Combining FUCA, CURLI, and Weighting Methods in the Decision-Making of Selecting Technical Products

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ABSTRACT

Determining the optimal one from the available alternatives is useful in numerous aspects of life. The process of selecting technical products from an available catalog also follows this pattern. This study was carried out to select the best from two types of technical products, the ones that serve in daily life at home, and products that are used in the agriculture field. Air conditioners and washing machines are considered indispensable items in every household. These two types of products directly affect human lives and also indirectly influence labor productivity. Unmanned Aerial Vehicles (UAVs) are used in numerous tasks in the agriculture field, such as inspecting irrigation systems, checking for factors that can harm agricultural products, etc. However, making the decision to buy one of those three types of products may become complicated. This research was conducted to select the best alternative for each of those products. The different types of air conditioners, washing machines, and drones considered in this study were 9, 8, and 7, respectively. Two methods, i.e. RS (Rank Sum) and PIPRECIA (PIvot Pairwise RElative Criteria Importance Assessment) were used to determine the weights for the criteria of each product category. The FUCA (Faire Un Choix Adéquat) method was used in combination with the two weighting methods mentioned above to rank the alternatives of each product category. The CURLI (Collaborative Unbiased Rank List Integration) method was used to complete this task. So, for each product category, there will be three different ranking results. An interesting thing has been achieved is that for each product category, these different ranking results gave the same best solution.

Keywords-MCDM; weighting method; FUCA method; CURLI method

I. INTRODUCTION

Air conditioners and washing machines are nowadays considered indispensable items of our daily life. They also contribute directly to the improvement of labor productivity. However, choosing and buying these products can be complicated. A question that is often asked is how to buy "the best" product among various candidate products, since for each product, there are many different alternatives on the market. Choosing a product based on only one or a few criteria can easily lead to bad purchases. To choose the best product, it is necessary to consider all the relevant criteria. This process is termed as Multi-Criteria Decision-Making (MCDM) [1]. Such problems also occur in the selection of UAVs for agricultural production. However, the authors of this study can state with certainty that up to now there have not been any studies applying MCDM methods to select air conditioners, washing machines, and UAVs.

Up to now, there is not an exact estimation of how many MCDM methods there are, but certainly, they are more than one hundred [2]. In addition, over time, new MCDM methods are constantly being presented [3]. The MCDM methods are divided into two groups, the first group consists of methods that need to determine weights for the criteria, and the second consists of methods that do not [4].

FUCA is a method that needs to determine weights for the criteria (the first group) [5, 6]. This method has a major difference from the methods in its class. The difference is that it does not need to perform data normalization [5, 6]. This method has been used for MCDM in many different fields, such as ranking companies [7-10], selecting chemical manufacturing process [11], selecting lathes [12], etc. However, to the best of our knowledge, the application of the FUCA method in selecting air conditioners, washing machines, and UAVs has not been conducted yet. As mentioned above, when using the FUCA method, it is necessary to determine weights for the criteria. However, if the weights are only determined based on the classic numerical techniques, it could lose the objectivity of the MCDM problem as well as skip the importance of the expert's opinions. For household items, it is important to consider the opinions of customers. PIPRECIA is a criterion weighting method that considers the decision makers opinions. Using this method, it is possible to determine criteria weights considering the opinions of different groups of individuals [13]. This method has also been used to calculate the criteria weights in several fields [12-18]. However, up to

now, this method has not been used to determine the criteria weights for the of air conditioners, washing machines, and UAVs. Furthermore, if only the PIPRECIA method is used to determine the criteria weights, the question whether the ranking results change when using a different weighting method needs to be answered. The decision makers can have a strong belief in an alternative when it is determined to be the best for various weighting methods. Therefore, in addition to the PIPRECIA, in this study, another weighting method was used, which is the RS weighting method [19]. This is a simple method to determine the weights for the criteria by only one formula. This method is used to determine the criteria weights based on the decision makers' opinion on the priority of the criteria. In recent times, it is also applied to determine the criteria weights in various different cases [20-25].

Using the FUCA method in combination with two weighting methods (PIPRECIA and RS) is a solution that belongs to the first group of the MCDM methods. Some methods that belong to the second group are the PSI (Preference Selection Index) method, the PEG (Pareto-Edgeworth Grierson) method, and the CURLI method [26]. There is a difference between the CURLI method and the other methods of this group. When using the PSI and PEG methods, it is needed to perform data normalization, but when using the CURLI method, the data do not need to be normalized. Which means that when using the CURLI method, the decision makers do not need to determine the criteria weights and normalize data, thus eliminating the problem of choosing a proper criteria weighting and data normalization method. Recently, it has also been applied in MCDM in various different aspects [26-31]. In this study, the CURLI method will be applied to select air conditioners, washing machines, and UAVs.

II. THE USED WEIGHTING METHODS

To calculate the weight distribution by using the RS method, the criteria are first arranged in descending order of priority. This arrangement is made according to the opinions of the decision maker (buyer). After the criteria have been arranged in a descending order, their weights are calculated according to (1) [19]:

$$w_j = \frac{2(n+1-j)}{n(n+1)} \quad (1)$$

where n is the number of criteria and j is the order of the jth criterion.

The PIPRECIA method was used to calculate the weights for the criteria in the following way [13]:

Step 1: Select experts (buyers) and ask their opinions on the importance of the criteria.

Step 2: Each expert will determine the relative importance of the criteria s_j, starting from the second criterion. The criterion's importance is expressed as (2):

$$s_j = \begin{cases} > 1 \; when \; C_j > C_{j-1} \\ 1 \; when \; C_j = C_{j-1} \\ < 1 \; when \; C_j < C_{j-1} \end{cases} \quad (2)$$

Step 3: For each expert, determine the coefficient k_j according to:

$$k_j = \begin{cases} 1 & j = 1 \\ 2 - s_j & j > 1 \end{cases} \quad (3)$$

Step 4: Determine the recalculated weights of the criteria according to:

$$q_j = \begin{cases} 1 & j = 1 \\ \frac{q_{j-1}}{k_j} & j > 1 \end{cases} \quad (4)$$

Step 5: Calculate the weights of the criteria according to the opinion of each expert according to:

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \quad (5)$$

Step 6: Calculate the weights of the criteria according to (6) and (7), where K is the number of experts and the index r represents the r-th expert.

$$w_j^* = \left(\prod_{r=1}^{K} w_j^r\right)^{1/K} \quad (6)$$

$$w_j = \frac{w_j^*}{\sum_{j=1}^{n} w_j^*} \quad (7)$$

III. THE USED MCDM METHODS

A. The FUCA Method

The steps to rank the alternatives according to the FUCA method are [5, 6]:

Step 1: Rank the alternatives for each criterion (r_{ij}). Suppose there are m alternatives, the worst alternative will be ranked in the m-th place and the best alternative as first.

Step 2: Calculate the score of each alternative according to:

$$v_i = \sum_{j=1}^{n} r_{ij}.w_j \quad (8)$$

Step 3: Rank the alternatives according to the values of v_i. The best alternative is the alternative with the smallest v_i and vice versa.

B. The CURLI Method

After having the decision matrix, the steps for ranking the alternatives using the CURLI method include [32]:

Step 1: Scoring the alternatives for each criterion. The scoring result of each criterion is a square matrix of level m. So with n criteria, we will have n scoring matrices. Some examples of scoring are:

- If in the cell corresponding to column 1 and row 2, the value A_1 is better than that of A_2, the score is equal to 1, which means $A_2P_1 = 1$.
- If in the cell corresponding to column 2 and row 1, the value of A_2 is worse than that of A_1, the score is -1, which means $A_1P_2 = -1$.
- If in the cell corresponding to column 2 and row m, the value of A_2 is equal to that of A_m, the score is 0, which means $A_mP_2 = 0$.

Scoring is performed for all the cells that do not lie on the main diagonal of the matrix. In the cells that lie on the main diagonal of the matrix, the score is 0 ($A_iP_i = 0$), where $i = 1 \div m$. This matrix is called the scoring matrix for each criterion (Table I).

TABLE I. A SCORING MATRIX EXAMPLE

No.	P_1	P_2	P_i	P_m
A_1	$A_1P_1 = 0$	$A_1P_2 = -1$	$A_1P_i = \dots$	$A_1P_m = \dots$
A_2	$A_2P_1 = 1$	$A_2P_2 = 0$	$A_2P_i = \dots$	$A_2P_m = \dots$
A_i	$A_iP_1 = \dots$	$A_1P_2 = \dots$	$A_iP_i = 0$	$A_iP_m = \dots$
A_m	$A_mP_1 = \dots$	$A_mP_2 = 0$	$A_mP_i = \dots$	$A_mP_m = 0$

Step 2: Add all the scoring matrices for each criterion into a single matrix. Thus, we get a matrix called the process scoring matrix.

Step 3: Rearrange the rows and columns of the process scoring matrix so that the new matrix has the maximum number of cells with negative values above the main diagonal. After rearranging, the alternative that lies on the first row is considered as the best alternative.

IV. SELECTING THE BEST AIR CONDITIONER, WASHING MACHINE, AND UAV

A. Air Conditioner Selection

Nine types of air conditioner of the Daikin brand were introduced by the supplier with product codes 1HP-MSAFC-10CRDN8, 1.5HP-GC-12IS33, 1HP-ATKC25UAVMV, 1.5HP -RAS-H13H4KCVG-V, 1HP-FTKB25WMVMV, 1.5HP-CU/ CS-PU12XKH-8M, 1HP-CU/CS-XU9XKH-8, 1.5HP-CU/CS-XU12XKH-8, and 1.5HP-FTKB35WMVMV. They are denoted by A1, A2, A3, A4, A5, A6, A7, A8, and A9 alternatives, respectively. Ten criteria were used to evaluate each type of air conditioner, including:

- C1: Is the cost (dong). Dong is the currency of Vietnam, 1 USD is equivalent to about 23500 dongs.
- C2: Is the effective cooling area (m^2).
- C3: Is the amount of electricity consumed (kW/h).
- C4: Is the average cooling speed (BTU).
- C5: Is the power of device (HP).
- C6: Is the warranty period (month).
- C7: is the maximum noise level of the indoor unit (dB).
- C8: is the maximum noise level of the outdoor unit (dB).
- C9: Is the weight of the indoor unit (kg).
- C10: Is the weight of the outdoor unit (kg).

A survey was carried out among 6 experts to determine the priority of the criteria. All the experts gave the same opinion. The criteria are arranged in descending order of priority as: C1 > C2 > C3 > C4 > C5 > C6 > C7 > C8 > C9 > C10. The data on the types of air conditioners are summarized in Table II. The criterion type (the larger the better, or the smaller the better) of each criterion is also summarized in the last row of this table. The most remarkable points from Table II are that C1 is the smallest at A1, C2 is the largest at A6 and A8, C3 is the smallest at A9, C4 is the largest at A4, and so on. Hence, it is clear that the ranking could not be completed by relying solely on the obtained data in this Table. All 10 criteria must be considered in order to identify the optimal alternative. This is the reason why applying MCDM methods is essential.

TABLE II. TYPES OF AIR CONDITIONER

No.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	6590000	15	1.1	9000	1	36	39	51.5	7.4	21.7
A2	7390000	20	1.3	4095	1.5	36	32	50	8.5	21
A3	11590000	45	0.68	8500	1	12	38	47	8	23
A4	11990000	20	1.18	12000	1.5	24	24	48	9	21
A5	10990000	15	0.82	8500	1	12	36	47	8	19
A6	13890000	60	1.07	11900	1.5	12	28	48	8	23
A7	13490000	45	0.68	8700	1	12	19	47	10	18
A8	16890000	60	0.95	11900	1.5	12	19	48	10	23
A9	13490000	20	0.6	11900	1.5	12	37	47	8	22
Type	**Min**	**Max**	**Min**	**Max**	**Max**	**Max**	**Min**	**Min**	**Min**	**Min**

Equation (1) was applied to calculate the weights of the criteria according to the RS method. Accordingly, the weights of the criteria C1, C2, C3, C4, C5, C6, C7, C8, C9, and C10 have the values of 0.2929, 0.1929, 0.1429, 0.1096, 0.0846, 0.0646, 0.0479, 0.0336, 0.0211, and 0.0100, respectively. To calculate the weights according to the PIPRECIA method, a survey was also carried out with the opinions of 6 experts and (2) was used. Table III is a summary of experts' opinions on the relative importance of the criteria.

Applying the (3)-(7), the weights of the criteria were determined as shown in Table IV. Step 1 of the FUCA method was applied to rank the alternatives for each criterion. The results are summarized in Table V. Step 2 of the FUCA method was applied to calculate the score for each alternative with two different sets of weights (8). The results were summarized in Table VI. Step 3 of the FUCA method was applied to rank the alternatives. The results are summarized in Table VI.

Step 1 of the CURLI method was applied to score the alternatives for each criterion. The results are presented in Tables VII - XVI. The process scoring matrix was determined by applying the step 2 of the CURLI method as shown in Table XVII. The process scoring matrix was rearranged according to step 3 of the CURLI method, and the results were shown in Table XVIII.

TABLE III. EXPERT OPINIONS ON THE RELATIVE IMPORTANCE OF THE CRITERIA s_j

Criteria	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6
C1						
C2	0.98	0.9	0.8	0.9	0.98	0.9
C3	0.96	0.96	0.96	0.9	1	1
C4	0.95	0.95	0.95	0.95	0.95	1
C5	0.94	0.94	0.9	0.9	0.95	0.94
C6	0.93	0.92	0.92	0.92	0.93	0.93
C7	0.9	0.9	0.9	0.9	0.9	0.9
C8	0.89	0.89	0.89	0.8	0.89	0.89
C9	0.85	0.6	0.5	0.8	0.8	0.75

TABLE IV. THE WEIGHTS OF THE CRITERIA DETERMINED USING THE PIPRECIA METHOD

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Weight	0.1370	0.1259	0.1215	0.1167	0.1089	0.1013	0.0921	0.0819	0.0641	0.0508

TABLE V. RANKING THE ALTERNATIVES OF EACH CRITERION

No.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	1	8.5	7	5	7.5	1.5	9	9	1	5
A2	2	6	9	9	3	1.5	5	8	6	3.5
A3	4	3.5	2.5	7.5	7.5	6.5	8	2.5	3.5	8
A4	5	6	8	1	3	3	3	6	7	3.5
A5	3	8.5	4	7.5	7.5	6.5	6	2.5	3.5	2
A6	8	1.5	6	3	3	6.5	4	6	3.5	8
A7	6.5	3.5	2.5	6	7.5	6.5	1.5	2.5	8.5	1
A8	9	1.5	5	3	3	6.5	1.5	6	8.5	8
A9	6.5	6	1	3	3	6.5	7	2.5	3.5	6

TABLE VI. ALTERNATIVE SCORE AND RANKING WITH THE FUCA METHOD

No.	RS weight		PIPRECIA weight	
	v_i	Rank	v_i	Rank
A1	5.4545	8	5.4927	9
A2	5.3455	7	5.3288	7
A3	5.0182	6	5.2138	6
A4	4.6455	2	4.5532	2
A5	5.6182	9	5.3998	8
A6	4.7636	3	4.8387	4
A7	4.8636	5	4.7480	3
A8	4.8000	4	4.9445	5
A9	4.4909	1	4.4803	1

TABLE VII. ALTERNATIVES SCORE FOR CRITERION C1

No.	P1	P2	P3	P4	P5	P6	P7	P8	P9
A1	0	-1	-1	-1	-1	-1	-1	-1	-1
A2	1	0	-1	-1	-1	-1	-1	-1	-1
A3	1	1	0	-1	1	-1	-1	-1	-1
A4	1	1	1	0	1	-1	-1	-1	-1
A5	1	1	-1	-1	0	-1	-1	-1	-1
A6	1	1	1	1	1	0	1	-1	1
A7	1	1	1	1	1	-1	0	-1	0
A8	1	1	1	1	1	1	1	0	1
A9	1	1	1	1	1	-1	0	-1	0

TABLE VIII. ALTERNATIVES SCORE FOR CRITERION C2

No.	P1	P2	P3	P4	P5	P6	P7	P8	P9
A1	0	1	1	1	0	1	1	1	1
A2	-1	0	1	0	-1	1	1	1	0
A3	-1	-1	0	-1	-1	1	0	1	-1
A4	-1	0	1	0	-1	1	1	1	0
A5	0	1	1	1	0	1	1	1	1
A6	-1	-1	-1	-1	-1	0	-1	0	-1
A7	-1	-1	0	-1	-1	1	0	1	-1
A8	-1	-1	-1	-1	-1	0	-1	0	-1
A9	-1	0	1	0	-1	1	1	1	0

TABLE IX. ALTERNATIVES SCORE FOR CRITERION C3

No.	P1	P2	P3	P4	P5	P6	P7	P8	P9
A1	0	-1	1	-1	1	1	1	1	1
A2	1	0	1	1	1	1	1	1	1
A3	-1	-1	0	-1	-1	-1	0	-1	1
A4	1	-1	1	0	1	1	1	1	1
A5	-1	-1	1	-1	0	-1	1	-1	1
A6	-1	-1	1	-1	1	0	1	1	1
A7	-1	-1	0	-1	-1	-1	0	-1	1
A8	-1	-1	1	-1	1	-1	1	0	1
A9	-1	-1	-1	-1	-1	-1	-1	-1	0

TABLE X. ALTERNATIVES SCORE FOR CRITERION C4

No.	P1	P2	P3	P4	P5	P6	P7	P8	P9
A1	0	-1	-1	1	-1	1	-1	1	1
A2	1	0	1	1	1	1	1	1	1
A3	1	-1	0	1	0	1	1	1	1
A4	-1	-1	-1	0	-1	-1	-1	-1	-1
A5	1	-1	0	1	0	1	1	1	1
A6	-1	-1	-1	1	-1	0	-1	0	0
A7	1	-1	-1	1	-1	1	0	1	1
A8	-1	-1	-1	1	-1	0	-1	0	0
A9	-1	-1	-1	1	-1	0	-1	0	0

According to the data in Table XVIII, the ranking order of the alternatives is: A9 > A6 > A8 > A3 > A4 > A7 > A1 > A2 > A5. Figure 1 shows the ranking results of the air conditioners using the FUCA method and the CURLI method.

TABLE XI. ALTERNATIVES SCORE FOR CRITERION C5

No.	P1	P2	P3	P4	P5	P6	P7	P8	P9
A1	0	1	0	1	0	1	0	1	1
A2	-1	0	-1	0	-1	0	-1	0	0
A3	0	1	0	1	0	1	0	1	1
A4	-1	0	-1	0	-1	0	-1	0	0
A5	0	1	0	1	0	1	0	1	1
A6	-1	0	-1	0	-1	0	-1	0	0
A7	0	1	0	1	0	1	0	1	1
A8	-1	0	-1	0	-1	0	-1	0	0
A9	-1	0	-1	0	-1	0	-1	0	0

TABLE XII. ALTERNATIVES SCORE FOR CRITERION C6

No.	P1	P2	P3	P4	P5	P6	P7	P8	P9
A1	0	0	-1	-1	-1	-1	-1	-1	-1
A2	0	0	-1	-1	-1	-1	-1	-1	-1
A3	1	1	0	1	0	0	0	0	0
A4	1	1	-1	0	-1	-1	-1	-1	-1
A5	1	1	0	1	0	0	0	0	0
A6	1	1	0	1	0	0	0	0	0
A7	1	1	0	1	0	0	0	0	0
A8	1	1	0	1	0	0	0	0	0
A9	1	1	0	1	0	0	0	0	0

TABLE XIII. ALTERNATIVES SCORE FOR CRITERION C7

No.	P1	P2	P3	P4	P5	P6	P7	P8	P9
A1	0	1	1	1	1	1	1	1	1
A2	-1	0	-1	1	-1	1	1	1	-1
A3	-1	1	0	1	1	1	1	1	1
A4	-1	-1	-1	0	-1	-1	1	1	-1
A5	-1	1	-1	1	0	1	1	1	-1
A6	-1	-1	-1	1	-1	0	1	1	-1
A7	-1	-1	-1	-1	-1	-1	0	0	-1
A8	-1	-1	-1	-1	-1	-1	0	0	-1
A9	-1	1	-1	1	1	1	1	1	0

TABLE XIV. ALTERNATIVES SCORE FOR CRITERION C8

No.	P1	P2	P3	P4	P5	P6	P7	P8	P9
A1	0	1	1	1	1	1	1	1	1
A2	-1	0	1	1	1	1	1	1	1
A3	-1	-1	0	-1	0	-1	0	-1	0
A4	-1	-1	1	0	1	0	1	0	1
A5	-1	-1	0	-1	0	-1	0	-1	0
A6	-1	-1	1	0	1	0	1	0	1
A7	-1	-1	0	-1	0	-1	0	-1	0
A8	-1	-1	1	0	1	0	1	0	1
A9	-1	-1	0	-1	0	-1	0	-1	0

TABLE XV. ALTERNATIVES SCORE FOR CRITERION C9

No.	P1	P2	P3	P4	P5	P6	P7	P8	P9
A1	0	-1	-1	-1	-1	-1	-1	-1	-1
A2	1	0	1	-1	1	1	-1	-1	1
A3	1	-1	0	-1	0	0	-1	-1	0
A4	1	1	1	0	1	1	-1	-1	1
A5	1	-1	0	-1	0	0	-1	-1	0
A6	1	-1	0	-1	0	0	-1	-1	0
A7	1	1	1	1	1	1	0	0	1
A8	1	1	1	1	1	1	0	0	1
A9	1	-1	0	-1	0	0	-1	-1	0

It can be seen from Figure 1 that the ranking orders of the alternatives are not completely the same when using FUCA and CURLI. The ranking orders of the alternatives are also not the same when using RS and PIPRECIA. This issue is consistent with the findings in [1]. However, in every performed case, A9 is always ranked as 1st. Accordingly, among the 9 considered types of air conditioners, the 1.5HP-FTKB35WMVMV is determined to be the best.

TABLE XVI. ALTERNATIVES SCORE FOR CRITERION C10

No.	P1	P2	P3	P4	P5	P6	P7	P8	P9
A1	0	-1	1	-1	-1	1	-1	1	1
A2	1	0	1	0	-1	1	-1	1	1
A3	-1	-1	0	-1	-1	0	-1	0	-1
A4	1	0	1	0	-1	1	-1	1	1
A5	1	1	1	1	0	1	-1	1	1
A6	-1	-1	0	-1	-1	0	-1	0	-1
A7	1	1	1	1	1	1	0	1	1
A8	-1	-1	0	-1	-1	0	-1	0	-1
A9	-1	-1	1	-1	-1	1	-1	1	0

TABLE XVII. THE PROCESS SCORING MATRIX

No.	P1	P2	P3	P4	P5	P6	P7	P8	P9
A1	0	-1	1	0	-2	4	-1	4	4
A2	1	0	2	1	-2	5	0	3	2
A3	-1	-2	0	-2	-1	1	-1	0	1
A4	0	-1	2	0	-2	0	-2	0	0
A5	2	2	1	2	0	2	1	1	3
A6	-4	-5	-1	0	-2	0	-1	0	0
A7	1	0	1	2	-1	1	0	1	3
A8	-4	-3	0	0	-1	0	-1	0	1
A9	-4	-2	-1	0	-3	0	-3	-1	0

TABLE XVIII. THE PROCESS SCORING MATRIX AFTER REARRANGEMENT

No.	P9	P6	P8	P3	P4	P7	P1	P2	P5
A9	0	0	-1	-1	0	-3	-4	-2	-3
A6	0	0	0	-1	0	-1	-4	-5	-2
A8	1	0	0	0	0	-1	-4	-3	-1
A3	1	1	0	0	-2	-1	-1	-2	-1
A4	0	0	0	2	0	-2	0	-1	-2
A7	3	1	1	1	2	0	1	0	-1
A1	4	4	4	1	0	-1	0	-1	-2
A2	2	5	3	2	1	0	1	0	-2
A5	3	2	1	1	2	1	2	2	0

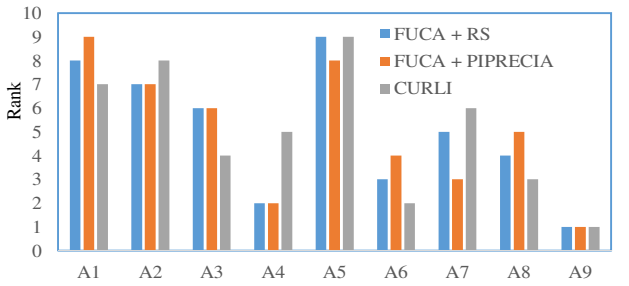

Fig. 1. Ranking of the air conditioner types.

B. Washing Machine Selection

Eight types of washing machines were introduced by the supplier with product codes WW80T3020WW/SV, WA90T5260BY/SV, WW95TA046AX/SV, WW10T634DLX/SV, WW10TA046AE/SV, WW90T634DLN/SV, WA12T5360BV/SV, and WA10T5260BV/SV. They are denoted by A1, A2, A3, A4, A5, A6, A7, and A8 alternatives, respectively. The 12 criteria used to evaluate each alternative were arranged in descending order of priority:

- C1: Is the mass of τηε fabric that can be processed in one wash (kg).
- C2: Is the cost (dong).
- C3: Is the efficiency of electricity use (Wh/kg).
- C4: Is the maximum spin speed (rev/min).
- C5: Is the engine warranty period (years).
- C6: Is the cover material (Stainless Steel = SS, Powder Coated Metal = PCM). According to experts' opinions, SS is better than PCM.
- C7: Is the weight (kg).
- C8: Is the height (cm).
- C9: Is the width (cm).
- C10: Is the depth (cm).
- C11: Is the length of the water supply pipe (cm).
- C12: Is the length of the drainpipe (cm).

The data for the 8 washing machines are summarized in Table XIX. Each criterion type (the larger the better, or the smaller the better) is also listed in the last row. According to the data in Table XIX, C1 is the largest at A7, C2 is the smallest at A2, C3 is the smallest at A7, C4 is the largest at A4-A6, etc. This demonstrates that MCDM methods are highly recommended for identifying the best alternative in this problem. The relative importance between the criteria was also obtained by surveying the opinions of 6 experts. The results are summarized in Table XX. The weights of the criteria were calculated according to both RS and PIPRECIA and are summarized in Table XXI.

TABLE XIX. WASHING MACHINE TYPES

No.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
A1	8	6990000	12.6	1200	11	SS	58	83.7	59.5	49.3	106	165
A2	9	5990000	10.6	700	20	PCM	40	105	61	67.5	109	121
A3	9.5	10290000	11.9	1400	20	SS	65	84.3	60	60	212	145
A4	10	10990000	13.1	1400	20	SS	67	85	60	60.6	211	154
A5	10	8790000	13.1	1400	20	SS	65	85	60	55	195	140
A6	9	9990000	13	1400	20	PCM	67	84.2	60	61.5	214	131
A7	12	8390000	7.2	700	20	PCM	43	109	61	65.5	106	115
A8	10	7190000	8.8	700	20	PCM	41	108	60	65	106	115
Type	**Max**	**Min**	**Min**	**Max**	**Max**	**SS is better than PCM**	**Max**	**Max**	**Max**	**Max**	**Max**	**Max**

TABLE XX. EXPERTS' OPINION ON THE RELATIVE IMPORTANCE OF THE CRITERIA S_j

Criteria	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6
C1						
C2	0.98	0.99	0.92	0.97	0.92	0.9
C3	0.94	0.95	0.94	0.92	0.97	0.95
C4	0.92	0.92	0.92	0.92	0.95	0.95
C5	0.97	0.98	0.98	0.95	0.95	0.95
C6	0.97	0.94	0.92	0.92	0.92	0.92
C7	0.96	0.96	0.96	0.94	0.94	0.94
C8	0.95	0.95	0.99	0.92	0.95	0.95
C9	0.99	0.92	0.92	0.92	0.92	0.92
C10	0.89	0.89	0.89	0.85	0.96	0.96
C11	0.88	0.9	0.9	0.85	0.9	0.95
C12	0.98	0.8	0.9	0.85	0.9	0.95

TABLE XXI. CRITERIA WEIGHTS

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
RS Weight	0.1538	0.1410	0.1282	0.1154	0.1026	0.0897	0.0769	0.0641	0.0513	0.0385	0.0256	0.0128
PIPRECIA weight	0.1120	0.1064	0.1008	0.0942	0.0909	0.0851	0.0811	0.0773	0.0724	0.0663	0.0601	0.0535

Ranking of the washing machines is conducted with steps similar to those of the precious section. The results are illustrated in Figure 2. Observing Figure 2, it can be seen that the ranking orders of the alternatives are not completely the same when using FUCA and CURLI. The ranking orders of the alternatives are also not completely the same when using the weighting methods RS and PIPRECIA. However, all the cases determined that A7 is the 1st alternative and A1 ranked 8th. Accordingly, WA12T5360BV/SV is the best type and WW80T3020WW/SV is the worst type among the 8 considered washing machines. After ranking the two product categories (air conditioner, washing machine) we can see that the best alternative determined by the CURLI method is always similar to the one determined when using the FUCA method. Also, when using the FUCA method to determine the best alternative, that alternative does not depend on the weights for the criteria.

C. UAV Selection

Seven types of agricultural UAVs were considered [33-39]. Their models are: U25L-4, U30L-6, D16L-4, U50 Max, D72L-8, Agras T40, and Agras T30. They are designated as the alternatives A1, A2, A3, A4, A5, A6, and A7. Nine criteria are applied to evaluate each alternative. The criteria include

Maximum takeoff weight (Kg), Aircraft weight (Kg), Aircraft medicine box capacity (lt), Flight Altitude (m), Max Fly Time (unloaded) (mins), Fly Time (loaded), Max Spray Width (m), Max Spray Flow (lt), Min Spray Efficiency (hct/h). These criteria are denoted by C1-C9, in that order. Among these criteria, C2 is defined as the cost factor; the remaining 8 criteria are defined as the benefit factors. The specific data of the UAVs are indicated in Table XXII. The opinions of six experts on the relative importance of the criteria were obtained. The results of the survey are summarized in Table XXIII.

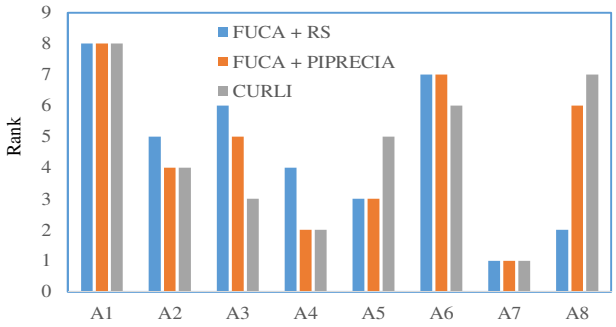

Fig. 2. Ranking of the washing machine types.

TABLE XXII. UAV SPECIFICATION [33-39]

No.	C1	C2	C3	C4	C5	C6	C7	C8	C9
A1	51	19	25	30	25	13	8	12	10
A2	66.5	24	30	30	30	13	12	10	10
A3	36	15	16	30	25	13	8	8	5
A4	82	42	40	30	20	15	10	4.5	6.8
A5	147	52	72	30	25	13	15	5	10
A6	90	50	40	45	18	6	11	12	10
A7	65	26.3	25	45	20.5	7.8	11	12	10

TABLE XXIII. EXPERT OPINION ON THE RELATIVE IMPORTANCE OF THE CRITERIA S_j

Criteria	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6
C1						
C2	0.98	0.97	0.99	0.97	0.97	0.94
C3	0.99	0.9	0.95	0.92	0.97	0.97
C4	0.96	0.95	0.99	0.9	0.92	0.95
C5	0.98	0.96	0.98	0.9	0.92	0.98
C6	1	0.99	0.97	0.95	0.95	1
C7	0.92	0.91	0.9	0.99	0.9	0.92
C8	0.98	1	0.91	0.92	0.95	0.95
C9	0.92	0.9	1	0.99	0.98	0.9

TABLE XXIV. CRITERIA WEIGHTS

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
RS Weight	0.2000	0.1778	0.1556	0.1333	0.1111	0.0889	0.0667	0.0444	0.0222
PIPRECIA weight	0.1314	0.1276	0.1215	0.1153	0.1102	0.1077	0.1001	0.0955	0.0909

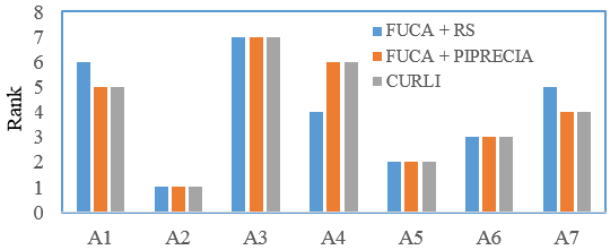

Fig. 3. The UAV ranking results based on different MCDM methods.

RS and PIPRECIA were used to calculate the weights of the criteria. The results are presented in Table XXIV. The ranking of alternatives in this case is implemented in the same way as above, and the results are illustrated in Figure 3. Figure 3 shows that the ranking results of the UAVs are similar. Specifically, the combination of the FUCA method and the PIPRECIA method gives ranking results that are completely consistent with those of the CURLI method. This result gives us a solid conclusion that A2 is the best alternative and A3 is the worst. Accordingly, out of the 7 surveyed UAV types, the U30L-6 is determined to be the best.

V. CONCLUSION

Ranking the alternatives to determine the best ones for three product categories, namely air conditioners, washing machines, and UAVs was carried out for the first time in this study. Four methods including RS, PIPRECIA, FUCA, and CURLI were applied simultaneously to accomplish this task. The main findings of this study are:

- The best found alternative is the same regardless of the method used.
- Among the considered alternatives, 1.5HP-FTKB35WMVMV was the best air conditioner type.
- The WA12T5360BV/SV is the best out of eight candidate washing machines.
- The U30L-6 is the best alternative among the seven types of UAVs considered.

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