International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
e-ISSN: 2455-2585
Volume7 , Issue 4 , April 2021

Optimal Choice of Agricultural Drone using MADM Methods

R D Rakhade[1], N V Patil[2], M R Pardeshi[3]

1, 2, 3Department of Mechanical Engineering, K.K. Wagh Institute of Engineering Education and Research, Nashik – 422 003, Maharashtra, India,

1rdrakhade@kkwagh.edu.in, 2nvpatil@kkwagh.edu.in, 3mrpardeshi@kkwagh.edu.in

Abstract
This paper presents an opening for optimum alternative of agriculture drone for little forming space by using Multi Attribute Decision Making (MADM) strategies particularly Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Drones are also called as unmanned aerial vehicles (UAVs) having various works in forming sector and play important role to spray pesticide, assist in planning irrigation schedules etc. A structured and economical perspective choice of agriculture drone is important, to settle on a best option for critical tasks into account. MADM methods are interpretative processes which are well suited in choice of different drones. This work suggests AHP and TOPSIS to judge drone alternatives for choice of method. In this work proposes a comprehensive list of key factors that have a significant influence on drone selection. A total of 10 sub-criteria have been identified and grouped under three main criteria, namely, (i) Functional output (ii) Economic consideration, (iii) Technical input. These entire criteria area unit extracted from on-line literature and skilled opinion. AHP technique is employed to work out on weights of every attribute and afterward, it is applied to MADM methods to rank a drone substitutes. Result of study shows that Agriculture Drone one (NAL410 model) was designated because the best suited for tiny forming space.

Keywords: Agriculture application, Drone, MADM method, AHP method, TOPSIS method

I. INTRODUCTION

Morden agriculture could be a new means of farm management that is predicated on observation, activity and response to internal changes and / or external parameters associated with crops. Main objective of this management approach is to use a lot of restricted resources of farms with efficiency (so on cut back prices of agricultural production) whereas conjointly increasing the yield [1]. Availability of drone influences on rise in quality of such systems. Presently, the world of plausible applications of this kind of technology is continually growing [2]. Objectives of this paper is to present variables associated with specifications of chosen drone and a chance of selecting an optimum model drone to be used within the method of spray chemical to maintaining health of crops using MADM technique.

MADM ways facilitate to settle on a most effective mode by taking in account varied attribute and interpreting all the alternatives. An academic literature has some samples appliance of MADM in agriculture sector. Out of those select drones for precision agriculture with AHP [3]; provide a survey regarding a potential use of drone in precision agriculture [4]; exploring forthcoming challenges of using agricultural call support systems in Agriculture 4.0 [5]. UAV route planning based on CSA AHP and TOPSIS [6] although drone play a very vital role within the design of an efficient spray system for agriculture sector, an academic literature concerning choice of drone is proscribed. The work represented during this paper has 2 specific goals: (1) Selection of optimal drone technologies (2) to offer an analytic method that's supported MADM ways for most effective selection among the choice drone.

Figure1. Drone [7]

Drone Figure 1 [7] has ability of chemical fog which will be directly passed to any or all levels of the crop by the sturdy air flow generated by propellers. Drones offer to create a perfect dynamic system, Super protection, easy to deal with harsh environment of plant protection, Intelligent multiple redundancy protection, running data real-time output. In this study, the choice of optimum drone can enhance potency of distinctive harsh setting of plant protection. Following are some description of paper. Section 2 provides proposes critical factors that have a significant influence on this selection process. Section 3 introduces AHP and TOPSIS decision making model by illustrating each step of model. Section 4 actual selection procedure of optimal solution among all different types drones available in market considering for small scale farm. Finally, conclude and present most suitable drone selection in Section 5.

II. AGRICULTURAL SPRAY DRONE AND ITS CRITERION SELECTION

Main aim of this study is to beat complexness of drone analysis method for agricultural purpose, integrated with MADM ways that area unit multi attribute decision-making ways area unit used for choice method. These strategies embrace a straightforward analytic method, basic calculations, and lower level of process complexness. Several variants of delivery drones are available in market that can successfully handle agriculture operations. These drones possess distinguishing features that might make one drone more preferred over another depending on particular use cases. Therefore, selecting appropriate drone for delivery process is critical for both efficiency and economics. This paper proposes a comprehensive list of key factors that have a significant influence on drone selection. A total of 10 sub-criteria have been identified and grouped under three main criteria namely, (i) Functional output (ii) Economic consideration, (iii) Technical input. These entire criteria area unit extracted from on-line literature and skilled opinion. Detailed descriptions for each sub-criterion are provided in this section while Figure 2 visualizes hierarchical representation of sub-criterions under each main criterion.

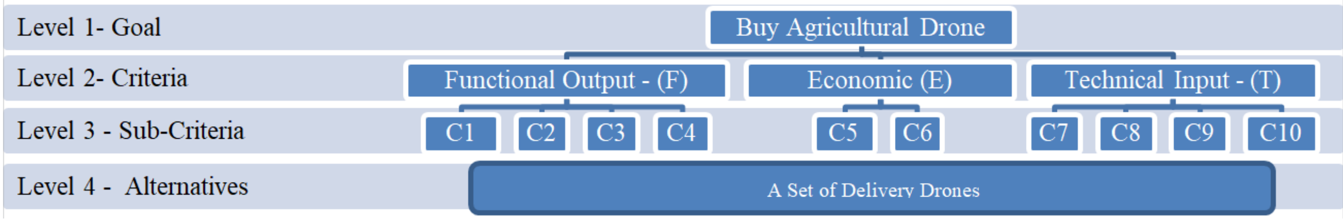

Figure2. Developing a hierarchical structure with goal

2.1 Functional Output (F)

Flight time (C1): This indicates time that a drone can fly with payload condition. It is measured unit in minutes.

Capacity of spray (C2): This factor represents load carrying capacity of drones and is highly compatible with motor capacity of it. It is measured unit in litres

Flying speed (C3): This sub-criterion stands for maximum allowable speed of the drone. It is measured unit in m/s

Spray Width (C4): This sub-criterion indicate maximum horizontal distance covered by nozzle to spray pesticide on crop. It is measured unit in meters.

2.2 Economical Consideration (E)

Product cost (C5): This cost includes all infrastructure costs (fixed, variable, and overhead cost) associated with each unit of a drone. It is measured unit in rupees

GST cost (C6): This cost associate with Goods and Services Tax, it is a tax that customers need to bear after they obtain any product or services, like food, clothes, things of daily desires, transportation etc. It is measured unit in rupees.

2.3 Technical Input (T)

Battery (C7): Battery use as primary source for drone, which drone consumes charge/fuel per unit time. Also, in consideration for this criterion is total number of recharges or refuels that can occur and when items such as batteries will need to be replaced. It is measured unit in mAh.

Remote Distance (C8): The maximum distance covered by drone and controlled by operator through remote is called remote distance. A transmitter that comes with consumer drones have a maximum range, operates in frequency band. It is measured unit in meters.

Motor (C9): As drone needs thrust in the air to float, it should use some powerful motors. The cheap, lightweight, small, and powerful motors used in drones. Capacity of motor is measured in KV

Aircraft Frame (C10): Drones use rotors for propulsion and control. Basically aircraft frame of drone is classified on basis of number of rotor used in drone.

III. PRINCIPLES MADM METHODS

This study applies two MADM techniques, AHP to see weights of attribute and AHP- TOPSIS to rank substitutes and choose most effective substitute by scrutiny each in this way. A short descriptive methodology is provided as follows.

3.1 AHP method

A decision hierarchy structure of AHP contains different levels that are goal, criteria, sub criteria, and alternatives. The choice method or conniving weights in AHP has 5 major steps [8]:

Step 1: Verify goal and analyse attributes. Develop a hierarchical data structure with a goal.

Step 2: Find relative importance of various attributes with regards to goal. Prepare relative importance matrix of attribute employing a Saaty's scale.

Step 3: Find relative normalized weight (w_j) of each attribute by (i) Calculating geometric mean (GM) of i-th row, (ii) Normalizing geometric means of rows in comparison matrix. Calculate matrices A3 and A4 such that A3 = A1 * A2 and A4 = A3 / A2, where A2 = $[w_1, w_2, \ldots, w_j]^T$. Determine maximum Eigen value λ_{max} that is average of matrix A4.

Step 4: Calculate consistency index. CI represented as follows

$$CI = \frac{\lambda\max - M}{M-1} \quad (3.1)$$

Step 5: Find the consistency ratio. Generally, a CR of 0.1 or less is taken into account. Refer Table 1 for random index (RI).

$$CR = \frac{CI}{RI} \quad (3.2)$$

Table 1 Random Index (RI)

No of Criteria	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

After finding weight to various attribute next to see rank of other by exploitation calculated weights. Each selected model of drone is rated with relation to each attribute. The overall performance score of alternatives is given by using equation 3.3.

$$Pi = \sum_{j=1}^{M} W_j * m_{ij\,normal} \quad (3.3)$$

Where, W_j represents weight of each attribute, $(m_{ij})_{normal}$ is normalized value of m_{ij}, and Pi is overall score of alternative Ai. The highest value of Pi is taken into account as best option.

3.2 TOPSIS Method

In TOPSIS technique each condition moves toward a monotonically ascending or descending order. So it offers an answer that's not solely nearest to theoretically best, that is conjointly extreme from theoretically worst. A short descriptive methodology is provided as follows. [08]:

Step 1: Verify goal and analyse attributes. Develop hierarchical data structure with a goal.

Step 2: Find normalized decision matrix, R_{ij}. This is represented as follows.

$$R_{ij} = m_{ij} / \left[\sum_{j=1}^{M} {m_{ij}}^2 \right]^{1/2} \quad (3.4)$$

Step 3: Decides relative importance of attribute with respect to goal

Step 4: Find weighted normalized decision matrix, V_{ij}. This is represented as follows.

$$V_{ij} = w_j R_{ij} \quad (3.5)$$

Step 5: Find best and worst solutions as follows.

$$V^+ = \{(\overset{Max}{\Sigma} V_{ij} / j\in J), (\overset{Min}{\Sigma} V_{ij} / j\in J') / i = 1,2\ldots\ldots,N\} = \{V_1^+, V_2^+, V_3^+,\ldots\ldots, V_M^+\} \quad (3.6)$$

$$V^- = \{(\overset{Min}{\Sigma} V_{ij} / j\in J), (\overset{Max}{\Sigma} V_{ij} / j\in J') / i = 1,2\ldots\ldots,N\} = \{V_1^-, V_2^-, V_3^-,\ldots\ldots V_M^-\} \quad (3.7)$$

Where J = (j= 1, 2, …..M) / j is integrated with beneficial attributes, and
J' = (j= 1,2,…..M) / j is integrated with non-beneficial attributes.

Step 6: Obtain separation measures. A separation of each alternative from ideal one is given in following equations.

$$S_i^+ = \{ \sum_{J=1}^{M} ((V_{ij} - V_j^+)^2) \}^{0.5} \qquad i = 1,2\ldots\ldots,N \quad (3.8)$$

$$S_i^- = \{ \sum_{J=1}^{M} ((V_{ij} - V_j^+)^2) \}^{0.5} \qquad i = 1,2\ldots\ldots,N \quad (3.9)$$

Step 7: The relative closeness of a particular alternative to best solution, overall score Pi, is represented as follows.

$$Pi = \frac{S_i^-}{S_i^- + S_i^+} \quad (3.10)$$

Step 8: The highest value of Pi is taken into account as best option.

IV. APPLICATION OF MADM METHOD ON AGRICULTURAL SPRAY DRONE

In this study standardize foremost critical parameters of eleven drones that are out there of late and that are appropriate for agricultural use ([9] – [18]). Taking under consideration, established criteria variants of solutions to current problem were adopted for analyses, as shown in Table 2. In consideration, a total of 10 sub-criteria have been identified and grouped under three main criteria, namely, (i) Functional output (ii) Economic consideration, (iii) Technical input. Sub criteria were assumed, these include: the flight time (C1); pesticide tank capacity (C2); Flying speed (C3); Spray Width (C4); Product cost (C5); GST Cost (C6). battery capacity (C7); range of controller (C8); Motor rating (C9); number of rotor (C10). Out of 10 sub criteria 3 are non-beneficial such as C5, C6, C9 and remaining 7 are beneficial

Table2. Selected Drone model Data

Drone Model		Criteria									
		Functional output(F)				Economic (E)		Technical input (T)			
		C1 (min)	C2 (lit.)	C3 (m/s)	C4 (m)	C5 (Rs/-)	C6 (Rs/-)	C7 (mAh)	C8 (km)	C9 (KV)	C10 (No.)
NLA410	AD 1	12	10	10	3.5	231532	11577	32000	3	400	4
NLA610	AD 2	12	10	10	4	239955	11998	32000	3	1080	6
Magpi Drone	AD 3	15	10	5	4.5	370000	18500	16000	0.5	810	6

TASS Drone	AD 4	15	5	10	4.5	200000	10000	12000	1.5	800	8
Espy E5L	AD 5	12	5	10	3.5	250000	12500	16000	3	400	4
JMR 5L405	AD 6	12	5	9	4	320000	16000	12000	1	400	4
Prime AG1	AD 7	13	5	9	4	245000	12250	12000	1	800	8
IRS Drone	AD 8	10	10	9	4	400000	20000	12000	1.5	810	6
ASAP100408	AD 9	10	10	10	5	445000	22250	32000	3	400	4
Windelite Drone	AD 10	13	10	12	4	500000	25000	12000	1	400	4
Phoenix Drone	AD 11	17	10	7	3	500000	25000	16000	1	810	6

Table 3 represents the relative importance matrix of main three criteria's and valise consistency ratio (CR) defined by using equation 3.1. Evaluation of individual attribute was consistent and less than 10 %.
Similarly Table 4, Table 5, and Table 6 represents relative importance matrix of three sub criteria and value of CR was also less than 10%. Table 7 represents global weight of respective attribute which will be used to calculate the Pi score in table 8.

Table No. 3 Relative Importance of main group criteria

A1				GM	Weight - A2	A3	A4
Main group Criteria	F	E	T				
F	1	1.5	3	1.651	0.5	1.5	3
E	0.6667	1	2	1.1006	0.3333	1	3
T	0.3334	0.5	1	0.5503	0.1667	0.5	3
			Sum	3.3019	1	λ_{max}	3
Consequence ratio CR = 0.00							

Table No. 4 Relative Importance of functional output criteria

A1					GM	Weight - A2	A3	A4
Functional output criteria	C1	C2	C3	C4				
C1	1	1.3333	2	4	1.8072	0.4	1.6	4
C2	0.75	1	1.5	3	1.3554	0.3	1.2	4
C3	0.5	0.6667	1	2	0.9036	0.2	0.8	4
C4	0.25	0.3333	0.5	1	0.4518	0.1	0.4	4
				Sum	4.518	1	λ_{max}	4
Consequence ratio CR = 0.00								

Table No. 5 Relative Importance of Economic criteria

A1			GM	Weight - A2	A3	A4
Economic criteria	C5	C6				
C5	1	1	1	0.5	1	2
C6	1	1	1	0.5	1	2
		Sum	2	1	λ_{max}	2
Consequence ratio CR = 0.00						

Table No. 6 Relative Importance of Technical input criteria

A1					GM	Weight - A2	A3	A4
Technical Criteria	C7	C8	C9	C10				
C7	1	1.3333	2	4	1.8072	0.4	1.6	4
C8	0.75	1	1.5	3	1.3554	0.3	1.2	4

C9	0.5	0.6667	1	2	0.9036	0.2	0.8	4
C10	0.25	0.3333	0.5	1	0.4518	0.1	0.4	4
				Sum	4.518	1	λ_{max}	4
Consequence ratio CR = 0.00								

Table No. 7 Global weights of each criteria

Weights of criteria		Local Weight of Sub Criteria		Global Weight Criteria
Functional output	0.5	C1	0.4	0.2
		C2	0.3	0.15
		C3	0.2	0.1
		C4	0.1	0.05
Economic	0.3333	C5	0.5	0.1667
		C6	0.5	0.1667
Technical Input	0.1667	C7	0.4	0.0667
		C8	0.3	0.05
		C9	0.2	0.0333
		C10	0.1	0.0167

Table 8 represent normalization and Pi score value of attribute and score of alternatives, highest value of Pi is taken into account as best option.

Table No. 8. Normalization and Pi score

Selected Model	Attributes										Pi Score
	C1 (min)	C2 (lit.)	C3 (m/s)	C4 (m)	C5 (Rs/-)	C6 (Rs/-)	C7 (mAh)	C8 (km)	C9 (KV)	C10 (No.)	
AD 1	0.7059	1	0.8333	0.7	0.8638	0.8638	1	1	1	0.5	0.8558
AD 2	0.7059	1	0.8333	0.8	0.8335	0.8335	1	1	0.3704	0.75	0.8339
AD 3	0.8824	1	0.4167	0.9	0.5405	0.5405	0.5	0.1667	0.4938	0.75	0.6639
AD 4	0.8824	0.5	0.8333	0.9	1	1	0.375	0.5	0.5	1	0.7965
AD 5	0.7059	0.5	0.8333	0.7	0.8	0.8	0.5	1	1	0.5	0.7262
AD 6	0.7059	0.5	0.75	0.8	0.625	0.625	0.375	0.3333	1	0.5	0.6228
AD 7	0.7647	0.5	0.75	0.8	0.8163	0.8163	0.375	0.3333	0.5	1	0.69
AD 8	0.5882	1	0.75	0.8	0.5	0.5	0.375	0.5	0.4938	0.75	0.6283
AD 9	0.5882	1	0.8333	1	0.4494	0.4494	1	1	1	0.5	0.7091
AD 10	0.7647	1	1	0.8	0.4	0.4	0.375	0.3333	1	0.5	0.6596
AD 11	1	1	0.5833	0.6	0.4	0.4	0.5	0.3333	0.4938	0.75	0.6506

AHP Rank – AD1- AD2- AD4- AD5- AD9- AD7- AD3- AD11- AD10- AD8- AD6

Next TOPSIS methods that are apply on given problem to determine rank of alternative. Table 9 represent normalize value for TOPSIS method by using equation 3.4

Table No. 9 Normalization

Selected Model	Attribute									
	C1 (min)	C2 (lit.)	C3 (m/s)	C4 (m)	C5 (Rs/-)	C6 (Rs/-)	C7 (mAh)	C8 (km)	C9 (KV)	C10 (No.)
AD 1	0.2788	0.3536	0.3226	0.2616	0.1977	0.1977	0.4739	0.4485	0.1752	0.2132
AD 2	0.2788	0.3536	0.3226	0.299	0.2049	0.2049	0.4739	0.4485	0.4729	0.3198
AD 3	0.3485	0.3536	0.1613	0.3363	0.316	0.316	0.2369	0.0747	0.3547	0.3198
AD 4	0.3485	0.1768	0.3226	0.3363	0.1708	0.1708	0.1777	0.2242	0.3503	0.4264
AD 5	0.2788	0.1768	0.3226	0.2616	0.2135	0.2135	0.2369	0.4485	0.1752	0.2132
AD 6	0.2788	0.1768	0.2903	0.299	0.2733	0.2733	0.1777	0.1495	0.1752	0.2132
AD 7	0.302	0.1768	0.2903	0.299	0.2092	0.2092	0.1777	0.1495	0.3503	0.4264
AD 8	0.2323	0.3536	0.2903	0.299	0.3416	0.3416	0.1777	0.2242	0.3547	0.3198

AD 9	0.2323	0.3536	0.3226	0.3737	0.38	0.38	0.4739	0.4485	0.1752	0.2132
AD 10	0.302	0.3536	0.3871	0.299	0.427	0.427	0.1777	0.1495	0.1752	0.2132
AD 11	0.3949	0.3536	0.2258	0.2242	0.427	0.427	0.2369	0.1495	0.3547	0.3198

Table 10 Represent weighted normalize value using TOSIS method equation no. 3.5 and also calculate V+, V^- value for respective attribute with the help of equation 3.6 and 3.7.

Table 11 represents separation of each alternative from ideal one is given by equations 3.8 and 3.9. A set of alternative is generated in descending order in this step; the highest value of Pi is taken into account as best option using equation 3.10.

Table No. 10 Weighted Normalization

Selected Model	**Attribute**									
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
	(min)	**(lit.)**	**(m/s)**	**(m)**	**(Rs/-)**	**(Rs/-)**	**(mAh)**	**(km)**	**(KV)**	**(no.)**
AD 1	0.0558	0.053	0.0323	0.0131	0.033	0.033	0.0316	0.0224	0.0058	0.0071
AD 2	0.0558	0.053	0.0323	0.0149	0.0342	0.0342	0.0316	0.0224	0.0158	0.0107
AD 3	0.0697	0.053	0.0161	0.0168	0.0527	0.0527	0.0158	0.0037	0.0118	0.0107
AD 4	0.0697	0.0265	0.0323	0.0168	0.0285	0.0285	0.0118	0.0112	0.0117	0.0142
AD 5	0.0558	0.0265	0.0323	0.0131	0.0356	0.0356	0.0158	0.0224	0.0058	0.0071
AD 6	0.0558	0.0265	0.029	0.0149	0.0455	0.0455	0.0118	0.0075	0.0058	0.0071
AD 7	0.0604	0.0265	0.029	0.0149	0.0349	0.0349	0.0118	0.0075	0.0117	0.0142
AD 8	0.0465	0.053	0.029	0.0149	0.0569	0.0569	0.0118	0.0112	0.0118	0.0107
AD 9	0.0465	0.053	0.0323	0.0187	0.0633	0.0633	0.0316	0.0224	0.0058	0.0071
AD 10	0.0604	0.053	0.0387	0.0149	0.0712	0.0712	0.0118	0.0075	0.0058	0.0071
AD 11	0.079	0.053	0.0226	0.0112	0.0712	0.0712	0.0158	0.0075	0.0118	0.0107
V+	0.079	0.053	0.0387	0.0187	0.0285	0.0285	0.0316	0.0224	0.0078	0.0142
V-	0.0465	0.0265	0.0161	0.0112	0.0712	0.0712	0.0118	0.0037	0.021	0.0071

Table No. 11 Overall Score

Selected Model	S^+	S^-	Pi Score
AD1	0.0265	0.0694	0.7237
AD2	0.0278	0.0675	0.7083
AD3	0.0492	0.0448	0.4766
AD4	0.0372	0.0678	0.6457
AD5	0.0414	0.0578	0.5827
AD6	0.051	0.0411	0.4463
AD7	0.0434	0.0556	0.5616
AD8	0.0579	0.0371	0.3905
AD9	0.0599	0.0445	0.4262
AD10	0.0683	0.0392	0.3647
AD11	0.067	0.0431	0.3915

TOPSIS Rank – AD1- AD2- AD4- AD5- AD7- AD3- AD6- AD9- AD11- AD8- AD10

IV. CONCLUSION

Drones have extremely distributed technical options that verify requirement to pick out specific criteria their assessment. The correctness of distributed analyses depends on these criteria. The bestowed problems supported the strategy of multi-criteria optimization area unit doable to be utilized in broadly speaking understood agriculture sector; significantly within the context of the spray of chemical to crop to take care of their health and improve its productivity. By application of MADM technique, the result distinctly display best-suited device is Agriculture Drone 1(NAL410 model). Overall conclusion is that, adopted AHP and TOPSIS methodology are associates in optimum choice for selecting the optimum drone; however these are not the only methods suggested. It looks fair to acquire benefit of strategies directly using each attribute values for comparison method.

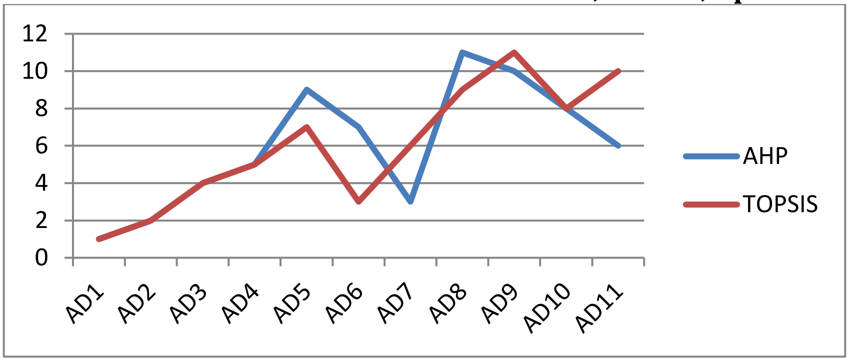

Figure 3: Comparison of AHP and TOPSIS

REFERENCES

[1] Nixon, How To Select an Agriculture Drone: An In-Depth Buyer's Guide, http://bestdroneforthejob.com, march 24, 2016.
[2] Cavoukian A., Privacy and Drones: Unmanned Aerial Vehicles, Information and Privacy Commissioner of Ontario, Canada 2012.
[3] Imre Petkovicset al., Selection of Unmanned Aerial Vehicle for Precision Agriculture with Multi-criteria Decision Making Algorithm, IEEE 15th International Symposium on Intelligent Systems and Informatics, September 14-16, 2017.
[4] Panagiotis Radoglou et al., A compilation of UAV applications for precision agriculture, Computer Network, Volume 172, 107148, 2020.
[5] Zhaoyu Z, Decision support systems for agriculture 4.0: Survey and challenges, computer and electronics in agriculture, vol 170, 105256, 2020
[6] X Li et al., UAV route evaluation algorithm based on CSA-AHP and TOPSIS, IEEE, 2017
[7] http://m.landle.com/aboutus.html
[8] Rao R V, Decision Making in the Manufacturing Environment, Springer Series in Advanced Manufacturing ISSN 1860-5168, ISBN 978-1-84628-818-0 e-ISBN 978-1-84628-819-7, 2007
[9] http://m.landle.com/aboutus.html
[10] https://www.indiamart.com/magpienterprise/
[11] http://tasstechnology.com/
[12] http://www.espydrones.com
[13] https://www.indiamart.com/electrogigtechnologies/
[14] https://www.indiamart.com/utech-rising-technology/
[15] https://www.indianrobostore.com/
[16] https://www.asapagritech.com/
[17] https://windelite.com/
[18] https://www.indiamart.com/phoenix