular shape when plotted, representing the range and most likely value of an expert's opinion. TFNs are especially useful for translating linguistic terms (like "somewhat important" or "strongly important") into numerical values, allowing subjective judgments to be processed mathematically in fuzzy logic models like FAHP.

The membership function of a TFN, μ_{TFN} describes the degree to which each value within the range belongs to the fuzzy set, and is mathematically defined as follows:

$$\mu_{TFN} = \begin{cases} \dfrac{x-l}{m-l} & ; \quad l \leq x \leq m \\ \dfrac{u-x}{u-m} & ; \quad m \leq x \leq u \\ 0 & ; \quad otherwise \end{cases} \tag{1}$$

At this stage, the decision-maker refers to Table 1 to guide the selection of appropriate linguistic terms when performing pairwise comparisons between criteria and among alternatives. These qualitative

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judgments are then translated into numerical values based on the standard AHP scale (ranging from 1 to 9). The resulting inputs are used to construct pairwise comparison matrices (PCMs), which systematically capture the expert's preferences. The general structure of the PCM, A^k based on the 1-9 scale, is represented in Eq. (2).

$$A^k = \begin{bmatrix} 1 & d_{12}^k & \cdots & d_{1n}^k \\ d_{21}^k & 1 & & d_{2n}^k \\ \vdots & & \ddots & \vdots \\ d_{n1}^k & d_{n2}^k & \cdots & 1 \end{bmatrix} \quad (2)$$

Here, k represents the k-th expert, and $d_{11}^k, d_{12}^k, \ldots, d_{nn}^k$ denote the expert's pairwise comparison inputs for each factor, using a numerical scale from 1 to 9. It is important to note that these matrices are reciprocal in nature, meaning $d_{ji}^k = 1/d_{ij}^k$, and $d_{ii}^k = 1$ for all $i, j = 1,2, \ldots, n$. In other words, if the expert's preference d_{ij}^k is recorded in the upper triangle of the matrix, the corresponding reciprocal value d_{ji}^k will appear in the lower triangle. This reciprocal structure ensures the matrix consistently and accurately reflects the expert's judgments on the relative importance of each factor.

Table 1. Linguistic variables, along with their associated crisp scales and corresponding TFNs, used for pairwise comparisons

Linguistic Variables	AHP Scale (Non-Fuzzy Numbers)	Fuzzy AHP Scale (TFNs)	Fuzzy AHP Scale (Reciprocal TFNs)
Equally Important	1	(1,1,1)	(1,1,1)
Somewhat Important	3	(2,3,4)	(1/4,1/3,1/2)
Fairly Important	5	(4,5,6)	(1/6.1/5,1/4)
Strongly Important	7	(6,7,8)	(1/8,1/7,1/6)
Very Strongly Important	9	(9,9,9)	(1/9,1/9,1/9)
Intermediate Value	2	(1,2,3)	(1/3,1/2,1)
	4	(3,4,5)	(1/5,1/4,1/3)
	6	(5,6,7)	(1/7,1/6,1/5)
	8	(7,8,9)	(1/9,1/8,1/7)

To ensure the reliability of the expert evaluations, the consistency ratio (CR) is then calculated, verifying the logical consistency of the pairwise comparisons. Checking the consistency of the judgment matrix is essential, given the complexity of the decision-making process and the subjective nature of expert evaluations. To assess the reliability of the pairwise comparisons, the CR is computed using the following formula:

$$CR = \frac{CI}{RI} \quad (3)$$

where

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (4)$$

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In this calculation, λ_{max} refers to the maximum eigenvalue of the comparison matrix, while *n* represents the size of the matrix. The Random Index (*RI*), which reflects the average consistency of randomly generated matrices, is presented in Table 2.

Table 2. Random consistency index (RI) values for different matrix sizes

Matrix Order, *n*	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Random Index, *RI*	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

If the CR value is below 0.1 (or 10%), the matrix is considered to be consistent, and the evaluations are deemed acceptable. However, if the CR exceeds 0.1, the assessor is required to review and revise the matrix to improve consistency. It is important to note that the consistency check is performed using the crisp (non-fuzzy) version of the pairwise comparison matrix, as illustrated in Eq. (2).

Once the consistency of the experts' judgments has been verified, the pairwise comparison values are converted into Triangular Fuzzy Numbers (TFNs) based on the equivalence scale provided in Table 1. This conversion results in the formation of the Fuzzy Pairwise Comparison Matrix (FPCM) as illustrated below:

$$\tilde{A}^k = \begin{bmatrix} (1,1,1) & \tilde{d}_{12}^k & \cdots & \tilde{d}_{1n}^k \\ \tilde{d}_{21}^k & (1,1,1) & & \tilde{d}_{2n}^k \\ \vdots & & \ddots & \vdots \\ \tilde{d}_{n1}^k & \tilde{d}_{n2}^k & \cdots & (1,1,1) \end{bmatrix} \tag{5}$$

Here, $\tilde{d}_{11}^k, \tilde{d}_{12}^k, \ldots, \tilde{d}_{nn}^k$ denote the input values that have been converted from crisp (non-fuzzy) numbers into Triangular Fuzzy Numbers (TFNs), as shown in Table 1.

Next, the geometric mean of the fuzzy judgments is calculated to aggregate the assessments from multiple experts into a single set of unified fuzzy weights for each criterion. These fuzzy weights are then combined with the fuzzy evaluations of the investment alternatives. The result is an aggregated fuzzy weight that reflects the overall importance of each investment alternative with respect to the selected criteria.

The following shows the calculation to obtain the average value for the updated matrix elements.

$$\tilde{A} = [\tilde{d}_{ij}] = \frac{\sum_{k=1}^{K} \tilde{d}_{ij}^k}{K} \tag{6}$$

where *K* denotes the total number of experts. In this context, $\tilde{d}_{ij}^k = (l_{ij}^k, m_{ij}^k, u_{ij}^k)$ where l, m, and *u* represent the lower, middle, and upper values of the Triangular Fuzzy Numbers (TFNs), respectively.

The fuzzy geometric mean, $\tilde{r}_i$ for the fuzzy comparison values of each criterion *i* is determined using Eq. (7).

$$\tilde{r}_i = (\tilde{d}_{i1} \times \tilde{d}_{i2} \times \cdots \times \tilde{d}_{iN})^N \tag{7}$$

Here, *N* represents the total number of criteria or alternatives. Next, the vector summation of the geometric means, $\sum_{i=1}^{N} \tilde{r}_i$, is computed, followed by calculating its reciprocal, $(\sum_{i=1}^{N} \tilde{r}_i)^{-1}$, using Eq. (8) and Eq. (9), respectively.

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$$\sum_{i=1}^{N} \tilde{r}_i = \left(\sum l_{\tilde{r}_i}, \sum m_{\tilde{r}_i}, \sum u_{\tilde{r}_i}\right) \tag{8}$$

$$\left(\sum_{i=1}^{N} \tilde{r}_i\right)^{-1} = \left(\frac{1}{\sum u_{\tilde{r}_i}}, \frac{1}{\sum m_{\tilde{r}_i}}, \frac{1}{\sum l_{\tilde{r}_i}}\right) \tag{9}$$

To calculate the fuzzy weight for each criterion $\widetilde{w}_i$, each geometric mean $\tilde{r}_i$ is multiplied by the reciprocal of the total vector summation of geometric means, as outlined in Eq. (10).

$$\widetilde{w}_i = \tilde{r}_i \times \left(\sum_{i=1}^{N} \tilde{r}_i\right)^{-1} \tag{10}$$

The defuzzification process is subsequently carried out to transform the fuzzy weights into crisp numerical values, allowing for a clear and objective comparison among the alternatives. The calculation method for this process is shown as follows.

$$M_i = \frac{\tilde{l}_i + \widetilde{m}_i + \tilde{u}_i}{3} \tag{11}$$

Next, the normalized value of M_i must be calculated to obtain the normalized weight Z_i, which represents the final weight. This is achieved using the following method:

$$Z_i = \frac{M_i}{\sum_{i=1}^{N} M_i} \tag{12}$$

This process is not limited to obtaining the final weight values for the criteria alone but is also extended to determine the final weights for each alternative. The same computational steps, as outlined from Eq. (2) to Eq. (12), are applied. However, while the final weight for each criterion is calculated only once, the final weights for the alternatives must be computed separately for each criterion. In other words, the weighting process for alternatives is repeated based on the total number of criteria.

Once the final weights for all criteria and alternatives have been obtained, the final step in the FAHP method is to calculate the total score for each alternative, denoted as ${T_A}^n$, using the following formula:

$${T_A}^n = \sum_{i=1}^{N} Z_{A_i}^{\,n} \times Z_{C_i} \tag{13}$$

Here, n represents the n-th alternative, N is the number of criteria, $Z_{A_i}^{\,n}$ is the final weight of the alternative with respect to a given criterion, and Z_{C_i} is the final weight of the corresponding criterion.

Based on these values, an investment analysis is performed to compute the overall scores for each investment option. Finally, the most suitable investment alternative is determined through a final ranking and decision-making process, providing a structured and reliable basis for investment selection.

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By following these systematic steps, the research framework provides a comprehensive approach for evaluating investment alternatives, ensuring robust and reliable decision-making outcomes that reflect expert insights despite inherent uncertainties.

3. RESULTS AND DISCUSSION

Data were collected using structured questionnaires distributed to two financial advisors, each with over ten years of professional experience in providing investment recommendations, portfolio planning, and risk assessment for clients. In this study, an individual was considered an expert if they possessed substantial professional experience in investment advisory, practical knowledge of financial markets, and active involvement in guiding clients' decision-making. This criterion ensures that the pairwise comparisons are grounded in reliable, informed, and contextually relevant judgments. The experts were asked to provide pairwise comparisons of the evaluation criteria as well as the investment alternatives, using linguistic terms that were subsequently converted into Triangular Fuzzy Numbers (TFNs) for analysis.

Each expert was provided with a complete set of questionnaires that required them to perform pairwise comparisons among all evaluation criteria and among all investment alternatives with respect to the four criteria: capital, profit, risk, and sustainability. Consequently, each expert generated a total of five pairwise comparison matrices (PCMs).

To ensure the reliability of the data, each PCM was subjected to a consistency check by calculating the Consistency Ratio (CR). A matrix was considered reliable if its CR value was below 0.1, which is the threshold recommended in AHP literature. All matrices in this study met this requirement, confirming that the expert judgments were logically consistent.

The validity of the data was ensured through three measures. First, experts were selected based on substantial professional experience in investment advisory, ensuring the judgments reflected domain knowledge. Second, the use of linguistic variables converted into Triangular Fuzzy Numbers (TFNs) allowed subjective judgments to be expressed more realistically, reducing cognitive bias. Third, the application of defuzzification and normalization produced crisp, comparable values, thereby enhancing the interpretability and accuracy of the results. Together, these steps ensured that the collected data were both valid and reliable for subsequent analysis.

3.1 Consistency test

Table 3 through Table 7 present the input data provided by Expert 1 (Exp1) and Expert 2 (Exp2), along with the Consistency Ratio (CR) results for each PCM. All CR values were found to be less than 0.1, indicating an acceptable level of consistency in the judgments. If a CR value exceeds 0.1, the judgment would be considered inconsistent, necessitating a re-evaluation or replacement of the expert's input.

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Table 3. Pairwise comparison matrix for criteria, including the consistency ratio for expert 1 and 2

Criteria	**Capital**		**Profit**		**Risk**		**Sustainability**	
	Exp1	Exp2	Exp1	Exp2	Exp1	Exp2	Exp1	Exp2
Capital	1	1	4	3	3	8	8	9
Profit	1/4	1/3	1	1	1/4	2	2	1
Risk	1/3	1/8	4	1/2	1	1	2	1/3
Sustainability	1/8	1/9	1/2	1	1/2	3	1	1
CR							0.076	0.069

Table 4. Pairwise comparison matrix for alternative with respect to capital, including the consistency ratio for expert 1 and 2

Alternative with respect to Capital	**Gold**		**Stock**		**Property**		**Cryptocurrency**	
	Exp1	Exp2	Exp1	Exp2	Exp1	Exp2	Exp1	Exp2
Gold	1	1	2	3	5	3	4	5
Stock	1/2	1/3	1	1	6	2	3	7
Property	1/5	1/3	1/6	1/2	1	1	2	4
Cryptocurrency	1/4	1/5	1/3	1/7	1/2	1/4	1	1
CR							0.087	0.079

Table 5. Pairwise comparison matrix for alternative with respect to profit, including the consistency ratio for expert 1 and 2

Alternative with respect to Profit	**Gold**		**Stock**		**Property**		**Cryptocurrency**	
	Exp1	Exp2	Exp1	Exp2	Exp1	Exp2	Exp1	Exp2
Gold	1	1	2	1	3	5	5	2
Stock	1/2	1	1	1	2	5	3	1/2
Property	1/3	1/5	1/2	1/5	1	1	6	8
Cryptocurrency	1/5	1/2	1/3	2	1/6	8	1	1
CR							0.087	0.079

Table 6. Pairwise comparison matrix for alternative with respect to risk, including the consistency ratio for expert 1 and 2

Alternative with respect to Risk	**Gold**		**Stock**		**Property**		**Cryptocurrency**	
	Exp1	Exp2	Exp1	Exp2	Exp1	Exp2	Exp1	Exp2
Gold	1	1	2	2	3	5	5	4
Stock	1/2	1/2	1	1	2	6	7	3
Property	1/3	1/5	1/2	1/6	1	1	6	2
Cryptocurrency	1/5	1/4	1/7	1/3	1/6	1/2	1	1
CR							0.072	0.087

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Table 7. Pairwise comparison matrix for alternative with respect to sustainability, including the consistency ratio for expert 1 and 2

Alternative with respect to Sustainability	Gold		Stock		Property		Cryptocurrency	
	Exp1	Exp2	Exp1	Exp2	Exp1	Exp2	Exp1	Exp2
Gold	1	1	1	2	5	3	2	5
Stock	1	1/2	1	1	5	2	1/2	3
Property	1/5	1/3	1/5	1/2	1	1	1/8	6
Cryptocurrency	1/2	1/5	2	1/3	8	1/6	1	1
CR							0.079	0.087

3.2 Fuzzy geometric mean

Since all CR values were within acceptable limits, the next step was to convert the crisp values in the PCMs into Triangular Fuzzy Numbers (TFNs) using the scale provided in Table 1. Each expert's TFNs were then averaged to generate a combined input for further computation. The averaged TFNs for all PCMs are presented in Tables 8 to 12.

Table 8. Average of pairwise comparison matrix for criteria

Criteria	Capital	Profit	Risk	Sustainability
Capital	(1,1,1)	(2.5,3.5,4,.5)	(4.5,5.5,6.5)	(8,8.5,9)
Profit	(0.225,0.292,0.417)	(1,1,1)	(0.6,1.125,1.667)	(1,1.5,2)
Risk	(0.181,0.229,0.321)	(1.667,2.25,3)	(1,1,1)	(0.625,1.167,1.75)
Sustainability	(0.111,0.118,0.127)	(0.667,0.75,1)	(1.167,1.75,2.5)	(1,1,1)

Table 9. Average of pairwise comparison matrix for alternative with respect to capital

Alternative w.r.t capital	Gold	Stock	Property	Cryptocurrency
Gold	(1,1,1)	(1.5,2.5,3.5)	(3,4,5)	(3.5,4.5,5.5)
Stock	(0.292,0.417,0.75)	(1,1,1)	(3,4,5)	(4,5,6)
Property	(0.208,0.267,0.375)	(0.238,0.333,0.6)	(1,1,1)	(2,3,4)
Cryptocurrency	(0.183,0.225,0.292)	(0.188,0.238,0.333)	(0.267,0.375,0.667)	(1,1,1)

Table 10. Average of pairwise comparison matrix for alternative with respect to profit

Alternative w.r.t profit	Gold	Stock	Property	Cryptocurrency
Gold	(1,1,1)	(1,1.5,2)	(3,4,5)	(2.5,3.5,4.5)
Stock	(0.667,0.75,1)	(1,1,1)	(2.5,3.5,4.5)	(1.167,1.75,2.5)
Property	(0.208,0.267,0.375)	(00.25,0.35,0.625)	(1,1,1)	(2.556,3.063,3.571)
Cryptocurrency	(0.25,0.35,0.625)	(0.625,1.167,1.75)	(3.571,4.083,4.6)	(1,1,1)

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Table 11. Average of pairwise comparison matrix for alternative with respect to risk

Alternative w.r.t risk	Gold	Stock	Property	Cryptocurrency
Gold	(1,1,1)	(1,2,3)	(3,4,5)	(3.5,4.5,5.5)
Stock	(0.333,0.5,1)	(1,1,1)	(3,4,5)	(4,5,6)
Property	(0.208,0.267,0.375)	(0.238,0.333,0.6)	(1,1,1)	(3,4,5)
Cryptocurrency	(0.183,0.225,0.292)	(0.188,0.238,0.333)	(0.238,0.333,0.6)	(1,1,1)

Table 12. Average of pairwise comparison matrix for alternative with respect to sustainability

Alternative w.r.t sustainable	Gold	Stock	Property	Cryptocurrency
Gold	(1,1,1)	(1,1.5,2)	(3,4,5)	(2.5,3.5,4.5)
Stock	(0.667,0.75,1)	(1,1,1)	(2.5,3.5,4.5)	(1.167,1.75,2.5
Property	(0.208,0.267,0.375)	(0.25,0.35,0.625)	(1,1,1)	(2.556,3.063,3.571)
Cryptocurrency	(0.25,0.35,0.625)	(0.625,1.167,1.75)	(3.571,4.083,4.6)	(1,1,1)

Subsequently, the Fuzzy Geometric Mean was computed using Eq. (7), Eq. (8), and Eq. (9). The results, including the vector summation of the geometric mean and their reciprocals, are displayed in Tables 13 and 14. Table 13 shows the vector summation of the geometric mean for the criteria, while Table 14 displays the corresponding results for all alternatives with respect to each criterion.

Table 13. Vector summation of geometric mean of criteria

Criteria	TFN
Vector summation	(4.887,5.922,7.004)
Reciprocal	(0.143,0.169,0.205)

Table 14. Vector summation of geometric mean of alternatives with respect to all criteria

Alternative w.r.t.	Capital	Profit	Risk	Sustainability
Vector summation	(4.231,5.384,6.789)	(4.304,5.472,6.876)	(4.136,5.366,6.875)	(4.304,5.472,6.876)
Reciprocal	(0.147,0.186,0.236)	(0.145,0.183,0.232)	(0.145,0.186,0.242)	(0.145,0.183,0.232)

The process continued with the calculation of fuzzy weights for all criteria and alternatives, as described in Eq. (10). These fuzzy weights were then defuzzified and normalized using Eq. (11) and Eq. (12). The results are presented in Table 15 (for criteria) and Table 16 (for alternatives with respect to all criteria).

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Table 15. Fuzzy weight, defuzzified and normalized value for all criteria

Criteria	Fuzzy Weight	Defuzzified	Normalized	Rank
Capital	(0.44,0.604,0.826)	0.6233	0.5966	1
Profit	(0.087,0.142,0.223)	0.1502	0.1438	3
Risk	(0.094,0.149,0.234)	0.1589	0.1520	2
Sustainability	(0.077,0.106,0.154)	0.1125	0.1076	4
Total		1.0449	1.000	

Table 16. Fuzzy weight, defuzzified and normalized value for all alternative with respect to criteria

Criteria	Alternative	Fuzzy Weight	Defuzzified	Normalized
Capital	Gold	(0.293,0.482,0.739)	0.5046	0.4693
	Stock	(0.201,0.316,0.514)	0.3437	0.3197
	Property	(0.082,0.134,0.23)	0.1487	0.1383
	Cryptocurrency	(0.045,0.07,0.119)	0.0782	0.0727
Total			**1.0752**	**1.0000**
Profit	Gold	(0.24,0.392,0.601)	0.4109	0.3827
	Stock	(0.171,0.268,0.425)	0.2880	0.2683
	Property	(0.088,0.134,0.222)	0.1478	0.1376
	Cryptocurrency	(0.125,0.208,0.347)	0.2269	0.2114
Total			**1.0736**	**1.0000**
Risk	Gold	(0.261,0.456,0.729)	0.4820	0.4433
	Stock	(0.205,0.331,0.566)	0.3674	0.3379
	Property	(0.09,0.144,0.249)	0.1610	0.1481
	Cryptocurrency	(0.044,0.068,0.119)	0.0768	0.0707
Total			**1.0872**	**1.0000**
Sustainability	Gold	(0.24,0.392,0.601)	0.4109	0.3827
	Stock	(0.171,0.268,0.425)	0.2880	0.2683
	Property	(0.088,0.134,0.222)	0.1478	0.1376
	Cryptocurrency	(0.125,0.208,0.347)	0.2269	0.2114
Total			**1.0736**	**1.0000**

3.3 Final ranking of investment alternatives

The final step was to determine the ranking of each investment alternative. As shown in Table 17, the total score for each alternative was computed by multiplying its normalized value with the normalized weight of each criterion, then summing the products. The alternative with the highest total score was ranked first, followed by the next highest, and so on. This ranking process is illustrated in Eq. (13).

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Table 17. Ranking of the alternative

Alternative	Capital	Profit	Risk	Sustainability	Total (Summation the product of alternative and criteria)	Rank
	0.5966	0.1438	0.1520	0.1076		
Gold	0.4693	0.3827	0.4433	0.3827	0.4436	1
Stock	0.3197	0.2683	0.3379	0.2683	0.3095	2
Property	0.1383	0.1376	0.1481	0.1376	0.2359	3
Cryptocurrency	0.0727	0.2114	0.0707	0.2114	0.1605	4

Table 17 summarizes the final ranking of investment alternatives which include Gold, Stock, Property, and Cryptocurrency. The ranking is based on the total score calculated from the weighted sum of normalized fuzzy values across four evaluation criteria: capital, profit, risk, and sustainability. The criteria weights, derived through FAHP, are as follows: Capital (0.5966), Profit (0.1438), Risk (0.1520), and Sustainability (0.1076). Notably, Capital carries the highest weight, indicating that the experts considered it the most influential factor in investment decision-making.

Gold emerged as the top-ranked investment alternative, with the highest total score of 0.4436. This result reflects Gold’s strong performance across all four criteria, especially under the heavily weighted capital category, where it scored 0.4693. Its relatively high values in profit, risk, and sustainability further contributed to its dominance. This suggests that Gold is perceived as a relatively secure and stable investment, making it favorable under current financial conditions in Malaysia.

Stock was ranked second, with a total score of 0.3095. It showed moderately strong values in capital (0.3197) and risk (0.3379), though it was slightly less competitive in profit (0.2683) and sustainability (0.2683) compared to Gold. Nonetheless, its balanced performance across all criteria indicates that stocks remain a viable investment option, albeit with slightly higher perceived risk and volatility than gold.

Property ranked third, with a total score of 0.2359. It consistently scored lower across all criteria, particularly in capital (0.1383) and profit (0.1376). Despite being traditionally viewed as a stable long-term investment, these findings suggest that the high capital requirements and slower liquidity may reduce its appeal, especially in comparison to more liquid assets like gold and stocks.

Cryptocurrency was ranked last, with the lowest total score of 0.1605. While it performed reasonably well in profit (0.2114) and sustainability (0.2114), it’s extremely low scores in capital (0.0727) and risk (0.0707) significantly affected its overall ranking. This outcome reflects the experts’ cautious stance on cryptocurrencies, likely due to their high volatility, regulatory uncertainty, and speculative nature, making them less suitable for risk-averse investors in the Malaysian context.

The findings indicate that among the four alternatives, Gold is the most preferred investment, followed by Stock, Property, and Cryptocurrency. The strong emphasis placed on capital as the most critical factor influenced the rankings significantly. These insights can aid individual investors and financial planners in prioritizing investment options that align with their financial goals and risk tolerance.

4. CONCLUSIONS

This study employed the Fuzzy Analytic Hierarchy Process (FAHP) to support investment decision-making in the Malaysian context by evaluating and ranking four popular investment options namely gold, stocks,

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property, and cryptocurrency. These options were assessed based on four essential criteria which are capital requirement, profit potential, risk level, and sustainability.

Through structured expert input and the integration of fuzzy logic, the methodology successfully addressed the vagueness and imprecision commonly found in human judgment, particularly when evaluating qualitative aspects. The analysis revealed that gold emerged as the most preferred investment alternative, followed by stocks, property, and cryptocurrency. This ranking was significantly influenced by the capital criterion, which had the greatest weight in the final decision-making process. Gold's high score reflects its historical reputation for financial stability and relatively lower risk, making it a favorable choice for conservative investors.

Overall, the FAHP method demonstrated its strength in handling complex, multi-criteria decisions by offering a structured and transparent evaluation process. The study contributes meaningful insights for individual investors and financial advisors seeking rational, data-driven approaches to selecting suitable investment avenues.

Based on the findings of this study, several recommendations can be drawn to support more informed investment decisions. Individual or young investors, particularly those with limited experience, are encouraged to consider gold and stocks as preferred investment options, as they demonstrated the highest rankings based on the selected evaluation criteria. However, investment choices should still be guided by personal financial goals, risk tolerance, and long-term objectives. Financial advisors may find the FAHP approach useful as a structured decision-support tool, enabling them to provide clients with more data-driven and transparent recommendations.

Future research is recommended to expand the number of evaluation criteria, such as liquidity, market volatility, and taxation, to reflect a more comprehensive investment landscape. Additionally, incorporating inputs from a larger and more diverse group of experts could enhance the accuracy and generalizability of the results. From a policy perspective, the application of FAHP could be extended to national financial literacy initiatives, offering tools and frameworks to guide the public in making sound, rational investment decisions.

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6. CONFLICT OF INTEREST STATEMENT

The authors declare that this research was conducted without any personal, commercial, or financial conflicts of interest, and that no conflicts exist with the funders.

7. AUTHOR'S CONTRIBUTIONS

Mohd Fazril Izhar Mohd Idris: Conceptualisation, supervision, methodology, formal analysis, investigation, writing- review and editing, and validation; **Khairu Azlan Abd Aziz**: Conceptualisation, methodology, and formal analysis; **Ardini Athirah Mhd Munawar**: Conceptualisation, methodology, formal analysis, and writing-original draft.

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