Indonesian Journal of Electrical Engineering and Computer Science
Vol. 7, No. 1, July 2017, pp. 276 ~ 286
DOI: 10.11591/ijeecs.v7.i1.pp276-286

A Condorcet Voting theory based AHP approach for MCDM problems

Sweta Bhattacharya*[1], V Raju[2]
[1]School of Information Technology & Engineering, VIT University, Vellore, India
[2]Institute of Industry and International Programme, VIT University, Vellore, India
*Corresponding author, e-mail: sweta.b@vit.ac.in

Abstract

Analytical Hierarchical Process has been used as a useful methodology for multi-criteria decision making environments with substantial applications in recent years. But the weakness of the traditional AHP method lies in the use of subjective judgement based assessment and standardized scale for pairwise comparison matrix creation. The paper proposes a Condorcet Voting Theory based AHP method to solve multi criteria decision making problems where Analytical Hierarchy Process (AHP) is combined with Condorcet theory based preferential voting technique followed by a quantitative ratio method for framing the comparison matrix instead of the standard importance scale in traditional AHP approach. The consistency ratio (CR) is calculated for both the approaches to determine and compare the consistency of both the methods. The results reveal Condorcet- AHP method to be superior generating lower consistency ratio and more accurate ranking of the criterion for solving MCDM problems.

Keywords: *Multi-criteria decision making (MCDM), Analytic Hierarchy Process (AHP), Condorcet Voting Theory, Decision Support System, Condorcet-AHP*

1. Introduction

The use of computer and associated technologies has affected human lives significantly by facilitating communication and information accessible to revolutionize all aspects of the society. The data generated due to the use of information technology has open doors for further analysis and decision making. As a result, optimized decision making has become extremely important for group decisions and deriving the best possible solutions in various sectors of human lives such as Marketing, Education, Policy Decisions and many others. Operations research has helped to resolve such complex decision making problems. Multi-criteria decision making (MCDM) is one of the most popular operations research based approach which has achieved immense popularity in resolving decision problems under the involvement of multiple decision criteria [1, 2]. Multi criteria decision-making has the capability to solve real life problems where multiple alternatives need to be evaluated critically based on certain defined decision criteria which are often contradictory in nature. The final ranking of these alternatives are based on analysing the impact of the alternatives on the criteria considering the benefit of the decision taker. Hence this method is extremely helpful in resolving real time issues in the industry, business and federal governmental spectrum. There are various approaches under the scope of MCDM and all of them basically use numerical techniques to choose the best among a set of alternatives. The Weighted Sum Model, Weighted Product Model, Analytical Hierarchy Process (AHP), Electre Method and TOPSIS method are some of the popular MCDM approaches [3]. The present study focuses on creating a decision support system for analysing factors using Analytical Hierarchy Process (AHP) in combination with Condorcet Theory on a career choice data pertaining to higher education research in the Indian context. In a traditional AHP based approach, the criteria involved in decision making are prioritized with the help of a pairwise comparison weighting and the importance of one criterion over the other are decided based on subjective assessment of the decision maker using a standard importance scale developed by Thomas Saaty (1980). The accuracy of this judgement depends on the consistency ratio (CR) value which is considered accurate if less than 0.10. But there exists chances of error due to the limitation of using standard scale. It becomes extremely difficult to connect the criterion importance to the standard scale value and which ends up in a situation of dilemma. As an

Received March 19, 2017; Revised May 30, 2017; Accepted June 14, 2017

example, there could be situation wherein the decision maker finds it difficult to distinguish among the scale points and conclude if an alternative is 6 or 7 times more important than the other.

This paper focuses on creating a decision support system for analyzing the factors using Analytical Hierarchy Process (AHP) in combination with Condorcet Theory. The unique contribution of the paper lies in its use of Condorcet voting approach wherein the comparison matrix is generated based on a voting method to decide on the importance of a criterion over the other and then use of a quantitative ratio based approach to frame the pair wise comparison matrix instead of the standard importance scale. In the paper, the traditional AHP based approach and the Condorcet-AHP approach is applied on the same data set to compare the results generated using both the techniques. The accuracy of the results are compared based on the consistency ratio value and rankings of the criteria in similar studies conducted in the same domain. The generated computed consistency ratio (CR) value and the final ranking of the factors in this paper reveal Condorcet-AHP method to be a better approach in solving multi-criteria decision making problems**.** The next section provides detailed description of both the approaches.

The research method section discusses the detailed steps involved in the traditional AHP and Condorcet-AHP approach. The results computed for both the approaches are also shown in the result section which helps to understand the advantages and disadvantages of both the approaches and conclude on the superiority of the Condorcet-AHP based approach.

2. Research Method

2.1 Analytical Hierarchy Process (AHP)

Analytical Hierarchy process is a method developed by Thomas Saaty in 1980 at the Wharton School of Business which helps in solving complex decision making problems considering subjective evaluation measurements [4-6]. It basically breaks a complex problem into multiple hierarchical levels as depicted in Figure 1 [5-6]. AHP is based on the method of "measurement through pairwise comparisons relying on the judgements of experts to derive priority scales" [7-8]. The process uses a hierarchical structure which measures and analyses the various factors simplifying its complexity and combines the factors to derive at the final decision [8]. The AHP process consists of six major phases. The first phase involves defining the problem considering all the associated assumptions and perspectives based on which decision would be taken [9]. The second phase creates the hierarchical structure defining the overall goal and the intermediate levels [9-10]. The third stage encompasses of using a pair-wise comparison of the criteria in terms of the goal [10]. The pairwise comparison helps to compute the relative weight of the criteria with respect to the goal and thus the pairwise comparison matrix is created. Quantitative data can be used for performing the comparison by finding the ratio and if quantitative data is not available qualitative comparison can be performed using the standard importance scale by Thomas Saaty (1980) as shown in Table 1 [11].

The accuracy of the decision depends on expert's ability of quantifying the comparison of the criteria using the relevant values from the scale and constructing the pairwise matrix. This matrix acts as the basis of all the computations involved in the AHP process. The fourth phase involves calculation of the relative weights of the elements at each level. This is done by adding the elements in the column to normalize the matrix and then deriving the normalized matrix by diving each column element by its column sum. The normalized average of each criterion is calculated by computing the average of each row. Finally the consistency ratio is calculated to check for consistency issues and if found, the comparison matrix is reviewed and improvised by the subject matter experts and decision takers to achieve consistency [11-12].

Table 1. Importance Scale and descriptions

Importance Scale	Importance Description
1	Equal importance of "i" and "j"
3	Moderate importance of "i" over "j"
5	Strong importance of "i" over "j"
7	Very Strong importance of "i" over "j"
9	Absolute Importance of "i" over "j"

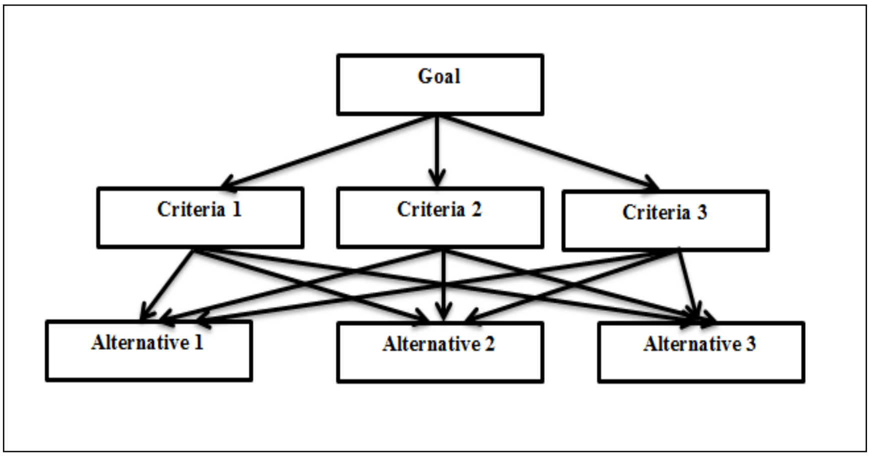

Figure 1. Structure of AHP

Assuming the size of the comparison matrix (A) is n × n where n denotes the number of criteria being compared to a specific goal or parent criteria. The components of the matrix are a_{ij} and these elements need to be transitive and reciprocative in order to make the matrix consistent [13].

$$a_{ij} = a_{ik} * a_{jk} \quad (1)$$

$$a_{ij} = \frac{1}{a_{jk}} \quad (2)$$

Where, i, j and k are the elements of the matrix A. The comparison matrix where $a_{ij} = 1 \; when \; i = j$ would look like the following [13]:

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \quad (3)$$

The matrix A is normalized to matrix N in order to perform a consistency check. The N matrix would look like the following [13]:

$$N = \begin{bmatrix} w_{11} & w_{12} & w_{13} \\ w_{21} & w_{22} & w_{23} \\ w_{31} & w_{32} & w_{33} \end{bmatrix}, \text{Where } w_{ij} = a_{ij} \quad (4)$$

$$w_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}, \quad (5)$$

Where, sum of all the columns is equal to $\sum_{i=1}^{n} a_{ij}$

The relative weight of each row is computed by dividing the sum of the values of each row by n. Hence the weight of "i" can be computed using the following formula [13]:

$$i = w_{ij} = \frac{\sum_{i=1}^{n} w_{ij}}{n} \quad (6)$$

The matrix A is considered as consistent if A × w = n × w and the equation is considered as an Eigen value problem wherein the largest Eigen value is λ_{max} ≥ n. The consistency ratio (CR) is calculated as [13]:

CR = CI/RI = Consistency Index / Relative Index (7)

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (8)$$

$$RI = \frac{1.98\,(n-2)}{n} \quad (9)$$

The value of CR determines the consistency of the judgement. The CR value of less than 0.10 is considered acceptable or else revision of the values of a_{ij} is recommended [14].

The fifth step involves reviewing of the final decisions and ensuring that it coincides with the expectations of the decision taker. The sixth and final stage involves complete documentation of all the above mentioned stages for the purpose of record and analysis of the process for continuous process improvement.

Analytical Hierarchy Process (AHP) has been widely used to solve various multi-criteria decision making problems. Some of the most popular domains of AHP application have been in selection, ranking and prioritization, design, evaluation, measurement and allocation related issues. As an example, AHP was used to resolve supplier selection problem where three main criteria and six sub criteria for supplier selection were evaluated to decide upon the best supplier. The results of the selection were further validated by the supplier management team in Carglass, Turkey resulting in better productivity in the company [15]. AHP was also used for the selection of the best team leader for a project which yielded better accuracy and robustness in choosing the most fitting leader [16]. Insurance decisions are often the most difficult ones to make and AHP method was used to resolve such dilemmatic issues and rank insurance companies in Turkey. The companies were ranked based on their financial criteria using AHP which helped to choose the best insurance provider. The final results were validated performing sensitivity analysis which helped to evaluate the robustness of the solution [17]. AHP method has been used in electrical engineering domain for optimized multi-generated planning under various uncertain factors which has improved voltage quality variation issues and reduced power loss [18]. An uncommon application of AHP has been in the improvement of polygraph survey results which are used as a tool for lie detection. AHP was used to improve the accuracy of lie detection using actual survey results in order to obtain more authenticity of the results of the tests [19]. AHP has been widely used in the manufacturing industry where design plays a major role. The decision regarding design of a product development is extremely critical especially in the manufacturing of real world products and systems. AHP in this sector has immensely helped in the layout selection process where the best layout is selected from various layout options [20]. AHP has also been used to resolve mining engineering problems. Ten design patterns which impacted the usage of a backfill support system were identified for a platinum mining project. These ten parameters were weighted as per their relative importance and finally the results of the AHP evaluation helped to validate that a back fill support system was much beneficial than a conventional support system in mining engineering [21].

Although AHP plays a major role in decision making and evaluating qualitative and quantitative measure but the entire method is based on its third stage wherein the comparison matrix is created based on subjective analysis of the criteria involved using the standardized importance scale. Hence there exist chances of biased judgement lagging in accuracy. The Condorcet theory voting algorithm discussed in the following section helps to deal with this issue thereby increasing accuracy of the AHP technique.

2.2 Condorcet Theory Voting Algorithm

Condorcet theory is a method for pairwise comparison developed by the famous philosopher and mathematician Marquis de Condorcet [22-23]. The theory is majorly used in voting wherein candidates are compared pairwise and each voter submits a ballot, ranking the preference of the nominated candidates. It is a majoritarian method wherein a candidate is considered a winner in an election if it is able to win over all other candidates in a pairwise comparison. In the sense, the candidates with higher number of votes in the pairwise comparison is declared winner. The same theory is used for the pairwise comparison of the criteria. As part of the study similar to voting method, a poll data set was used to find the preference of the factors that affected teaching career choice pertinent to this case study. Each score data from the respondents in the data set were considered and Condorcet voting algorithm was applied. In a Condorcet voting algorithm each vote is given a point based on the preference comparing each criterion over the other. If one criterion is preferred over the other then the preferred one wins a point over the non-preferred criterion. Votes with equal priority given to both the candidates are elimininated from consideration. The total count of points for all the responses is counted in the data set to compute the total scores. Hence each vote is considered important. After the scores are computed, the quantitative ratio method is used to determine the importance of one criterion over the other. Since the comparison is based on actual poll scores in addition to application of Condorcet voting theory, the comparison matrix framed definitely proves to be more accurate in terms of the consistency ratio and also in deriving the ranking of the criteria involved [22-23]. The detailed description of the Condorcet theory algorithm is mentioned in the methodology section. Once the comparison matrix is framed accurately, the regular steps of AHP method for normalized matrix creation and normalized average computation is followed.

The next section defines the problem of the existing approach and highlights the contribution of the paper in solving multi-criteria decision making problem. Both the approaches are used on a higher education data set pertaining to teaching career choice. The data set contains three factors (Altruistic, Extrinsic and Intrinsic) that affect teaching career choice among engineering graduates. The traditional AHP and Condorcet – AHP method basically ranks the importance of these three factors in the choice of teaching career related decisions. The resultant ranking of the factors generated using both the methods are compared based on the consistency ratio value and the aptness of the most prioritized factor mentioned in similar career choice related studies.

2.3 Problem Definition and Research Gap

The major disadvantage of AHP method is the artificial constraint in the use of 9 – point scale which makes it difficult for decision makers to differentiate scale points to conclude on the importance of one criterion or factor over the other. AHP method has also been modified to a 2 point scale to encounter time constraints of decision makers wherein the decision maker could decide on whether an alternative is more or less important than the other. But all of these methods have the common disadvantage of being solemnly dependent on individual judgement of the decision maker giving room for biased and erroneous results. The application of Condorcet theory in the AHP process helps to resolve this issue by providing more accurate comparison of the alternative and creation of pairwise comparison matrix based on actual voting results on the preference based alternatives supported by a quantitative ratio-based method.

3. Results and Analysis

The higher education data set pertaining to teaching career choice has been chosen for implementation of both the approaches. As per the data set, the main contributing factors that affected career choice decisions among engineering graduates were altruistic, extrinsic and intrinsic factors. But it was extremely important to rank the three contributing factors and decide on the most important one from the perspective of existing graduates so that policy related development can be made for that specific factor. This would be extremely beneficial for higher education research as faculty crunch is a gleaming issue in the Indian higher education system. The ranking would highlight the most significant reasons affecting teaching career choice decisions and necessary policy amendments to the highest prioritized factor would enable more individuals to choose teaching career eradicating faculty shortage issues in the country.

The source of the data set was a voting poll conducted on 300 students wherein the students were asked to rate each of the three criteria and provide scores for the same. Out of 300, 250 opinions were complete and were considered for the analysis. Once the scores were received two methodologies were performed:

1. A traditional AHP based ranking and Computation of consistency ratio (CR)
2. Condorcet-AHP based ranking and Computation of consistency ratio (CR)
3. Comparison of both approaches based on the consistency ratio (CR) value

In the AHP based approach the average score received for each of the criteria were used as the basis of subjective judgement of creating the comparison matrix for AHP. In the sense, the subjective assessment of deciding on the standard importance scale point in the traditional AHP method were based on the average scores received for each crtiteria in the voting poll. The steps followed in the traditional AHP approach were [24]:

1. Determination of the relative importance of the criteria based on scores received from the responses for the criteria acting as the basis of the subjective judgement as per the scale of Thomas Saaty (1980) from 1 to 9
2. Creation of pairwise comparison matrix based on the ratings of subjective judgement
3. Normalization of the matrix to perform consistency check by dividing each element of the matrix by its column sum
4. Computation of the relative weight of each row of the matrix by dividing the sum of the values of each row by the total number of rows
5. Calculation of the Consistency Ratio (CR) to evaluate the accuracy of the pairwise comparison of the criteria and also the ranking computed

Hence, the entire computation was based on the importance scale point decision which was subjective and hence there existed scope of error when relating the average scores to the standard importance scale in the traditional approach. This was the main point of consideration in the second approach wherein actual poll results were considered in the Condorcet voting theory to decide on the most preferred criteria followed by the ratio based quantitative approach for creating the pair wise comparison matrix instead of the 9 point importance scale.

In the Condorcet – AHP approach, all the traditional steps of the AHP method as mentioned above were followed except the process of creating the pairwise comparison matrix using Condorcet voting algo and computation of quantitative ratio method to frame the matrix. The algorithm used for Condorcet voting method is:

Step 1: *count = 0*
Step 2: *for each of the P respondents'* P_i *do*
Step 3: *If* P_i *ranks* C_1 *above* C_2*, count ++*
Step 4: *If* P_i *i ranks* C_2 *above* C_1*, count - -*
Step 5: *If count > 0, rank* C_1 *better than* C_2
Step 6: *Else rank* C_2 *better than* C_1

The total scores of the criteria were computed using the Condorcet theory and the comparison matrix was framed using quantitative ratio based approach instead of the traditional scale of Thomas Saaty. The consistency ratio was compared for both the approaches. As already mentioned that the CR value of less than 0.10 was considered acceptable, the lower the value of the consistency ratio (CR), the ranking is considered to be more accurate.

3.1. Traditional AHP based Ranking

The average scores from the responses revealed the following comparisons for the three criteria:

1. Extrinsic factors was not equally important than Altruistic factor, but was slightly lower than moderately important based on subjective judgement. Hence the importance scale of extrinsic to altruistic factor would be "2"
2. In case of pairwise comparison between intrinsic and altruistic factor, intrinsic was slightly more than moderately important and lower than strongly important to altruistic factor. Hence the importance rating was "4"
3. Extrinsic factor was not equally important to altruistic factor and slightly lower than moderately important to altruistic factor. Hence the importance rating was "2"

The pairwise comparison matrix based on the subjective judgement is shown in Table 3 followed by the process of normalized matrix creation as shown in Table 4 and Table 5. The computation of the relative weights for generation of ranking of the criteria is shown in Table 6.

Table 3. Pairwise Comparison Matrix

	A	E	I
A	1	1/2	1/4
E	2	1	1/4
I	4	4	1

Table 4. Summation of the Columns

	A	E	I
A	1	1/2	1/4
E	2	1	1/4
I	4	4	1
	Σ7	**Σ5.5**	**Σ1.5**

Table 5. Normalized Matrix (Dividing each element with the column sum)

0.143	0.090	0.167
0.286	0.180	0.167
0.571	0.721	0.667

Table 6. Computation of Relative Weights for ranking

Altruistic	0.143	0.090	0.167	Average = 0.133	Rank 3
Extrinsic	0.286	0.180	0.167	Average = 0.211	Rank 2
Intrinsic	0.571	0.721	0.667	Average = 0.653	Rank 1

Hence based on the relative weights it was concluded that intrinsic factor is the highest ranked factor, followed by extrinsic and finally altruistic factor is the lowest ranked factor. The calculation of consistency ratio (CR) was computed which required calculation of consistency index (CI) and Random Index (RI). In order to compute the value of consistency index (CI), the calculation of the largest Eigen value (λ_{max}) was needed to be done.

λ_{max} = (7*0.133+5.5*0.211+1.5*0.653) = 3.071

We thus considered the matrix to be consistent and the equation as an Eigen value problem wherein the largest Eigen value, λ_{max} ≥ n, the value of “n=3” being a 3*3 matrix.

$$\text{CI} = \frac{\lambda_{max}-n}{n-1} = \frac{3.07-3}{3-1} = 0.0355,\ \text{RI} = \frac{1.98\ (\text{n}-2)}{\text{n}} = 0.66,$$

Hence the value of CR = 0.0355/0.66 = 0.053

3.2. Condorcet-AHP based Ranking

In case of Condorcet-AHP based approach the individual voting in terms of preference of the three factors from the 250 responses were considered. The opinions where equal preferences were given for both the factors were eliminated from the counts considered. The pairwise comparison of the votes were done for each criteria pairs namely A-E, A-I and E-I. The consolidated results of the preferences are shown in Table 7, Table 8 and Table 9.

Table 7. Comparison of Altruistic (A) and Extrinsic (E) factor

Votes where A is given more priority than E	135
Votes where E is given more priority than A	104
Votes with equal priority to A and E (eliminated from count)	11
Quantitative Ratio of A:E = 135/104	1.298
Quantitative Ratio of E:A = 104/135	0.770

Table 8. Comparison of Altruistic (A) and Intrinsic (I) factor

Votes where A is given more priority than I	133
Votes where I is given more priority than A	106
Votes with equal priority to A and I eliminated	11
Quantitative Ratio of A:I = 133/106	1.254
Quantitative Ratio of I:A = 106/133	0.796

Table 9. Comparison of Extrinsic (E) and Intrinsic (I) factor

Votes where E is given more priority than I	83
Votes where I is given more priority than E	156
Votes with equal priority to E and I eliminated	11
Quantitative Ratio of E:I= 83/156	0.532
Quantitative Ratio of I:E= 156/83	1.879

The pairwise comparison matrix generated from the quantitative ratio is shown in Table 10.

Table 10. Pairwise Comparison Matrix

	A	E	I
A	1	1.298	1.254
E	0.770	1	0.532
I	0.796	1.879	1

The normalized matrix is shown in Table 11 and Table 12.

Table 11. Summation of the Columns

	A	E	I
A	1	1.298	1.254
E	0.770	1	0.532
I	0.796	1.879	1
	Σ2.566	**Σ4.177**	**Σ2.786**

Table 12. Normalized Matrix (Dividing each element with the column sum)

0.389	0.310	0.450
0.300	0.239	0.190
0.310	0.449	0.358

The computation of the relative weights for ranking is shown in Table 13.

Table 13. Computation of Relative Weights for ranking

Altruistic	0.389	0.310	0.450	Average = 0.383	Rank 1
Extrinsic	0.300	0.239	0.190	Average = 0.243	Rank 3
Intrinsic	0.310	0.449	0.358	Average = 0.372	Rank 2

The results of the Condorcet-AHP based ranking reveal altruistic factor as the highest ranked factor, followed by intrinsic and finally extrinsic factor is the lowest ranked factor.

The calculation of consistency ratio (CR) was computed based on the computation of consistency index (CI) and Random Index (RI).

λ_{max} = (2.566*0.383+4.177*0.243+2.786*3.752) = 3.033.

Thus the matrix can be considered to be consistent and the equation as an Eigen value problem wherein the largest Eigen value, λ_{max} ≥ n, the value of "n=3" because it was a 3*3 matrix.

$$\text{CI} = \frac{\lambda_{max}-n}{n-1} = \frac{3.033-3}{3-1} = 0.0165, \ \text{RI} = \frac{1.98\,(\text{n}-2)}{\text{n}} = 0.66$$

Hence the value of Consistency Ratio (CR) = 0.0165/0.66 = 0.025

The results clearly revealed that:

Condorcet-AHP approach CR<Traditional AHP CR

The comparison of the Consistency Ratio (CR) for the traditional AHP based approach and the Condorcet-AHP approach showed that the later one is a better one having a lower consistency ratio yielding more accurate and significant ranking of the criterion factors.

3.3. Contribution of the proposed Condorcet-AHP based approach

The resultant ranking generated using the Condorcet-AHP approach completely coincides with results of studies conducted in career choice related studies in various contexts. The study by Pop & Turner (2009) showed altruistic factor as the major motive behind teaching career choices [25]. The result of the proposed method is also supported by the study by Richardson & Watt (2005) and Young (1995) where altruistic factor was identified as the most significant factor motivating teaching career choices among graduates [26-27]. Similar facts were revealed in the study conducted by Kyriacou & Coulthard (2000) where altruistic and intrinsic factors were identified as the most significant factors for teaching career choices [28]. In all the above mentioned studies, intrinsic factor stood as the second important factor affecting teaching career decisions. Hence the ranking based on the Condorcet-AHP approach could be considered more accurate than the traditional AHP method as it generated altruistic factor as the highest prioritized reason followed by the intrinsic factor being the second most important factor.

The contribution of the proposed Condorcet-AHP based approach is visible from the value of the consistency ratio which is much lower in case of the proposed method (0.025) in comparison to the consistency ration of the traditional method (0.053). The lower the value of consistency ratio than 0.10, the judgement is considered to be more consistent. Hence in the case of Condorcet-AHP based approach we can consider it to be more consistent that the traditional AHP method based on the CR value.

Also, the accuracy in the results of the proposed method lies in the determination of priority weights of the graduates who have given opinions on the factors and helps to identify their chances to choose or reject the career option. In order to understand that, the overall priority weight of each graduate was computed using the following formula:

Overall Priority Weight = [(Normalized Average score of a factor) * (Individual Score of the respondent in that factor) / (Total score of all the respondents in that factor)] (10)

The graduates are ranked based on the overall priority weight wherein the highest weight gets the first ranking followed by the others using similar approach. The difference in the ranking using the traditional AHP and Condorcet-AHP based approach is shown for 20 students in Figure 2 which further supports the fact that the Condorcet-AHP based approach has been more accurate in solving multi-criteria decision making problem. The proposed Condorcet-AHP based ranking has been compared with the career choice of these 20 students considered for the study and their post graduate choices have matched to a significant level in reality.

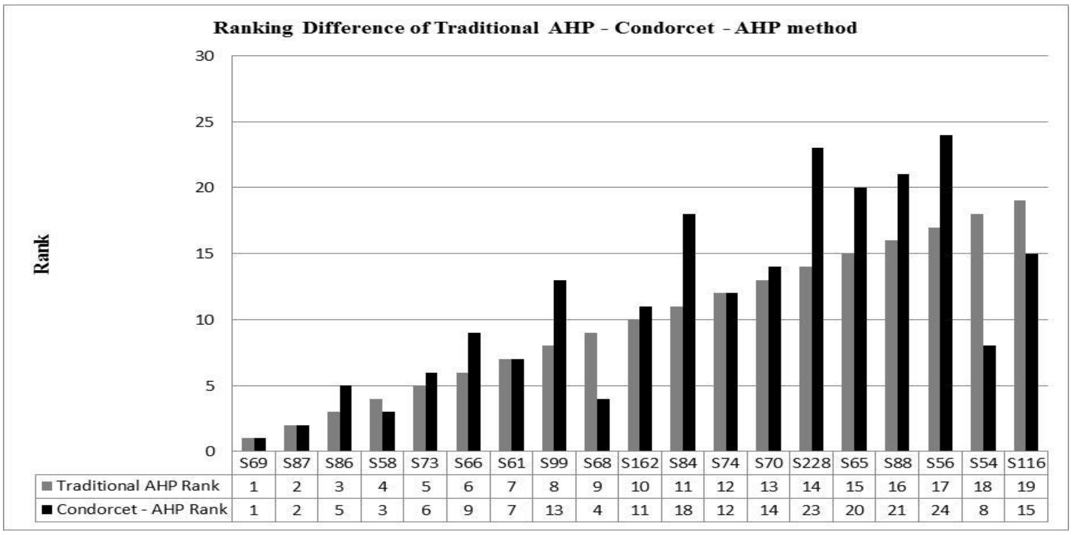

Figure 2. Ranking Difference of Tradition AHP and Condorcet – AHP based method

4. Conclusion

This paper solves the major weakness of the traditional AHP method due to the use of subjective judgement and standard importance scale in framing the pairwise comparison matrix which often leads to erroneous results and dilemma. The Condorcet voting theory based AHP method helps to eliminate this issue using an unbiased voting method to decide on the importance of the criterion followed by a quantitative ratio based approach for the pairwise comparison matrix creation. In the paper, both the approaches were used on a career choice related data set in the context of the Indian higher education system. The major factors pertaining to career choice decisions considered were Altruistic, Extrinsic and Intrinsic factors which were ranked using both the approaches and respective consistency ratios were generated using bot the methods. The rankings generated using traditional AHP based approach identified intrinsic factor as the highest ranking factor affecting teaching career choice decisions. On the contrary, the Condorcet-AHP based approach computed altruistic factor as the most important motivating factor behind teaching career choice decisions. This result completely coincided with other studies done in the teaching career related spectrum in various contexts which supported the accuracy of the result generated using Condorcet-AHP based approach. The value of the consistency ratio also revealed Condorcet-AHP method to be more consistent with lower value of consistency ratio in comparison to the traditional – AHP based approach. Hence it can be concluded that the Condorcet-AHP based approach has been far more accurate and successful in ranking and resolving multi-criteria decision making problem and hence can be used in to resolve similar MCDM cases.

As an extension to this study and future research, deep learning methods and techniques can be combined with the proposed approach to provide more insight and reveal various other patterns and predictions on the same.

References

[1] Nallusamy S, Sri Lakshmana Kumar D, Balakannan K., Chakraborty, P S. MCDM Tools Application for Selection of Suppliers in Manufacturing Industries using AHP, Fuzzy Logic and ANN. *International Journal of Engineering Research in Africa*. 2016; 19: 130-137. Khan Akhtar, Maity Kalipada. A Novel MCDM Approach for Simultaneous Optimization for Some Correlated Machining Parameters in Tuning of CP – Titanium Grade 2. *International Journal of Engineering Research in Africa.* 2016; 22: 94-111. DOI: 10.4028/www.scientific.net/JERA.22.94.

[2] Seyed Hadi Mousavi-Nasab, Alireza Sotoudeh-Anvari. A comprehensive MCDM-based approach using TOPSIS, COPRAS and DEA as an auxiliary tool for material selection problems. *Materials and Design.* 2017; 121: 237-253. DOI: https://doi.org/10.1016/j.matdes.2017.02.041.

[3] Wind Yoram, Saaty Thomas L. Marketing applications of the analytic hierarchy process. *Management Science.* 1980; 26(7): 641-658. DOI: http://dx.doi.org/10.1287/mnsc.26.7.641.

[4] Ho William. Integrated analytic hierarchy process and its applications–A literature review. *European Journal of Operational Research*. 2008; 186(1): 221-228. DOI: 10.1016/j.ejor.2007.01.004
[5] Dweiri Fikri, Faris M Al-Oqla. Material selection using analytical hierarchy process. *International Journal of Computer Applications in Technology.* 2006; 26(4): 182-189. DOI: 10.1504/IJCAT.2006.010763.
[6] Saaty, Thomas L. How to make a decision: the analytic hierarchy process. *European Journal of Operational Research*. 1990; 48(1): 9-26. DOI: https://doi.org/10.1016/0377-2217(90)90057-I.
[7] Russo De FSM, Rosaria Roberto Camanho. Criteria in AHP: a systematic review of literature. *Procedia Computer Science.* 2015; 55: 1123-1132. DOI: doi.org/10.1016/j.procs.2015.07.081
[8] Haller W, Tiedeman E, Whitaker R. *Expert choice-User Manual*. Pittsburgh, PA: Expert Choice. 1996.
[9] Saaty, Thomas L, Decision Making with Analytical Hierarchy Process. *International Journal of Services Sciences*. 2008; 1(1): 83-98. DOI: https://doi.org/10.1504/IJSSci.2008.01759.
[10] Bhushan S, Bharath A. Network QoS Aware Service Ranking Using Hybrid AHP – Promethee Method in Multi-Cloud Domain. *International Journal of Engineering Research in Africa*. 2016; 24: 137-152. DOI: 10.4028/www.scientific.net/JERA.24.153.
[11] Ming Xiang He, Xin An. Information Security Risk Assessment Based on Analytic Hierarchy Process. *Indonesian Journal of Electrical Engineering and Computer Science*. 2016; 1(3): 656-654. DOI: http://dx.doi.org/10.11591/ijeecs.v1.i3.pp656-664
[12] Dweiri Fikri, Kumar S, Khan SA, Jain V. Designing an integrated AHP based decision support system for supplier selection in automotive industry. *Expert Systems with Applications.* 2016; 62: 272-283, DOI: 10.1016/j.eswa.2016.06.030.
[13] Qiong Sun, Zhengran Gao. The Small and Medium-sized Enterprises Performance Evaluation Model based on DEA and AHP Method. *Indonesian Journal of Electrical Engineering and Computer Science*. 2013; 11(11): 6400-6405, DOI: http://dx.doi.org/10.11591/telkomnika.v11i11.3470.
[14] Eylem Koc, Hasan Arda Burhan. An Analytical Hierarchy Process (AHP) approach to a Real World Supplier Selection Problem: A Case Study of Carglass Turkey, *Global Business Management Research.* 2014; 6: 11-14.
[15] Zahraa Abed Aljasim Muhisn, Mazni Omar, Mazida Ahmad, Sinan Adnan Muhisn, Team Leader Selection by Using an Analytic Hierarchy Process (AHP) Technique. Journal of Software. 2015; 10(10): 1216-1217. DOI: 10.17706/jsw.10.10.1216-1227.
[16] Ilyas Akhisar. *Performance Ranking of Turkish Insurance Companies: The AHP Application*. Proceedings of the 8th International Management Conference. 2014: 27-34. DOI: 10.14784/JFRS.2014117324.
[17] Wanxing Sheng, Limei Zhang, Wei Tang, Jinli Wang, Hengfu Fang. Optimal Multi-Distributed Generators Planning under Uncertainty using AHP and GA. *Indonesian Journal of Electrical Engineering and Computer Science.* 2014; 12(4): 2582-2591. DOI: http://dx.doi.org/10.11591/telkomnika.v12i4.4824.
[18] Zhixia Jiang, Yibo Liu, Pinchao Meng. Polygraph Survey and Evaluation Based on Analytic Hierarchy Process. *Indonesian Journal of Electrical Engineering and Computer Science.* 2014; 12(7): 5585-5590.
[19] Wei C C, Chien C F, Wang M J J. An AHP-Based Approach to ERP System Selection. *International Journal of Production Economics*. 2005; 96(1): 47-62. DOI: 10.1016/j.ijpe.2004.03.004.
[20] Kluge P, Malan D F. The application of the analytical hierarchical process in complex mining engineeing design problem. *The Journal of the South African Institute of Mining and Metallurgy.* 2011; 111: 847-855.
[21] Fernandes JEM, Gomes LFAM, Soares de Mello JCCB, Gomes Junior SF. Commuter Aircraft Choice using a Modified Borda Method using the Median. *Journal of Transport Literature*. 2013; 7(2): 71-91. DOI: http://dx.doi.org/10.1590/S2238-10312013000200009.
[22] Morais D C, Almeida A T. Group decision making on water resources based on analysis of individual rankings. *Omega*. 2012; 40: 42-52. DOI: 10.1007/978-3-319-11949-6.
[23] Qingli Yin. An Analytical Hierarchy Process Model for the Evaluation of College Experimental Teaching Quality. *Journal of Technology and Science Education*. 2013; 3(2): 59-65. DOI: http://dx.doi.org/10.3926/jotse.66.
[24] Pop Margareta Maria, Jeannine E Turner. "To be or not to be… a teacher? Exploring levels of commitment related to perceptions of teaching among students enrolled in a teacher education program. *Teachers and Teaching: theory and practice*. 2009; 15(6): 683-700.
[25] Richardson R, Watt H. I've decided to become a teacher: Influences on career change. *Teaching and Teacher Education.* 2005; 21(5): 475-489. DOI: doi:10.1016/j.tate.2005.03.007.
[26] Lee Yung-Jaan, Raymond De Young, Robert W. Marans. Factors influencing individual recycling behavior in office settings: A study of office workers in Taiwan. *Environment and Behavior*. 1995; 27(3): 380-403. DOI: 10.1177/0013916595273006.
[27] Kyriacou Chris, Melissa Coulthard. Undergraduates' views of teaching as a career choice. *Journal of Education for Teaching: International research and pedagogy*. 2000; 26(2): 117-126. DOI: 10.1080/02607470050127036.