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Abdel Nasser H. Zaied

Mahmoud Ismail

Abduallah Gamal

Nabil Mostafa

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An Integrated Neutrosophic and MOORA for Selecting Machine Tool

Abdel Nasser H. Zaied[1], Mahmoud Ismail[2], Abduallah Gamal[3,*] and Nabil M. AbdelAziz[4]

[2,3] Department of Operations Research, Faculty of Computers and Informatics, Zagazig University, Sharqiyah, 44511, Egypt.
[1,4]Department of Information Systems, Faculty of Computers and Informatics, Zagazig University, Sharqiyah, 44511, Egypt
* Correspondence: Abduallah Gamal; abduallahgamal@zu.edu.eg

Abstract: The selection of suitable machine tools for a manufacturing company is one of the significant points to achieving high competitiveness in the market. Besides, an appropriate choice of machine tools is very significant as it helps to realize full production quickly. Today's market offers many more choices for machine tool alternatives. There are also many factors one should consider as part of the appropriate machine tool selection process, including productivity, flexibility, compatibility, safety, cost, etc. Consequently, evaluation procedures involve several objectives, and it is often necessary to compromise among possibly conflicting tangible and intangible factors. For these reasons, multiple criteria decision making (MCDM) is a useful approach to solve this kind of problem. Most of the MCDM models are mathematical and ignore qualitative and often subjective considerations. The use of neutrosophic set theory allows incorporating qualitative and partially known information into the decision model. This paper describes a neutrosophic Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) based methodology for evaluation and selection of vertical CNC machining centers for a manufacturing company in Tenth of Ramadan, Egypt.

Keywords: Machine Tool; Neutrosophic MOORA; MCDM

1. Introduction

Selecting an appropriate machine tool is one of the most complicated and time-consuming problems for manufacturing companies due to many feasible alternatives and conflicting objectives. The determination and evaluation of positive and negative characteristics of one alternative relative to others is a difficult task. The selection process of suitable machine tools has to begin with a critical evaluation of the procedures on the shop floor by considering an array of quantitative, qualitative, and economic concerns. Hence the decision-maker (engineer or manager) needs a lot of criteria to be found and a large amount of data to be analyzed for a proper and sufficient evaluation. Consequently using proper machine tools in a manufacturing facility can improve the production process, provide effective utilization of resources, increase productivity, and enhance system flexibility, repeatability, and reliability. Many potential criteria, such as flexibility, compatibility, safety, maintainability, cost, etc. must be considered in the selection procedure of a machine tool. Therefore machine tool selection can be viewed as a multiple criteria decision making (MCDM) problem in the presence of many quantitative and qualitative criteria. The MCDM methods deal with the process of making decisions in the presence of multiple criteria or objectives. A decision-maker (DM) is required to choose among quantifiable or non-quantifiable and various criteria. The DM's evaluations on qualitative criteria are always subjective and thus imprecise. The objectives are usually conflicting, and therefore, the solution is highly dependent on the preferences of the DM. Besides, it is complicated to develop a selection criterion that can precisely describe the choice of one alternative over another. The evaluation data of machine tool alternatives suitability for various subjective criteria and the weights of the criteria are usually expressed in linguistic terms. This makes neutrosophic logic a more natural approach to this kind of problems.

Many researchers have attempted to use fuzzy MCDM methods for selection problems. The purpose of this paper is to present a hybrid method between MOORA and Neutrosophic in the framework of neutrosophic for the selection of machine tool with a focus on multi-criteria and multi-group environment. These days, Companies, organizations, factories seek to provide a fast and a good service to meet the requirements of peoples or customers. The selecting of the best supplier increasing the efficiency of any organization whether company, factory according to [1]. Hence, for selecting the best supplier selection there are much of methodologies we presented some of them such as fuzzy sets (FS), Analytic network process (ANP), Analytic hierarchy process(AHP), (TOPSIS) technique for order of preference by similarity to ideal solution, (DSS) Decision support system, (MOORA)multi-objective optimization by ratio analysis.

1.1 Supplier selection

A Supplier choice is viewed as one of the most significant parts of creation and indecency the board for some, association's administration. The primary objective of provider choice is to recognize providers with the most outstanding ability for gathering an association needs reliably and with the base expense. They are utilizing a lot of standard criteria and measures for abroad examination of providers. Be that as it may, the degree of detail used for inspecting potential providers may differ contingent upon an association's needs.

The fundamental reason and target objective of determination are to recognize high-potential providers. To pick providers, the present association judge of every provider as per the capacity of gathering the association reliably and financially savvy its needs utilizing choice criteria and proper measure. Criteria and standards are created to be material to every one of the providers being considered and to mirror the company's needs and its supply and innovation technique. We show supplier evaluation and selection process in Fig.1 and in Fig.2.

Figure 1. Supplier evaluation and selection process.

Figure 2. Supplier evaluation and selection process.

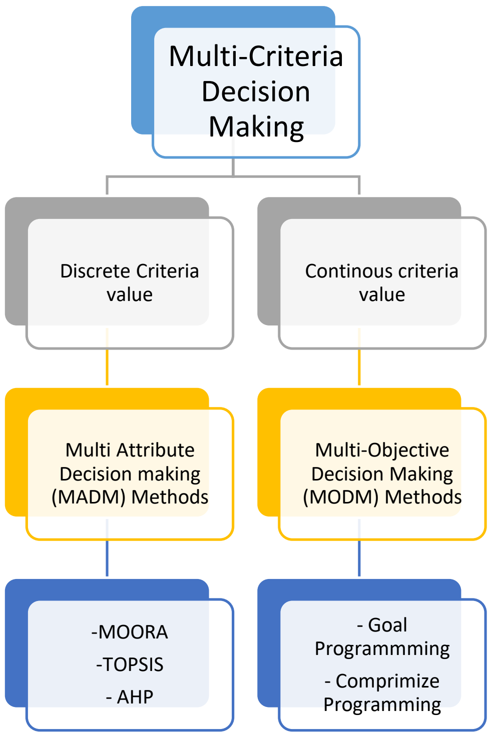

Figure 3. MOORA method belongs to MADM

1.2 MOORA

Multi-Objective Optimization based on Ratio Analysis (MOORA), otherwise called multi-criteria or multi-property advancement. MOORA the technique looks to rank or chooses the best elective from accessible choice was presented by Brauers and Zavadskas in 2006. The MOORA technique has a considerable scope of utilizations to settle on choices in the clashing and troublesome region of production network condition.

MOORA can be connected in the task determination, process structure choice, area choice, item choice and so on the way toward characterizing the choice objectives, gathering essential data and choosing the best ideal option is known as necessary leadership process. The fundamental thought of the MOORA technique is to ascertain the general execution of every opportunity as the contrast between the wholes of its standardized exhibitions, which has a place with expense and advantage criteria. This strategy connected in different fields effectively, for example, venture the executives. Fig.3 shows to which category belongs the method of MOORA.

1.3 Neutrosophic

There are numerous vulnerabilities in everyday life. The rationale of old-style science regularly lacks to clarify these vulnerabilities. Since it isn't always conceivable to call a circumstance or occasion right or wrong, for instance, we can't generally call the climate cold or hot. It very well may be heated for a few, frozen for a few and cool for other people.

Comparable circumstances in which we stay ambivalent may show up in the expert capability appraisal. It is frequently hard to decide if work is done or an item delivered is consistently definite great or unmistakable awful. Such a circumstance lessens the unwavering quality of assessing proficient proficiencies. To adapt to these vulnerabilities, Smarandache characterized the idea of the neutrosophic rationale and neutrosophic set [2] in 1998. In the concept of the neutrosophic explanation and neutrosophic bunches, there is a T level of participation, and I level of indeterminacy and F level of non-enrollment. These degrees are characterized autonomously of one another. It has a neutrosophic esteem (T, I, F) structure. A condition is dealt with as indicated by the two its precision and its error and its vulnerability. In this way, neutrosophic rationale and neutrosophic set assistance us to clarify numerous vulnerabilities in our lives. Furthermore, various scientists have made examinations on this hypothesis [3 - 7].

We present some of the methodologies that are used in the multi-criteria decision making and presenting the illustration between supplier selection, MOORA, and Neutrosophic. Hence the goal of this paper to present the hybrid of the MOORA method with neutrosophic as a methodology for MCDM.

This is ordered as follows: Section 2 gives an insight into some basic definitions on neutrosophic sets and MOORA. Section 3 explains the proposed methodology of neutrosophic MOORA model. In Section 4 a numerical example is presented in order to explain the proposed methodology. Finally, the conclusions

2. Preliminaries

In this Section, the fundamental definitions including neutrosophic set, single-esteemed neutrosophic sets, trapezoidal neutrosophic numbers and tasks on trapezoidal neutrosophic numbers are characterized.

Definition 2.1 Let X be a space of points and $x \in X$. A neutrosophic set A in X is definite by a truth-membership function $T_A(x)$, an indeterminacy-membership function $I_A(x)$ and a falsity-membership function $F_A(x)$, $T_A(x)$, $I_A(x)$ and $F_A(x)$ are real standard or real nonstandard subsets of]-*0, 1*+[. That is $T_A(x)$:$X \rightarrow$]-0, 1+[,$I_A(x)$:$X \rightarrow$]-0, 1+[and $F_A(x)$:$X \rightarrow$]-0, 1+[. There is no restriction on the sum of $T_A(x)$, $I_A(x)$ and $F_A(x)$, so $0- \leq \sup(x) + \sup x + \sup x \leq 3+$.

Definition 2.2: Let X be a universe of discourse. A single valued neutrosophic set A over X is an object taking the form $A = \{\langle x, T_A(x), I_A(x), F_A(x), \rangle : x \in X\}$, where $T_A(x)$:$X \rightarrow$ [0,1], $I_A(x)$:$X \rightarrow$ [0,1] and $F_A(x)$:$X \rightarrow$[0,1] with $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$ for all $x \in X$. The intervals $T_A(x)$, $I_A(x)$ and $F_A(x)$ represent the truth-membership degree, the indeterminacy-membership degree and the falsity membership degree of x to A, respectively. For convenience, a SVN number is represented by A= (a, b, c), where a, b, $c \in$ [0, 1] and $a+b+c \leq 3$.

Definition 2.3: Suppose that $\alpha_{\tilde{a}}$, $\theta_{\tilde{a}}$, $\beta_{\tilde{a}}$ ϵ [0,1] and a_1 , a_2 , a_3 , a_4 ϵ R where $a_1 \leq a_2 \leq a_3 \leq a_4$. Then a single valued trapezoidal neutrosophic number, $\tilde{a}$=$\langle(a_1 , a_2 , a_3 , a_4); \alpha_{\tilde{a}} , \theta_{\tilde{a}} , \beta_{\tilde{a}}\rangle$ is a special neutrosophic set on the real line set R whose truth-membership, indeterminacy-membership and falsity-membership functions are defined as:

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}} \left(\frac{x-a_1}{a_2-a_1}\right) & (a_1 \leq x \leq a_2) \\ \alpha_{\tilde{a}} & (a_2 \leq x \leq a_3) \\ \alpha_{\tilde{a}} \left(\frac{a_4-x}{a_4-a_3}\right) & (a_3 \leq x \leq a_4) \\ 0 & otherwise \end{cases} \quad (1)$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{(a_2-x+\theta_{\tilde{a}}(x-a_1))}{(a_2-a_1)} & (a_1 \leq x \leq a_2) \\ \alpha_{\tilde{a}} & (a_2 \leq x \leq a_3) \\ \frac{(x-a_3+\theta_{\tilde{a}}(a4-x))}{(a_4-a_3)} & (a_3 \leq x \leq a_4) \\ 1 & otherwise \end{cases}, \quad (2)$$

$$F_{\tilde{a}}(x) = \begin{cases} \frac{(a_2-x+\beta_{\tilde{a}}(x-a_1))}{(a_2-a_1)} & (a_1 \leq x \leq a_2) \\ \alpha_{\tilde{a}} & (a_2 \leq x \leq a_3) \\ \frac{(x-a_3+\beta_{\tilde{a}}(a4-x))}{(a_4-a_3)} & (a_3 \leq x \leq a_4) \\ 1 & otherwise \end{cases}, \quad (3)$$

Where $\alpha_{\tilde{a}}$, $\theta_{\tilde{a}}$ and $\beta_{\tilde{a}}$ and represent the maximum truth-membership degree, minimum indeterminacy-membership degree and minimum falsity-membership degree respectively. A single valued trapezoidal neutrosophic number $\tilde{a}$=$\langle(a_1 , a_2 , a_3 , a_4); \alpha_{\tilde{a}} , \theta_{\tilde{a}} , \beta_{\tilde{a}}\rangle$ may express an ill-defined quantity of the range, which is approximately equal to the interval $[a_2 , a_3]$.

Definition 2.4: Let $\tilde{a}$=$\langle(a_1 , a_2 , a_3 , a_4); \alpha_{\tilde{a}} , \theta_{\tilde{a}} , \beta_{\tilde{a}}\rangle$ and $\tilde{b}$=$\langle(b_1 , b_2 , b_3 , b_4); \alpha_{\tilde{b}} , \theta_{\tilde{b}} , \beta_{\tilde{b}}\rangle$ be two single valued trapezoidal neutrosophic numbers and $\Upsilon \neq 0$ be any real number. Then,

1. Addition of two trapezoidal neutrosophic numbers

   $\tilde{a}+\tilde{b}$ =$\langle(a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \theta_{\tilde{a}} \vee \theta_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}\rangle$

2. Subtraction of two trapezoidal neutrosophic numbers

   $\tilde{a}-\tilde{b}$ =$\langle(a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \theta_{\tilde{a}} \vee \theta_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}\rangle$

3. Inverse of trapezoidal neutrosophic number

   $\tilde{a}^{-1}$ =$\langle(\frac{1}{a_4} , \frac{1}{a_3} , \frac{1}{a_2} , \frac{1}{a_1}) ; \alpha_{\tilde{a}} , \theta_{\tilde{a}} , \beta_{\tilde{a}}\rangle$ where $(\tilde{a} \neq 0)$

4. Multiplication of trapezoidal neutrosophic number by constant value

   $$\Upsilon\tilde{a} = \begin{cases} \langle(\Upsilon a_1 , \Upsilon a_2 , \Upsilon a_3 , \Upsilon a_4); \alpha_{\tilde{a}} , \theta_{\tilde{a}} , \beta_{\tilde{a}}\rangle & \text{if } (\Upsilon > 0) \\ \langle(\Upsilon a_4 , \Upsilon a_3 , \Upsilon a_2 , \Upsilon a_1); \alpha_{\tilde{a}} , \theta_{\tilde{a}} , \beta_{\tilde{a}}\rangle & \text{if } (\Upsilon < 0) \end{cases}$$

5. Division of two trapezoidal neutrosophic numbers

   $$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \langle(\frac{a_1}{b_4} , \frac{a_2}{b_3} , \frac{a_3}{b_2} , \frac{a_4}{b_1}); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \theta_{\tilde{a}} \vee \theta_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}\rangle & \text{if } (a_4 > 0 , b_4 > 0) \\ \langle(\frac{a_4}{b_4} , \frac{a_3}{b_3} , \frac{a_2}{b_2} , \frac{a_1}{b_1}); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \theta_{\tilde{a}} \vee \theta_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}\rangle & \text{if } (a_4 < 0 , b_4 > 0) \\ \langle(\frac{a_4}{b_1} , \frac{a_3}{b_2} , \frac{a_2}{b_3} , \frac{a_1}{b_4}); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \theta_{\tilde{a}} \vee \theta_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}\rangle & \text{if } (a_4 < 0 , b_4 < 0) \end{cases}$$

6. Multiplication of trapezoidal neutrosophic numbers

$$\tilde{a}\tilde{b} = \begin{cases} \langle(a_1b_1 , a_2b_2 , a_3b_3 , a_4b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \theta_{\tilde{a}} \vee \theta_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}\rangle & \text{if } (a_4 > 0 , b_4 > 0) \\ \langle(a_1b_4 , a_2b_3 , a_3b_2 , a_4b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \theta_{\tilde{a}} \vee \theta_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}\rangle & \text{if } (a_4 < 0 , b_4 > 0) \\ \langle(a_4b_4 , a_3b_3 , a_2b_2 , a_1b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \theta_{\tilde{a}} \vee \theta_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}\rangle & \text{if } (a_4 < 0 , b_4 < 0) \end{cases}$$

3. Methodology

The functionality of linguistic variables, words have more extent to describe the semantic and sentimental expressions compared with numbers. This research chooses trapezoidal neutrosophic numbers, which includes nine parameters to model linguistic variables. The trapezoidal neutrosophic scales used in this proposed research exhibited in Table 1.

Table 1. Semantic expressions for the significance weights of criteria

Linguistic expressions	Trapezoidal neutrosophic numbers (T, I, I, F; $\alpha_{ã}$, $\theta_{ã}$, $\beta_{ã}$)
Just Equal (JE)	(0.1, 0.2, 0.3, 0.4; 0.5, 0.1, 0.3)
	(0.2, 0.3, 0.3, 0.4; 0.8, 0.2, 0.3)
Equal importance (EI)	(0.3, 0.4, 0.4, 0.5; 1.0, 0.1, 0.1)
Weak importance of one over another (WIO)	(0.4, 0.5, 0.5, 0.6; 0.7, 0.3, 0.2)
Essential or strong importance (VRS)	(0.5, 0.6, 0.6, 0.7; 0.9, 0.2, 0.1)
	(0.6, 0.7, 0.7, 0.8; 0.8, 0.3, 0.5)
Very Strong Importance (AS)	(0.7, 0.8, 0.8, 0.9; 0.8, 0.3, 0.5)
	(0.9, 1.0, 1.0,1.0; 0.1, 0.2, 0.2)

In this section, the steps of the suggested neutrosophic MOORA framework are presented with detail. The suggested framework consists of such steps as follows:

Step 1. Constructing model and problem structuring.

a. Constitute a group of decision-makers.
b. Formulate the problem based on the opinions of decision-makers

Step 2. Making the pairwise comparisons matrix and determining the weight based on opinions of (DMs).

a. Identify the criteria and sub criteria C = {C_1, C_2, $C_3 \ldots C_m$}.
b. Making matrix among criteria n × m based on opinions of decision-makers.

$$W = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ Cn \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_m \end{array} \\ \begin{bmatrix} (l_{11}, m_{11l}, m_{11u}, u_{11}) & (l_{11}, m_{11l}, m_{11u}, u_{11}) & \cdots & (l_{1n}, m_{1nl}, m_{1nu}, u_{1n}) \\ (l_{21}, m_{21l}, m_{21u}, u_{21}) & (l_{22}, m_{22l}, m_{22u}, u_{22}) & \cdots & (l_{2n}, m_{2nl}, m_{2nu}, u_{2n}) \\ \cdots & \cdots & \cdots & \cdots \\ (l_{n1}, m_{n1l}, m_{n1u}, u_{n1}) & (l_{n2}, m_{n2l}, m_{n2u}, u_{n2}) & \cdots & (l_{nn}, m_{nnl}, m_{nnu}, u_{nn}) \end{bmatrix} \end{array} \quad (4)$$

c. Decision-makers make pairwise comparisons matrix between criteria compared to each criterion.
d. According to, the opinion of decision-makers should be among from 0 to 1 not negative. Then, we transform neutrosophic matrix to pairwise comparisons deterministic matrix by adding (α, θ, β) and using the following equation to calculate the accuracy and score.

i. $$S(ã_{ij}) = \frac{1}{16}[a_1 + b_1 + c_1 + d_1] \times (2 + \alpha_{ã} - \theta_{ã} - \beta_{ã}) \quad (5)$$

ii. $$A(ã_{ij}) = \frac{1}{16}[a_1 + b_1 + c_1 + d_1] \times (2 + \alpha_{ã} - \theta_{ã} + \beta_{ã}) \quad (6)$$

e. We obtain the deterministic matrix by using S ($ã_{ij}$).

f. From the deterministic matrix we obtain the weighting matrix by dividing each entry on the sum of the column.

Step 3. Determine the decision-making matrix (DMM). The method begin with define the available alternatives and criteria.

$$R = \begin{matrix} \\ A_1 \\ A_2 \\ A_3 \\ An \end{matrix} \begin{matrix} C_1 & C_2 & \dots & C_m \\ \end{matrix} \begin{bmatrix} (l_{11}, m_{11l}, m_{11u}, u_{11}) & (l_{11}, m_{11l}, m_{11u}, u_{11}) & \cdots & (l_{1n}, m_{1nl}, m_{1nu}, u_{1n}) \\ (l_{21}, m_{21l}, m_{21u}, u_{21}) & (l_{22}, m_{22l}, m_{22u}, u_{22}) & \cdots & (l_{2n}, m_{2nl}, m_{2nu}, u_{2n}) \\ \cdots & \cdots & \cdots & \cdots \\ (l_{n1}, m_{n1l}, m_{n1u}, u_{n1}) & (l_{n2}, m_{n2l}, m_{n2u}, u_{n2}) & \cdots & (l_{nn}, m_{nnl}, m_{nnu}, u_{nn}) \end{bmatrix} \quad (7)$$

Where A_i represents the available alternatives where i = 1… n and the C_j represents criteria

a. Decision makers (DMs) make pairwise comparisons matrix between criteria compared to each criterion. Using the Eqs. (5, 6) to calculate the accuracy and score.

b. We obtain the deterministic matrix by using S ($\tilde{a}_{ij}$).

Step 4. Calculate the normalized decision-making matrix from previous matrix (DMM).

a. Thereby, normalization is carried out, where the Euclidean norm is obtained according to Eq. (8) to the criterionE_j.

i. $$|Ey_j| = \sqrt{\sum_1^n E_i^2} \quad (8)$$

The normalization of each entry is undertaken according to Eq. (9)

ii. $$NE_{ij} = \frac{E_{ij}}{|E_j|} \quad (9)$$

Step 5. Compute the aggregated weighted neutrosophic decision matrix (AWNDM) as the following:

i. $$\acute{X} = X \times W \quad (10)$$

Step 6. Compute the contribution of each alternative Ny_i the contribution of each alternative

i. $$Ny_i = \sum_{i=1}^{g} Ny_i - \sum_{j=g+1}^{m} Nx_j \quad (11)$$

Step 7. Rank the alternatives.

4. Practical example

4.1 Case study

A real-world case issue is chosen to represent the utilization of the proposed methodology. The picked organization is a medium-sized assembling endeavor, which utilizes around 75 individuals and situated in the Tenth of Ramadan, Egypt. It makes a wide assortment of extra parts for the car business. In particular, the organization concentrated on sizeable measured gathering and assembling organizations working for the car business. Its creation fan is full including motor mountings, encasings, front suspension arms, fan sharp edges, indoor regulator lodgings, numerous sorts of riggings, entryway rollers, entryway handles, and so forth. The organization likewise delivers molds which are utilized to fabricate the elastic, metal, and aluminum parts. While different kinds of CNC and manual machine devices are utilized for normal generation, once in a while manual machine apparatuses are for the most part utilized as reinforcements. The organization is a metal machining activity venture demonstrating qualities of both occupation shop and clump creation. Thus client request sizes go in a wide edge. Truly, the organization has gotten an abnormal state of benefits, which began to decay as a result of a decrease in the interest level because of an innovative change and economic situations.

For instance, once in a while an essential client's requests require the expansion of the new CNC machining focuses. In addition, in some cases existing client requests require improved machining abilities including the buy of the specific CNC machining focuses. Therefore, the organization the board chose to pull in new clients by offering new aptitudes which incorporate growing machining limit and ability, lessening creation costs, expanding item quality, and shortening conveyance time. This is a basic inspiration for the first venture. First, a project team, including three engineers and two managers working for the company, was constructed. Then a detailed interview was conducted to determine the most suitable type of equipment for the company’s competitiveness. At this point, new vertical CNC machining centers for the company’ immediate needs were decided to purchase. The company considered four different alternative models of the three different manufacturers, which are denoted as A1, A2, A3, and A4, respectively. Furthermore, a detailed questionnaire related to the data regarding the qualitative and quantitative criteria for the machine tool selection model was prepared. Then a lot of face-to-face interviews were held to develop reliable information on the selected criteria and alternatives. After a set of interviews, four criteria were determined to perform the analysis. The four criteria are cost, operative flexibility, installation easiness, maintainability, and serviceability, which are denoted as C1, C2, C3, and C4, respectively. Cost is the purchasing cost of the machine tool. Operative flexibility means the possibility of using the machine tool as desired. It must be utilized when needed. Installation easiness means having the positive effects of the convenience of installation. Simple installation is practical and fast, along with installation time savings without requiring any particular technical ability.

Maintainability imparts to a machine tool an inherent ability to be maintained with reduced person-hours and skill levels, and fewer tools and support equipment. It is also the probability that a machine can be kept in an operational condition. Serviceability is defined as the ease with which all maintenance activities can be performed on a system. It is also defined as the ease with which all services, including implementation services, post-implementation professional services, and managed services can be performed.

4.2 Results

The aim of using Neutrosophic MOORA is to determine the importance weight of the criteria, then used to the ranking of the alternatives.

Step 1. Constitute a group of decision-makers.

Step 2. We determine the importance of each criteria based on opinion of all decision-makers as in Table 2, using the Eq.4.

Table 2. The comparison matrix between criteria for calculating weights

weights	C_1	C_2	C_3	C_4	W
C_1	(0.5, 0.5,0.5,0.5)	(0.2, 0.3, 0.3, 0.4; 0.8, 0.2, 0.3)	(0.5, 0.6, 0.6, 0.7; 0.9, 0.2, 0.1)	(0.9, 1.0, 1.0,1.0; 0.1, 0.2, 0.2)	0.17
C_2	(0.2, 0.3, 0.3, 0.4; 0.8, 0.2, 0.3)	(0.5, 0.5,0.5,0.5)	(0.7, 0.8, 0.8, 0.9; 0.8, 0.3, 0.5)	(0.2, 0.3, 0.3, 0.4; 0.8, 0.2, 0.3)	0.23
C_3	(0.7, 0.8, 0.8, 0.9; 0.8, 0.3, 0.5)	(0.4, 0.5, 0.5, 0.6; 0.7, 0.3, 0.2)	(0.5, 0.5,0.5,0.5)	(0.9, 1.0, 1.0,1.0; 0.1, 0.2, 0.2)	0.33
C_4	(0.9, 1.0, 1.0,1.0; 0.1, 0.2, 0.2)	(0.5, 0.6, 0.6, 0.7; 0.9, 0.2, 0.1)	(0.2, 0.3, 0.3, 0.4; 0.8, 0.2, 0.3)	(0.5, 0.5,0.5,0.5)	0.27

We show the weights of criteria in Fig.4.

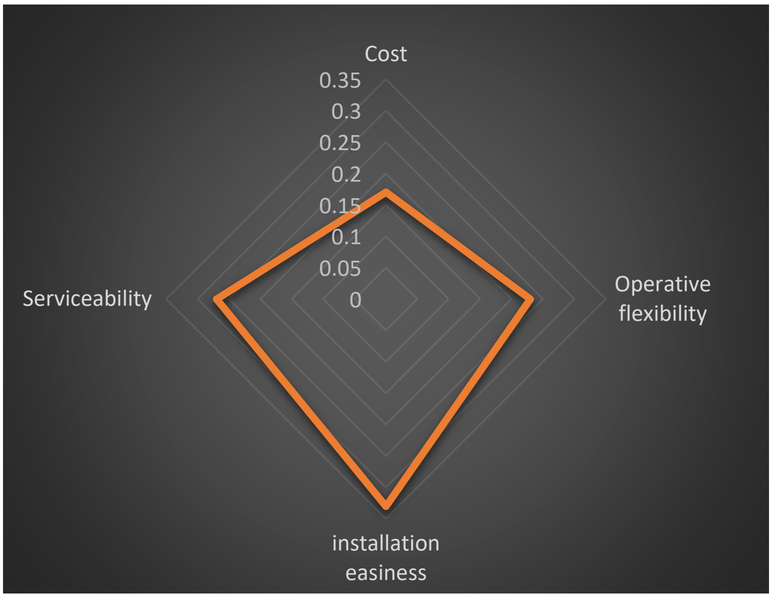

Figure 4. Weights of criteria.

Step 3. Construct the matrix that representing the ratings given by every DM between the criteria and alternatives, by using the Eq.7.

Every decision maker makes the evaluation matrix via comparing the four alternatives relative to each criteria by using the trapezoidal neutrosophic numbers scale in Table 1 as shown in Table 3.

Table 3. The comparison matrix between criteria for calculating weights

	C_1	C_2	C_3	C_4
A_1	(0.4, 0.5, 0.5, 0.6; 0.7, 0.3, 0.2)	(0.2, 0.3, 0.3, 0.4; 0.8, 0.2, 0.3)	(0.5, 0.6, 0.6, 0.7; 0.9, 0.2, 0.1)	(0.5, 0.6, 0.6, 0.7; 0.9, 0.2, 0.1)
A_2	(0.2, 0.3, 0.3, 0.4; 0.8, 0.2, 0.3)	(0.5, 0.6, 0.6, 0.7; 0.9, 0.2, 0.1)	(0.9, 1.0, 1.0,1.0; 0.1, 0.2, 0.2)	(0.9, 1.0, 1.0,1.0; 0.1, 0.2, 0.2)
A_3	(0.7, 0.8, 0.8, 0.9; 0.8, 0.3, 0.5)	(0.9, 1.0, 1.0,1.0; 0.1, 0.2, 0.2)	(0.9, 1.0, 1.0,1.0; 0.1, 0.2, 0.2)	(0.9, 1.0, 1.0,1.0; 0.1, 0.2, 0.2)
A_4	(0.2, 0.3, 0.3, 0.4; 0.8, 0.2, 0.3)	(0.5, 0.6, 0.6, 0.7; 0.9, 0.2, 0.1)	(0.2, 0.3, 0.3, 0.4; 0.8, 0.2, 0.3)	(0.2, 0.3, 0.3, 0.4; 0.8, 0.2, 0.3)

From previous Table 3 we can determine the weight of each criteria by using Eq.5 or Eq.6 in the similarity case.

Step 4. Calculate the normalized decision-making matrix from Table 3, by using Eq. (8, 9).then calculating the weights using Eq.9.

a. Sum of squares and their square roots in Table 4.

Table 4. Sum of squares and their square roots

	C_1	C_2	C_3	C_4
A_1	0.11	0.20	0.32	0.27
A_2	0.11	0.23	0.26	0.20
A_3	0.10	0.16	0.08	0.18
A_4	0.25	0.19	0.11	0.07
SS	0.17	0.14	0.20	0.14
SR	0.35	0.39	0.44	0.38

b. Objectives divided by their square roots in Table 5.

Table 5. Objectives divided by their square roots

	C_1	C_2	C_3	C_4
A_1	0.28	0.55	0.65	0.47
A_2	0.32	0.38	0.50	0.55
A_3	0.25	0.44	0.12	0.16
A_4	0.64	0.21	0.25	0.17

Step 5. Compute the contribution of each alternative by using Eq.11 as presented in Table 6

Table 6. Ranking of the alternatives.

	C_1	C_2	C_3	C_4	Y_i	Rank
A_1	0.43	0.19	0.47	0.46	0.65	2
A_2	0.45	0.56	0.24	0.33	0.85	1
A_3	0.23	0.43	0.35	0.32	0.60	3
A_4	0.65	0.32	0.33	0.28	0.45	4

Step 6. Rank the alternatives.

The higher the closeness means the better the rank, so the relative closeness to the ideal solution of the alternatives can be substituted as follows: A2 > A1 > A3 > A4 as shown in Fig.5. A2 is defined as the best alternative for this company. The obtained result is discussed in the company just as to investigate the meaningfulness of the selected alternative.

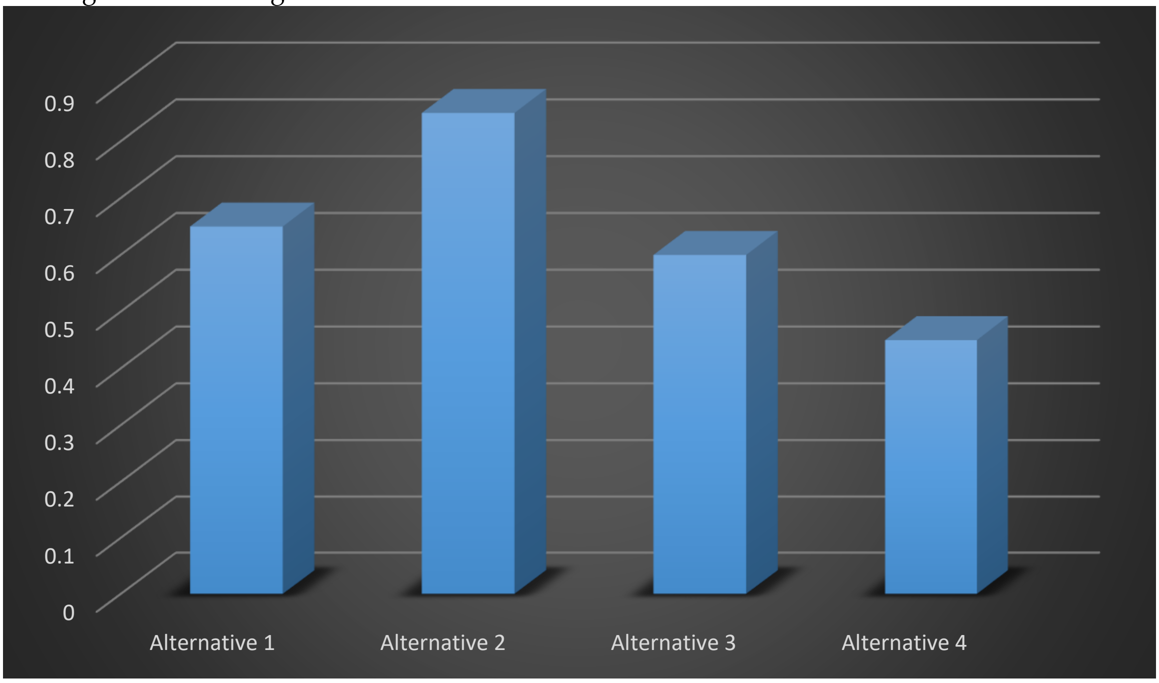

Figure 5. Ranking of the alternatives.

5. Conclusions

In this paper, a methodology based on neutrosophic and MOORA for selecting the most suitable machine tools is suggested. Also, the ranking scores are the outcomes of the methodology, and by using ranking scores, DM can obtain not only a ranking of the alternatives but also the degree of superiority among the alternatives. For dealing uncertainty and improving lack of precision in evaluating criteria and machine tool alternatives, neutrosophic methods are used. Our approach applies trapezoidal numbers into traditional MOORA method. By applying for neutrosophic numbers, DM enables to get better results in the overall importance of criteria and real alternatives.

As a result of the study, we find that the proposed method is practical for ranking machine tool alternatives concerning multiple conflicting criteria.

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