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DECISION SUPPORT SYSTEM FOR SMARTPHONE RECOMMENDATION: THE COMPARISON OF FUZZY AHP AND FUZZY ANP IN MULTI-ATTRIBUTE DECISION MAKING

Okfalisa[1*], Hidayati Rusnedy[1], Dwi Utari Iswavigra[1], B. Pranggono[2], Elin Haerani[1], Toto Saktioto[3]
[1]Department of Informatics, Universitas Islam Negeri Sultan Syarif Kasim, Indonesia
[2]Department of Engineering and Mathematics, Sheffield Hallam University, United Kingdom
[3]Department of Physics, Universitas Riau, Indonesia

Abstract
Previous researches outlined the advantages of the Analytical Hierarchy Process (AHP) and Analytic Network Process (ANP) methods in solving Multi-Attribute Decision Making (MADM) problems. The advancement of the above methods was continually developed as an effort to cover up various weaknesses. Mainly related to the consistency and linguistic variables in translating the expert opinions. Thus, it initialized the emergence of Fuzzy AHP (F-AHP) and Fuzzy ANP (F-ANP). Due to the restricted operation of these algorithms in smartphone selection, this research attempted to investigate the effectiveness of both methods in providing the analysis of criteria weight, the final recommendation weight, the product recommendation weight, and the execution time in DSS-SmartPhoneRec application development. A survey of one hundred respondents of University students identified the dominant criteria in selecting the smartphone, namely price, Random Access Memory (RAM), processor, internal memory, and camera. Hence, five alternative products were then chosen as the appropriate smartphones' recommendations based on the respondent's preferences. As an automatic tool, a DSS-SmartPhoneRec application was built to analyze and compare between F-AHP and F-ANP methods in resolving the smartphone selection cases. It revealed that the level of consistency of criteria weight, the final weight of recommendation, and the weight that the product-based F-ANP was 40% greater than F-AHP. In terms of execution time, F-AHP had a shorter time than F-ANP. Meanwhile, the comparison of products recommendation from DSS-SmartPhoneRec and a manual test showed that F-ANP was 16% more in line with the respondents' predilection. In a nutshell, the DSS-SmartPhoneRec administered the devote smartphone recommendations based on the user's expectation. The comparison analysis furnished a learning outcome for the users in determining the appropriate MADM method tailored to the type of cases.

Keywords:
Decision Support System;
F-AHP;
F-ANP;
Recommendation System;
Smartphone Selection;

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Corresponding Author:
Okfalisa
Department of Informatics
Universitas Islam Negeri Sultan Syarif Kasim, Indonesia
Email: okfalisa@gmail.com

INTRODUCTION

Multi-Attribute Decision Making (MADM) is an important part of modern decision science. Thus, MADM becomes one of the decision-making methods that is effectively used in choosing the alternatives based on several attributes [1]. These groups of alternatives and their attributes are then evaluated and analyzed to aid the decision-makers in deciding. MADM has been widely applied in various scientific fields in the decision-making process, such as in the fields of engineering, economics, management, and transportation planning [2]. MADM can find the foremost desired alternative by ranking its feasibility as a recommendation for decision-makers in supporting the decision-making process [3]. The diverse MADM methods have been developed to resolve the numerous decision problems, like AHP, ANP, F-AHP, and F-ANP.

However, it cannot be ignored that the fuzzy nature of human life makes MADM analysis more difficult. This is related to the human being's subjective judgment, thus pushing the emergence of fuzzy logic theory in handling the ambiguity of decision making and uncertainty among factors in evaluations [4]. Chang is the first researcher to propose the development of the AHP method by adding Fuzzy numbers to overcome the shortcomings that exist in the AHP method [5] [6]. F-AHP uses fuzzy ratios to replace the exact ratios in AHP, and it also uses mathematical operations and fuzzy logic to replace the ordinary mathematical operations on AHP [7] [8]. The use of fuzzy ratios in F-AHP is due to the inability of AHP to accommodate inaccuracy and subjectivity factors in the process of pair-wise comparisons or pair-wise comparisons for each criterion and alternative [9]. Meanwhile, F-ANP, as ANP development can overcome the shortcomings of the AHP method, especially in terms of the reciprocal relationship between decision levels and attributes through vague data processing [10] [11]. F-AHP and F-ANP implementations in assorted decision-making platforms including Mahdiyar et al. that utilized F-ANP on green roof type selection [12]; Büyüközkan and Ifi employed F-ANP integrated with MADM hybrids to evaluate the green suppliers [13]; Bhattacharya et al. enforced F-ANP based on balanced scorecard for green supply chain performance measurement [14]. Meanwhile, F-AHP is used to calculate the weight for different criteria that impact in developing the heart diseases in a patient [15]. Kar applied AHP that integrated with Fuzzy in a hybrid group decision support system for supplier selection [16]. In the other study, Samuel et al. applied the F-AHP technique to compute the global weights of attributes in heart failure risk prediction [17].

F-AHP and F-ANP provide similar operation stages, comprising the treatment of criteria from human responses. It is to perform a paired matrix process, to investigate the preferences of alternatives, and to produce a ranking solution of the problem as advisements. A fuzzy number in the above methods can provide strong dependencies and feedback among different indexes. Furthermore, the embedded defuzzification in AHP and ANP overcomes the bias and vague due to incomplete information or knowledge, complexity, uncertainty within the decision environment. Thus it delivers the correct judgment or objective evaluation of decision-maker assessment. Therefore, this research tried to study how the F-AHP and F-ANP applications are based on decision support systems in solving the case of smartphone recommendations. The previous studies that are conducting a similar comparison platform of F-AHP and F-ANP in MADM viz. Mudjirahardjo et al. who tried to develop a recommendation system to select thesis topics based on F-AHP and F-ANP [9]. Yücenur et al. applied the same method in selecting suppliers of problems in global supply chains [18]. Meanwhile, other studies from Demirel et al. employed the above methods to evaluate the risks based on Turkish Agricultural strategies [19]. Unfortunately, implementing F-AHP and F-ANP for the smartphone selection case has not yet been found. Molinera et al., tried designing a decision support system for recommending smartphones using fuzzy ontologies [20]. The design application used linguistic modeling to provide users with preferences on smartphone features in fuzzy logic. The result showed that fuzzy ontologies help the decision-maker to select the alternatives that are closest to the user desired as the perfect choice, and it provided the user preferences to become easier. Considering the significant values of fuzzification on MADM, and the benefits of AHP and ANP, this research attempted to inquiry about each aspect in recommending a smartphone. The comparison of the above methods is seen from the aspect of structures graphical development, the value of the Consistency Index (CI), and the Consistency Ratio (CR) on weighting criteria, comparison of matrices, and execution time. Accuracy testing is also carried out to identify the suitability of the recommendation results with the user's priorities.

MATERIAL AND METHOD

The Formulation of Criteria and Alternatives

Currently, the smartphone becomes a crucial tool. This equipment authorizes people to communicate, surf the internet, execute programs, conducting work and business, handling management process, carrying out education works, etc. Besides, the new normal situation triggered by Covid-19 limits the people's movements and activities thus increases the significant utilization of smartphones [21]. Moreover, the smartphone's role can replace the virtues of personal computers through the portative, flexible, lightweight, and easy use of devices anywhere, anytime, and for any kind of activity.

The relationship between smartphones in the educational platform has been studied and showed the potential use of this appliance in improving and transforming data, information, and knowledge for educational purposes [22] [23]. Thus, the smartphone could promote innovative educational outcomes. In Indonesia, 95% of university students owned their smartphones [24]. This number is significantly higher than the ownership rate of the overall population in Indonesia. It is also worth noting that smartphone ownership is growing rapidly among university students all over the world [25]. They can have more than one device. Hence, this research designed a prototype of a DSS mechanism based on the F-AHP and F-ANP model towards the preference smartphone recommendation solution for university students. As a case study, a survey was conducted at the Faculty of Science and Technology, UIN Suska Riau. The objective of the survey is to determine the criteria and alternatives that can be used by university students in selecting a smartphone. The survey was carried out by filling out a Google online form that randomly disseminates into 100 university students. As a result, several criteria and alternative types of smartphones from the side perspectives of university students are obtained. The priority criteria in the smartphone's selection include as follows.

a. Product price. The previous researches such as R. N. P. Atmojo et al., H. Karjaluoto et al., and S. Belbag et al. used this item as their consideration criteria [26, 27, 28].
b. Random Access Memory (RAM) is a smartphone feature related to the capacity of smartphones in accommodating the installations of applications in smartphones.
c. The processor is reviewed by R. N. P. Atmojo et al. and D. Abdullah et al. as the substantial embedded tool in smartphones to ensure the flexibility of access to an application in a smartphone [26] [29].
d. Internal memory is smartphone features that can store several data with a certain amount of capacity [30].
e. The camera, as a smartphone device, captures and stores every moment of activity in the forms of pictures and videos. The device is becoming a special criterion for a millennial generation at the university, thus triggers smartphone production with advanced camera features [31].

Meanwhile, the favourite alternative smartphone among university students includes Oppo F11, Oppo Reno, Vivo S1, Vivo Z1 Pro, and Redmi Note 7.

MADM Approaches

Previous studies have found that the AHP method is one of the powerful and flexible weighted scoring decisions making processes to help people set priorities and make the best decision for the complex or unstructured problem [32]. Through a hierarchical process, AHP can break down criteria into several sub-criteria levels, until decision alternatives are performed [33] [34]. The AHP is capable of accommodating the experience and knowledge of the experts in defining the criteria affecting the decision process [35]. F. Dweiri et al. applied AHP in the industrial application by proposing a ranking of the forecasting method for production planning in a supply chain [36]. I. M. Mahdi and K. Alreshaid adopted a decision support system approach using AHP for selecting the proper project delivery method [37]. In the other study, Okfalisa et al. have successfully applied AHP in assigning priority values to KPIs as criteria used to measure and monitor the organizational performance [38] and in weighting the priority indicators for measuring the Islamic banking sustainability [39].

ANP is an improved version of the AHP method and further developed by Saaty [40]. It provides more accurate results with many complicated models through the analysis of criteria feedback and interrelations among pair criteria. ANP with the more pair-wise comparison matrices solve the inconsistent result in AHP, limited to heuristics and approximations of comparison matrices, thus affecting the priority order [41] [42]. Some previous studies using ANP include S. Zaim et al. who deployed the AHP and ANP method of decision making in selecting the most appropriate maintenance strategy for an organization with critical production requirements [43], R. Rajesh adopted grey theory and ANP for quantifying various resilient strategies of risk mitigation [44]. In the other study, M. Aminu et al. presented an ANP based spatial decision support system for sustainable tourism planning in Cameron Highlands, Malaysia [45].

The integration of fuzzy logic in MADM, as well as F-AHP and F-ANP, have been proven can scale down the bias and uncertainty of decision making [4]. The mathematical operation in fuzzy logic has been successfully overwhelmed the inaccuracy and subjectivity of AHP and ANP [7, 8, 9]. Regarding the respondent's transcriber, the fuzzy theory in AHP and ANP afford the linguistic variables schema, thus offering more objective and particular assessment [46]. Moreover, the Gaussian fuzzy numbers as a pair-wise comparison scale cater to the priorities values with different selection attributes and sub-attributes. Thus, the priority weights for main attributes, sub-attributes, and alternatives are combined to determine the priority weights of the alternatives. Hence, the best alternative as the highest priority weight alternative will be introduced [47].

Research Method

This study began by identifying problems related to criteria and alternatives used in determining smartphone selection. The supporting criteria were formulated through the literature reviews. To adapt the university students' needs, a random survey of 100 questionnaires from students Year I up to Year IV was delivered with five Likert scales. In a nutshell, five preference criteria were descriptively analyzed using statistic tool Statistical Package for the Social Sciences (SPSS) as significant indicators for university students in selecting a smartphone such as a price, RAM, processor, internal memory, and camera. Meanwhile, the alternative smartphone product that was the priority and widely bought by university students viz., Oppo F11, Oppo Reno, Vivo S1, Vivo Z1 Pro, and Redmi Note 7. The distribution of respondents can be depicted in Figure 1.

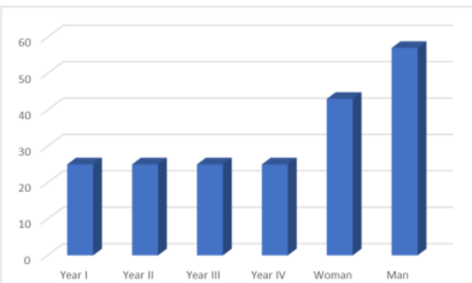

Figure 1. Respondents Distribution

To operate DSS based on F-AHP and F-ANP work, a web-based questionnaire with a 1-9 of the Saaty scale was simulated on twenty-five respondents [48]. This component was the basic input for building a database management system (DMS) in DSS and smartphone recommendation features. Furthermore, analytical models of F-AHP and F-ANP on the DSS based subsystem model were quantitatively established. The two above models were parallelly applied according to the algorithmic stages of each method. It was started with a problem hierarchy structure development, determination of weighting values, vector values calculation, defuzzification, and normalization [49][50]. The overflow algorithm of F-AHP and F-ANP is explained below.

Fuzzy AHP

The following are F-AHP step processes [51].

1. They are structuring the problem hierarchy and pair-wise matrix comparisons between criteria with Triangular Fuzzy Number (TFN) scale to find consistent values (CR ≤ 0.1) on the comparison matrix. Furthermore, the value of the AHP comparison matrix will be changed into the F-AHP value.
2. Calculating the value of Fuzzy Synthesis *(Si)*:

$$\sum_{j=1}^{m} M_{gi}^{j} \times \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} \quad (1)$$

   Explanation:
   S_i = fuzzy synthesis value
   M = TFN number
   m = number of criteria
   i = rows
   j = column
   g = parameter *(l,m,u)*
3. Computing the vector value (V), $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ are defined as a vector value. $V(M_2 \geq M_1) = sup[min(\pi M_1(x)), min(\pi M_2(y))]$

$$VM_2 \geq M_1 = \begin{Bmatrix} 1 \quad if\ m_2 \geq m_1 \\ 0 \quad if\ l_1 \geq u_2 \\ \dfrac{l_{1-u_2}}{(m_2-u_2)-(m_2-l_2)} \end{Bmatrix} \quad (2)$$

4. Defuzzification Ordinary Value (d').
   For k = 1,2, n; k ≠ l, it obtains the vector weight value:

$$W' = (d'(A_1), d'(A_2), \ldots d'(An))^T \quad (3)$$

5. Normalizing value of fuzzy vector weights *(W)*

$$d(A_n) = \frac{d'}{\sum_{i=1}^{n} d(A_n)} \quad (4)$$

   The normalized value of fuzzy vector weights.

$$W = (d(A_1), d(A_2), \ldots, d(An))^T \quad (5)$$

   Where *W* is a non-fuzzy number.
6. Calculating the final weight of recommendation.
7. This step is processed by summing the multiplication of the criteria values against each alternative value.

Fuzzy ANP

The emphasis of F-ANP is the consideration of the feedback dependency relationship between criteria and within criteria

[49][50]. The working step process as follows [52][53].

1. Create a problem structure, and calculate pair-wise matrix comparisons and priority vector-like AHP. In ANP, the pair-wise comparison is performed in a matrix framework, and a local priority vector can be determined as an estimate of the relative importance of the elements being compared.
2. Super matrix formation: if the criteria are interrelated, then a network replaces the hierarchy.
3. The alternative with the highest overall priority will be selected as the best alternative in the first rank.

The comparative analysis of each activity process between the two methods was displayed and explained as well as the weight values, CI/CR values, recommendation result, and the execution time. The subsystem dialogues of the DSS user interface were designed from the input display of questionnaires, weighting step processes, until ranking the recommended smartphone products as an output present.

The application was codified using PHP programming and My SQL for the database. To test the optimality of the DSS-SmartphoneRec application, a Black-box, and User Acceptance Test (UAT) testing was carried out. Completing UAT, the comparison between DSS-SmartphoneRec calculations and respondent manual preferences was accuracy analyzed using the formula in (6).

$$Accuracy = \frac{The\ similar\ Amount\ of\ Data}{Total\ Data} \times 100\% \quad (6)$$

The flow research activity can be seen in Figure 2.

RESULTS AND DISCUSSION

The analysis was conducted by simulating twenty-five respondents represented by three ranking respondents.

Comparative Analysis of Structure

The development of the hierarchical and network structure of the case study can be seen in Figure 3a and Figure 3b. The structure in Figure 3a showed the correlation between criteria and alternatives based on F-AHP. Meanwhile, Figure 3b presented the reciprocal correlation and dependency between criteria in F-ANP.

Comparative Analysis of Weight Criteria and Recommendation

Referencing on F-AHP and F-ANP calculation (See (1)-(5) and step process of F-AHP and F-ANP), the comparison of the criteria weight vector and the recommendation weight in smartphone selection was presented in Table 1. Table 1 explained that the normalized vector values of criteria and the final recommendation of the weight of criteria on F-ANP provided had more consistency values rather than F-AHP.

Comparative Analysis of Product Recommendation

Based on the elaboration of the final stages in F-AHP and F-ANP, the highest-ranking of smartphone products was delivered as the recommendations as listed in Table 2. Table 2 informed that the suggestion ranking of smartphone products from F-AHP and F-ANP had a similar position, especially for the products ranking in 1 to 3. From the three students, only student number 2, who received a different product recommendation ranked 4th and 5th.

Comparative Analysis of Execution Time

The execution time of the DSS-SmartPhoneRec application for three students was explained in Table 3. To process time, F-AHP required a quick running timer compared to F-ANP. This was due to the matrix comparison reciprocation of F-ANP. Thus, it affected processing circulation time.

Comparative Analysis of Accuracy Testing

A simulation testing of twenty-five students based on (6) for seventeen similar data of F-AHP and twenty-one data of F-ANP indicated that F-ANP produced a greater percentage of accuracy (84%) than F-AHP (68%).

DSS-SmartPhoneRec Designed and Development

The system architecture designed of the DSS-SmartPhoneRec application can be seen in Figure 4. The design was created according to the DSS components, namely management model, knowledge-based management of criteria and alternatives, comparison analysis of both methods, and interface design of input and output.

To show the DSS-SmartPhoneRec application, Figure 5 was demonstrated as the time analysis interface. The prototype of the DSS-SmartPhoneRec application had been tested by applying Black-box testing. Thus it showed that all related functions had been running well following the expected output. UAT testing was conducted on twenty-five respondents, thus 85% of them stated that the DSS-SmartPhoneRec application helped them in making the right selection of Smartphone products.

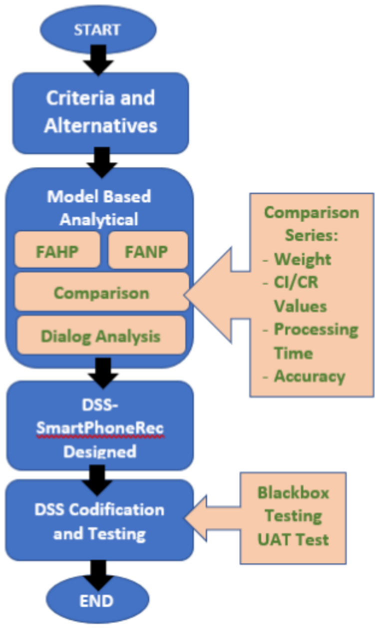

Figure 2. The research flow activities

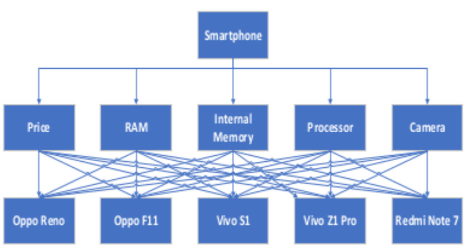

Figure 3a. F-AHP structure

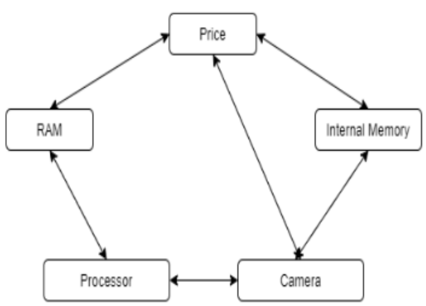

Figure 3b. F-ANP structure

Table 1. The comparison Values of Vector and Recommendation Weight

No Student	Smartphone				
	Criteria Weight Vector			Recommendation Weight	
	Criteria	F-AHP	F-ANP	F-AHP	F-ANP
1	Price	0,17	0,66	0,19	0,74
	RAM	0,19	0,74	0,29	0,84
	Internal Memory	0,21	0,77	0,25	0,78
	Process	0,24	0,65	0,12	0,42
	Camera	0,20	0,57	0,16	0,62
2	Price	0,31	0,77	0,21	0,74
	RAM	0,26	0,78	0,26	0,82
	Internal Memory	0,13	0,65	0,22	0,78
	Process	0,06	0,55	0,16	0,44
	Camera	0,25	0,67	0,16	0,64
3	Price	0,23	0,68	0,23	0,74
	RAM	0,20	0,84	0,29	0,83
	Internal Memory	0,14	0,61	0,17	0,72
	Process	0,03	0,48	0,16	0,44
	Camera	0,40	0,73	0,15	0,61

Table 2. Products Recommendation Analysis

Respondents	Smartphone			
	F-AHP		F-ANP	
1	0,29	Vivo Z1 Pro	0,84	Vivo Z1 Pro
	0,25	Oppo F11	0,78	Oppo F11
	0,19	Oppo Reno	0,74	Oppo Reno
	0,16	Vivo S1	0,62	Vivo S1
	0,12	Redmi Note 7	0,42	Redmi Note 7
2	0,26	Vivo Z1 Pro	0,82	Vivo Z1 Pro
	0,22	Oppo F11	0,78	Oppo F11
	0,21	Oppo Reno	0,74	Oppo Reno
	0,16	Redmi Note 7	0,64	Vivo S1
	0,16	Vivo S1	0,44	Redmi Note 7
3	0,29	Oppo F11	0,83	Oppo F11
	0,23	Oppo Reno	0,74	Oppo Reno
	0,17	Vivo Z1 Pro	0,72	Vivo Z1 Pro
	0,16	Vivo S1	0,61	Vivo S1
	0,15	Redmi Note 7	0,44	Redmi Note 7

Table 3. The comparison Values of Execution Time

Respondents	Smartphone	
	F-AHP	F-ANP
1	0.00704407	0.02339696
2	0.00920915	0.02478790
3	0.01122212	0.02207493

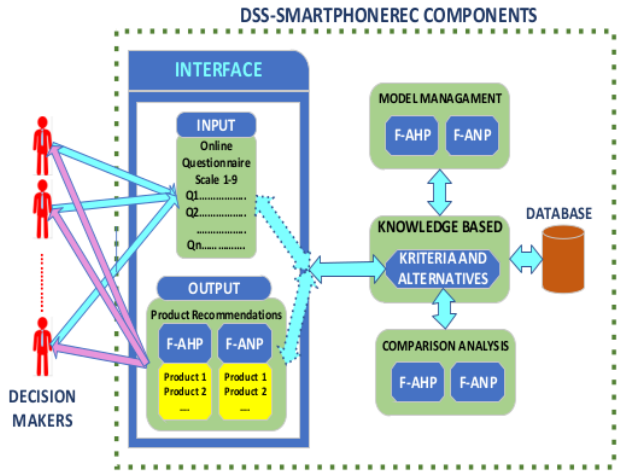

Figure 4. DSS-SmartPhoneRec system architecture

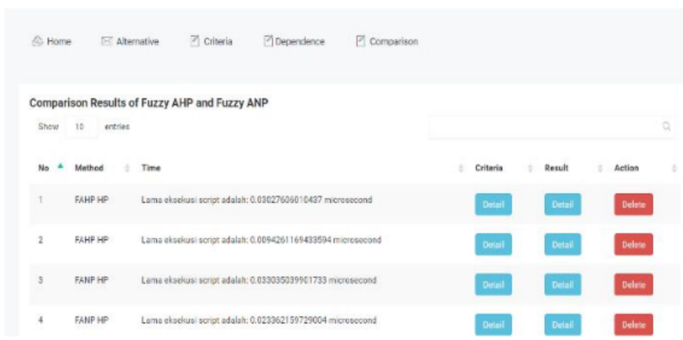

Figure 5. DSS-SmartPhoneRec system interface for execution time

CONCLUSION

Comparing the weighting and consistency values in pairing matrix development found that F-ANP provides better performance with an average value of 40% higher than F-AHP. This result impacts on the final weight of smartphone product recommendations suggested by F-ANP. The fuzzification on to the two MADM methods has been successfully increased the consistency values of criteria and reduced the bias level and ambiguity in linguistic variable problems of the questionnaire. Due to the matrix comparison process between and within criteria is reciprocal, the execution time for F-ANP takes a longer execution time than F-AHP. Crossing reference, the suggested products of DSS-SmartPhoneRec and manual product selection reveal that F-ANP accuracy is 16% better than F-AHP. In a nutshell, F-ANP provides effective and optimal recommendations for smartphone selection and fulfils user preferences. In the future, several cases will be required to confirm the effectiveness of the F-ANP method further. Besides, the possible integration of the F-ANP method and other methods such as Fuzzy TOPSIS, hybrid, and fuzzy Grey needs to be more explored and studied on the way to improve the effectiveness of this method in MADM decision making.

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