iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 Issue: XII Month of publication: December 2021

DOI: https://doi.org/10.22214/ijraset.2021.39638

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 9 Issue XII Dec 2021- Available at www.ijraset.com

Selection of 3D Printer for Innovation Centre of Academic Institution Based on AHP and TOPSIS Methods

R. D. Rakhade[1], N. V. Patil[2], M. R. Pardeshi[3], B. G. Patil[4]
[1, 2, 3, 4]Department of Mechanical Engineering, K. K. Wagh Institute of Engineering Education and Research, Nashik – 422 003,

***Abstract:** This paper describes a computer-based tool for the selection of 3D printer for educational propose by using Multi Attribute Decision Making (MADM) strategies particularly Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). In education, 3D printing technologies facilitate improved learning, skills development, and increased student and teacher engagement with the subject matter. Furthermore, 3D printing sparks greater creativity and collaboration in solving problems, to settle on a best option for teaching learning process tasks into account. MADM methods are interpretative processes which are well suited in choice of different 3D printers. This work suggests AHP and TOPSIS to judge 3D printer alternatives for choice of method, based on the AHP and TOPSIS methodology, ranks available techniques by a score resulting from the composition of priorities at different levels, each considering homogeneous and independent evaluation criteria. In this work proposes a comprehensive list of key factors that have a significant influence on 3D printer selection. In this work type of material used for printing considered as common for all printers such as ABS (Acrylonitrile Butadiene Styrene), PLA (Polylactic Acid), PET or Polyethylene terephthalate etc. A total of 09 sub-criteria have been identified and grouped under three main criteria, namely, (i) Physical Characteristics (ii) Economic consideration, (iii) Operational Requirements. These entire criteria area unit extracted from on-line literature and skilled opinion. Result of study shows that 3D Printer one (ET4 PRO 3IDEA model) was designated because the best suited for Innovation Centre Academic Institution.*
***Keywords:** 3D printer, MADM method, AHP method, TOPSIS method, Innovation Centre, Academic Institution*

I. INTRODUCTION

Innovation is characterized by breaking patterns both by thinking differently and acting in new ways. A natural way to put across new innovative ideas is to communicate, share experiences and in collaboration with others build a thorough understanding of given ideas, concepts and range of feasible manifestations (i.e. prototypes). Shared learning and exchange of experiences across intra-organizational levels is seen as a way of assessing critical areas of improvement for the engineering role in industry [1]. Main Objectives of this paper is to present variables associated with specifications of chosen 3D printer and a chance of selecting an optimum model 3D Printer to be used to facilitate improved learning, skills development, and increased student and teacher engagement with the subject matter 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 different sector. 3D printing applications are proliferated in all the fields due to its speed, low cost, customisation and its sustainability. Rakhade R. D.et al. [2] reported the application of MADM methods in agriculture sector. Prabhu S.R. et al. [3] have used for academic application. Severini et al. [4] have used the 3D printer for food industry application. Schubert et al. [5] reported the recent applications of 3D printers in medical field. Dwivedi et al. [6] have examined the applications of rapid prototyping (RP) in automobile sectors. Pei et al. [7] have investigated the implications of AM process in textile field. Panda et al. [8] reported that the selection of suitable 3D printer for the particular application is difficult task and involves several evaluation criteria. It is essential to select the appropriate 3D printer for a particular application; the improper selection of 3D printers may adversely affect the profitability of the organisation. The conflicting nature of the assessment criteria of 3D printer selection process can be resolved by using multi criteria decision making (MCDM) technique. The purpose of this paper is to deal with the selection of opt 3D printer for the innovation centre of academic institution. The work represented during this paper has 2 specific goals: (1) Selection of optimal 3D printing technologies (2) to offer an analytic method that's supported MADM ways for most effective selection among the choice 3D printers.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 9 Issue XII Dec 2021- Available at www.ijraset.com

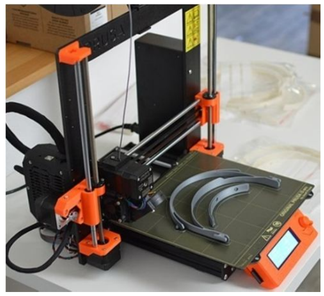


Figure1. 3D Printer [9]

3D Printer Figure 1 [9] uses computer-aided design (CAD) to create three-dimensional objects through a layering method. Sometimes referred to as additive manufacturing, 3D printing involves layering materials, like plastics, composites or bio-materials to create objects that range in shape, size, rigidity and colour. 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 of 3D printers available in market considering for demonstrate purpose to students in innovation centre. Finally, conclude and present most suitable 3D printer selection in Section 5.

II. 3D PRINTER AND ITS CRITERION SELECTION

Main aim of this study is to beat complexness of 3D printer analysis method for educational 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 3D printer are available in market that can successfully handle demonstrate purpose to students in teaching learning process. These 3D printers possess distinguishing features that might make one 3D printer more preferred over another depending on particular use cases. Therefore, selecting appropriate 3D printer is critical for both teaching and learning process. This paper proposes a comprehensive list of key factors that have a significant influence on 3D printer selection. A total of 9 sub-criteria have been identified and grouped under three main criteria namely, (i) Physical Characteristics (ii) Economic consideration, (iii) Operational Requirements. 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.

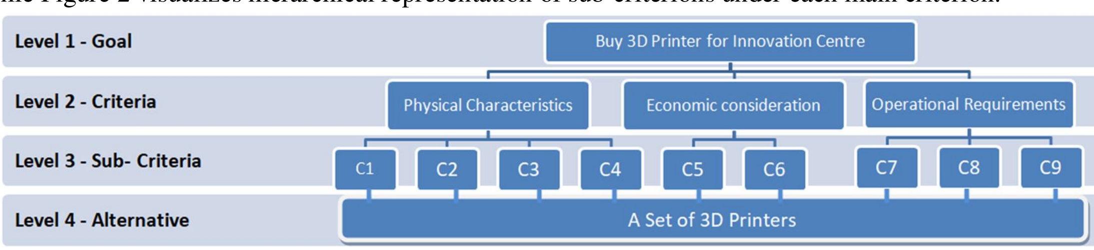


Figure2. Developing a hierarchical structure with goal

A. Physical Characteristics (P)

1) *Print Size (C1):* This indicates volume of a printer gives the maximum size that one object can have in order to be printed.
2) *Layer Thickness (C2):* Layer thickness in 3D printing is a measure of the layer height of each successive addition of material in the additive manufacturing or 3D printing process in which layers are stacked
3) *Build Speed (C3):* 3D printing speed measures the amount of manufactured material over a given time period.
4) *Printer Weight (C4):* The total weight of a 3D printer comes down to its size, what it's made from, and the design of the printer

B. Economical Consideration (E)

1) *Product Cost (C5):* This cost includes all infrastructure costs (fixed, variable, and overhead cost) associated with each unit of a 3D printer.
2) *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.

C. Operational Requirements (O)

1) *Power Consumption (C7):* Power consumption refers to the electrical energy per unit time, supplied to operate 3D printer
2) *Power Requirement (C8):* The amount of potential energy between two points on a circuit
3) *Extruder Temp Maximum (C9):* Extrusion temperature is the temperature the extruder heats to during print. It depends on a few other variables, mainly the properties of the plastic filament and print speed.

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.

A. 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 [10]:

1) *Step 1:* Verify goal and analyse attributes. Develop a hierarchical data structure with a goal.
2) *Step 2:*Find relative importance of various attributes with regards to goal. Prepare relative importance matrix of attribute employing a Saaty's scale.
3) *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.
4) Step 4: Calculate consistency index. CI represented as follows

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

5) *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 3D printer 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.

B. 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.[10]:

1) *Step 1:* Verify goal and analyse attributes. Develop hierarchical data structure with a goal.
2) Step 2: Find normalized decision matrix, R_{ij}. This is represented as follows.

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

3) Step 3: Decides relative importance of attribute with respect to goal
4) *Step 4:* Find weighted normalized decision matrix, V_{ij}. This is represented as follows.

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

5) *Step 5:* Find best and worst solutions as follows.

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

$$= \{V_1^+, V_2^+, V_3^+, \ldots\ldots, V_M^+\}$$

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

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.

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

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

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

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

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

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

IV. APPLICATION OF MADM METHOD ON 3D PRINTERS

In this study standardize foremost critical parameters of ten 3D printers that are out there of late and that are appropriate for educational use ([11] – [17]). 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 9 sub-criteria have been identified and grouped under three main criteria, namely, (i) Physical Characteristics (ii) Economic consideration, (iii) Operational Requirements. Sub criteria were assumed, these include: Print Size (C1); Layer Thickness (C2); Build Speed (C3); Printer Weight (C4); Product cost (C5); GST Cost (C6). Power Consumption (C7); Power Requirement (C8); Extruder Temp Maximum (C9). Out of 9 sub criteria 4 are non-beneficial such as C5, C6, C7, C8 and remaining 5 are beneficial

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.

Table2. Selected 3D Printers model Data

3D Printers Model		Criteria								
		Physical Characteristics (P)				Economic (E)		Operational Requirements (O)		
		C1 (mm)	C2 (mm)	C3 (mm/s)	C4 (kg)	C5 (Rs/-)	C6 (Rs/-)	C7 (W)	C8 (V)	C9 (^{0}C)
CUB 1.1	3D 1	250	0.4	150	21	75000	13500	200	240	260
ET4 PRO	3D 2	250	0.3	100	7.4	13983	2517	240	240	255
PRATHAM	3D 3	250	0.4	120	16	72000	13860	240	230	280
ELEGOO MARS,	3D 4	420	0.2	50	6.2	52000	9360	60	240	280
FDM	3D 5	540	0.4	150	40	79860	14375	480	220	280
ENDER 5 PRO,	3D 6	300	0.4	60	11.8	32203	5796	350	240	260
CR-10 V2	3D 7	400	0.4	100	11.5	55000	9900	350	230	260
CR-10 S PRO V2	3D 8	400	0.4	100	17.5	60000	10800	480	240	260
ENDER 3	3D 9	250	0.4	100	7.8	20000	3600	350	265	270
ENDER 3 PRO	3D 10	250	0.4	180	7.8	22000	3960	350	220	270

Table No. 3 Relative Importance of main group criteria

Main group Criteria	A1 P	A1 E	A1 O	GM	Weight -A2	A3	A4
P	1.0000	1.5000	3.0000	1.6510	0.5000	1.5000	3.0000
E	0.6667	1.0000	2.0000	1.1006	0.3333	1.0000	3.0000
O	0.3333	0.5000	1.0000	0.5503	0.1667	0.5000	3.0000
			Sum	3.3019	1	λ_{max}	3
Consequence ratio CR = 0.00							

Table No. 4 Relative Importance of Physical Characteristics Criteria

Functional output criteria	A1 C1	A1 C2	A1 C3	A1 C4	GM	Weight -A2	A3	A4
C1	1.0000	1.3333	2.0000	4.0000	1.8072	0.4000	1.6000	4.0000
C2	0.7500	1.0000	1.5000	3.0000	1.3554	0.3000	1.2000	4.0000
C3	0.5000	0.6667	1.0000	2.0000	0.9036	0.2000	0.8000	4.0000
C4	0.2500	0.3333	0.5000	1.0000	0.4518	0.1000	0.4000	4.0000
				Sum	4.518	1	λ_{max}	4
Consequence ratio CR = 0.00								

Table No. 5 Relative Importance of Economic criteria

Economic criteria	A1 C5	A1 C6	GM	Weight -A2	A3	A4
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 Operational Requirement Criteria

Technical Criteria	A1 C7	A1 C8	A1 C9	GM	Weight -A2	A3	A4
C7	1.0000	1.0000	2.0000	1.2599	0.4000	1.2000	3.0000
C8	1.0000	1.0000	2.0000	1.2599	0.4000	1.2000	3.0000
C9	0.5000	0.5000	1.0000	0.6300	0.2000	0.6000	3.0000
			Sum	3.1498	1.0000	λ_{max}	3
Consequence ratio CR = 0.00							

Table No. 7 Global weights of each criteria

Weights of criteria		Local Weight of Sub Criteria		Global Weight Criteria
Physical Characteristics	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
Operational Requirement	0.1667	C7	0.4	0.0667
		C8	0.4	0.0667
		C9	0.2	0.0333

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 (mm)	C2 (mm)	C3 (mm/s)	C4 (kg)	C5 (Rs/-)	C6 (Rs/-)	C7 (W)	C8 (V)	C9 (^{0}C)	
3D 1	0.4630	1.0000	0.8333	1.0000	0.1864	0.1864	0.3000	0.9167	0.9286	0.5501
3D 2	0.4630	0.7500	0.5556	0.3524	1.0000	1.0000	0.2500	0.9167	0.9107	0.7197
3D 3	0.4630	1.0000	0.6667	0.7619	0.1942	0.1816	0.2500	0.9565	1.0000	0.5238
3D 4	0.7778	0.5000	0.2778	0.2952	0.2689	0.2689	1.0000	0.9167	1.0000	0.5238
3D 5	1.0000	1.0000	0.8333	1.9048	0.1751	0.1751	0.1250	1.0000	1.0000	0.6953
3D 6	0.5556	1.0000	0.3333	0.5619	0.4342	0.4343	0.1714	0.9167	0.9286	0.5708
3D 7	0.7407	1.0000	0.5556	0.5476	0.2542	0.2542	0.1714	0.9565	0.9286	0.5720
3D 8	0.7407	1.0000	0.5556	0.8333	0.2331	0.2331	0.1250	0.9167	0.9286	0.5735
3D 9	0.4630	1.0000	0.5556	0.3714	0.6992	0.6992	0.1714	0.8302	0.9643	0.6487
3D 10	0.4630	1.0000	1.0000	0.3714	0.6356	0.6356	0.1714	1.0000	0.9643	0.6833

AHP Rank – 3D 2- 3D 5- 3D 10- 3D 9- 3D 8- 3D 7- 3D 6- 3D 1- 3D 4- 3D 3

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

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 9 Issue XII Dec 2021- Available at www.ijraset.com

Table No. 9 Normalization

Selected Model	C1 (mm)	C2 (mm)	C3 (mm/s)	C4 (kg)	C5 (Rs/-)	C6 (Rs/-)	C7 (W)	C8 (V)	C9 (^{0}C)
3D 1	0.2291	0.3369	0.4039	0.3778	0.4432	0.4376	0.1899	0.3205	0.3072
3D 2	0.2291	0.2526	0.2693	0.1331	0.0826	0.0816	0.2278	0.3205	0.3013
3D 3	0.2291	0.3369	0.3231	0.2879	0.4255	0.4492	0.2278	0.3071	0.3308
3D 4	0.3849	0.1684	0.1346	0.1115	0.3073	0.3034	0.0570	0.3205	0.3308
3D 5	0.4949	0.3369	0.4039	0.7196	0.4720	0.4659	0.4557	0.2938	0.3308
3D 6	0.2750	0.3369	0.1616	0.2123	0.1903	0.1879	0.3323	0.3205	0.3072
3D 7	0.3666	0.3369	0.2693	0.2069	0.3250	0.3209	0.3323	0.3071	0.3072
3D 8	0.3666	0.3369	0.2693	0.3148	0.3546	0.3501	0.4557	0.3205	0.3072
3D 9	0.2291	0.3369	0.2693	0.1403	0.1182	0.1167	0.3323	0.3539	0.3190
3D 10	0.2291	0.3369	0.4847	0.1403	0.1300	0.1284	0.3323	0.2938	0.3190

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	C1 (mm)	C2 (mm)	C3 (mm/s)	C4 (kg)	C5 (Rs/-)	C6 (Rs/-)	C7 (W)	C8 (V)	C9 (^{0}C)
3D 1	0.0458	0.0505	0.0404	0.0189	0.0739	0.0729	0.0127	0.0160	0.0102
3D 2	0.0458	0.0379	0.0269	0.0067	0.0138	0.0136	0.0152	0.0160	0.0100
3D 3	0.0458	0.0505	0.0323	0.0144	0.0709	0.0749	0.0152	0.0154	0.0110
3D 4	0.0770	0.0253	0.0135	0.0056	0.0512	0.0506	0.0038	0.0160	0.0110
3D 5	0.0990	0.0505	0.0404	0.0360	0.0787	0.0777	0.0304	0.0147	0.0110
3D 6	0.0550	0.0505	0.0162	0.0106	0.0317	0.0313	0.0222	0.0160	0.0102
3D 7	0.0733	0.0505	0.0269	0.0103	0.0542	0.0535	0.0222	0.0154	0.0102
3D 8	0.0733	0.0505	0.0269	0.0157	0.0591	0.0583	0.0304	0.0160	0.0102
3D 9	0.0458	0.0505	0.0269	0.0070	0.0197	0.0194	0.0222	0.0177	0.0106
3D 10	0.0458	0.0505	0.0485	0.0070	0.0217	0.0214	0.0222	0.0147	0.0106
V+	0.0990	0.0505	0.0485	0.0360	0.0138	0.0136	0.0038	0.0147	0.0110
V-	0.0458	0.0253	0.0135	0.0056	0.0787	0.0777	0.0304	0.0177	0.0100

Table No. 11Overall Score

Selected Model	S^+	S^-	Pi Score
3D 1	0.1020	0.0436	0.5993
3D 2	0.0666	0.0943	1.1717
3D 3	0.1035	0.0371	0.5279
3D 4	0.0777	0.0563	0.8400
3D 5	0.0953	0.0716	0.8578
3D 6	0.0678	0.0719	1.0296
3D 7	0.0731	0.0534	0.8447
3D 8	0.0794	0.0494	0.7670
3D 9	0.0674	0.0881	1.1328
3D 10	0.0642	0.0914	1.1747

TOPSIS Rank – 3D 2- 3D 10- 3D 9- 3D 6- 3D 5- 3D 4- 3D 7- 3D 8- 3D 1- 3D 3

V. CONCLUSION

3D Printers 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 do able to be utilized in broadly speaking understood educational sector; significantly 3D printing technologies facilitate improved learning, skills development, and increased student and teacher engagement with the subject matter By application of MADM technique, the result distinctly display best-suited device is 3D Printer one (ET4 PRO 3IDEA model). Overall conclusion is that, adopted AHP and TOPSIS methodology are associates in optimum choice for selecting the optimum 3D printer; however these are not the only methods suggested. It looks fair to acquire benefit of strategies directly using each attribute values for comparison method.

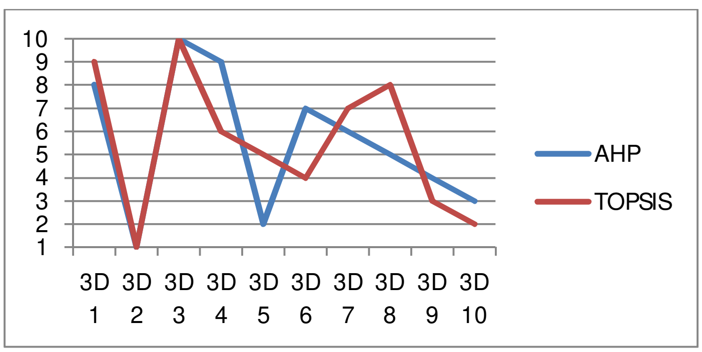


Figure 3: Comparison of AHP and TOPSIS

REFERENCES

[1] P. Adler, Shared Learning, Management Science 36: 938–957, 1990.

[2] R. D. Rakhade, et al., Optimal Choice of Agricultural Drone using MADM Methods, International Journal of Technological Innovation in Modern Engineering and Science (IJTIMES),e- ISSN :2455-2585, Volume 7, Issue 4,PP 1-7, 2021.

[3] S. R. Prabhu, et al., Selection of 3D printer based on FAHP integrated with GRA-TOPSIS, Int. J. Materials and Product Technology, Vol. 58, Nos. 2/3, pp.155–177, 2019

[4] C. Severini, et al., Printing a blend of fruit and vegetables. New advances on critical variables and shelf life of 3D edible objects, Journal of Food Engineering, Vol. 220, pp.89–100, 2917

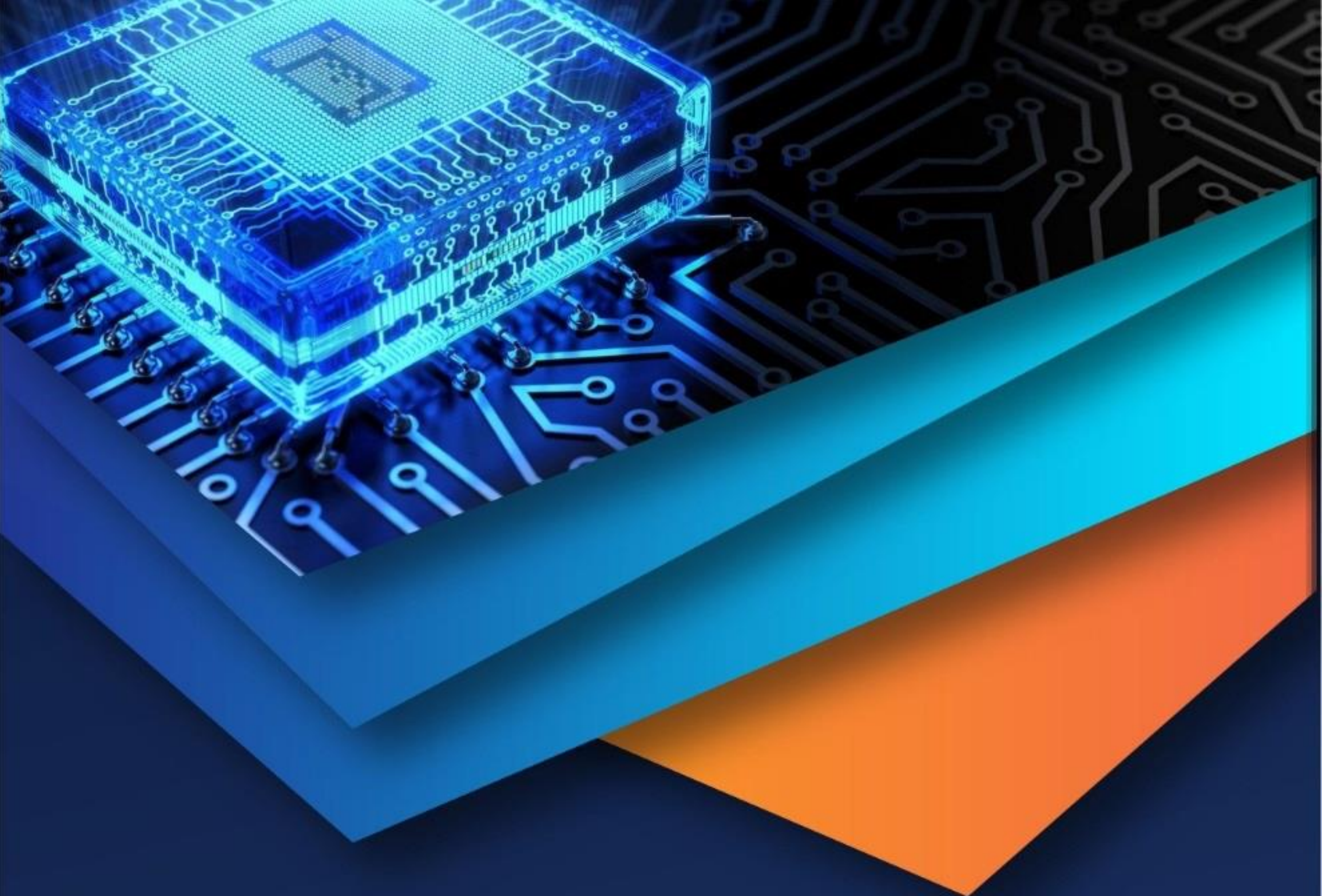
[5] C. Schubert, Innovations in 3D printing: a 3D overview from optics to organs, British Journal of Ophthalmology, Vol. 98, No. 2, pp.159–161, 2014

[6] G. Dwivedi, et al., Analysis of barriers to implement additive manufacturing technology in the Indian automotive sector, International Journal of Physical Distribution & Logistics Management, Vol. 47, No. 10, pp.972–991, 2017

[7] E. Pei, et al., Direct 3D printing of polymers onto textiles: experimental studies and applications, Rapid Prototyping Journal, Vol. 21, No. 5, pp.556–571, 2015

[8] B. N. Panda, Integrated AHP and fuzzy TOPSIS approach for the selection of a rapid prototyping process under multi-criteria perspective, All India Manufacturing Technology, Design and Research Conference, IIT Guwahati, India, 2014

[9] https://commons.wikimedia.org/wiki/File:3D_printer_EAC.jpg
[10] R. V. Rao, 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
[11] https://www.3dcubic.net/
[12] https://www.3idea.in/
[13] https://www.make3d.in
[14] https://protomont.com/
[15] https://dir.indiamart.com/pune/fdm-3d-printer.html
[16] https://www.indiamart.com/proddetail/creality-ennder-5-pro-22432169733.html
[17] https://www.3dspectratech.com/



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY