

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 1, January 2019

Selection of Hydraulic Press on the Basis of Fuzzy Multi Objective Optimization Ratio Analysis (MOORA) Method

Sumit S. Patil¹, Ayyankali Muthuraja²

M. Tech Design, Dept. of Mechanical Engineering, Sandip University SCOE, Nashik, Maharashtra, India¹

Associate Professor, Dept. of Mechanical Engineering, Sandip University, SCOE, Nashik, Maharashtra, India²

ABSTRACT: In the present work, to meet the challenges of global competitiveness, manufacturing organizations area unit currently facing the issues of choosing applicable producing ways, product and process designs, manufacturing processes and technologies, and machinery and equipment. The selection selections become a lot of complicated because the call manufacturers within the producing atmosphere need to assess a good vary of alternatives supported a collection of conflicting criteria. To aid these choice processes, varied multi-objective higher cognitive process (MODM) ways area unit currently offered. application of multi-objective optimization on the basis of ratio analysis (MOORA) method is applied for solving multiple criteria (objective) optimization problem in Hydraulic press. Vertical and horizontal hydraulic press machine for squeezing and flaring process which include selection on the basis of linguistic variable triangular fuzzy logic number criteria in hydraulic press are considered in this paper. In all these cases, the results obtained using the MOORA method trying to match with those derived by the previous researchers which prove the applicability, potentiality, and flexibility of this method while solving this problems in present day manufacturing environment.

KEYWORDS: MODM, MOORA, Hydraulic Press, Linguistic Variable, Triangular Fuzzy Number.

I. INTRODUCTION

The fuzzy MOORA technique was introduced by Brauers and Zavadskas [4]. when the matter happens on the positioning, different call manufacturers with varied interests and values ,make decision-making method far more tough. Multi-objective optimisation within the method of at the same time optimizing two or a lot of conflicting alternatives subjective to sure constraints. Such techniques, therefore appear to be associate applicable tool for ranking or choosing the simplest different from a collection of obtainable choices [1].

Multi-objective optimisation on the premise of magnitude relation analysis (MOORA) is that the recent and noval tool fictional and used within the several scientific comes. In alternative facet, in each call setting their square measure huge data and undetermined scenario that have an effect on call method and plainly its outcomes. therefore to improve the choice preciseness and to beat unclearness in uncertain setting, the fuzzy theory and fresh linguistic fuzzy approaches try and get a lot of reliable solutions [3]

within the mechanical press, there square measure two totally different operations needed the separate machine in order that the vertical and horizontal machine during this case the victimisation this multi-criteria higher cognitive process MOORA technique is however useful victimisation fuzzy criteria is given during this paper.[5].and the techniques for the hydraulic press.

II. MOORA METHOD

Multi objective optimisation (or programming), conjointly referred to as multicriteria or multi attribute optimisation, is that the method of at the same time optimizing two or additional conflicting attributes (objectives) subject to bound

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 1, January 2019

constraints. The MOORA methodology, initial introduced by Brauers [1] is such a multi objective optimisation technique which will be with success applied to unravel varied kinds of advanced deciding issues within the producing atmosphere. The MOORA methodology starts with a choice matrix showing the performance of different alternatives with reference to various objectives.[2],[4].

The fuzzy MOORA procedure for ranking of best knowledge flow practicing for hydraulic press is given below

Step 1: construct the fuzzy decision matrices.

The fuzzy decision matrices are constructed by respondents using the appropriate linguistic variables for the alternative with respect to criteria.

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \cdots & \tilde{x}_{mn} \end{bmatrix} \tilde{w} = [\tilde{w}_1 \quad \tilde{w}_2 \quad \tilde{w}_3]$$

Where \tilde{x}_{ij} is the performance rating of decision makers who are responsible for assessing m alternatives ($A_i, i = 1, \dots, m$), with respect to the importance of each of the n criteria ($C_j, j = 1, \dots, n$). A fuzzy rating of all decision makers is the given by triangular numbers ($\tilde{x}_{ij} = a_{ij}, b_{ij}, c_{ij}$)

The scale for alternative rating is given in Table 1.

Table 1 The fuzzy linguistic scale for alternatives

Intensity of importance	Linguistic variable	Triangular fuzzy number
1	Very poor (VP)	(0,0,1)
2	Poor (P)	(0,1,3)
3	Medium poor (MP)	(1,3,5)
4	Fair (F)	(3,5,7)
5	Medium good (MG)	(5,7,9)
6	Good(G)	(7,9,10)
7	Very good (VG)	(9,10,10)

In this table 1 we have considered some linguistic variables with the help of this linguistic variables we are study the triangular fuzzy number.

Table 2 Decision Matrix

Criteria	Vertical Hydraulic Press	Horizontal Hydraulic Press
Criteria 1	G	F
Criteria 2	G	MG
Criteria 3	F	P
Criteria 4	G	G
Criteria 5	VG	G
Criteria 6	G	MG
Criteria 7	G	MG
Criteria 8	VG	MG
Criteria 9	G	MG
Criteria 10	VG	G

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 1, January 2019

In the table 2 shows the decision number for the vertical hydraulic press and horizontal hydraulic press from this we considered the 10 criteria's.

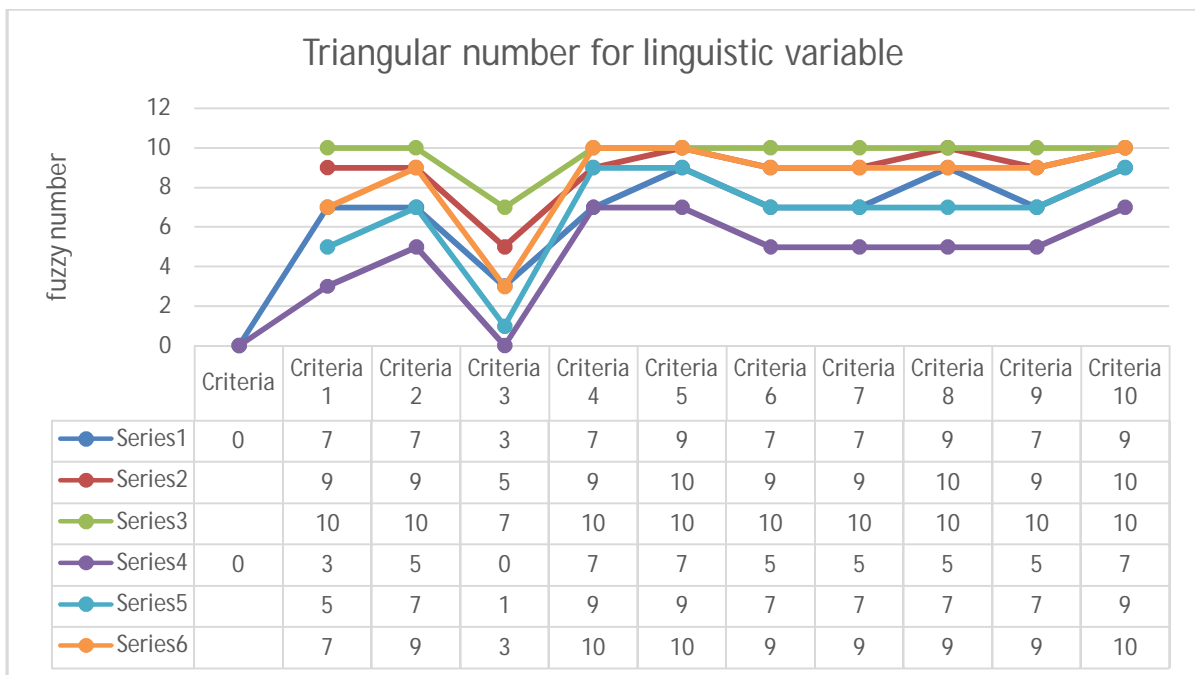
Step 2: Aggregate rating for each alternative expressed in triangular fuzzy numbers.

Assuming that a decision group has k number of decision makers. The aggregated fuzzy ratings (\tilde{x}_{ij}) of each criterion with respect to alternatives are calculated as

$$\tilde{x}_{ij} = \frac{1}{k} [\tilde{D}_K] \dots \dots \dots (1)$$

Table 3 Triangular number for respective linguistic variable.

Criteria	Vertical Hydraulic Press			Horizontal Hydraulic Press		
Criteria 1	7	9	10	3	5	7
Criteria 2	7	9	10	5	7	9
Criteria 3	3	5	7	0	1	3
Criteria 4	7	9	10	7	9	10
Criteria 5	9	10	10	7	9	10
Criteria 6	7	9	10	5	7	9
Criteria 7	7	9	10	5	7	9
Criteria 8	9	10	10	5	7	9
Criteria 9	7	9	10	5	7	9
Criteria 10	9	10	10	7	9	10



International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 1, January 2019

For this squeezing and flaring operation considered the 10 different criteria for the vertical and horizontal hydraulic press for that triangular fuzzy number consideration shown in the table and graph.

Step 3: Normalize the fuzzy-decision Matrix.

The decision matrix is normalized to remove sample-to-sample variability by transforming the various criteria scales into a comparable scale. MOORA refers to a magnitude relation system during which every response of an alternate on associate objective is compared to the divisor, that is representative for all alternatives regarding that objective. The normalized fuzzy-decision matrix denoted by x_{ij} is shown as following formula.

$$x_{ij} = (a_{ij}, b_{ij}, c_{ij}), i = 1, 2, \dots, m ; j = 1, 2, \dots, n$$

Here, the linear scale transformation can be used to transform the various criteria scales into a comparable scale. Therefore, we can obtain the normalized fuzzy decision matrix x_{ij} .

Where,

$$a_{ij}^* = a_{ij} / \sqrt{\sum_{i=1}^m [(a_{ij})^2 + (b_{ij})^2 + (c_{ij})^2]} \dots \dots \dots (2)$$

$$b_{ij}^* = b_{ij} / \sqrt{\sum_{i=1}^m [(a_{ij})^2 + (b_{ij})^2 + (c_{ij})^2]} \dots \dots \dots (3)$$

$$c_{ij}^* = c_{ij} / \sqrt{\sum_{i=1}^m [(a_{ij})^2 + (b_{ij})^2 + (c_{ij})^2]} \dots \dots \dots (4)$$

Table 4 Determine the SQRT for triangular number of each criteria

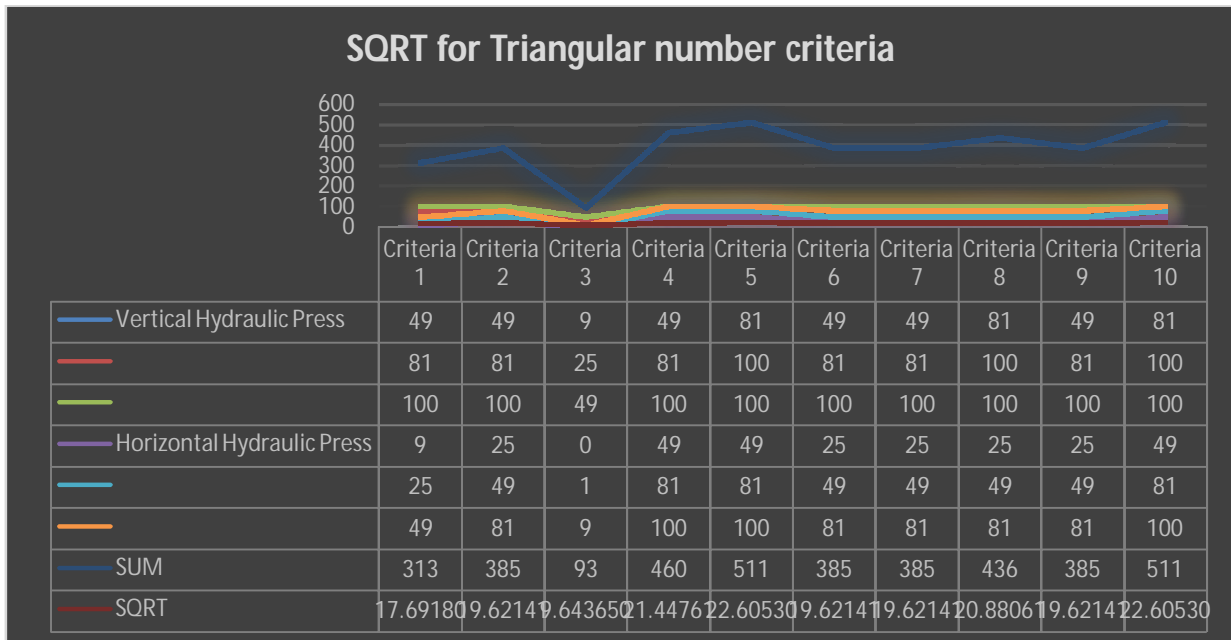
Criteria	Vertical Hydraulic Press			Horizontal Hydraulic Press			SUM	SQRT
Criteria 1	49	81	100	9	25	49	313	17.69180601
Criteria 2	49	81	100	25	49	81	385	19.62141687
Criteria 3	9	25	49	0	1	9	93	9.643650761
Criteria 4	49	81	100	49	81	100	460	21.44761059
Criteria 5	81	100	100	49	81	100	511	22.60530911
Criteria 6	49	81	100	25	49	81	385	19.62141687
Criteria 7	49	81	100	25	49	81	385	19.62141687
Criteria 8	81	100	100	25	49	81	436	20.88061302
Criteria 9	49	81	100	25	49	81	385	19.62141687
Criteria 10	81	100	100	49	81	100	511	22.60530911

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 1, January 2019



We can calculate the SQRT of this triangular number and we are also calculate the sum .calculating things shown in graph and the table.

Table 5 Normalised fuzzy decision matrix.

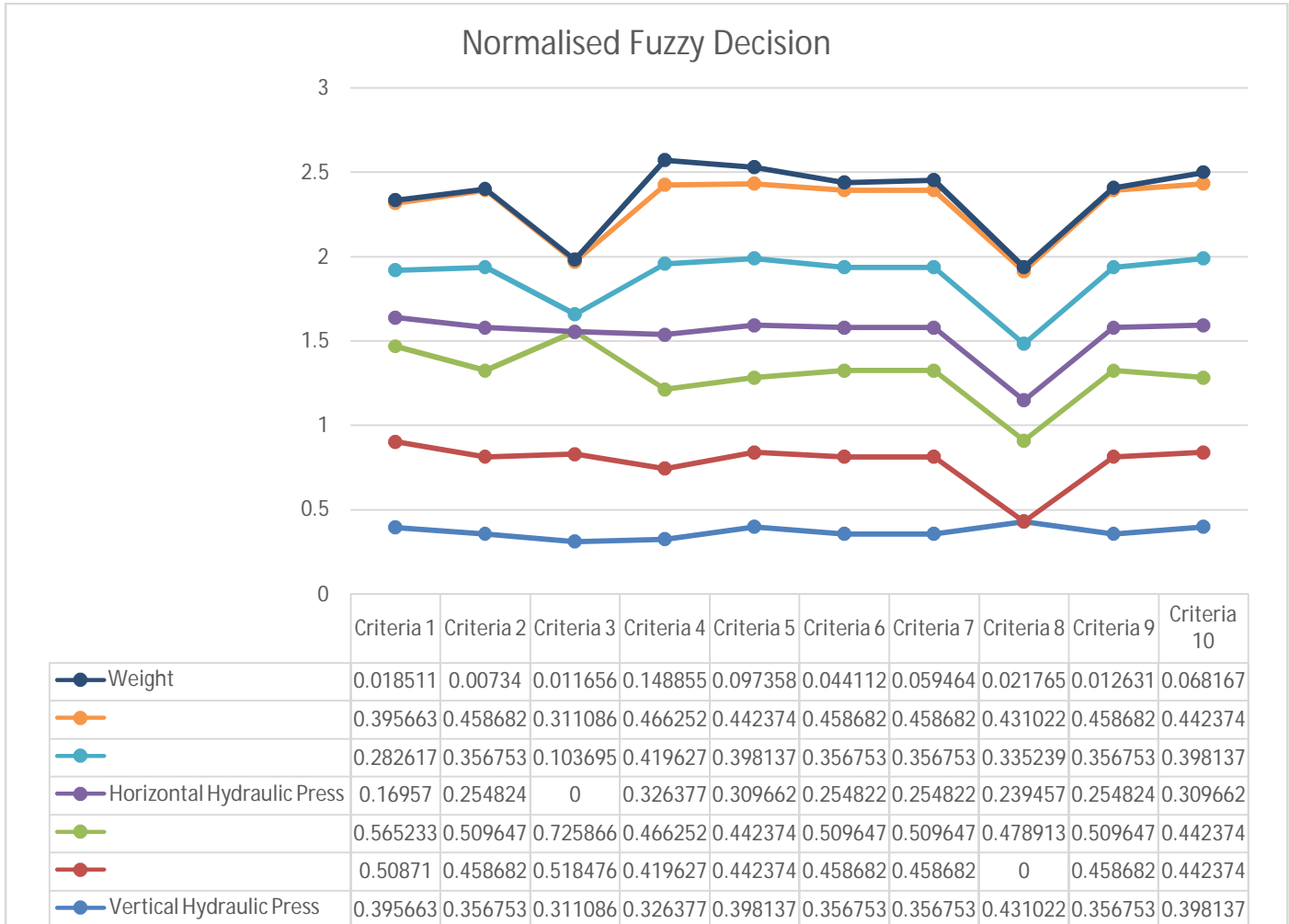
Criteria	Vertical Hydraulic Press			Horizontal Hydraulic Press			Weight
Criteria 1	0.395663	0.50871	0.565233	0.16957	0.282617	0.395663	0.018511
Criteria 2	0.356753	0.458682	0.509647	0.254824	0.356753	0.458682	0.00734
Criteria 3	0.311086	0.518476	0.725866	0	0.103695	0.311086	0.011656
Criteria 4	0.326377	0.419627	0.466252	0.326377	0.419627	0.466252	0.148855
Criteria 5	0.398137	0.442374	0.442374	0.309662	0.398137	0.442374	0.097358
Criteria 6	0.356753	0.458682	0.509647	0.254822	0.356753	0.458682	0.044112
Criteria 7	0.356753	0.458682	0.509647	0.254822	0.356753	0.458682	0.059464
Criteria 8	0.431022	0.478913	0.478913	0.239457	0.335239	0.431022	0.021765
Criteria 9	0.356753	0.458682	0.509647	0.254824	0.356753	0.458682	0.012631
Criteria 10	0.398137	0.442374	0.442374	0.309662	0.398137	0.442374	0.068167

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 1, January 2019



We are calculate the horizontal hydraulic press and vertical hydraulic press calculate the normalised fuzzy decision matrix. With the help of the AHP method and some TOPSIS study we calculate the weight. Which is shown in table and graph

Step 4: weighted normalized decision matrix.

The weighted normalized fuzzy decision matrix is obtained as following matrix \tilde{v}

$$\tilde{v} = [\tilde{v}_{ij}^a, \tilde{v}_{ij}^b, \tilde{v}_{ij}^c], i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

Where,

$$[\tilde{v}_{ij}^a = a_{ij}^* \otimes \tilde{w}_j] \dots \dots \dots (5)$$

$$[\tilde{v}_{ij}^b = b_{ij}^* \otimes \tilde{w}_j] \dots \dots \dots (6)$$

$$[\tilde{v}_{ij}^c = c_{ij}^* \otimes \tilde{w}_j] \dots \dots \dots (7)$$

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 1, January 2019

Table 6 weighted normalized fuzzy decision matrix

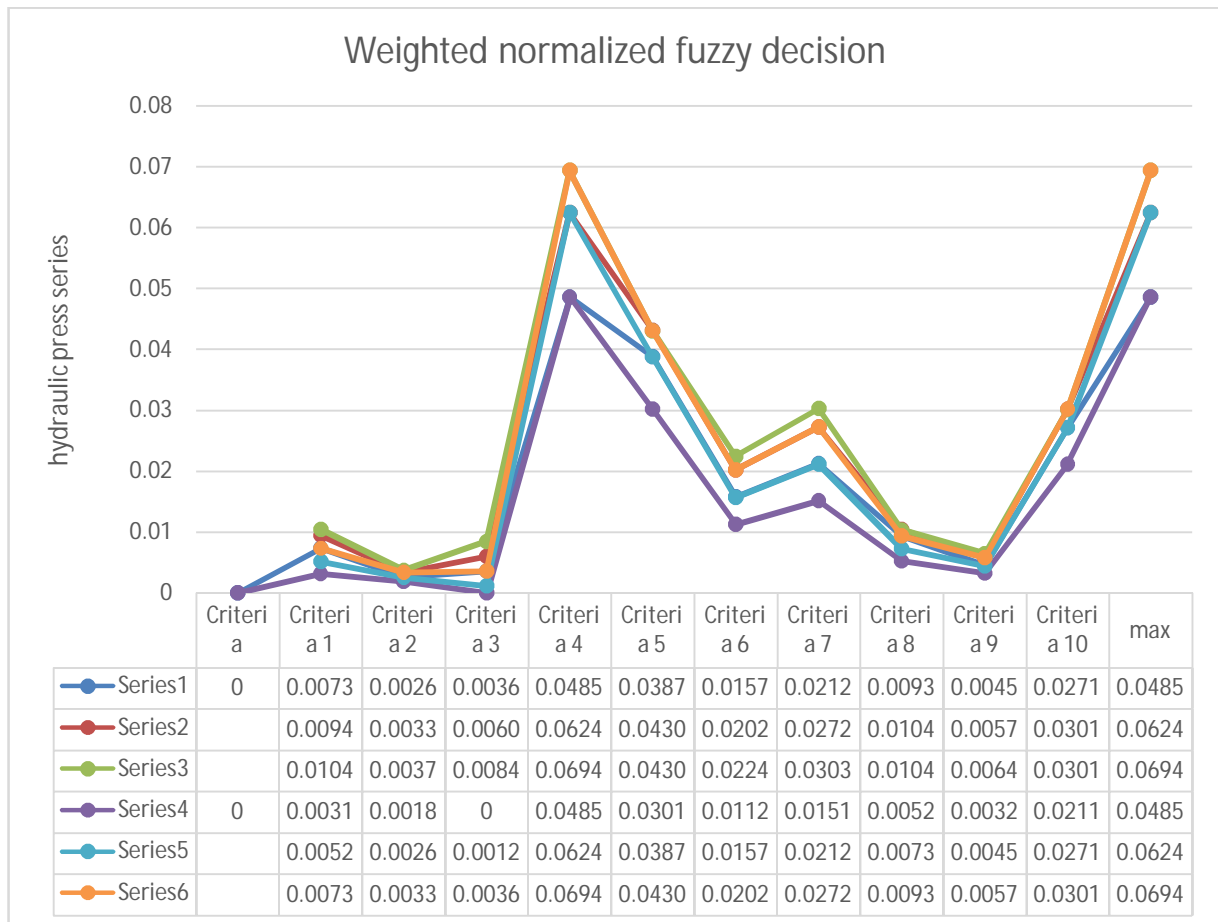
Criteria	Vertical Hydraulic Press			Horizontal Hydraulic Press		
Criteria 1	0.007324	0.009417	0.010463	0.003139	0.005231	0.007324
Criteria 2	0.002618	0.003367	0.003741	0.00187	0.002618	0.003367
Criteria 3	0.003626	0.006043	0.008461	0	0.001209	0.003626
Criteria 4	0.048583	0.062464	0.069404	0.048583	0.062464	0.069404
Criteria 5	0.038762	0.043069	0.043069	0.030148	0.038762	0.043069
Criteria 6	0.015737	0.020234	0.022482	0.011241	0.015737	0.020234
Criteria 7	0.021214	0.027275	0.030306	0.015153	0.021214	0.027275
Criteria 8	0.009381	0.010423	0.010423	0.005212	0.007296	0.009381
Criteria 9	0.004506	0.005794	0.006438	0.003219	0.004506	0.005794
Criteria 10	0.02714	0.030156	0.030156	0.021109	0.02714	0.030156
max	0.048583	0.062464	0.069404	0.048583	0.062464	0.069404

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 1, January 2019



We studied the weighted normalised fuzzy decision matrix for the vertical and horizontal hydraulic press for the squeezing and flaring operations from that calculate the maximum value shown in the table as well as graph.

Step 5: The normalized performance are added for beneficial criteria and subtracted for non-beneficial criteria, computed as follows:

$$\tilde{y}_i = \sum_{j=1}^g \tilde{v}_{ij} - \sum_{j=g+1}^n \tilde{v}_{ij} \dots\dots\dots(8)$$

Here,

$\sum_{j=1}^g \tilde{v}_{ij}$, benefit criteria for 1.....g

$\sum_{j=g+1}^n \tilde{v}_{ij}$, non-benefit criteria for g + 1,.....,n

g, maximum number of criteria to be done

(n - g), minimum number of criteria to be done

Step 6: The fuzzy reference point

Next, the reference point theory chooses for maximization a reference point, which has as co-ordinate the highest co-ordinate per objective of all alternatives. The reference point approach chooses for maximization a reference point, which has as co-ordinates the highest co-ordinate per objective of all the alternatives[3]. (For example, where we have consider three alternatives. The alternatives are described as follows: A (10;100), B (100;20) , C (50;50). In this case the maximal objective reference point \tilde{v}_j maximum result in (100;100).

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 1, January 2019

For beneficial criteria,

$$\tilde{x}_j^+ = (\max a_{ij}^* \max b_{ij}^*, \max c_{ij}^*), \text{ where } j \leq g \dots\dots\dots(9)$$

For Non-beneficial criteria

$$\tilde{x}_j^+ = (\min a_{ij}^* \min b_{ij}^*, \min c_{ij}^*), \text{ where } j > g \dots\dots\dots(10)$$

$$\forall i = 1, 2, \dots, m ; j = 1, 2, \dots, n$$

The deviation between the standardized evaluation value \tilde{v} and the reference point \tilde{x}_j^+ can be defined as,

$$P_i = \min_i (\max_j d |\tilde{v}_j - \tilde{x}_{ij}^+|) \dots\dots\dots(11)$$

Table 8: deviation between the standardized evaluation value \tilde{v} and reference point \tilde{x}_j^+

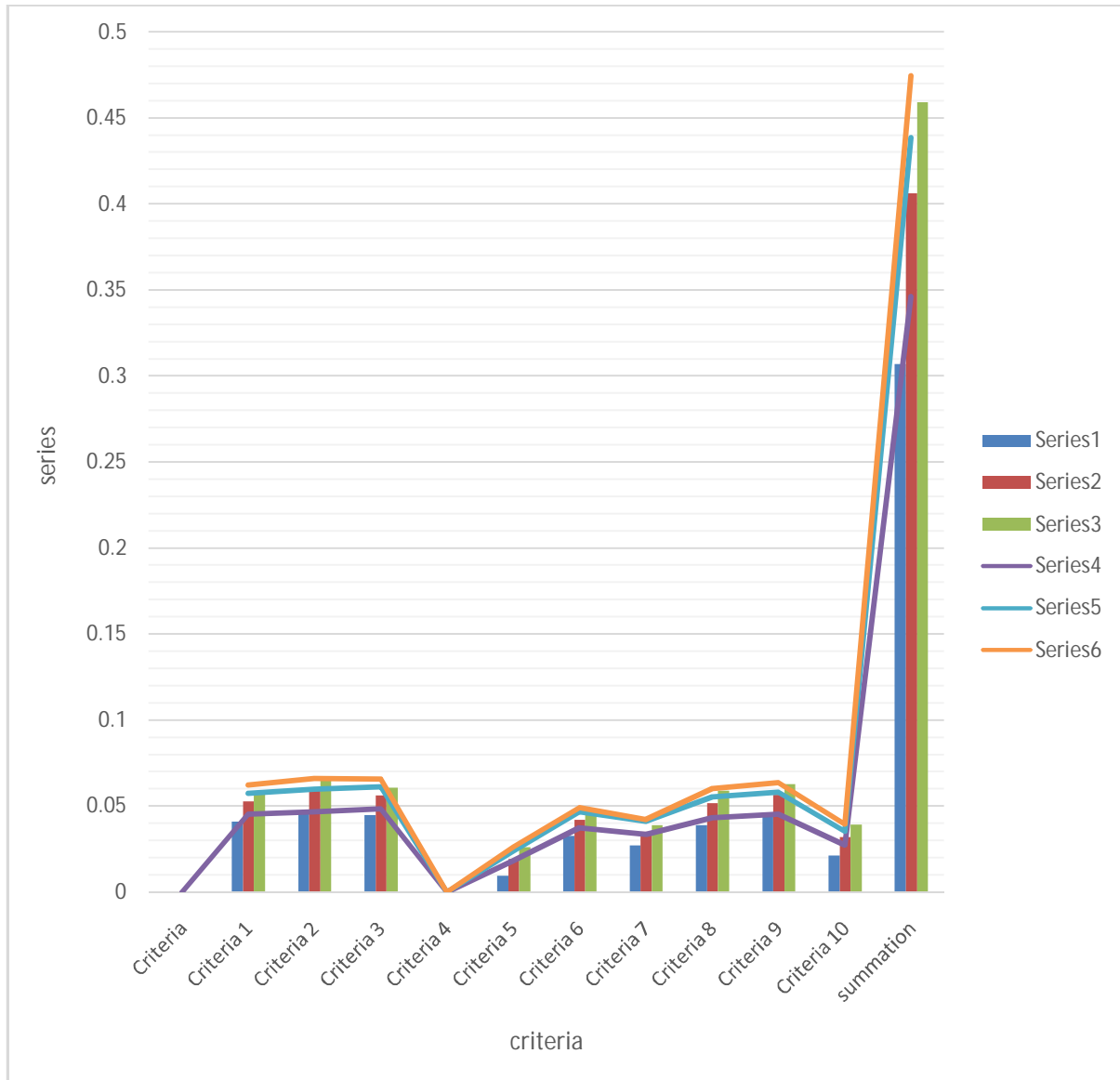
Criteria	Vertical Hydraulic Press			Horizontal Hydraulic Press		
Criteria 1	0.041259	0.053047	0.058941	0.045444	0.057232	0.06208
Criteria 2	0.045964	0.059097	0.065663	0.046712	0.059845	0.066038
Criteria 3	0.044957	0.056421	0.060944	0.048583	0.061255	0.065778
Criteria 4	0	0	0	0	0	0
Criteria 5	0.009821	0.019395	0.026335	0.018435	0.023702	0.026335
Criteria 6	0.032846	0.04223	0.046922	0.037342	0.046726	0.049171
Criteria 7	0.027369	0.035189	0.039098	0.03343	0.04125	0.042129
Criteria 8	0.039202	0.05204	0.058981	0.043371	0.055168	0.060023
Criteria 9	0.044077	0.05667	0.062967	0.045364	0.057957	0.06361
Criteria 10	0.021442	0.032308	0.039249	0.027474	0.035324	0.039249
Summation	0.306937	0.406397	0.4591	0.346155	0.438459	0.474413

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 1, January 2019



Considering the maximum reference point and the beneficial and non beneficial criteria's for this two different hydraulic press we are shown in the graph and summation for the press in the table.

Step 7: Defuzzify the fuzzy decision matrix.

There are four defuzzification methods commonly used : (i) centered method (or centre of area -COA) ; (ii) the mean of maximum (MOM) ; (iii) the cut method ;(iv) the signed distance method. The fuzzy values of weighted normalized fuzzy decision matrix converted into crisp values using the BNP values. The equation gives the defuzzified value of fuzzy number.

$$BNP_{ij} = \frac{[(\tilde{v}_{ij}^c - \tilde{v}_{ij}^a) + (\tilde{v}_{ij}^b - \tilde{v}_{ij}^a)]}{3} + \tilde{v}_{ij}^a, \forall i, j \dots\dots\dots(12)$$

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 1, January 2019

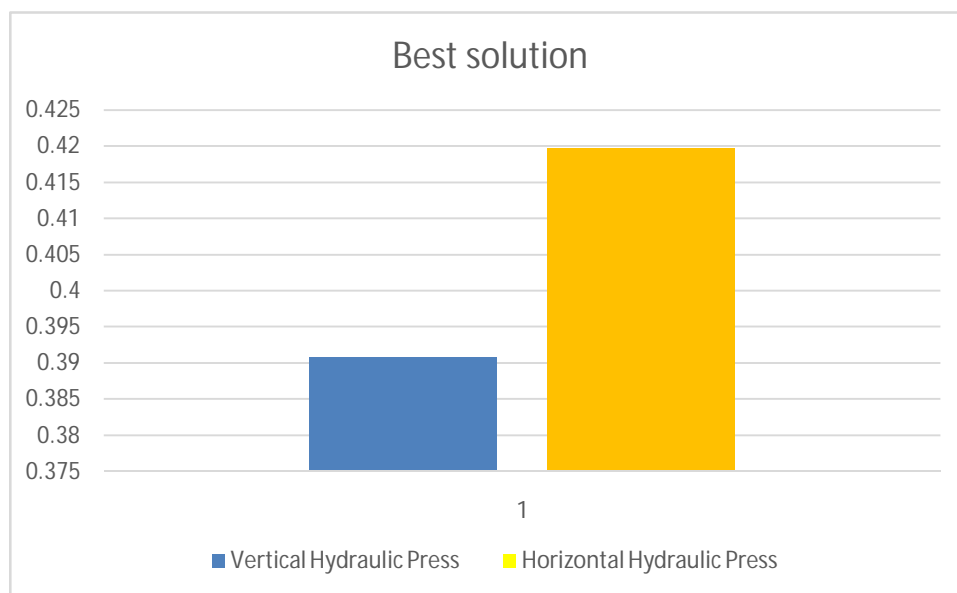
Table 9 Defuzzify fuzzy decision matrix

Vertical Hydraulic Press			Horizontal Hydraulic Press		
0.306937	0.406397	0.4591	0.346155	0.438459	0.474413
0.390811			0.419676		

From this above table the summation for hydraulic press horizontal and vertical that diffuzify the fuzzy decision using the BNP crisp formula from that calculate the ratio value.

Step 8 : select the best alternative solution

According to the criteria the best solution for the squeezing and flaring operation in the hydraulic press is shown Table 10 Best solution



Using the BNP formula we are calculated the ratio value for the horizontal and vertical hydraulic press and shown in the graph for the best alternative solution.

III. ADVANTAGES OF MOORA METHOD OVER THE OTHER MULTI OBJECTIVE METHODS

- 1.The MOORA method handles both beneficial and non-beneficial criteria and employs separate the mathematical process in the contrast to other methods. For Example, SAW method does not treat the beneficial and non-beneficial criteria separate and during the normalization process the non-beneficial criteria are transformed into the beneficial criteria.
- 2.The procedure of MOORA method produces the overall performance of alternatives with respect to various criteria. So, these benefits build the MOORA methodology simple to use and versatile. The MOORA method reflects the subjective part of selection procedure by integrating the criteria of weight to the computational procedure.
- 3.The mathematical background of MOORA method is not complex so it is easily understandable. The step of computational procedure does not require the software package, namely they are performed by MS Excel programme.
- 4.The necessary time for making the final selection is not too long. There is no limit about the number of criteria and the alternatives of the problems. Adding of any further parameter doesn't have an effect on the process procedure.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 1, January 2019

IV. RESULT

Here, in this research we are considering the linguistic criteria for the triangular fuzzy number for comparing the which machine is more suitable for squeezing, flaring operation and for that we considered the ten criteria's from that criteria. MOORA method is very easy and simple for implementation than other like MODM, GRAMethods. MOORA method is very stable method for decision making problems. We got the result the Horizontal hydraulic machine is most suitable machine for the squeezing and flaring operations than vertical hydraulic press machine. And we also got rank of this machine.

Table 11 Result

Best Solution	Hydraulic Press	Ranking	Percentage
0.419676	Horizontal Hydraulic Press	1	52%
0.390811	Vertical Hydraulic Press	2	48%



All tables calculation are done and from that we got the two BNP ratio values for the vertical and horizontal hydraulic press using the criteria for MOORA method we ranked that values and concluded the best solution given in the graphical (Pie Chart) as well as above tabular form with the ranking and percentage.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 1, January 2019

V. CONCLUSION

In this paper, the selection of hydraulic press using MOORA method is presented. We considered the linguistic criteria using triangular fuzzy number for the selection for squeezing and flaring of the hydraulic press. In all these criteria, it is observed that the top ranked alternative tried to match with those derived past research MOORA is basically simple ratio analysis. It involved less amount of calculation which may be quite useful for the decision maker who may not have strong mathematical background. The MOORA method considers the attribute according to importance and can provide better accurate evaluation of the alternatives. This method is computationally very simple, robust and comprehensible which also considers the qualitative and quantitative attributes while offering more criteria and logical selection approach but it is not convenient for large qualitative attributes. Application of this method in a wide range of selection of problem in real time manufacturing environment. In our case for criteria of linguistic variable triangular fuzzy number helps to decision for the squeezing and flaring operations which is most suitable machine and it gives the result, horizontal machine is most suitable machine.

VI. ACKNOWLEDGEMENT

The work was supported by Samarth Engineers and designers and industrial guide Mr. Nikhil Bhamre sir. Research department of Sandip University. Sincere appreciation is due to technical staff in Department of mechanical engineering in Sandip University, Nashik. I would like to thank to Dr. Ayyankalai Muthuraja and Department of Mechanical Engineering, Sandip university Nashik, for their constant support and cooperation to carry out this task.

REFERENCES

1. Brauers WKM, Optimization methods for a stakeholder society. A revolution in economic thinking by multiobjective optimization. Kluwer Academic Publishers, Boston, 2004
2. Brauers WKM, Zavadskas EK, Peldschus F, Turskis Z, Multiobjective decision-making for road design. Transport 23:183–193, 2008
3. Brauers WKM, Zavadskas EK, Robustness of the multiobjective MOORA method with a test for the facilities sector. Technological and Economic Development of Economy: Baltic J on Sustainability 15:352–375, 2009
4. Brauers WKM, Zavadskas EK, The MOORA method and its application to privatization in a transition economy. Control Cybern 35:445–469, 2006
5. Brauers WKM, Multi-objective contractor's ranking by applying the MOORA method. J of Business Economics and Management 4:245–255, 2008
6. Brauers WKM, Zavadskas EK, Peldschus F, Turskis Z, Multi-objective optimization of road design alternatives with an application of the MOORA method. Proc of the 25th Int Sym on Automation and Robotics in Construction, Lithuania, 541–548, 2008
7. Kalibatasa D, Turskis Z, Multicriteria evaluation of inner climate by using MOORA method. Inf Tech and Con 37:79–83, 2008
8. Lootsma FA, Multi-criteria decision analysis via ratio and difference judgement. Springer, London, 1999
9. Bhangale PP, Agrawal VP, Saha SK, Attribute based specification, comparison and selection of a robot. Mech Mach Theory 39:1345–1366, 2004
10. Rao RV (2007) Decision making in the manufacturing environment using graph theory and fuzzy multiple attribute decision making methods. Springer, London
11. Karsak EE, Kuzgunkaya O, A fuzzy multiple objective programming approach for the selection of a flexible manufacturing system. Int J Prod Eco 79:101–111, 2002
12. Rao RV, Parnichkun M, Flexible manufacturing system selection using a combinatorial mathematics-based decisionmaking method. Int J Prod Res 47:6981–6998, 2008
13. Sun S, Assessing computer numerical control machines using data envelopment analysis. Int J Prod Res 40:2011–2039, 2002
14. Yurdakul M, Cogun, Development of a multi-attribute selection procedure for non traditional machining processes. Proc IMechE, J of EnggManuf 217:993–1009, 2003
15. Das Chakladar N, Chakraborty S, A combined TOPSIS/AHP method based approach for non-traditional machining processes selection. Proc IMechE, J of EnggManuf 222:1613–1623, 2008
16. Das Chakladar N, Das R, Chakraborty S, A digraph-based expert system for non-traditional machining processes selection. Int J Adv Manuf Tech 43:226–237, 2009
17. Byun HS, Lee KS, A decision support system for the selection of a rapid prototyping process using the modified TOPSIS method. Int J Adv Manuf Tech 26:1338–1347, 2004
18. Rao RV, Patel BK, Decision making in the manufacturing environment using an improved PROMETHEE method. Int J Prod Res 48:4665–4682, 2009
19. Pandey PC, Kengpol A, Selection of an automated inspection system using multi-attribute decision analysis. Int J Prod Econ 39:289–298, 1995
20. Ginevičius R, Podvezko V, Multi-criteria graphical analytical evaluation of the financial state of construction enterprises. Baltic J on Sustainability 14:452–461, 2008
21. Gadakh V. S., and Shinde V. B., Selection of cutting parameters in side milling operation using graph theory and matrix approach. International Journal of Advanced Manufacturing Technology. doi: 10.1007/s001700113256z, 2011