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CNC MACHINE TOOL APPRAISEMENT USING NON-VAGUE-TOPSIS APPROACH: AN EMPIRICAL RESEARCH

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Abstract-*In this scenario, the selection of the most appropriate Computer Numerical Control (CNC) machine tool has become one of the key factors for sustaining manufacturing sectors/production units at competitive global market place. Productivity, precision and accuracy etc. are the most important issues behind adaptation/exploration of CNC machine tools. So, in such a cases, subjective attributes are considered beside the objective attributes and complexity of the CNC machine tool selection decision problems is solved by considering subjective assessments (judgment) of expert panel, also called the decision-making group. In this paper, Hybrid approach (technique for order preference by similarity to ideal solution) based Multi-Criteria Decision Making (MCDM) approach has been explored for decision making in fuzzy MCDM environment for evaluating the most preferable CNC machine tool from a group of preferred options/alternatives.*

Keywords: Computer Numerical Control (CNC) machine tool; Generalized Trapezoidal Fuzzy Sets; TOPSIS; Multi-Criteria Decision Making (MCDM).

1. INTRODUCTION

In today's world of Emerged technology, advanced manufacturing machine tool play an important role to complete the production task to achieve the targeted goal of organization. In today's modern technology, computer numerical control (CNC) machine tool is widely used that function is being controlled by the application of digital electronic computers and circuitry. In present scenario, the problems of most feasible computer numerical control (CNC) machine tool selection among available alternatives has been become a critical factor to enhancing the production capacity, process, provide effective utilization of resources, increase productivity and improve system flexibility. The selection of an m/c tool among the alternatives is a multi-criteria decision-making (MCDM) problem including both qualitative and quantitative criteria. In conventional approaches, the machine tool selection problem tends to consider quantitative criteria that less effectively dealing with the impreciseness or vagueness nature of the linguistic assessment. Under many situations, the qualitative attribute of the alternatives such productivity, working automation; precision, accuracy etc are considered with respect to each qualitative attribute often imprecisely defined by experts panel judgment 'linguistic assessments'. In this paper, we used TOPSIS methodology (technique (technique for order preference by similarity to ideal solution) for the selection of turning CNC machine tool in multi-criteria decision making (MCDM) Trapezoidal Fuzzy environment.

In GDM, the brainstorming session is carried out, where the decision is not taken by single individual. It is taken by constituted committee. Each personnel, who are member of a constructed committee, deliver its own opinion for making the final decision against defined problem. The decisions, made by cluster of personnel's (group) are frequently unlike by others individual. Several questions are described amongst the individuals to conclude the results.

In GDM, decision built cooperatively by group of individuals tends to be more successful rather than decision built by a single individual. Social group behaviors influence the brainstorming session in GDM, for example groups high in cohesion, in combination with other antecedent conditions (e.g. ideological homogeneity and insulation from dissenting opinions) have been noted to have a negative effect for completing brainstorming session. The GDM brainstorming process is shown in fig. 2.

II. STATE OF ART AND PROBLEM FORMULATION

Hwang and Yoon (1981) proposed the technique for order preference by similarity to an ideal solution (TOPSIS), this technique is based on the concept that the ideal alternative has the best level for all attributes considered, whereas the negative ideal is the one with all the worst attribute values. Ayag, Gurcan and Ozdemir (2012) proposed modified TOPSIS and the Analytical Network Process (ANP) and presented a performance analysis on machine tool selection problem. The ANP method is used to determine the relative weights of a set of three valuation criteria, as the modified TOPSIS method is utilized to rank competing machine tool alternatives in terms of their overall performance. Abdi, (2009) investigated reconfigurable machining system characteristics in order to identify the crucial factors influencing the machine selection and the machine reconfiguration. Duran and Aguilo (2008) proposed an analytic hierarchical process (AHP) based on fuzzy numbers multi-attribute method for the evaluation and justification of an advanced manufacturing system. Finally, a case study of machine tool selection is used to illustrate and validate the proposed approach. Chu (2009) developed a new fusion method of fuzzy information to managing information assessed in different linguistic scales (multi-granularity linguistic term sets) and numerical scales. The flexible manufacturing system adopted in the Taiwanese bicycle industry is employed in this study to demonstrate the computational process of the proposed method.

Jiyang (2010) presented a comprehensive evaluation model for machine tool selection. Then Logarithmic least squares method based on fuzzy pair wise comparison matrix is applied for assessment of uncertain weights of selection criteria, the ways to determine performance value of the alternative with respect to qualitative and quantitative criteria has been discussed respectively.

Korena and Shpitalni (2010) defined the core characteristics and design principles of reconfigurable manufacturing systems (RMS) and described the structure recommended for practical RMS with RMS core characteristics. After that, a rigorous mathematical method is introduced for designing RMS with this recommended structure.

Volume 1, Issue 8, Pages 20-30, September 2017

III. HYBRID APPROACH

Let $E=\{e_1,e_2,...,e_q\}$ be the set of decision-makers in the group decision making process. $A=\{A_1,A_2,...,A_m\}$ be the set of alternatives, and $C=\{C_1,C_2,...,C_n\}$ be the set of criteria-attributes. Suppose that $\tilde{\tilde{a}}_{ijk}=(a_{ijk1},a_{ijk2},a_{ijk3})$ is the attribute value given by decision maker e_k, where $\tilde{\tilde{a}}_{ijk}$ is a trapezoidal fuzzy number for the alternative A_i with respect to the attribute C_j.

Normalize the decision matrix $X=(x_{ij})_{mn}$ using the following equation:

$$r_{ij}=\frac{x_{ij}}{\sqrt{\sum_{j=1}^{n} x^2_{ij}}},\quad i=1,2,3,.......m,,\quad j=1,2,3,.......n$$

……………..………..(1)

Here r_{ij} is the normalized criterion rating. The normalization method mentioned above is to preserve the property that the range of a normalized trapezoidal fuzzy number $\tilde{r}_{ij}$ belongs to the closed interval $[0,1]$.

Let $W=(w_{1,}\ w_{2,..........},w_n)$ be the relative weight vector about the criteria, evaluatedby fuzzy AHP satisfying $\sum_{j=1}^{n} w_j=1$.

Calculate the weighted normalized decision matrix $v=(v_{ij})_{mn}$ ……………………....(2)

Applied C. L. Hwang and K. Yoon (1981) to make decision:

IV. CASE STUDY

A case study has been carried out by a well known advance manufacturing organization which produce the customize product situated at western part of India. To select the most feasible alternative, a committee of four expert panel decision makers, DM1, DM2, DM3, and DM4 has been formed from quality assurance manager, manager of production unit and their team. The decision making committee assesses the concerned alternatives based on a structured model (criteria hierarchy), (Table 1) for the selection of best CNC m/c tool alternative. Structured model involved the twenty criteria in which C9, C12, C17 are non-beneficial criteria and rest of the criteria are beneficial. Criteria importance weights and criteria ratings of each alternative have been expressed as linguistic terms which have been transformed further in scale numbers, as given in Table 2. appropriateness ratings (assigned by DMs) for various alternatives have been shown in Tables 3. ranking order of various alternatives has been showed in Table 4. Hence, Alternative sorting is as following proceeding.

$$\mathbf{A_3>A_2>A_1>A_4>A_5}$$

Proposed fuzzy based CNC machine tool evaluation module: Procedural steps

Procedural steps of CNC machine tool evaluation module have been highlighted below-

Step 1: Form a committee of decision-makers, and then identify the evaluation criteria of CNC turning m/c tool.

Volume 1, Issue 8, Pages 20-30, September 2017

Step 2: Choose the appropriate linguistic variables for the importance weight of the criteria and the linguistic ratings for CNC m/c tool selection.

Step 3: Aggregate the rating the decision makers' ratings to get the aggregated fuzzy rating $\tilde{x}_{ij}$ of best CNC m/c tool evaluation A_j under criterion C_j .

Step 4: Construct the fuzzy- decision matrix and the normalized decision matrix.

Step 5: Construct weighted normalized fuzzy decision matrix.

Step 6: Determine PIS and NIS.

Step 7: Calculate the distance of each CNC FPIS and FNIS, respectively.

Step 8: Calculate the closeness coefficient of each CNC alternatives.

Step 9: According to the closeness coefficient, we can understand the assessment status of every CNC machine tool and determine the best CNC machine tool among available alternatives ranking order.

V. CONCLUSION

Fuzzy multi-criteria analysis under the group decision making process provides an effective framework for ranking and selecting the potential alternatives in terms of their overall performance with respect to conflicting criteria. In this paper, the multiple attribute decision-making TOPSIS (technique for order positive solution to ideal solution) analytical methodology has been explored an effectively in subjective attributes (fuzzy) environment. The proposed methodology enables the committee to incorporate and aggregate multiple fuzzy information given by decision-makers with multiple information attributes. In this paper, the best CNC turning machine tool has been selected from all other preferred choices. The research resulted that alternative A3 is the best choice from all the preferred choice ***Fig: 1-4*** shown the ranking

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Table 1. *CNC machine tool index*

Attributes/Criteria
Productivity (C_1)
Flexibility (C_2)
Schedule Utilization (C_3)
Adaptability (C_4)
Precision (C_5)
Reliability(C_6)
Safety& Environment(C_7)
Maintenance &Service(C_8)
Capacity (C_9)

Functionality (C_{10})
Customization (C_{11})
Capital Cost (C_{12})
Convenient For Use (C_{13})
Accuracy (C_{14})
Efficiency (C_{15})
Risk (C_{16})
Resource Consumption (C_{17})
Environment Impact (C_{18})
Product Quality (C_{19})
Working Automation (C_{20})

Table 2. *The scale for assigning attributes ratings* $\otimes U$ *and weights* $\otimes w$

(Attribute/criteria ratings)	
Absolutely Poor (AP)	10%
Very Poor (VP)	20%
Poor (P)	30%
Medium Poor (MP)	40%
Fair (F)	50%
Medium Good (MG)	60%
Good (G)	70%
Very Good (VG)	80%
Absolutely Good (AG)	90%
Good (GGG)	100%

Table 3. *Rating for A1, A2,A3*

Attributes/Criteria	**Rating a1**					
	P1	**P2**	**P3**	**P4**	**P5**	**P6**
Productivity (C_1)	**10**	**10**	**10**	**10**	**10**	**10**
Flexibility (C_2)	**20**	**20**	**20**	**20**	**20**	**20**
Schedule Utilization (C_3)	**30**	**30**	**30**	**30**	**30**	**30**
Adaptability (C_4)	**40**	**40**	**40**	**40**	**40**	**40**
Precision (C_5)	**50**	**50**	**50**	**50**	**50**	**50**
Reliability(C_6)	**60**	**60**	**60**	**60**	**60**	**60**
Safety& Environment(C_7)	**70**	**70**	**70**	**70**	**70**	**70**
Maintenance &Service(C_8)	**80**	**80**	**80**	**80**	**80**	**80**
Capacity (C_9)	**90**	**90**	**90**	**90**	**90**	**90**
Functionality (C_{10})	**100**	**100**	**100**	**100**	**100**	**100**
Customization (C_{11})	**10**	**10**	**10**	**10**	**10**	**10**
Capital Cost (C_{12})	**20**	**20**	**20**	**20**	**20**	**20**
Convenient For Use (C_{13})	**30**	**30**	**30**	**30**	**30**	**30**
Accuracy (C_{14})	**40**	**40**	**40**	**40**	**40**	**40**
Efficiency (C_{15})	**50**	**50**	**50**	**50**	**50**	**50**

Risk (C_{16})	**60**	**60**	**60**	**60**	**60**	**60**
Resource Consumption (C_{17})	**70**	**70**	**70**	**70**	**70**	**70**
Environment Impact (C_{18})	**80**	**80**	**80**	**80**	**80**	**80**
Product Quality (C_{19})	**90**	**90**	**90**	**90**	**90**	**90**
Working Automation (C_{20})	**100**	**100**	**100**	**100**	**100**	**100**
Rating a2						
Productivity (C_1)	**20**	**20**	**20**	**20**	**20**	**20**
Flexibility (C_2)	**30**	**30**	**30**	**30**	**30**	**30**
Schedule Utilization (C_3)	**40**	**40**	**40**	**40**	**40**	**40**
Adaptability (C_4)	**50**	**50**	**50**	**50**	**50**	**50**
Precision (C_5)	**60**	**60**	**60**	**60**	**60**	**60**
Reliability(C_6)	**70**	**70**	**70**	**70**	**70**	**70**
Safety& Environment(C_7)	**80**	**80**	**80**	**80**	**80**	**80**
Maintenance &Service(C_8)	**90**	**90**	**90**	**90**	**90**	**90**
Capacity (C_9)	**100**	**100**	**100**	**100**	**100**	**100**
Functionality (C_{10})	**10**	**10**	**10**	**10**	**10**	**10**
Customization (C_{11})	**20**	**20**	**20**	**20**	**20**	**20**
Capital Cost (C_{12})	**30**	**30**	**30**	**30**	**30**	**30**
Convenient For Use (C_{13})	**40**	**40**	**40**	**40**	**40**	**40**
Accuracy (C_{14})	**50**	**50**	**50**	**50**	**50**	**50**
Efficiency (C_{15})	**60**	**60**	**60**	**60**	**60**	**60**
Risk (C_{16})	**70**	**70**	**70**	**70**	**70**	**70**
Resource Consumption (C_{17})	**80**	**80**	**80**	**80**	**80**	**80**
Environment Impact (C_{18})	**90**	**90**	**90**	**90**	**90**	**90**
Product Quality (C_{19})	**100**	**100**	**100**	**100**	**100**	**100**
Working Automation (C_{20})	**10**	**10**	**10**	**10**	**10**	**10**
Rating a3						
Productivity (C_1)	**30**	**30**	**30**	**30**	**30**	**30**
Flexibility (C_2)	**40**	**40**	**40**	**40**	**40**	**40**
Schedule Utilization (C_3)	**50**	**50**	**50**	**50**	**50**	**50**
Adaptability (C_4)	**60**	**60**	**60**	**60**	**60**	**60**
Precision (C_5)	**70**	**70**	**70**	**70**	**70**	**70**
Reliability(C_6)	**80**	**80**	**80**	**80**	**80**	**80**
Safety& Environment(C_7)	**90**	**90**	**90**	**90**	**90**	**90**
Maintenance &Service(C_8)	**100**	**100**	**100**	**100**	**100**	**100**
Capacity (C_9)	**10**	**10**	**10**	**10**	**10**	**10**
Functionality (C_{10})	**20**	**20**	**20**	**20**	**20**	**20**
Customization (C_{11})	**30**	**30**	**30**	**30**	**30**	**30**
Capital Cost (C_{12})	**40**	**40**	**40**	**40**	**40**	**40**
Convenient For Use (C_{13})	**50**	**50**	**50**	**50**	**50**	**50**
Accuracy (C_{14})	**60**	**60**	**60**	**60**	**60**	**60**
Efficiency (C_{15})	**70**	**70**	**70**	**70**	**70**	**70**
Risk (C_{16})	**80**	**80**	**80**	**80**	**80**	**80**
Resource Consumption (C_{17})	**90**	**90**	**90**	**90**	**90**	**90**

Environment Impact (C_{18})	**100**	**100**	**100**	**100**	**100**	**100**
Product Quality (C_{19})	**10**	**10**	**10**	**10**	**10**	**10**
Working Automation (C_{20})	**20**	**20**	**20**	**20**	**20**	**20**
Rating a4						
Productivity (C_1)	**30**	**30**	**30**	**30**	**30**	**30**
Flexibility (C_2)	**40**	**40**	**40**	**40**	**40**	**40**
Schedule Utilization (C_3)	**50**	**50**	**50**	**50**	**50**	**50**
Adaptability (C_4)	**60**	**60**	**60**	**60**	**60**	**60**
Precision (C_5)	**70**	**70**	**70**	**70**	**70**	**70**
Reliability(C_6)	**80**	**80**	**80**	**80**	**80**	**80**
Safety& Environment(C_7)	**90**	**90**	**90**	**90**	**90**	**90**
Maintenance &Service(C_8)	**100**	**100**	**100**	**100**	**100**	**100**
Capacity (C_9)	**10**	**10**	**10**	**10**	**10**	**10**
Functionality (C_{10})	**20**	**20**	**20**	**20**	**20**	**20**
Customization (C_{11})	**30**	**30**	**30**	**30**	**30**	**30**
Capital Cost (C_{12})	**40**	**40**	**40**	**40**	**40**	**40**
Convenient For Use (C_{13})	**50**	**50**	**50**	**50**	**50**	**50**
Accuracy (C_{14})	**60**	**60**	**60**	**60**	**60**	**60**
Efficiency (C_{15})	**70**	**70**	**70**	**70**	**70**	**70**
Risk (C_{16})	**80**	**80**	**80**	**80**	**80**	**80**
Resource Consumption (C_{17})	**90**	**90**	**90**	**90**	**90**	**90**
Environment Impact (C_{18})	**100**	**100**	**100**	**100**	**100**	**100**
Product Quality (C_{19})	**10**	**10**	**10**	**10**	**10**	**10**
Working Automation (C_{20})	**20**	**20**	**20**	**20**	**20**	**20**
Rating a5						
Productivity (C_1)	**30**	**30**	**30**	**30**	**30**	**30**
Flexibility (C_2)	**40**	**40**	**40**	**40**	**40**	**40**
Schedule Utilization (C_3)	**50**	**50**	**50**	**50**	**50**	**50**
Adaptability (C_4)	**60**	**60**	**60**	**60**	**60**	**60**
Precision (C_5)	**70**	**70**	**70**	**70**	**70**	**70**
Reliability(C_6)	**80**	**80**	**80**	**80**	**80**	**80**
Safety& Environment(C_7)	**90**	**90**	**90**	**90**	**90**	**90**
Maintenance &Service(C_8)	**100**	**100**	**100**	**100**	**100**	**100**
Capacity (C_9)	**10**	**10**	**10**	**10**	**10**	**10**
Functionality (C_{10})	**20**	**20**	**20**	**20**	**20**	**20**
Customization (C_{11})	**30**	**30**	**30**	**30**	**30**	**30**
Capital Cost (C_{12})	**40**	**40**	**40**	**40**	**40**	**40**
Convenient For Use (C_{13})	**50**	**50**	**50**	**50**	**50**	**50**
Accuracy (C_{14})	**60**	**60**	**60**	**60**	**60**	**60**
Efficiency (C_{15})	**70**	**70**	**70**	**70**	**70**	**70**
Risk (C_{16})	**80**	**80**	**80**	**80**	**80**	**80**
Resource Consumption (C_{17})	**90**	**90**	**90**	**90**	**90**	**90**
Environment Impact (C_{18})	**100**	**100**	**100**	**100**	**100**	**100**
Product Quality (C_{19})	**10**	**10**	**10**	**10**	**10**	**10**

Working Automation (C_{20})	20	20	20	20	20	20

Table 4. *Computations of* CC_i

Alternatives	CC_i	Ranking
A_1	0.547	3
A_2	0.558	2
A_3	0.561	1
A_4	0.527	4
A_5	0.519	5

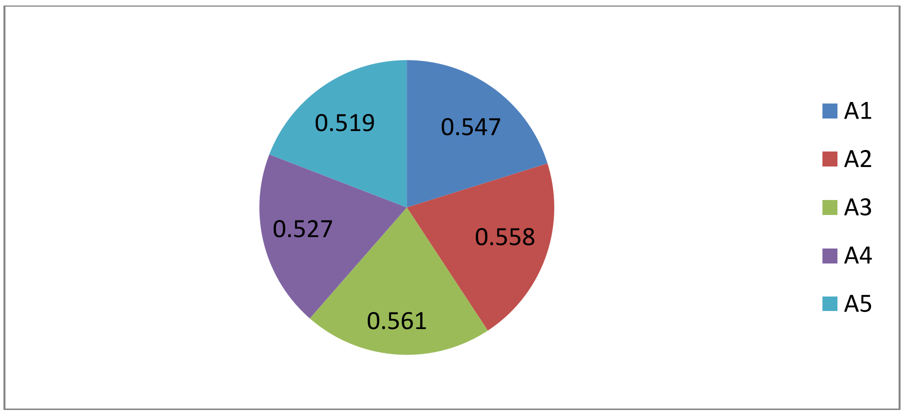

Fig:1 Ranking by pie chart

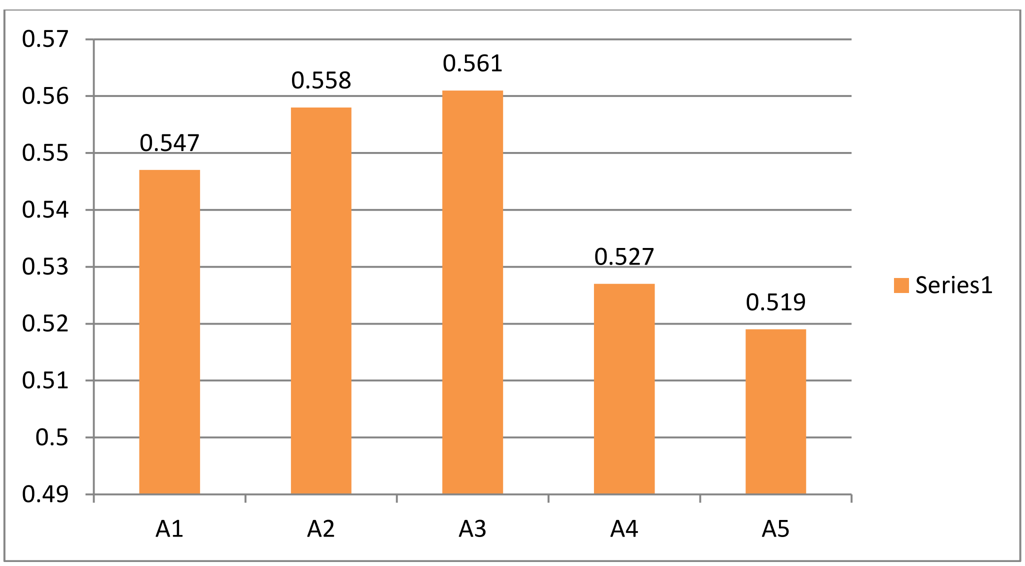

Fig 2 Ranking by bar chart

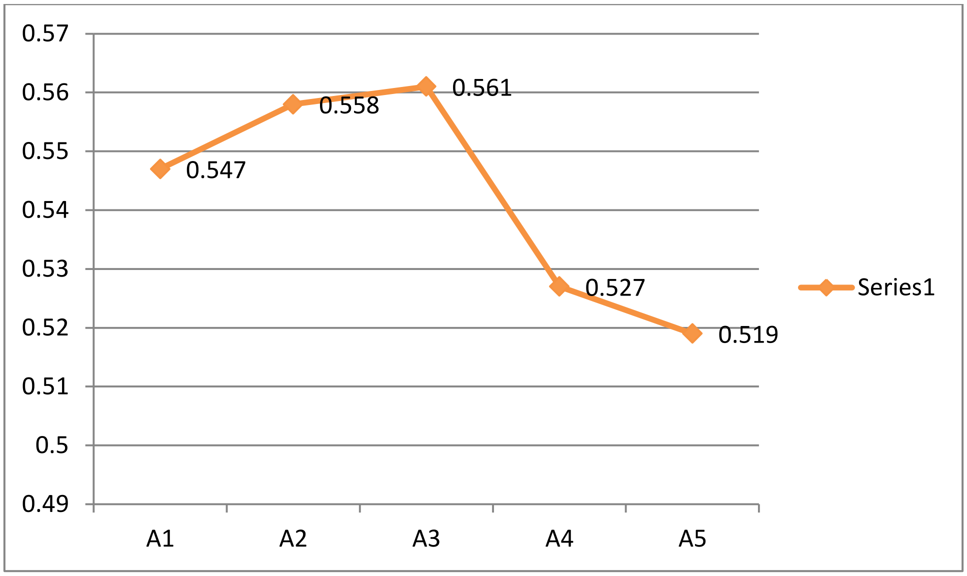

Fig 3. Ranking by line chart

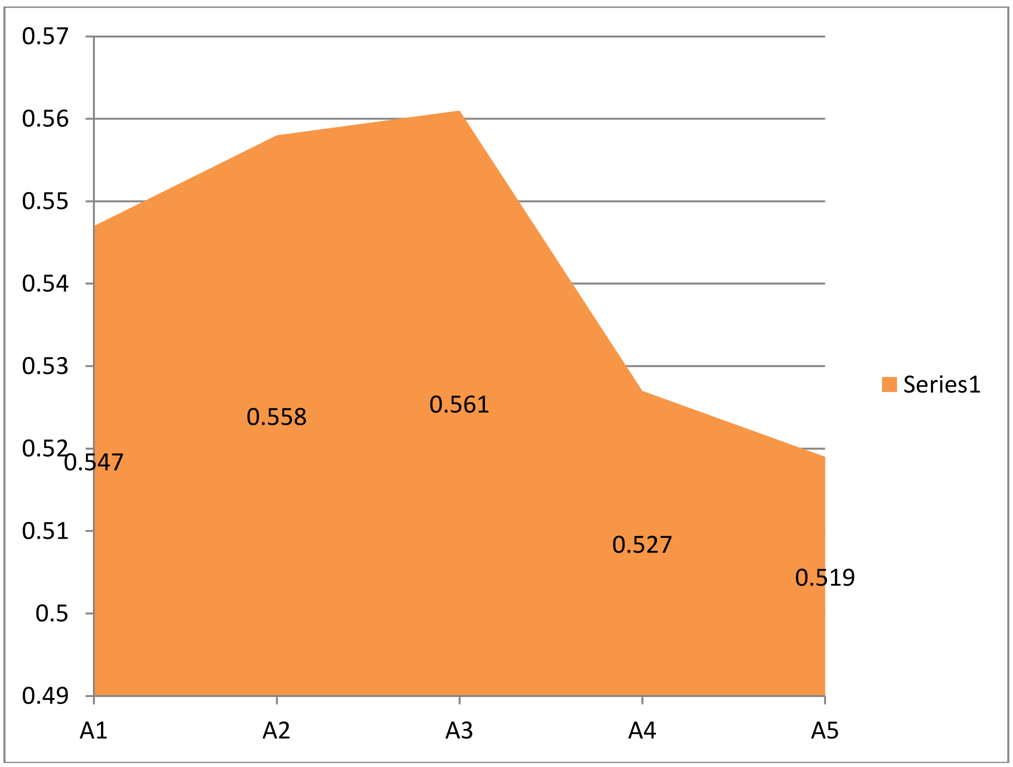

Fig:4. Ranking by pie chart

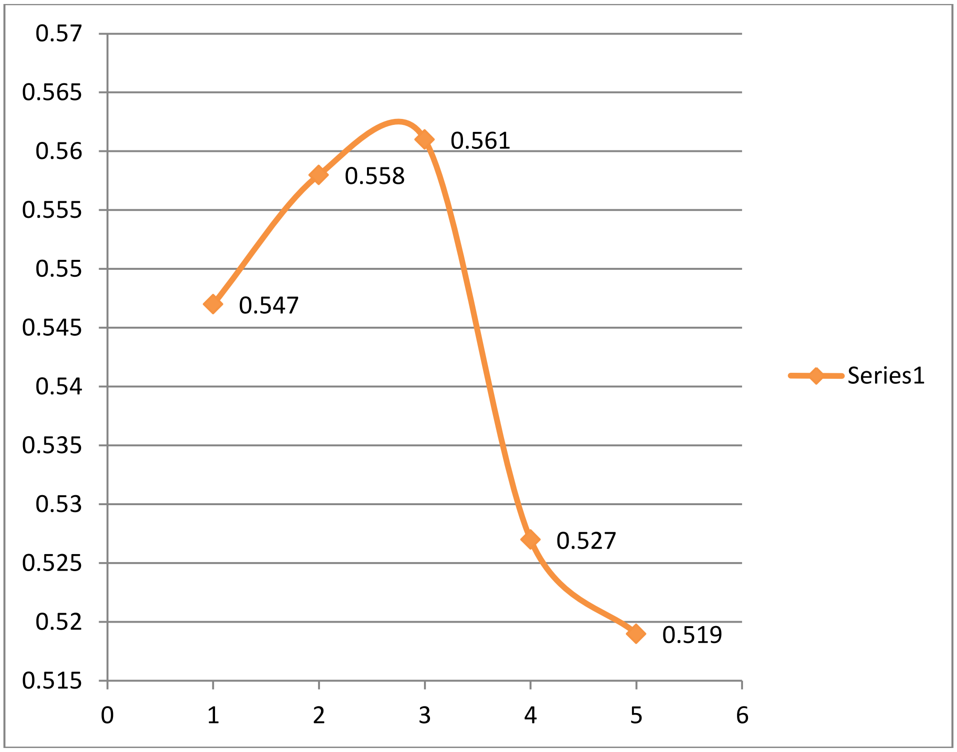

Fig:4. Ranking by sak line chart

BIOGRAPHY

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