CNC Machine tool selection using MCDM techniques and application of software SANNA

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Abstract: *Machine tool selection is a very complex procedure. It involves deep analysis of various factors affecting functioning and performance. CNC machine tool selection is also a such kind of problem[5]. Objective of this study is to perform various MCDM methods for selecting most appropriate machine tool. AHP method is used to calculate the weights of various criteria[10] . The numerical problem considered for MCDM application is related to CNC machine manufactured by leading companies of the world. Various criteria are well examined and weightage is assigned to each criteria on this basis. There are used three normal MCDM methods viz. TOPSIS , MOORA, COPRAS and one outranking method namely ELECTRE I. Weights obtained by AHP method are used for all successive applications .MS-Excel add-in application SANNA (System for ANalysis of Alternatives) is used for evaluation through TOPSIS and ELECTRE methods. Results demonstrate an effective method for selecting CNC machine tool. Analysis of complexity is carried out for each method to arrive on best method along with the best alternative.*

Keywords— *CNC Machine tool, MCDM, SANNA, MOORA, TOPSIS, ELECTREI, COPRAS*

I. INTRODUCTION

Decision making is very important part of any manufacturing firm in all fields. In today's world of advanced technology, CNC machines are mainly used due to its inherent qualities of high accuracy and automation. Due to highly advanced features of CNC machine tools[4], there cost is also very high. It is need of any organization to select best alternative of CNC machine tool available in market to increase efficiency and cost effectiveness. Aptness of different machine tool depends upon purpose of application, hence there is needed an approach which quantifies this purpose in form of numerical data. MCDM methods are very effective decision making technique used in various organizations.

In MCDM methods objective is divided into a set of alternatives and criteria. Various criteria possess different prominence on basis of which weights are assigned to each criteria and MCDM model is applied to arrive at selection of best alternative. Assigning of weightage requires profound knowledge of criteria and available alternatives, hence judgment made by experts bears huge importance. These judgments are given on basis of questionnaire prepared for the selected problem. SANNA is a MS-EXCEL add-in application used for applying MCDM technique on a given set of data. It is capable of handling MCDM problems having at most 50 criteria and 180 alternatives. There are various module provided in software like data, methods ,weights to accomplish the goal. Only a limited number of methods are listed in data base of this add-in application like TOPSIS, WSA, ELECTRE I, ELECTREIII , PROMETHEE. For the purpose of current study SANNA add-in application is used for applying ELECTRE I method.

To accomplish CNC machine tool selection using MCDM [3] , seven criteria are selected[1] viz. Number of tools, Number of axes, Machine weight ,Horse power , Floor Layout, Maximum RPM and turning diameter[3]. Goal of current study is to select CNC machine tool for high product variety so all criteria are positive criteria except Floor layout and Machine weight which are kept minimum to ensure that machine occupy less space and is light in weight. AHP method is used to determine the weights of each criterion. TOPSIS, MOORA, COPRAS and ELECTRE I methods are applied for ranking of alternative. As a conclusion complexity of various methods are compared and best method is selected along with ranking of alternatives. Also the variation and similarities obtained in results are discussed.

II. METHODOLOGY

There are many management techniques available for machine tool selection. Accordingly different set of data is required. As far as CNC machine tool selection by MCDM technique is concerned procedure followed for current study may be adopted[6]. Leaflets of various companies are collected from online and offline sources[3] and relevant criteria along with alternatives are enlisted. AHP method by T.L.Saaty[12] is used for calculating weights of various criteria. Pairwise comparison matrix of various criteria is prepared and values are assigned according to Saaty's scale. Value provided in pairwise comparison matrix is a result of questionnaire prepared for recording expert's judgment. To check the consistency of judgment, Consistency Ratio (CR) is checked which must be less than 0.1 otherwise the questionnaire, expert's opinion or both are changed. Once the weights of criteria are calculated, different MCDM methods are applied to get the rankings of alternatives. Calculations obtained in various methods and complexity associated helps in determining the best MCDM method for CNC machine tool selection problem. A block diagram of complete procedure is shown in Fig.1. Entire methodology is divided into four stages viz. S-I, S-II, S-III and S-IV. In beginning of first stage, type of production system is needed to be decided. Different production system requires varying weightage and optimization of criteria. For instance a production system based on product technology does not require enough variety hence CNC machine tool for such system is required to have high speed to process the material with less number of tools. In contrary to this job shop based production system requires CNC machine tool with more number of axes and tools to ensure product variety. Various CNC machine tools are available in market with varying cost and features. Data of these tools are provided in the leaflets provided along with machines or the website of companies[7]. For the purpose of current study data are collected with the reference of research paper [3].After creating database of various options main factors affecting selection procedure are enlisted known as criteria in MCDM calculations [9]. This completes the stage I.

Stage II involves assigning weights to various criteria. This stage is vital as it includes the judgment scheme of experts to assign values to each criterion according to Saaty's scale. Expert uses questionnaire already prepared for the problem and also their general intelligence. Brainstorming is also used for this purpose. Experts should be personals belonging to CNC manufacturing having expertise in both technical and managerial related concerns. Judgment made by experts is verified by checking consistency ratio, this completes stage II. Third stage includes mathematical formulation of data and its handling. Various MCDM methods are applied to acquire ranking of alternatives as per the data formulated in decision matrix. Analysis of results obtained is discussed in Stage IV to conclude complexity associated with each method and suitability to current case study. Fig.1 shows block diagram of whole procedure.

III. ILLUSTRATIVE CASE STUDY

Current study comprises of CNC machine tool manufactured by four leading companies of world viz. NAKAMURA,DOSSAN,ROMI, MAZAK[3]. In accordance with the judgment of experts related to CNC & Previous literature work all the data related to four types of vertical CNC is collected along with their specification[3] which are treated as criteria[3] .The below mentioned criteria are considered :

i. Diameter (Dia)
ii. RPM
iii. No. Of Tools (NOT)
iv. No. Of Axes (NOA)
v. Machine Weight (MW)
vi. Floor Layout (FL)
vii. Horse power (HP)

Data are formulated in Table I as decision matrix along with the optimization of criteria

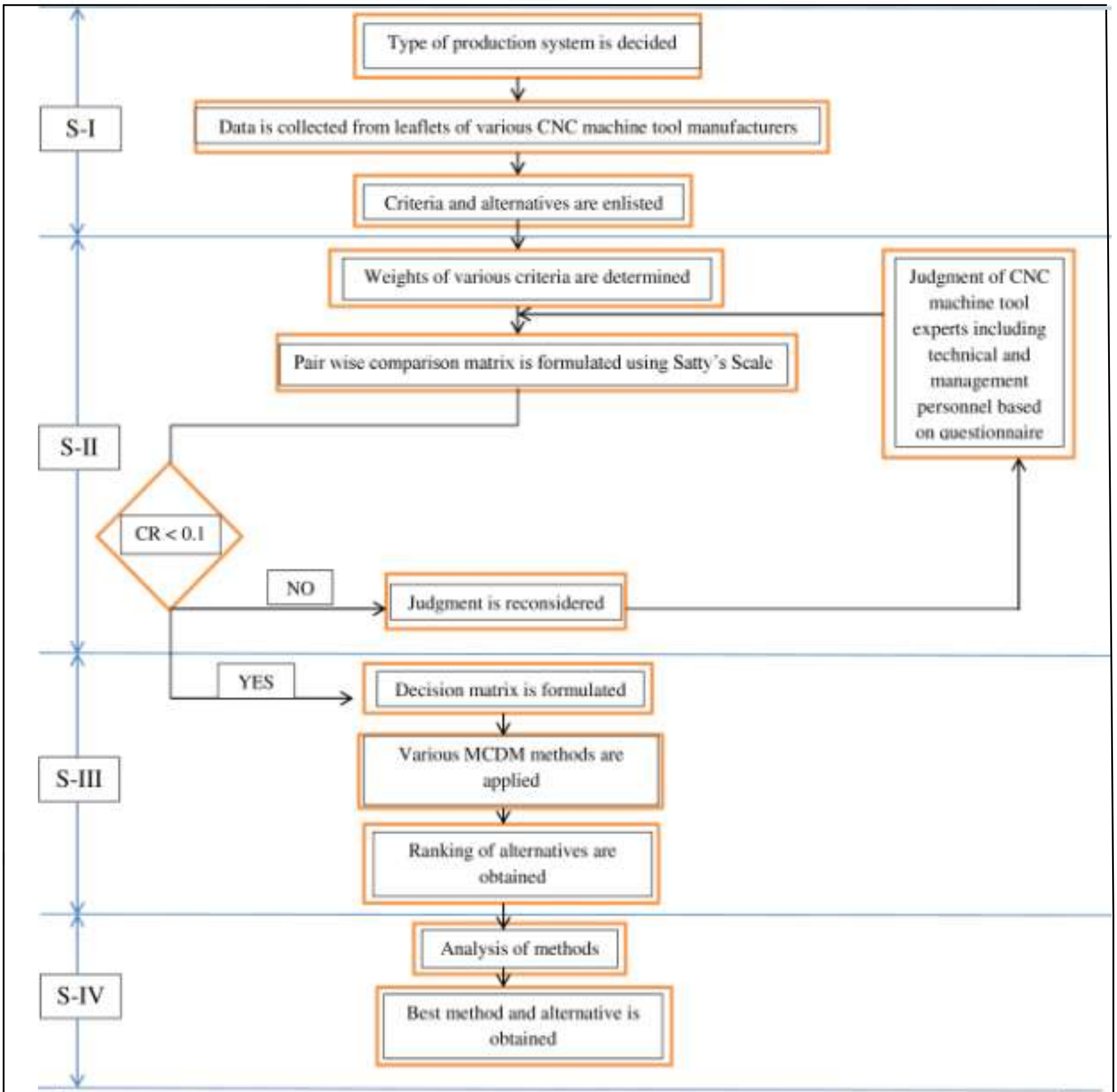

Figure1. Block diagram of whole procedure

Table I: Decision Matrix

Optimization	Max Diameter(in)	Max RPM	Max No. of Tools	Max No. of Axes	Min Machine Weight(lbs)	Min Floor Layout	Max Horse power
NAKAMURA	7.48	5000	24	9	26400	1074.52	15
DOSSAN	9.5	6000	12	8	16534	921.188	20
ROMI	11.02	6000	12	4	19000	2620.8	25
MAZAK	16.93	4000	12	6	24250	1881.49	30

(A) Determination of weights by AHP(Analytical hierarchy process) Method: T.L. Saaty in 1980's developed method of pair wise comparison to determine weights of various criteria[8]. It is very useful method rapidly used for determining the weights[9].

Step I: Pair wise comparison according to Saaty's nine-point scale

Table II: Pair wise comparison Matrix

	Dia(in)	RPM	NOT	NOA	MW(lbs)	FL	HP
Dia(in)	1	0.5	1	1	2	1	0.5
RPM	2	1	2	2	2	2	0.5
NOT	1	0.5	1	1	2	1	0.5
NOA	1	0.5	1	1	2	1	0.5
MW	0.5	0.5	0.5	0.5	1	0.5	0.33
FL	1	0.5	1	1	2	1	0.33
HP	2	2	2	2	3	3	1

Step II. Normalization by Geometric mean:

$$w_i = \frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}} \qquad i, j = 1,2,\dots n$$

i= No. of rows
j= No. of columns
n=No of rows/column or criteria.

a_{ij} *are elements of pair wise comparision matrix and* W_i *are normalised values*

Table III : Normalized Matrix with priority vectors

	Dia(in)	RPM	NOT	NOA	MW(lbs)	FL	HP	GM	PV
Dia(in)	1	0.5	1	1	2	1	0.5	0.905	0.119
RPM	2	1	2	2	2	2	0.5	1.485	0.195
NOT	1	0.5	1	1	2	1	0.5	0.906	0.112
NOA	1	0.5	1	1	2	1	0.5	0.906	0.112
MW(lbs)	0.5	0.5	0.5	0.5	1	0.5	0.33	0.521	0.068
FL	1	0.5	1	1	2	1	0.33	0.855	0.112
HP	2	2	2	2	3	3	1	2.03	0.267
	8.5	5.5	8.5	8.5	14	9.5	3.67	7.612	1

Step III. Consistency check: Consistency is checked by parameter known as Consistency Ratio(CR)

$$CR = \frac{CI}{RI}$$

Where $CR \leq 0.10$

Eigen Value ,λ_{max} =

(8.5×0.119)+(5.5×0.195)+(8.5×0.112)+(8.5×0.112)+(14×0.068)+(9.5×0.112)+(3.67×0.267)=7.112

Consistency Index, CI = $\frac{(7.112-7)}{(7-1)}$ =0.0186

Consistency Ratio, CR = $\frac{CI}{RI}$ = $\frac{0.01862}{1.32}$ $= 0.0141$

As, CR < 0.1 , Comparison is consistent

Hence the priority vectors obtained in last column of Table III are the corresponding weights of the criteria.

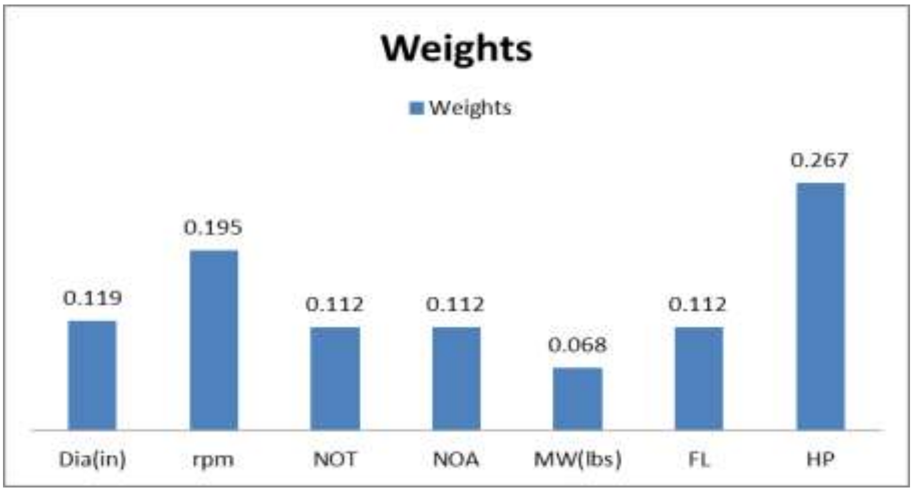

Fig2. Weights of various criteria

(B) TOPSIS Method: TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) was developed by Hwang and Yoon in 1980 is considered as one of its most commonly accepted variants[11]. The basic concept of this method is that the selected alternative should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution in some geometrical sense. SANNA add-in supports TOPSIS method hence can be evaluated using it[2].

TOPSIS Method

Actual problem for 4 alternatives and 7 criteria

Input data:

	MAX Dia(in)	MAX RPM	MAX NOT	MAX NOA	MIN MW(lbs)	MIN FL	MAX HP
NAKAMURA	7.48	5000	24	9	26400	1074.52	15
DOSSAN	9.5	6000	12	8	16534	921.188	20
ROMI	11.02	6000	12	4	19000	2620.8	25
MAZAK	16.93	4000	12	6	24250	1881.49	30
Weights	0.11900	0.19500	0.11200	0.11200	0.06800	0.11200	0.26700

Fig.3 Decision matrix formulated in SANNA

Modified input data:

	MAX Dia(in)	MAX RPM	MAX NOT	MAX NOA	MAX MW(lbs)	MAX FL	MAX HP
NAKAMURA	7.48	5000	24	9	0	1546.28	15
DOSSAN	9.5	6000	12	8	9866	1699.612	20
ROMI	11.02	6000	12	4	7400	0	25
MAZAK	16.93	4000	12	6	2150	739.31	30
Weights	0.12081	0.19797	0.11371	0.11371	0.06904	0.11371	0.27107

Fig.4 Modified input data to consider non-benefit criteria

Normalised criterion matrix R:

	MAX Dia(in)	MAX RPM	MAX NOT	MAX NOA	MAX MW(lbs)	MAX FL	MAX HP
NAKAMURA	0.31772	0.47036	0.75593	0.64122	0.00000	0.64061	0.32350
DOSSAN	0.40352	0.56443	0.37796	0.56998	0.78809	0.70413	0.43133
ROMI	0.46808	0.56443	0.37796	0.28499	0.59111	0.00000	0.53916
MAZAK	0.71911	0.37629	0.37796	0.42748	0.17174	0.30629	0.64700
Weights	0.12081	0.19797	0.11371	0.11371	0.06904	0.11371	0.27107

Fig.5 Normalized Decision matrix

Weighted criterion matrix W:

	MAX Dia(in)	MAX RPM	MAX NOT	MAX NOA	MAX MW(lbs)	MAX FL	MAX HP	di+	di-	ci
NAKAMURA	0.03838	0.09312	0.08595	0.07291	0.00000	0.07284	0.08769	0.11576	0.09561	0.45232
DOSSAN	0.04875	0.11174	0.04298	0.06481	0.05441	0.08006	0.11692	0.08236	0.11300	0.57841
ROMI	0.05655	0.11174	0.04298	0.03240	0.04081	0.00000	0.14615	0.10889	0.08246	0.43095
MAZAK	0.08688	0.07449	0.04298	0.04861	0.01186	0.03483	0.17538	0.08765	0.10797	0.55194
Weights	0.12081	0.19797	0.11371	0.11371	0.06904	0.11371	0.27107			
Ideal	0.08688	0.11174	0.08595	0.07291	0.05441	0.08006	0.17538			
Basal	0.03838	0.07449	0.04298	0.03240	0.00000	0.00000	0.08769			

Fig.6 Weighted Normalized Decision matrix and calculation of closeness coefficient

Table IV: Ranking according to TOPSIS method

CNC Machine	C_i	Rank
NAKAMURA	0.45232	3
DOSSAN	0.57841	1
ROMI	0.43095	4
MAZAK	0.55194	2

(C) MULTI OBJECTIVE OPTIMIZATION ON THE BASIS OF RATIO ANALYSIS (MOORA) METHOD: Multi objective optimization (or programming) is also known as multi criteria / multi attribute optimization, is the process of concurrently optimizing two or more disagreeing attributes(objective) subjected to certain constrain[14]. MOORA method, first introduced by Brauers (2004) is such a multi objective optimization technique that can be successfully applied to solve various types of complex decision making problems in the manufacturing environment. MOORA method starts with a decision matrix showing the performance of different alternatives with respect to various attributes (objectives). MOORA method is incompatible with SANNA add-in so elaborative calculation is carried out.

Step I. Develop the initial decision matrix, X shown

$$X = [x_{ij}]_{m*n} = \begin{bmatrix} X_{11} & X_{12} \cdots\cdots & X_{1n} \\ X_{21} & X_{22} \cdots\cdots & X_{2n} \\ \vdots & \vdots & \vdots \end{bmatrix}$$

Step II. Normalization of decision matrix is done by dividing each element of decision matrix with the square root of the sum of squares of each alternative per attribute which is represented as:

$$X_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=0}^{m} x^2}} \qquad \text{[For i= 1,2,3 . . . . n]}$$

Step III. For multi-objective optimization, these normalized performances are added in case of maximization (for beneficial attributes) and subtracted in case of minimization (for non-beneficial attributes)[14].Then the optimization problem is shown in equation-

$$Y_i = \sum_{j=1}^{g} x^* - \sum_{j=g+1}^{n} x^*$$

Step IV. To provide weightage to each attribute, it is multiplied with corresponding weight, equation becomes as follows:

$$Y_i = \sum_{j=1}^{g} W_j x^* - \sum_{j=g+1}^{n} W_j x^* \quad [j = 1,2,3 \ldots\ldots n]$$

Here, W_j is the weight of the j^{th} criteria

The y_i value is determined by summation of corresponding element of maximum (benefit criteria) and minimum (non-benefit criteria) in weighted Normalized Decision Matrix for given alternative. Hence ranking is obtained with ranking in increasing order of y_i

Table V: Weighted Normalized Decision Matrix

Weights	0.119	0.195	0.112	0.112	0.068	0.112	0.267
Criteria	Dia(in)	RPM	NOT	NOA	MW(lbs)	FL	HP
NAKAMURA	0.0381	0.0940	0.0907	0.0769	0.0409	0.0335	0.0863
DOSSAN	0.0484	0.1128	0.0453	0.0683	0.0257	0.0287	0.1151
ROMI	0.0561	0.1128	0.0453	0.0341	0.0295	0.0818	0.1439
MAZAK	0.0863	0.0753	0.0454	0.0513	0.0376	0.0587	0.1727

Table VI: Ranking obtained by MOORA

Alternatives	y_i	Q_i	**Ranking**
NAKAMURA	0.3116	0.9287	3
DOSSAN	0.3355	1	1
ROMI	0.2809	0.8372	4
MAZAK	0.3350	0.9985	2

(D) COPRAS method : In 1996 researchers developed Complex Proportional Assessment method abbreviated as COPRAS. Final ranking in COPRAS method is obtained by following equation:

$$Z_j = S_{+j} + \frac{S_{-min}\sum_{j=1}^{n} S_{-j}}{S_{-j}\sum_{j=1}^{n}\frac{S_{-min}}{S_{-j}}} \text{----------------------(1)}$$

Where, S_{-min} is value of minimum criteria attribute , S_{+j} denotes maximum criteria attribute and Z_j is value of final ranking of j^{th} alternative.

Step I. Normalized decision matrix is obtained by direct summation ratio technique

$$Normalised\ x_{ij} = \frac{x_{ij}}{\sum x_{ij}}$$

Table VII: Normalized Decision matrix

Optimization	Max	Max	Max	Max	Min	Min	Max
Criteria	Dia(in)	RPM	NOT	NOA	MW(lbs)	FL	HP
NAKAMURA	0.1664	0.2380	0.4	0.3333	0.3063	0.1653	0.1666
DOSSAN	0.2114	0.2857	0.2	0.2962	0.1918	0.1417	0.2222
ROMI	0.2452	0.2857	0.2	0.1481	0.2204	0.4033	0.2777
MAZAK	0.3768	0.1904	0.2	0.2222	0.2813	0.2895	0.3333

Step II :.Weighted Normalized Decision Matrix:

$$Weighted\ normalised\ x_{ij} = normalised\ x_{ij} \times w_j$$

Table VIII: Weighted Normalized Decision Matrix

Weight	0.119	0.195	0.112	0.112	0.068	0.112	0.267
Criteria	Dia(in)	RPM	NOT	NOA	MW(lbs)	FL	HP
NAKAMURA	0.0198	0.0464	0.0448	0.0373	0.0208	0.0185	0.0445
DOSSAN	0.0252	0.0557	0.0224	0.0331	0.0130	0.0159	0.0593
ROMI	0.0292	0.0557	0.0224	0.0166	0.0150	0.0452	0.0741
MAZAK	0.0448	0.0371	0.0224	0.0249	0.0191	0.0324	0.0890

Step III. Benefit and non- Benefit criteria matrix is formulated using following equation:

$$\sum benefit = Sum(all\ \max x_{ij})$$

$$\sum non\ \ benefit = Sum(all\ \min x_{ij})$$

Table IX:. Benefit and non-Benefit criteria matrix

	$\sum_{j=1}^{7} S_{+j}$	$\sum_{j=1}^{7} S_{-j}$	$\sum_{j=1}^{7} \frac{1}{S_{-j}}$
NAKAMURA	0.1928	0.0394	25.4127
DOSSAN	0.1958	0.0289	34.5743
ROMI	0.1981	0.0602	16.6213
MAZAK	0.2183	0.0516	19.3938
		$\sum_{i=1}^{4}\sum_{j=1}^{7} S_{-j}$ = 0.18	$\sum_{i=1}^{4}\sum_{j=1}^{7} \frac{1}{S_{-j}}$= 96.0022

Step IV: For final ranking equation (1) is used

Table X: Ranking according to COPRAS method

	Z_j	Pi (%)	Rank
NAKAMURA	0.2405	91.6823	3
DOSSAN	0.2623	100.0000	1
ROMI	0.2348	89.4978	4
MAZAK	0.2572	98.0359	2

(E) ELECTRE I Method: ELECTRE is a part of multi-criteria decision analysis methods which originated in Europe in mid of 1960s. ELECTRE stands for: ELimination and Choice Expressing Reality. This method was proposed by Bernard Roy and his fellow at SEMA consultancy firm. There are many versions of ELECTRE method like ELECTRE I , ELECTRE II , ELECTRE IV. ELECTRE I is an outranking methods used for determining best alternative rather than ranking of alternatives[15]. Further versions of ELECTRE facilitates the user to determine rankings of alternatives. SANNA is compatible with only ELECTRE I and ELECTRE III but for the current study only ELECTRE I is used.

Input data:

	MAX Dia(in)	MAX RPM	MAX NOT	MAX NOA	MIN MW(lbs)	MIN FL	MAX HP
NAKAMURA	7.48	5000	24	9	26400	1074.52	15
DOSSAN	9.5	6000	12	8	16534	921.188	20
ROMI	11.02	6000	12	4	19000	2620.8	25
MAZAK	16.93	4000	12	6	24250	1881.49	30
Weights	0.11900	0.19500	0.11200	0.11200	0.06800	0.11200	0.26700

Fig. 7 Decision Matrix

Modified input data:

	MAX Dia(in)	MAX RPM	MAX NOT	MAX NOA	MAX MW(lbs)	MAX FL	MAX HP
NAKAMURA	7.48	5000	24	9	0	1546.28	15
DOSSAN	9.5	6000	12	8	9866	1699.612	20
ROMI	11.02	6000	12	4	7400	0	25
MAZAK	16.93	4000	12	6	2150	739.31	30
Weights	0.12081	0.19797	0.11371	0.11371	0.06904	0.11371	0.27107

Fig8. Modified input data to consider optimization of Decision Matrix

Matrix C:

	NAKAMURA	DOSSAN	ROMI	MAZAK
NAKAMURA	---	0.22741	0.34112	0.53909
DOSSAN	0.77259	---	0.60812	0.60812
ROMI	0.65888	0.70355	---	0.38071
MAZAK	0.46091	0.50558	0.73299	---

Fig.9 Concordance Matrix

Matrix D:

	NAKAMURA	DOSSAN	ROMI	MAZAK
NAKAMURA	---	1.00000	1.00000	1.00000
Re-activation	0.00122	---	0.00203	0.00130
ROMI	0.20896	1.00000	---	0.14082
MAZAK	0.46512	1.00000	1.00000	---

Fig.10 Discordance Matrix

Matrix P:

	NAKAMURA	DOSSAN (EFEKT)	ROMI	MAZAK
NAKAMURA	0	0	0	0
DOSSAN	1	0	1	1
ROMI	0	0	0	0
MAZAK	0	0	0	0
C = 0.01000		D = 0.01000		

Fig.11 Aggregate Dominance Matrix

In above calculations by SANNA add-in, alternative marked with EFEKT denotes the best alternative and no rankings are obtained. DOSSAN is designated as most suitable option according to ELECTREI method.

IV. DISCUSSION AND CONCLUSION

There are number of MCDM methods available with varying applicability and simplicity. There is slight difference between the results obtained by different MCDM methods. Although the results obtained for current study are same, but there may be observed some deviation in the results obtained. Various MCDM methods are based on varying mathematical formulation so the data is handled in different ways in different methods[15]. For example MOORA method is based on the ratio analysis while TOPSIS is based on deviation from the positive ideal and negative ideal solution[16] . Hence the distance and ratio gives two different results. Some of the reasons due to which results obtained are different may be stated as:

(i) Different aggregation procedures and different normalization procedures sometimes leads to the selection of different most acceptable alternatives [16].

(ii) At the same time, different relative weights of criteria, used in the decision making model, can also have a significant impact on the selection of most appropriate alternatives, as well as ranking orders.

In this case of CNC machine tool selection weights are kept constant in all the methods and due to application of different methods, normalization process involved in each method is changed, but it does not made any changes in the ranking of CNC machines. Upon literature survey and related case studies it is found that results obtained by different MCDM methods may vary due to their mathematical formulation [16].Same case may result in varying rankings with different MCDM methods when other set of data is taken. Closer results are obtained if data is handled to higher decimal places.

Vector normalization procedure is used in the case of TOPSIS method which is based on deviation from ideal positive and negative solution. Selection of alternative is completely dependent on this deviation known as Euclidian distance[16]. The process of normalization and aggregation involves conversion of cost criteria into benefit criteria .

In MOORA method normalization procedure is based on vector normalization without conversion of cost criteria into benefit criteria[14]. Formula used for ranking purpose in MOORA method is developed in the manner to consider the cost and benefit criteria.

Hence it can be concluded that different MCDM methods have different areas of application for example TOPSIS is suitable for the location selection while ELECTREI[13] is used for the purpose where a single alternative is needed to be determined.

COPRAS method involves linear transformation for the purpose of normalization without the conversion of cost criteria into benefit criteria .It is very similar to MOORA method but the aggregation process used is more complex.

If the suitability of MCDM methods in given case is considered, it depends upon following criteria:

(i) Calculation involved in the method
(ii) Method of normalization causes change of criteria or not?
(iii) Ease of application of formula for ranking
(iv) Software support available for performing more complex calculations.

MOORA method can be considered as most suitable for the given problem. Calculations involved in MOORA method is less as compared to other MCDM methods used in the problem. Results can be obtained in simple three steps after formulating weighted normalized decision matrix. Method of normalization in MOORA involves vector normalization process without using change of criteria providing it an additional benefit for practical use . Change of criteria causes ambiguity in final matrices , but in MOORA approach positive and negative criteria are handled separately without merging or changing into single criteria. Final formula used in raking of alternatives by MOORA method involves direct subtraction of elements obtained by transformations in positive and negative criteria respectively.

Table XI: Ranking according to all methods used in illustration

	TOPSIS	MOORA	COPRAS	ELECTREI
Rank1	DOSSAN	DOSSAN	DOSSAN	DOSSAN
Rank2	MAZAK	MAZAK	MAZAK	
Rank3	NAKAMURA	NAKAMURA	NAKAMURA	
Rank4	ROMI	ROMI	ROMI	

For the given illustration it can be concluded that DOSSAN is the best alternatives and ROMI is most unsuitable alternative. MOORA is the best method to determine order of preference and ELECTREI is most suitable method for determining a single appropriate alternative.

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