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SMARTPHONE PURCHASING DECISION MAKING USING AN INTERVAL-VALUED INTUITIONISTIC FUZZY AHP APPROACH: A CASE STUDY IN MALANG CITY

Noor Hidayat[1], **Vira Hari Krisnawati**[2], **Sobri Abusini**[3], **Desfi Rahmatul Khairi**[4*]

[1,2,3,4]*Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya Jln. Veteran No.10-11, Ketawanggede, Lowokwaru, Malang, 65145, Indonesia*

*Corresponding author's e-mail: * **khairidesfi@gmail.com***

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ABSTRACT

The advancement of communication technology, particularly in the smartphone industry, has significantly influenced consumer purchasing behavior. This study aims to analyze the priority criteria in smartphone purchasing decisions using the Interval-valued Intuitionistic Fuzzy Analytic Hierarchy Process (IVIF-AHP) method. Data was collected through interviews with three experts in the smartphone industry in Malang City. The analysis results showed that camera quality (S_4) had the highest weight of 0.2725, followed by RAM/storage capacity (S_2) with a weight of 0.2365, and the multiple SIM feature (S_5) with a weight of 0.2245. Although battery life (S_3) and price (S_1) were also considered, they had lower weights of 0.1540 and 0.1125, respectively. These findings indicate that consumers prioritize features and quality over price. The application of the IVIF-AHP method allows handling uncertainty and produces more realistic priority weights that can be directly applied in marketing decision-making. This study also provides strategic implications for smartphone manufacturers: focus on promoting camera features and device performance, and consider the multiple-SIM feature in specific markets. In the future, adding other criteria, such as brand or screen size, could provide more comprehensive insights into decision-making.

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1. INTRODUCTION

The most popular form of communication is now smart or mobile phones with cutting-edge features [1]. Digitalization is being driven by the Fourth Industrial Revolution [2]. The intelligence of mobile phones has grown, as has their sensing capacity. The iPhone first appeared in 2007, and the Android operating system followed in 2008. Internet speed increased as telecom services switched from 2G to 3G and then to 4G networks [3]. The success of smartphones was driven by silicon processors with large capacities. Collectively, they sparked the development and popularity of smartphones. Smartphones are multifunctional devices that can be used for social networking, banking, mobile shopping, reading e-newspapers, taking high-definition photos, and recording high-definition movies [4]. Smart devices and phones should have features such as fingerprint sensors, voice and facial recognition, and more [5]. Communication technology has now entered the 5G era, which is being implemented in several major cities in Indonesia, such as Jakarta, Surabaya, Bandung, and Medan [6]. However, its coverage remains limited, reaching only about 9% of the national population [7]. Consequently, most users in Indonesia, including those in Malang City, still rely on 4G networks for their daily communication and smartphone usage.

In recent years, smartphone usage in Indonesia has increased significantly. According to the Central Statistics Agency (BPS) in August 2025, around 68.65% of Indonesia's population used smartphones in 2024, making the country one of those with the highest number of mobile internet users. Based on data from the Communication and Informatics Human Resources Research and Development Agency (Puslitbang Aptika), the highest proportion of smartphone ownership is found on Java Island (86.60%), indicating good telecommunication access and affordable device prices in the region. Specifically, in Malang City, around 89.52% of residents aged 5 years and over use mobile phones, showing a high level of smartphone adoption [8].

Marketing managers must recognize the importance of consumer purchasing behavior research in designing effective STP strategies to grow market share [9]. Consumer behavior is directly linked to marketing strategies [10]. This study captures consumer perceptions during the smartphone purchase process, enabling managers and engineers to adjust strategies and product designs and serving as a bridge between the market and industry. Findings also indicate that advertising strongly influences purchasing decisions [11]. Consumer behavior now extends beyond transactions to acquisition, consumption, and distribution [12]. Marketing strategies are guided by the marketing mix (4Ps for products and 7Ps for services [13], with exclusive branding emphasized as vital for smartphone sales [14]. Prior studies on smartphone purchasing behavior have been comprehensively analyzed. In today's competitive market, businesses, including smartphone producers, must understand consumer behavior to influence purchasing decisions. Consumer decision-making is complex and shaped by multiple factors [15]. In-depth analysis provides insights into key determinants and underlying motivations, supporting production management, pricing, research, and marketing strategies. Therefore, collecting and analyzing consumer perspectives is essential for decision-makers to streamline and improve the overall process [16].

The four primary steps of the purchase process are typically (i) identifying the need (issue), (ii) retrieving information, (iii) evaluating alternatives, and (iv) making a final decision. Because there are so many competing criteria to take into account, evaluating alternatives can be quite difficult. Because they have insufficient information, decision-makers frequently feel arbitrary and unsure about their preferences. The multicriteria decision-making technique can help decision-makers overcome these obstacles and guarantee an unbiased assessment of the options. Many competing criteria are prioritized through a multicriteria decision-making process that compares options based on them. To provide a more thorough assessment, it considers a wide range of elements, including both quantitative and qualitative features. Decision-makers can make more informed and objective choices by using multicriteria decision-making techniques [17].

One multicriteria decision-making technique that helps people or groups prioritize and choose between various decision aspects is the Analytic Hierarchy Process (AHP). By decomposing complicated issues into a hierarchical framework and making it easier to compare criteria and options, it provides an organized method for decision-making. According to Gompf et al [18], the AHP hierarchy facilitates the efficient organization and analysis of complicated problems. The Analytic Hierarchy Process (AHP) assigns numerical values to decision-makers' preferences, considers both quantitative and qualitative factors, and uses consistency tests to validate judgments. Its simplicity, flexibility, and support for sensitivity analysis make it suitable for diverse decision-making contexts [19]. The AHP approach has shown effectiveness in addressing a number of decision-making issues, including supply chain resilience assessment, transportation utilization, and releasing the influence of security features in the Internet paradigm [20], [21], [22].

Decision-making is often challenged by uncertainties arising from incomplete data, subjective judgments, and ambiguity, which may reduce the reliability of models. Although effective, AHP is also sensitive to such uncertainties, as decision-makers may struggle to assign precise numerical values in pairwise comparisons. To address this, researchers have integrated fuzzy set theory with AHP, thereby providing a framework for handling imprecise and subjective information. Unlike classical sets, fuzzy sets allow degrees of membership, enabling better representation of human judgment and linguistic preferences. The combination of fuzzy set theory and AHP thus offers a robust approach for improving decision-making under uncertainty [23], [24]. The need for greater adaptability in real-world contexts has driven the extension of fuzzy sets. The intuitionistic fuzzy set (IFS) enhances uncertainty modeling by incorporating membership, non-membership, and hesitation degrees [25]. Further, the interval-valued intuitionistic fuzzy set (IVIFS) allows parameters to be expressed as intervals, offering a more precise representation of uncertainty. When integrated with AHP, IVIFS improves the quality and reliability of decision outcomes [26].

The literature study indicates that there is a dearth of thorough studies that address the ambiguities in this field and talk about smartphone selection. This investigation is motivated by this information gap. The following is a description of the study's goals: The goals are (i) to identify criteria for smartphone purchases and give decision makers alternatives for smartphones; (ii) to model opinions using an interval-valued intuitionistic fuzzy AHP-based decision-making framework; (iii) to highlight the significance of each criterion in a fuzzy decision-making environment; (iv) to add to the body of knowledge already available in the literature on smartphone selection criteria; and (v) to give decision makers fresh, thorough, and useful advice.

2. RESEARCH METHODS

2.1 Interval-Valued Intuitionistic Fuzzy Set

In 1965, Zadeh introduced fuzzy logic to the literary world [27]. Classical logic is extended by fuzzy logic to deal with imprecision and uncertainty. In contrast to classical logic, which relies on rigid true-or-false values, fuzzy logic recognizes that many real-world issues involve components that are difficult to classify in such a straightforward way. It offers a framework capable of reasoning and decision-making that takes into account reality's inherent fuzziness. The fuzzy set serves as the foundation of fuzzy logic and provides an adaptable, natural way to handle uncertainty through linguistic variables. Membership levels can range from 0 (no membership) to 1 (full membership), which is called an intuitionistic fuzzy set (Ifs) [28]. IFS theory, an expanded form of fuzzy set theory, was proposed by Atanassov. While Zadeh's theory provides only a membership function specified between 0 and 1, Atanassov adds a non-membership function for IFSs.

Definition 1. *Let X be a set that isn't empty. In X, an IFS A is provided* [29]:

$$A = \{(x, \mu_A(x), v_A(x)) \mid x \in X\}, \tag{1}$$

where the function $\mu_A : X \to [0,1]$ and $v_A : X \to [0,1]$ defines the membership and non-membership degree of an element to the set A, respectively, with the condition that

$$0 \leq \mu_A(x) + v_A(x) \leq 1 \text{ for } \forall\ x \in X. \tag{2}$$

The degree of hesitancy is obtained as follows

$$\pi_A(x) = 1 - \mu_A(x) - v_A(x). \tag{3}$$

When assessing the criteria and options, interval numbers are employed to more accurately represent uncertainty [30]. In this study, the fuzziness and vagueness are addressed by using interval-valued fuzzy integers. The following are the IVIFS preliminary results [31].

Definition 2. *The Interval-valued intuitionistic fuzzy sets (IVIFSs) is donated* [32] Fig. 1.

$$A = \{(x, [\mu_A^-(x), \mu_A^+(x)], [v_A^-(x), v_A^+(x)]) \mid x \in X\}, \tag{4}$$

where,

$$0 \leq \mu_A^-(x), \mu_A^+(x),\ v_A^-(x), v_A^+(x) \leq 1 \text{ for } \forall\ x \in X \tag{5}$$

$$\mu_A^-(x) \leq \mu_A^+(x) \text{ and } v_A^-(x) \leq v_A^+(x) \tag{6}$$

$$\mu_A^+(x) + v_A^+(x) \leq 1 \text{ and } \mu_A^-(x) + v_A^-(x) \leq 1 \tag{7}$$

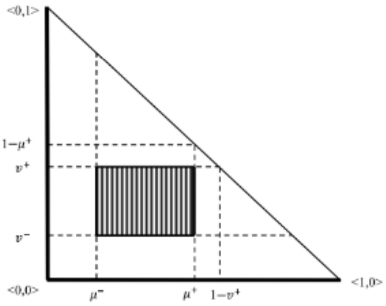

Figure 1. An Illustration of the Interval Valued Intuitionistic Fuzzy Set

The unknown degree (hesitancy degree) of an interval-valued intuitionistic fuzzy set can be calculated for each element $x \in X$ in A defined as in Eq. (8).

$$\pi_A(x) = [\pi_A^-(x), \pi_A^+(x)], \tag{8}$$

where,

$$\pi_A^-(x) = 1 - \mu_A^+(x) - v_A^+(x),$$

and

$$\pi_A^+(x) = 1 - \mu_A^-(x) - v_A^-(x).$$

Definition 3. *Let* $\boldsymbol{A} = ([\mu_A^-, \mu_A^+], [v_A^-, v_A^+])$, $\boldsymbol{A_1} = ([\mu_{A_1}^-, \mu_{A_1}^+], [v_{A_1}^-, v_{A_1}^+])$ *and* $\boldsymbol{A_2} = ([\mu_{A_2}^-, \mu_{A_2}^+], [v_{A_2}^-, v_{A_2}^+])$ *be three IVIFSs and* $\boldsymbol{\lambda > 0}$, *then their operations are defined as follows* [20].

$$A_1 \oplus A_2 = ([\mu_{A_1}^- + \mu_{A_2}^- - \mu_{A_1}^- . \mu_{A_2}^-\ , \mu_{A_1}^+ + \mu_{A_2}^+ - \mu_{A_1}^+ . \mu_{A_2}^+\ ], \quad [v_{A_1}^- . v_{A_2}^-\ , \ v_{A_1}^+ . v_{A_2}^+]) \tag{9}$$

$$A_1 \otimes A_2 = ([\mu_{A_1}^- . \mu_{A_2}^-\ , \ \mu_{A_1}^+ . \mu_{A_2}^+\ ], \ [v_{A_1}^- + v_{A_2}^- - v_{A_1}^- . v_{A_2}^-\ , \quad v_{A_1}^+ + v_{A_2}^+ - v_{A_1}^+ . v_{A_2}^+]) \tag{10}$$

$$\lambda A = ([1 - (1 - (\mu_A^-)^\lambda, 1 - (1 - (\mu_A^+)^\lambda], [(v_A^-)^\lambda (v_A^+)^\lambda]) \tag{11}$$

$$A^\lambda = ([(\mu_A^-)^\lambda (\mu_A^+)^\lambda], [1 - (1 - (v_A^-)^\lambda, 1 - (1 - (v_A^+)^\lambda]) \tag{12}$$

Definition 4. *Let* $\boldsymbol{A} = ([\mu_A^-(x), \mu_A^+(x)], [v_A^-(x), v_A^+(x)])$ *be an IVIFS of* $\boldsymbol{x \in X}$, *then score function* $'\boldsymbol{S}'$ *can be computed as* [33].

$$S(A) = \frac{\mu_A^- + \mu_A^+ - v_A^- - v_A^+}{2} \tag{13}$$

Definition 5. *Let* $\boldsymbol{A} = ([\mu_A^-(x), \mu_A^+(x)], [v_A^-(x), v_A^+(x)])$ *be an IVIFS of* $\boldsymbol{x \in X}$, *then Accuracy function* $'\boldsymbol{H}'$ *can be computed as* [33].

$$H(A) = \frac{\mu_A^- + \mu_A^+ + v_A^- + v_A^+}{2} \tag{14}$$

Definition 6. *Let* $\boldsymbol{\alpha_i = ([j_i, k_i], [l_i, m_i])}$ $\ (\boldsymbol{i = 1, 2, 3, \dots, n})$ *be a collection of IVIFNs. Then the interval valued intuitionistic fuzzy weighted averaging (IVIFWA) operator is defined as* $\boldsymbol{Q^n \to Q}$, *if* $\boldsymbol{IVIFWA_\omega(\alpha_1, \alpha_2, \alpha_3, \dots, \alpha_n) = \omega_1\alpha_1 \oplus \omega_2\alpha_2 \oplus \omega_3\alpha_3 \oplus \dots \oplus \omega_n\alpha_n}$, *where,* $(\boldsymbol{\omega = \omega_1, \omega_2, \omega_3, \dots, \omega_n})$ *is the weight vector an* $\boldsymbol{Q}$ *is the set of* $\boldsymbol{IVIFNs}$ *such that,* $\boldsymbol{\omega_x > 0, \sum_{i=1}^n \omega_i = 1}$. *The IVIFWA operator can be further expanded into following form* [22]:

$$\boldsymbol{IVIFWA_\omega(\alpha_1, \alpha_2, \alpha_3, \dots, \alpha_n)}$$

$$= \left(\left[1 - \left(\prod_{i=1}^{n} (1 - j_i)\right)^{\omega_i}\right]\right), \left(\left[1 - \left(\prod_{i=1}^{n} (1 - k_i)\right)^{\omega_i}\right]\right), \left(\left[\left(\prod_{i=1}^{n} (l_i)\right)^{\omega_i}, \left(\prod_{i=1}^{n} (m_i)\right)^{\omega_i}\right]\right) \tag{15}$$

If $\boldsymbol{\omega_i} = \left(\frac{1}{n}, \frac{1}{n}, \frac{1}{n}, \dots, \frac{1}{n}\right)$, then the IVIFWA operator will be reduced to [22]:

$$\boldsymbol{IVIFWA}(\alpha_1, \alpha_2, \alpha_3, \dots, \alpha_n)$$
$$= \left(\left[1 - \left(\prod_{i=1}^{n} (1 - j_i)\right)^{\frac{1}{n}}\right]\right), \left(\left[1 - \left(\prod_{i=1}^{n} (1 - k_i)\right)^{\frac{1}{n}}\right]\right), \left(\left[\left(\prod_{i=1}^{n} (l_i)\right)^{\frac{1}{n}}, \left(\prod_{i=1}^{n} (m_i)\right)^{\frac{1}{n}}\right]\right) \tag{16}$$

the above weighted averaging equation can be used directly for the cases where the weight are equally distributed.

2.2 Interval Valued Intuitionistic Analytic Hierarchy Process

Fuzzy logic-based AHP techniques have emerged which are more successful in managing ambiguity, imprecision, and subjective preferences by representing human judgements using linguistic phrases and fuzzy numbers. This feature guarantees a more accurate depiction of the preferences of decision makers [17]. The interval-valued intuitionistic fuzzy AHP approach is used in this study because of its efficacy. The application of the AHP approach to the interval-valued intuitionistic fuzzy set has attracted a lot of attention from scholars and has many uses in a variety of fields. The following is a list of some noteworthy research that have applied the interval-valued intuitionistic fuzzy AHP approach: evaluation of outsource manufacturers [31], corridor selection [32], transportation service quality evaluation [20], green supply chain [21], PhD supervisor selection [34], and etc. In this study, the linguistic scale used to express the importance level among criteria was adapted from previous relevant research [35] and then converted into Interval-Valued Intuitionistic Fuzzy Numbers (IVIFN). Figure 2 illustrates the hierarchical structure of the smartphone selection model used in this study. The IVIF AHP process considered in this study consists of the following steps:

Step 1: Construct the pairwise comparison matrix according to the expert's assessment using the linguistic scale given in Table 2.

Step 2: Construct the aggregated pairwise comparison matrix using Eq. (16).

Step 3: The consistency of aggregated pairwise comparisons is calculated using Hesitancy degree Eq. (8) and Random Index Table given in Table 3.

$$Consistency\ ratio = \frac{Random\ index - \left(\frac{\sum \pi_{A_{ij}}^{-}}{n}\right)}{n - 1}, \tag{17}$$

where n is the size of the matrix. According to Saaty [36] for a matrix to be consistent the CR ≤ 0.10.

Step 4: Score judgment of the aggregated pairwise comparison matrix is calculated using Eq. (18), $S = (s_{ij})_{n \times n}$.

$$S = \begin{bmatrix} ([\mu_{11}^{-} - v_{11}^{+}], [\mu_{11}^{+} - v_{11}^{-}]) & \dots & ([\mu_{1n}^{-} - v_{1n}^{+}], [\mu_{1n}^{+} - v_{1n}^{-}]) \\ \vdots & \ddots & \vdots \\ ([\mu_{n1}^{-} - v_{n1}^{+}], [\mu_{n1}^{+} - v_{n1}^{-}]) & \dots & ([\mu_{nn}^{-} - v_{nn}^{+}], [\mu_{nn}^{+} - v_{nn}^{-}]) \end{bmatrix}, \tag{18}$$

where $s_{ij} = ([\mu_{ij}^{-} - v_{ij}^{+}], [\mu_{ij}^{+} - v_{ij}^{-}])$.

Step 5: Formulate the interval exponential matrices (A) as given in Eq. (19) as follows:

$$A = \begin{bmatrix} \left[e^{(\mu_{11}^{-} - v_{11}^{+})}, e^{(\mu_{11}^{+} - v_{11}^{-})}\right] & \dots & \left[e^{(\mu_{1n}^{-} - v_{1n}^{+})}, e^{(\mu_{1n}^{+} - v_{1n}^{-})}\right] \\ \cdots & \ddots & \cdots \\ \left[e^{(\mu_{n1}^{-} - v_{n1}^{+})}, e^{(\mu_{11}^{+} - v_{11}^{-})}\right] & \dots & \left[e^{(\mu_{nn}^{-} - v_{nn}^{+})}, e^{(\mu_{nn}^{+} - v_{nn}^{-})}\right] \end{bmatrix}$$
$$= \begin{bmatrix} [\beta_{11}^{-}, \beta_{11}^{+}] & \dots & [\beta_{1n}^{-}, \beta_{1n}^{+}] \\ \cdots & \ddots & \cdots \\ [\beta_{n1}^{-}, \beta_{n1}^{+}] & \dots & [\beta_{nn}^{-}, \beta_{nn}^{+}] \end{bmatrix} \tag{19}$$

Step 6: Calculating the priority vector of each criterion using (20) as follows:

$$\widetilde{w}_i = \left[\frac{\sum_{j=1}^{n}\beta_{ij}^{-}}{\sum_{i=1}^{n}\sum_{j=1}^{n}\beta_{ij}^{+}}, \frac{\sum_{j=1}^{n}\beta_{ij}^{+}}{\sum_{i=1}^{n}\sum_{j=1}^{n}\beta_{ij}^{-}}\right] = [w_i^{-}, w_i^{+}], \quad (20)$$

where $i = 1,2,3,\ldots,n$.

Step 7: Construct the possibility degree matrices ($P = (p_{ij})_{m\times n}$) by using Eq. (21) as

$$\begin{cases} P(\widetilde{w}_i > \widetilde{w}_j) = p_{ij} = \dfrac{max\ (0,\ [w_i^{+} - w_j^{-}]) - max\ (0,\ [w_i^{-} - w_j^{+}])}{[w_i^{+} - w_i^{-}] + [w_j^{+} - w_j^{-}]} \\ P(\widetilde{w}_j > \widetilde{w}_i) = p_{ij} = \dfrac{max\ (0,\ [w_j^{+} - w_i^{-}]) - max\ (0,\ [w_j^{-} - w_i^{+}])}{[w_i^{+} - w_i^{-}] + [w_j^{+} - w_j^{-}]} \end{cases} \quad (21)$$

Step 8: Possibility degree is prioritized using Eq. (22) as

$$w_i = \frac{\sum_{j=1}^{n} p_{ij} - 1}{n} + 0.5 \quad (22)$$

Step 9: The weight is normalized as given in Eq. (23) and obtain the final weight as

$$w_i^T = \frac{w_i}{\sum_{i=1}^{n} w_i}. \quad (23)$$

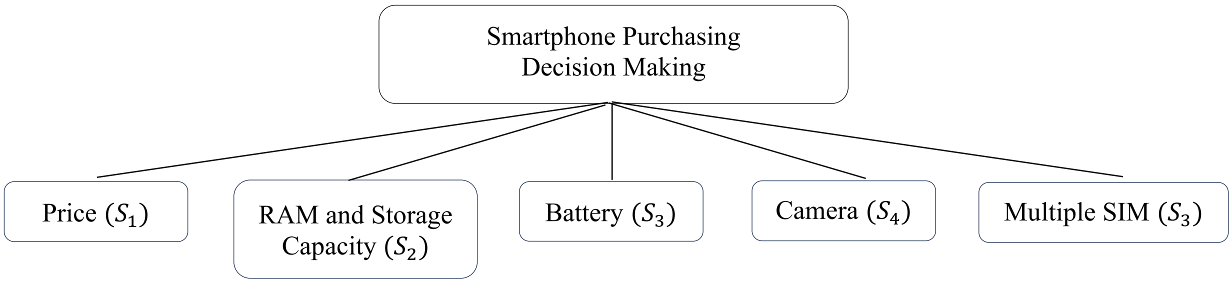

Figure 2. The Hierarchical Structure Smartphone Purchasing Decision Making

Table 1. References of Criteria

	Criteria	Reference
S_1	Price	[37]
S_2	RAM and Storage Capacity	[38]
S_3	Battery	[39]
S_4	Camera	[38]
S_5	Multiple SIM	[40]

Table 2. Linguistic Terms of IVIF-AHP [35]

Linguistic Terms	IVIFN Membership and Non-Membership Values			
	μ^{-}	μ^{+}	v^{-}	v^{+}
Absolutely low importance (ALI)	0.10	0.25	0.65	0.75
Very low importance (VLI)	0.15	0.30	0.60	0.70
Low importance (LI)	0.20	0.35	0.55	0.65
Medium low importance (MLI)	0.25	0.40	0.50	0.60
Equal importance (EI)	0.50	0.50	0.50	0.50
Medium high importance (MHI)	0.50	0.60	0.25	0.40
High importance (HI)	0.55	0.65	0.20	0.35
Very high importance (VHI)	0.60	0.70	0.15	0.30
Absolutely high importance (AHI)	0.65	0.75	0.10	0.25

Table 3. Random Index for Each Matrix Size

n	1 – 2	3	4	5	6	7	8	9
RI	0.0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

3. RESULTS AND DISCUSSION

Smartphones have become a highly sought-after communication tool worldwide, with various criteria influencing purchasing decisions. To obtain data for analyzing smartphone purchasing decision-making among the people in Malang City, data were collected from three experts who work as smartphone counter managers in Malang City. These experts were selected because they have direct experience in observing and assessing consumer purchasing behavior in the smartphone market. The following information is about experts in assessing consumer behavior.

Tabel 4. List of Smartphone Experts

No.	Expert Name	Description	Experience (in years)
1	Expert 1	Branch Manager of Meteor Cell Gajayana	9
2	Expert 2	Branch Manager of Erafone Malang Town Square	6
3	Expert 3	Branch Manager of Ivancell Mt. Haryono	10

3.1 Weight Calculation using IVIF-AHP

Step 1. The linguistic pairwise comparison matrix in Table 5 was obtained from interviews with several experts. The assessments were expressed using linguistic terms, which were then converted into Interval-Valued Intuitionistic Fuzzy Numbers (IVIFN) based on the scale presented in Table 2 to construct the IVIF AHP-based pairwise comparison matrix.

Table 5. The Linguistic Pairwise Comparison Matrix From The Experts.

	Expert 1					Expert 2					Expert 3				
	S_1	S_2	S_3	S_4	S_5	S_1	S_2	S_3	S_4	S_5	S_1	S_2	S_3	S_4	S_5
S_1	EI	VLI	MLI	ALI	ALI	EI	LI	MLI	ALI	ALI	EI	LI	LI	VLI	ALI
S_2		EI	HI	MLI	HI		EI	MHI	LI	HI		EI	MHI	LI	HI
S_3			EI	VLI	LI			EI	VLI	VLI			EI	ALI	MLI
S_4				EI	MHI				EI	MHI				EI	HI
S_5					EI					EI					EI

Step 2. The data from Table 5 provided by the experts are aggregated using Eq. (16), and the aggregated pairwise comparison matrix is presented in Table 6. The aggregate values $S_1 - S_2$ from Table 5 are calculated using the appropriate comparison scale, namely VLI, LI, and LI. The IVIF values associated with these terms are $([0.15,0.30],[0.60,0.70])$, $([0.2,0.35],[0.55,0.65])$, and $([0.2,0.35],[0.55,0.65])$ respectively, resulting in the aggregate value $S_1 - S_2$:

$$1-\left(\sqrt[3]{(1-0.15)\times(1-0.2)\times(1-0.2)}\right)=0.18$$

$$1-\left(\sqrt[3]{(1-0.30)\times(1-0.35)\times(1-0.35)}\right)=0.33$$

$$\sqrt[3]{(0.60)\times(0.55)\times(0.55)}=0.57$$

$$\sqrt[3]{(0.70)\times(0.65)\times(0.65)}=0.67.$$

Table 6. The Aggregate Pairwise Comparison Matrix

	S_1	S_2	S_3	S_4	S_5
S_1	[0.50,0.50] , [0.50,0.50]	[0.18, 0.33] , [0.57,0.67]	[0.23,0.38], [0.52,0.62]	[0.12,0.27], [0.63,0.73]	[0.10,0.25], [0.65,0.75]
S_2	[0.57,0.67], [0.18,0.33]	[0.50,0.50] , [0.50,0.50]	[0.52,0.62], [0.23,0.38]	[0.22,0.37], [0.53,0.63]	[0.55,0.65], [0.2,0.35]
S_3	[0.52,0.62], [0.23,0.38]	[0.23,0.38], [0.52,0.62]	[0.50,0.50], [0.50,0.50]	[0.13,0.28], [0.62,0.72]	[0.20,0.35], [0.55,0.65]
S_4	[0.63,0.73], [0.12,0.27]	0.53,0.63], [0.22,0.37]	[0.62,0.72], [0.13,0.28]	[0.50,0.50] , [0.50,0.50]	[0.52,0.62], [0.23,0.38]
S_5	[0.65,0.75], [0.10,0.25]	[0.20,0.35], [0.55,0.65]	[0.55,0.65], [0.20,0.35]	[0.23,0.38], [0.52,0.62]	[0.50,0.50] , [0.50,0.50]

Step 3. The consistency ratio is calculated for the aggregate pairwise comparison matrix using Eq. (17). The consistency ratio value found is 0.03, which is less than 0.1. Therefore, the aggregate pairwise comparison matrix is consistent.

Step 4. The judgment scores from the elements of the pairwise comparison matrix in Table 6 are calculated using Eq. (18). The judgment score matrix is shown in Table 7.

Table 7. The Judgment Score Matrix

	S_1	S_2	S_3	S_4	S_5
S_1	[0,0]	[−0.49 , −0.24]	[−0.39, −0,14]	[−0.61, −0,36]	[−0.65, −0.4]
S_2	[0.24,0.49]	[0,0]	[0.14,0.39]	[−0.41, −0.16]	[0.2,0.45]
S_3	[0.14,0.39]	[−0.39, −,14]	[0,0]	[−0.59, −0.34]	[−0.45, −0.2]
S_4	[0.36,0.61]	[0.16,0.41]	[0.34,0.59]	[0,0]	[0.14,0.39]
S_5	[0.4,0.65]	[−0.45, −0.2]	[0.2,0.45]	[−0.39, −0.14]	[0,0]

Step 5. The exponential interval matrix is calculated using the judgment scores from step 4. The exponential interval matrix is shown in Table 8.

Table 8. The Exponential Interval Matrix

	S_1	S_2	S_3	S_4	S_5
S_1	[1,1]	[0.61,0.79]	[0.68,0.87]	[0.54,0,70]	[0.52,0.67]
S_2	[1,27,1.63]	[1,1]	[1.15,1.48]	[0.66,0.85]	[1.22,1.57]
S_3	[1.15,1.48]	[0.68,0.87]	[1,1]	[0.55,0.71]	[0.64,0.82]
S_4	[1.43,1.84]	[1.17,1.50]	[1.41,1.8]	[1,1]	[1.15,1.48]
S_5	[1.49,1.92]	[0.64,0.82]	[1.22,1.57]	[0.68,0.87]	[1,1]

Step 6. The priority vector is calculated using the values in Table 8 with Eq. (20).

$$\sum_{j=1}^{n} \tilde{a}_{1j}^{-} = 3.35\ ,\sum_{j=1}^{n} \tilde{a}_{2j}^{-} = 5.3\ ,\sum_{j=1}^{n} \tilde{a}_{3j}^{-} = 4.02\ ,\sum_{j=1}^{n} \tilde{a}_{4j}^{-} = 6.16,\sum_{j=1}^{n} \tilde{a}_{5j}^{-} = 5.03.$$

$$\sum_{j=1}^{n} \tilde{a}_{1j}^{+} = 4.03\ ,\sum_{j=1}^{n} \tilde{a}_{2j}^{+} = 6.53\ ,\sum_{j=1}^{n} \tilde{a}_{3j}^{+} = 4.88\ ,\sum_{j=1}^{n} \tilde{a}_{4j}^{+} = 7.62,\sum_{j=1}^{n} \tilde{a}_{5j}^{+} = 6.18.$$

$$\sum_{i=1}^{n}\sum_{j=1}^{n} \tilde{a}_{ij}^{-} = 23.86,\quad \sum_{i=1}^{n}\sum_{j=1}^{n} \tilde{a}_{ij}^{+} = 29.24.$$

The priority vector:

$$\widetilde{w}_1 = \left[\frac{3.35}{29.24}, \frac{4.03}{23.86}\right] = [0.11,0.17],\qquad \widetilde{w}_4 = \left[\frac{6.16}{29.24}, \frac{7.62}{23.86}\right] = [0.21,032],$$

$$\widetilde{w}_2 = \left[\frac{5.3}{29.24}, \frac{6.53}{23.86}\right] = [0.18,0.27],\qquad \widetilde{w}_5 = \left[\frac{5.03}{29.24}, \frac{6.18}{23.86}\right] = [0.17,026].$$

$$\widetilde{w}_3 = \left[\frac{4.02}{29.24}, \frac{4.88}{23.86}\right] = [0.14,0.20],$$

Step 7. The degree of possibility is calculated using Eq. (21) and is shown in Table 9.

$$P(\widetilde{w}_1 > \widetilde{w}_2) = p_{ij} = \frac{\max(0,\ [w_1^+ - w_2^-]) - \max(0,\ [w_1^- - w_2^+])}{[w_1^+ - w_1^-] + [w_2^+ - w_2^-]}$$

$$= \frac{\max(0,[0.17-0.18]) - \max(0,[0.11-0.27])}{[0.17-0.11]+[0.27-0.18]} = \frac{0}{0.15} = 0.$$

$$P(\widetilde{w}_2 > \widetilde{w}_1) = p_{ij} = \frac{\max(0,\ [w_2^+ - w_1^-]) - \max(0,\ [w_2^- - w_1^+])}{[w_1^+ - w_1^-] + [w_2^+ - w_2^-]}$$

$$= \frac{\max(0,[0.27-0.11]) - \max(0,[0.18-0.17])}{[0.17-0.11]+[0.27-0.18]} = \frac{0.16-0.01}{0.15} = 1.$$

Step 8. The prioritized degree of possibility is calculated with Eq. (22) and is also shown in Table 9.

$$w_i = \frac{\sum_{j=1}^{n} p_{ij} - 1}{n} + 0.5$$

$$w_1 = \frac{0.75 - 1}{5} + 0.5 = 0.45,$$

$$w_2 = \frac{3.23 - 1}{5} + 0.5 = 0.95.$$

Step 9. The normalized weights are calculated using Eq. (23) and are presented in Table 9.

$$w_1^T = \frac{w_1}{\sum_{i=1}^{n} w_i}$$

$$w_1^T = \frac{0.45}{(0.45 + 0.95 + 0.62 + 1.09 + 0.9)} = 0.1125,$$

$$w_2^T = \frac{0.95}{(0.45 + 0.95 + 0.62 + 1.09 + 0.9)} = 0.2365.$$

Table 9. **Matrix of Possibility Degrees and Criteria Weights.**

	S_1	S_2	S_3	S_4	S_5	Degree Of Possibility	Weight
S_1	0.5	0	0.25	0	0	0.45	0.1125
S_2	1	0.5	0.87	0.3	0.56	0.95	0.2365
S_3	0.75	0.13	0.5	0	0.2	0.62	0.1540
S_4	1	0.7	1	0.5	0.75	1.09	0.2725
S_5	1	0.44	0.8	0.25	0.5	0.9	0.2245

3.2 Discussion

Based on the data above, the priority criteria in smartphone purchase decision-making show that Camera (S_4) as the highest weight of 0.2725. This indicates that camera quality is the primary factor considered by consumers. It is followed by RAM/Storage Capacity (S_2) with a weight of 0.2365 and Multiple SIM (S_5) with a weight of 0.2245, reflecting the importance of device performance and flexibility in supporting the use of multiple SIM cards. Battery (S_3) although important, has a relatively low weight of 0.1540, indicating that battery life is an additional consideration. Price (S_1) holds the lowest position with a weight of 0.1125, indicating that consumers are more focused on the features and quality of the smartphone than on its cost.

The degree of possibility matrix shows how each criterion is compared with one another. For example, the high values of S_4 compared to S_1, S_2 and others indicate that the camera is often considered more important than the other criteria. Meanwhile, the value of 1 for S_2 compared S_1 and S_5 compared S_1 indicates that RAM/Storage Capacity and Multiple SIM are consistently more important than price. RAM/ Storage Capacity and multiple SIM features are considered more important than price as they directly affect smartphone performance and user convenience. Larger RAM/Storage Capacity supports smooth multitasking, while multiple SIM feature is valued since many Indonesian users, including those in Malang, use more than one SIM card to separate personal and work needs or to optimize signal strength and data costs across different operators. Therefore, although price remains a consideration, functionality and efficiency tend to play a more decisive role in smartphone purchasing decisions.

The implications of these results for smartphone marketing strategy are that manufacturers should focus on promoting camera features and device performance as the main selling points. The Multiple SIM feature can also serve as an additional advantage, especially in developing markets where dual SIM usage is common. Although price has the lowest weight, manufacturers still need to offer products at a price that matches the value of the features provided to reach price-sensitive consumers.

The use of the Interval-valued Intuitionistic Fuzzy AHP (IVIF-AHP) method in this analysis provides flexibility in handling uncertainty and subjectivity in consumer preferences. By considering fuzzy values, this method generates realistic priority weights that can be directly applied in decision-making. However, it should be noted that the results of the analysis are highly dependent on the preferences of the decision-makers. Adding criteria such as brand, screen size, or operating system could provide more comprehensive insights. Therefore, this method not only helps consumers make better decisions but also supports manufacturers in developing more effective strategies.

4. CONCLUSION

This research concludes that consumer purchasing behavior, especially in the smartphone market is primarily driven by product features rather than price, with camera quality, RAM/storage capacity, and the ability to use multiple SIM emerging as the most influential factors. The application of the IVIF-AHP method confirmed that Camera (S_4) holds the highest priority, followed by RAM/Storage Capacity (S_2) and Multiple SIM (S_5), while battery life (S_3) and price (S_1) are less significant in influencing consumer choices These findings emphasize the critical role af advanced decison-making methods, such as AHP and IVIF-AHP, in analyzing consumer preferences under uncertainty and subjectivity.

Author Contributions

Noor Hidayat: Conceptalization, Methodology, Validation, Visualization, Supervision. Vira Hari Krisnawati: Methodology, Visualization, Supervision. Sobri Abusini: Review, Validation, Software. Desfi Rahmatul Khairi: Data Collection, Writing-Review, and Editing. All authors discussed the results and contributed to the final manuscript.

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Declarations

The authors declare no conflicts of interest to report study.

Declaration of Generative AI and AI-assisted technologies

Generative AI tools (e.g., ChatGPT) were used solely for language refinement (grammar, spelling, and clarity). The scientific content, analysis, interpretation, and conclusions were developed entirely by the authors. The authors reviewed and approved all final text.

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