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SELECTION OF MACHINE TOOL SYSTEM USING INTELLIGENT MULTI – ATTRIBUTE DECISION MAKING METHODS

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ABSTRACT

The selection of appropriate machines and equipments is one of the most critical decisions in the design and development of a successful manufacturing environment. Considering the detailed specifications related to the functional requirements, productivity, quality, flexibility, cost, etc., and the number of available alternative machine tools in the market, the selection procedure can be quite complicated and time consuming. In the present work an intelligent approach is introduces for the machine tool selection. A new approach is developed for Analytical Hierarchy process – AHP, which guides decision maker in calculating the relative importance of various criteria. In this way the AHP is better termed as an Intelligent AHP (IAHP). There are four main criteria such as productivity, flexibility, safety & environment and adaptability. Some important sub-criteria are used for the selection are machine power, spindle speed, tool magazine capacity, etc. to evaluate the machine tool system. The ranking is done using Elimination and Choice Expressing the Reality – ELECTRE method.

Keywords: *Intelligent Analytical Hierarchy Process – IAHP, Machine Tool Selection and ELECTRE – III*

1. Introduction

The selection of appropriate machines is one of the most critical decisions in the design and development of an efficient production environment. In this study, we propose a combination of decision making methods for machine tool selection using an intelligent analytical hierarchy process and Electre method. In the selection process, we first consider qualitative decision criteria that are related to the machine properties. The decision-maker can also take into account the economical considerations through cost analysis. In addition, the robustness of the selection procedure may be evaluated using sensitivity analysis. An illustrative example of machine tool selection using the proposed methodology and the software implementation are provided in [1].

Emrah et al. presented the selection of appropriate machine selection using decision support system. The major contribution of this study is combining the IAHP-based selection methodology with productivity, flexibility safety and reliability to evaluate several alternatives and make an accurate decision. In this work, an ELECTRE based outranking method is applied for the selection of best choice for the machine tool selection [1].

Competitive market conditions as a result of globalization, limited resources, etc. force companies to make careful decisions. Any waste of resources such as money, time, workforce, etc., due to inappropriate decisions, directly increases the costs of companies, which, in turn, is reflected to the customer. Machine tool selection is very critical for companies where machining process adds vital value on the product. Machining operations are used in the manufacturing of variety products due to the quality, flexibility and reduced lead times that can be achieved. For the majority of remaining production operations where machining is not used as the primary manufacturing process, it is used in the manufacturing of tooling that is vital to the production, such as dies and molds. Therefore, a poor decision would result in quality, flexibility, productivity, etc., problems which could have dramatic results. This study aims at developing a systematical, accurate, fast and practical decision-making process for machine tool selection.

A decision is a choice made from two or more alternatives. Decision-making is the process of sufficiently reducing uncertainty and doubt about alternatives to allow a reasonable choice to be made among them.

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A model for the selection of the most suitable machine from a range of machines available for the manufacture of particular part types was developed in [2]. There are four main criteria: machine procedures, lead time, labor cost, and operation shift; and three alternatives: conventional machines, NC machines, and flexible manufacturing cells.

A decision support framework designed to aid decision-makers in selecting the most appropriate machines for flexible manufacturing systems (FMS) is developed in [3]. The framework consists of two main stages. The first stage, called as the pre- screening stage, narrows down all possible configurations using AHP. The second stage uses a goal programming model.

The researchers in [4] investigated the compatibility of AHP to strategic planning in manufacturing. The objective is to develop or explore different planning alternatives ranging from extending the life of existing machinery to total replacement with a new manufacturing system and to evaluate these alternatives through economical and technological criteria.

A model that links machine alternatives to manufacturing strategy for machine tool selection is developed in [5]. The evaluation of investment in machine tools can model and qualify strategic considerations by using the AHP method. On the other hand, [6] claimed that although AHP is an effective tool for management decision-making, it can be defective if used improperly.

In [7] authors suggested a fuzzy multiple-attribute decision-making model to assist the decision-maker in dealing with the machine selection problem for FMS.

A model for an integrated machine tool selection and sequencing is proposed in [8]. The model, which is formulated as a 0-1 integer program, determines machine visiting sequences for all part types such that total production time for the production tools is balanced. In order to solve the model, a genetic algorithm approach based on a topological sort technique is developed.

A decision methodology for machine tool selection using the AHP technique gives a short list of the best-fitting machines. Afterwards the precision and reliability analysis as well as the cost analysis on the so-obtained machine ranking is also conducted. The methodology proposed by the authors is very flexible in the sense that it can be applied to other types of selection problems also. This may be considered as apart of the process planning system. The approach may be considered as a part of the process planning system. It can be integrated into the overall manufacturing planning systems. This may also be used to select the appropriate tools for machining, material handling system, robots, etc [9].

Machine selection has been a very important issue for manufacturing companies due to the fact that improperly selected machines can negatively affect the overall performance of a manufacturing system. In addition, the outputs of a manufacturing system depend mostly on appropriate selection of machines and its implementation. On the other hand, the selection of a new machine is a time-consuming and difficult process requiring advanced knowledge and experience deeply. So, the process can be difficult for engineers and managers. For a proper and effective evaluation, the decision maker may need a large amount of data be an expert, or at least be very familiar with the specifications of machine to select the most suitable one. The machine tool selection problem in a flexible manufacturing cell (FMC) is considered to describe the systematical methods offering the best solution. One of the key issues is the problem of machine selection in flexible manufacturing cell, which involves a number of attributes, e.g., purchasing cost, machine type, number of machines in a group, floor space required, time needed for production, etc [10].

2. Decision Making in Manufacturing

The decision making methods can be used as a strategic planning tool to evaluate efficiency and performance-based decision-making information. The objective of these methods is to help decision makers to make good decisions when dealing with complex situations and information. The tools used to support decision-making should assist the users to make well-founded decisions according to the prescriptive theories. The tools should, mark the users to feel comfortable in their work by supporting natural decision processes according to the descriptive sciences.

Manufacturing technologies have continually gone through gradual but revolutionary changes. These advancements in manufacturing technologies have brought about a metamorphism in the world industrial scene. They include CNC, CAD/CAM, FMS, robotics, rapid prototyping, environmentally sustainable technologies, *etc.*, which have become an integral part of manufacturing. Parallel to this, there are rapid strides in the development of new products, and the emergence of an open economy leading to global competition. Manufacturing industries are compelled to move away from traditional setups to more responsive and dynamic ones. Many new concepts have emerged from these changes, sustained by strategies aimed at meeting the challenges arising from global markets. Product attributes like quality, reliability, cost, life-cycle prediction, and the organizational ability to meet market pressures like delivery and service, have come into focus.

To meet the challenges, manufacturing industries have to select appropriate manufacturing strategies, product designs, manufacturing processes, work piece and tool materials, machinery and equipment, *etc*. The selection decisions are complex, as decision making is more challenging today. Necessary conditions for achieving efficient decision making consist in understanding the current and upcoming events and factors influencing the whole manufacturing environment, in exploring the nature of decision-making processes and the reach of different typologies of methods and techniques, and finally in structuring appropriately the decision-making approach based on a wide range of issues related to manufacturing systems design, planning, and management.

Decision makers in the manufacturing sector frequently face the problem of assessing a wide range of alternative options of conflicting criteria. Some of the decision-making situations in the manufacturing environment are: Machinability evaluation of work materials, Machine group selection in a flexible manufacturing cell, Facility location selection, Failure cause analysis of machine tools, robot selection for a given industrial application, selection of automated inspection systems, selection of material handling equipment etc. For the majority of these situations listed above, adequate attributes and alternatives are to be identified.

The objective of the present work is to demonstrate the use of ELECTRE – III as a decision making method in accordance with the computerized solution to AHP calculations (IAHP). Here, the combinatorial approach has proved that the combination of two or more decision making methods in a peculiar pattern the results can be obtained with high accuracy.

3. Basic Methodology for ELECTRE-III

The ELECTRE (Elimination Et Choix Traduisant la REalite – ELimination and Choice Expressing the Reality) method and its versions enjoy a wide acceptance in solving multiple criteria decision making (MCDM) problems.

In order to understand what the outranking approach is and what kind of real-world problems it refers to, it is necessary to specify what is supposed to be given initially.

i. A set of potential actions or alternatives is considered. Such actions are not necessarily exclusive, i.e., they can be put into operation jointly.

ii. A consistent family F of n criteria has been defined. This means that preferences of actors involved in the decision process are formed, argued and transformed by reference to points of view adequately reflected by criteria of F. e.g., $g_j(a)$ is called the j^{th} performance of a.

The ELECTRE method is a non-compensatory, MCDM technique. It uses various mathematical functions to indicate the degree of dominance of one alternative or group of alternatives over the remaining ones. It also facilitates comparisons between alternative schemes by assigning weights to decision criteria. The outranking relationships between alternatives are constructed and exploited eventually. ELECTRE requires an input of criteria evaluations for the alternatives, called decision matrix, preference information, expressed as weights, threshold, and other parameters.

The ELECTRE method is based on two phases. First, the outranking relation results in an outranking matrix. The second phase consists of exploring these relations. A discrete multiple criteria decision making problem is usually formulated with the following notations [11]:

- A set of alternatives $A = \{a_1, a_2, \cdots, a_n\}$
- A set of criteria $F = \{g_1, g_2, \cdots, g_m\}$
- $W = \{w_1, w_2, \cdots, w_n\}$ is the weight vector modeling the preferences of the decision maker. Let us assume that $\Sigma_{j=J}\, w_j = 1$.
- $g_j(a_i)$ is the evaluation of criteria g_j for alternative a_i. Let define the following comprehensive relational operators, to compare two alternatives, a and b , as follows:

  i. P is the strong preference relation, that is aPb denotes the relation "a is strongly preferred over b ".
  ii. I is the indifference relation, that is aIb denotes the relation "a is indifferent to b ".
  iii. Q is the weak preference relation, that is aQb denotes the relation "a is weakly preferred over b ".
  iv. R is the incomparability relation, that is aRb denotes that action "a and b are incomparable".
  v. S is the outranking relation, that is aSb denotes that "a is at least as good as b ".

vi. $\prec$ is the preference relation, that is $a \prec b$ that a is preferred (strongly or weakly) over b .

vii. The thresholds of the ELECTRE model are denoted as: q_j is the indifference threshold for the criterion g_j, p_j is the preference threshold for the criterion g_j and v_j is the veto threshold for the criterion g_j.

These thresholds can be constant and also variable (directly or inversely) along the scale of each criterion. The construction of an outranking relation requires the definition of a credibility index for the outranking relation aSb .It is defined using both a comprehensive concordance index, $c(a, b)$ and a discordance index for each criterion $g_j \in F$, that is, $d_j(a, b)$, for all $j \in J$. The concordance index is computed by considering individually for each criterion g_j the support it provides for the assertion aS_jb.

$c_j(a, b) = 1$ if $g_j(a) + q_j \geq g_j(b)$,

$c_j(a, b) = 0$ if $g_j(a) + p_j \geq g_j(b)$,

Otherwise

$$c_j(a, b) = \frac{p_j + g_j(a) - g_j(b)}{p_j - q_j} \qquad (1)$$

For computing the partial concordance matrix is defined with the elements:

$$c(a, b) = \frac{1}{w} \sum_{j=1}^{m} w_j c_j(a, b)$$

Whereby $w = \sum_{j=1}^{m} w_j$ *(2)*

The concordance matrix can be calculated as long as the veto threshold v_j has been defined; v_j (which can either be a constant or a function of e.g. the criteria performance too) allows the complete rejection of the aSb statement when the relation $g_j(b) > g_j(a) + v_j$ is valid for every criterion j. A discordance index reaches its maximal value when a criteria g_j puts its veto to the outranking relation; it is minimal when the criteria g_j is not discordant with that relation. To define the value of the discordance index on the intermediate zone a linear interpolation is used. The elements $d(a, b)$ can be computed as follows:

$d_j(a, b) = 1$ if $g_j(a) + v_j \leq g_j(b)$,

$d_j(a, b) = 0$ if $g_j(a) + p_j > g_j(b)$,

Otherwise

$$d_j(a, b) = \frac{g_j(b) - g_j(a) - p_j}{v_j - p_j} \qquad (3)$$

The last phase of the dominance model is the combination of the above with the elements $S(a, b)$ in order to produce the reliability matrix. Each element of the table estimates the respective statement aSb for each pair of values and expresses the dominance of the alternative (i.e. in terms of percentage) of the element's line opposite to its column. The elements of the reliability matrix $S(a, b)$ are compiled according to the following relations:

$$S(a, b) = \begin{cases} C(a, b) & \text{if } d_j \leq C(a, b) \quad \forall j \quad \text{or} \\ C(a, b) \bullet \prod_{j \in J(a,b)} \dfrac{1 - d_j(a, b)}{1 - C(a, b)} & J(a, b) \end{cases} \qquad (4)$$

Where $J(a, b)$ is the set of criteria for which $d_j(a, b) > C(a, b)$ is valid. The complete set of outranking degree is assembled as shown in following credibility matrix **S** :

$$\mathbf{S} = \begin{pmatrix} S(a_1, b_1) & S(a_1, b_2) & \cdots & S(a_1, b_n) \\ S(a_2, b_1) & S(a_2, b_2) & \cdots & S(a_2, b_n) \\ \vdots & \vdots & \vdots & \vdots \\ S(a_n, b_1) & S(a_n, b_2) & \cdots & S(a_n, b_n) \end{pmatrix} \qquad (5)$$

The next step is to create the hierarchy of the alternative solutions from the elements of the reliability matrix. The determination of the hierarchy rank is achieved by calculating the superiority ratio for each alternative. This ratio is calculated from the reliability matrix and is the fraction of the elements' sum of every alternative's line, to the sum of the elements of the alternative's respective column. The numerator represents the total dominance of the specific alternative over the rest and the denominator the dominance of the remaining alternative over the former.

4. Selection of Machine Tool System

The selection of appropriate machines is one of the most critical decisions in the design and development of an efficient production environment. In this study, we propose a decision support system for machine tool selection using an effective algorithm, the analytic hierarchy process. In the selection process, we first consider qualitative decision criteria that are related to the machine properties. Reliability and precision analyses may be included in the detailed evaluation procedure. Furthermore, the decision-maker may take into account the economical considerations through cost analysis. In addition, the robustness of the selection procedure may be evaluated using sensitivity analysis. An illustrative example of machine tool selection using the proposed methodology and the software implementation are provided in [1].

Competitive market conditions as a result of globalization, limited resources, etc. force companies to make careful decisions. Any waste of resources such as money, time, workforce, etc., due to inappropriate decisions, directly increases the costs of companies, which, in turn, is reflected to the customer. Machine tool selection is very critical for companies where machining process adds vital value on the product. Machining operations are used in the manufacturing of a variety of products due to the quality, flexibility and reduced lead times that can be achieved. For the majority of remaining production operations where machining is not used as the primary manufacturing process, it is used in the manufacturing of tooling that is vital to the production, such as dies and molds. Therefore, a poor decision would result in quality, flexibility, productivity, etc., problems which could have dramatic results. This study aims at developing a systematical, accurate, fast and practical decision-making process for machine tool selection.

A decision is a choice made from two or more alternatives. Decision-making is the process of sufficiently reducing uncertainty and doubt about alternatives to allow a reasonable choice to be made among them.

A decision support methodology for machine tool selection using the AHP technique gives a short list of the best-fitting machines. Afterwards the precision and reliability analysis as well as the cost analysis on the so-obtained machine ranking is also conducted. The methodology proposed by the authors is very flexible in the sense that it can be applied to other types of selection problems also. This may be considered as apart of the process planning system. The approach may be considered as a part of the process planning system. It can be integrated into the overall manufacturing planning systems. This may also be used to select the appropriate tools for machining, material handling system, robots, etc.

5. Issue of Machine Tool System Selection

In the problem addresses, there are four main categories, each having different requirements. The main criteria with the corresponding sub-criteria are productivity, flexibility, safety & environment, adaptability etc. Table 1 represents all the main and sub-criteria considered in the present work. These main criteria further dependent of some sub-criteria. For example, productivity depends on six sub-criteria such as maximum speed that can be attained, horsepower, tool changing time, ideal traverse time etc., while flexibility depends on nine sub-criteria. Safety and environment is also considered as an important criterion especially for satisfying regulations and standards. Adaptability is the suitability of machine to the existing environment or system [1, 9]

In addition to these main and sub-criteria, some machine features such as machine type, manufacturers, column construction, axis, number of ranges, etc. are also considered to allow the decision-maker to eliminate undesired machines.

Table 1: Criteria and Related Sub-Criteria for the Decision Setting of the Problem

Productivity	Flexibility	Safety and environment	Adaptability
Max. speed	U axis	Safety door	Taper type
Horse power	Articulated axis	Fire extinguisher	Space requirements
Tool change time	No. of pallets	Mist collector	CNC control type
Number of spindles	Rotary table		Coolant type
Rapid traverse speed	Total number of tools		
Cutting feed	Head changer		
	CNC or not?		
	Index table		
	Dual axis rotary table		

Table 1 has given all the possible main and sub-criteria for the selection procedure. The productivity and flexibility seems to be more important than the two vise, safety & environment and adaptability.

It is very clear from the data shown in Table 2 that some of the data are qualitative and required to be converted into numerical values. The qualitative data are converted by using the same method as that of the original authors had used and the data converted data are given in Table 3, showing MS-Maximum speed, TT-Tool change time, SP-Spindle power, NT-Number of tools, AA- Articulated axis, HC-Head changer.

Table 2: Machine Tool Selection Data

Machine Tool	MS	TT	SP	NT	AA	HC
MT_1	3150	32	35	80	Opt.	Std.
MT_2	4000	20	25	30	None	Std.
MT_3	6000	18	25	30	None	None
MT_4	7000	6	15	40	None	None
MT_5	5000	10	27	40	None	None
MT_6	8000	15	10	20	None	None

From the data of machine tool system selection it is clear that the first four criteria are represented by crisp scores whereas the last two are represented by linguistic term. Hence, it is required to normalize the data in its initial condition. In the various systems of converting the linguistic tem into the crisp data there is no space to consider the term "none". Here, an approach is used to give some crisp score to even the term "none" [13].

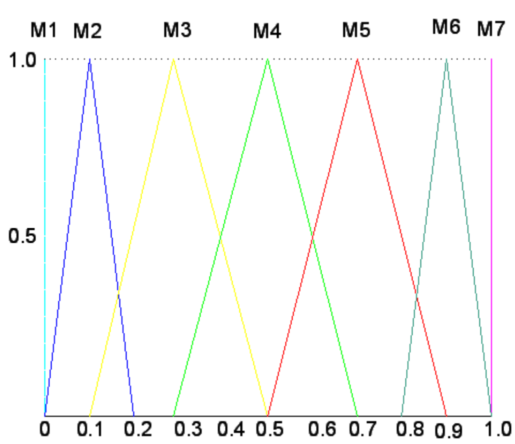


Fig. 1 Graphical Representation of Linguistic 7 Point Scale

The membership functions for all the seven point can be described as follows:

M1: None	M5: High
M2: Very low	M6: Very High
M3: Low	M7: Excellent
M4: Medium	

The crisp score of fuzzy number 'M' is obtained as follows:

$$\mu_{max}(x) = \begin{cases} x, 0 \le x \le 1 \\ 0, \text{otherwise} \end{cases} = \mu_R$$

$$\mu_{min}(x) = \begin{cases} 1 - x, 0 \le x \le 1 \\ 0, \text{otherwise} \end{cases} = \mu_L \quad (6)$$

The fuzzy max and fuzzy min of fuzzy numbers are defined in a manner such that absolute locations of fuzzy numbers can be automatically incorporated in the comparison cases. The left hand score of the fuzzy number 'M_i' is defined as follows from figure 1.

$$\mu_L(Mi) = \sup_x \left[\mu_{min}(x) \wedge \mu Mi(x)\right] \quad (7)$$

The $\mu_L M_i$ score is a unique, crisp, real number in [0, 1]. It is the maximum membership value of the intersection of fuzzy number Mi and the fuzzy min. The right score may be obtained in a similar manner:

$$\mu_R(Mi) = \sup_x \left[\mu_{max}(x) \wedge \mu Mi(x)\right] \quad (8)$$

The data of Table 2 is converted into the crisp score using he above equations and represented in Table 3. Te two criteria of the machine tool selection problem are given the crisp score.

Table 3: Crisp Values of All the Criteria of Machine Tool System Selection

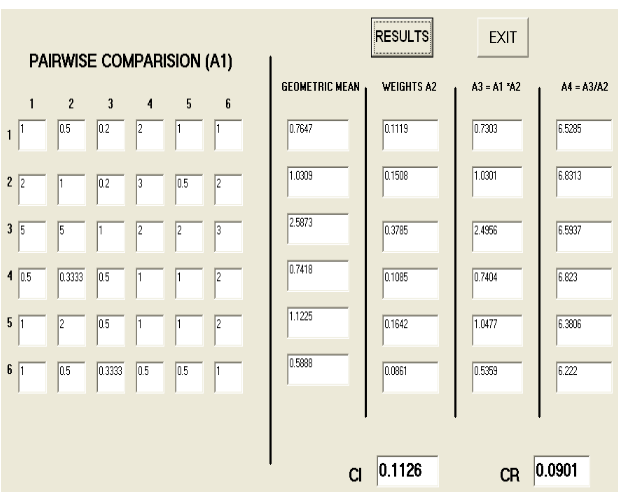
Machine Tool	MS	TT	SP	NT	AA	HC
MT_1	3150	32	35	80	1	1
MT_2	4000	20	25	30	0	1
MT_3	6000	18	25	30	0	0
MT_4	7000	6	15	40	0	0
MT_5	5000	10	27	40	0	0
MT_6	8000	15	10	20	0	0

6. Decision Methodologies for the Evaluation

The machine selection problem deals with selecting the best machine among a large number of alternatives under the defined decision criteria. In the proposed methodology Analytical hierarchical process [14] is used to find out the criteria weights by pair-wise comparison matrices.

An intelligent approach is developed for the entire calculations of AHP. This has reduced the time required in calculation of relative weights of criteria. This will help to simplify the pair-wise comparison of all the criteria. Decision makers can save their time by using this software. Thus, the decision makers can use this IAHP for further calculations.

Table 4: AHP Menu for the Machine Tool Selection


RESULTS EXIT

PAIRWISE COMPARISION (A1)

	1	2	3	4	5	6	GEOMETRIC MEAN	WEIGHTS A2	A3 = A1 *A2	A4 = A3/A2
1	1	0.5	0.2	2	1	1	0.7647	0.1119	0.7303	6.5285
2	2	1	0.2	3	0.5	2	1.0309	0.1508	1.0301	6.8313
3	5	5	1	2	2	3	2.5873	0.3785	2.4956	6.5937
4	0.5	0.3333	0.5	1	1	2	0.7418	0.1085	0.7404	6.823
5	1	2	0.5	1	1	2	1.1225	0.1642	1.0477	6.3806
6	1	0.5	0.3333	0.5	0.5	1	0.5888	0.0861	0.5359	6.222

CI 0.1126 CR 0.0901

The complete raking process using AHP and ELECTRE can be summarized in the following steps:

Step 1: Select main criteria and some important sub-criteria (Table 1) from the productivity, spindle power, maximum speed, tool change time and number of spindles are selected. From the other criteria articulated axis and total tool change time are being selected.

Step 2 Define threshold for the criteria g_j, namely indifference (q_j), preference (p_j), and veto (v_j). These thresholds can be constant and also variable along the scale of each criterion.

Step 3: Define partial concordance index, $C(a, b)$ concerning the coalition of criteria in which aSb using Eq. (2).

Step 4: After computing the partial concordance indices, the comprehensive concordance index is calculated as a weighted sum: shaping the concordance matrix including all $C(a, b)$ for all pair-wise relations of alternatives.

$$C(a, b) = \sum_{j \in J} w_j \times c_j(a.b) \qquad (9)$$

Step 5: Define discordance of criteria g_j describes the veto effect that the criteria provide against the assertion aS_jb .

The discordance indices $d_j(a, b)$ are computed separately for all criteria using Eq. (3). Having the concordance $C(a, b)$, and discordance, $d_j(a, b)$ indices, the reliability matrix calculated using Eq. (4) and (5).

Step 6: The hierarchy of the alternative solutions from the elements of the reliability matrix is formed by calculating the superiority ratio for each alternative. This ratio is calculated from the reliability matrix and is the fraction of the elements sum of every alternative's line, to the sum of the every alternative's respective column. The numerator represents the total dominance of the specific alternative over the rest and the denominator of the remaining alternatives over the former.

Based on the various parameters the evaluations of the Machine tools using ELECTRE is explained in the previous section. Referring to the methods, in terms of the indifference, preference and veto thresholds of the criteria all considered being as identical having the same indifference, preference and veto threshold of 0.2, 0.5, and 0.9, respectively [12].

Having calculated the concordance and discordance matrices, the reliability matrix $S(a,b)$ for all alternatives based on Eq. (4), as presented above. Table 5, shows the credibility matrix for all pair-wise relations between the machines.

According to these scores for machines are ranked from highest score (the best) to the lowest (the worst) as illustrated in Table 6. The results obtained by this methodology comprehend the results obtained by the original authors [1, 9].

Selecting the most suitable machine from the increasing number of available machines in the market is a challenging task. Productivity, precision, flexibility, and responsive manufacturing capabilities of the company depend on the machine properties. In this study, the machine tool selection problem is addressed and an IHP-based methodology is proposed. Machine properties and main and sub-decision criteria are investigated to apply the proposed methodology. The major contribution of this study is combining the IAHP - based selection methodology with reliability, precision, and cost analyses to evaluate several alternatives and make an accurate decision.

Table 5: Credibility Matrix for the Machine Tool System Selection

	MT_1	MT_2	MT_3	MT_4	MT_5	MT_6	Reliability Index
MT_1	1	1	0	1	0	1	0.8274
MT_2	0.93	1	1	0.	1	0	0.7618
MT_6	0.85	0.92	1	1	1	0	0.9637
MT_4	0	0.92	1	1	1	1	0.9637
MT_3	0.75	0	1	1	0	1	0.9408
MT_5	0	0	1	1	1	1	0.9365

Table 6: Machine Tool Selection Ranking

Rank	Machine Tool	Credibility Index
1	MT_1	0.9620
2	MT_3	0.9408
3	MT_5	0.9384
4	MT_4	0.9365
5	MT_2	0.8379
6	MT_6	0.6667

The proposed methodology is very flexible in the sense that it can be applied to other types of selection problems, e.g., selection of robot, selection of flexible manufacturing system etc.

Our methodology may be considered as a part of the process planning system. The approach may be integrated into the overall manufacturing planning system. The proposed decision methodology may also be used to select the appropriate tools for machining, etc. such integration will construct an intelligent computer-assisted process planning system that enables the design and control of the overall manufacturing activities.

7. Result and Discussions

The decision-maker has eliminated some alternatives by setting constraints on machine tool as power, machine type, manufacturer, etc. Six related criteria are selected by the decision maker. These values are normalized by dividing the highest as it is seen in the Table 3. According to the ELECTRE the final ranking is obtained to be as:

$$\mathbf{MT_1 \rightarrow MT_3 \rightarrow MT_5 \rightarrow MT_4 \rightarrow MT_2 \rightarrow MT_6}$$

The major contribution of this application is to introduce a new way to select the machine tools from the varieties available with decision-maker. The machine will be selected as per the need and as per the given criteria importance. For example, technical properties of the machine are more important than the cost, and also the decision-maker would like to buy a more reliable machine. There are constraints in this decision-making problem such as budget, available space in manufacturing area, precision values, power needs, flexibility of the machines etc. The best machine will satisfies these constraints also. Thus, the resulting ranking of this methodology aim at supporting the decision-maker in making their final selection more efficient in possibly all aspect.

8. Conclusions

A methodology based on an improved ELECTRE method is suggested for decision making in the manufacturing environment which helps in selection of a suitable alternative from among a large number of available alternatives for a given problem. AHP incorporation has developed a new combination in the decision making methods.

The proposed method considers the values of the criteria and their relative importance together, and hence it provides a better accurate evaluation of the alternatives. The method allows the decision maker to systematically assign the values of relative importance to the criteria based on his/her preferences.

The method represents the qualitative attribute on a conversion scale using fuzzy logic and helps the users in assigning the values. The threshold values assigned to the criterion gives a better kind of distillation to evaluate and rank the alternatives and lead to selection of a suitable alternative.

The improved ELECTRE method is a general method and can consider any number of quantitative and qualitative selection criteria simultaneously and offers a more objective and logical selection approach. The suggested methodology can be used for any type of selection problem involving any number of selection criteria.

By making some very minute changes the program developed can be used for any size of decision matrix.

The issue of selecting the best machine tool system has been discussed in the present work and the results corroborate the results obtained by the previous researchers.

The results obtained by these combined methodologies have proved that the same or similar kind of decision making problems can be solved by introducing few new decision methods like Axiomatic Design etc. [14,15]. The problem can also be solved using Axiomatic design principles and can be incorporated with the soft skills.

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