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The Place of AHP Method among the Multi-criteria Decision Making Methods in Forest Management

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Abstract As the name implies, Multi-criteria decision making methods (MCDM) are decision making tools that capable the selection of the most preferred choice in a context where several criteria apply simultaneously. The primary purpose of this study is to examine the status of MCDM in forest management. The study also aims to evaluate the strengths and weaknesses of each of the MCDM methods. In this research the most important criteria for the evaluating of MCDM were determined. Also the most MCDM methods were selected according to a team of forest management experts. AHP, FAHP, ANP, TOPSIS, VIKOR, WSM, DEA, Voting methods, PROMETHEE and ELECTRE were selected for MCDM in forest management and ease of using the method, easily interpreted parameters, ease of understanding the results, ability of having detailed sensitivity analysis, ability of using graphical design model, ability of the team decision support, ability of considering various constraints, accuracy in determining the results and velocity in the use of decision making method were determined as criteria for evaluation of MCDM methods. In the second phase of the research, experts weighted the MCDM methods relative to criteria for evaluating of MCDM methods with Likert scale. According to all criteria, AHP among the study methods was the optimal choice for decision making in forest management. Finally, a SWOT analysis was performed for better understanding of the results. The result showed that AHP method was not the ideal multi-criteria optimization method. In other words, this method had some weaknesses. Most of the weaknesses were related to the use of experts. In case of non-professional experts in pairwise comparisons, weaknesses points were highlighted in using AHP.

Keywords: AHP, ANP, FAHP, DEA, Power Index (PI).

1 Introduction

The concept of forest management has become a dominant paradigm for sustainable development. Due to forest roles in the timber production, reduction of negative environmental effects, local resident life, production of Oxygen, prevention of flood, conservation of ware and downpours, reduction of greenhouse gases and employment opportunities of a country's natural resources services and in general country’s sustainable development, forests have an essential role in sustainable development [1]. As the name implies, multi-criteria decision making methods (MCDM) are decision making tools that capable the selection of the most preferred

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choice in a context where several criteria apply simultaneously. There is a widespread need for MCDM in the forest management because of the variety of the forest functions. Economic, cultural, social, environmental and recreational functions must be considered in decision making related to the forest management. Forests have a variety of services that in decision making processes some of the roles of the forest and some other functions may face each other [2]. Cost-Benefit Analysis (CBA) has been done for decision making method in forestry. In CBA, costs of input parameters and benefit of output parameters are compared. Optimal alternative in decision making is the alternative with lower cost and higher revenue. In other words, optimal solution is gained from profit calculation of alternatives. But decision making in forestry have several complexities because of the socio-economic problems due to local resident, biodiversity roles in forests, tourism, timber production, and other forest functions. Decision making in forest management has several problems and we need the MCDM method [3].

Kangas [4] reports AHP as a tool to integrate public preferences for choosing strategic planning for forest management. Kurttila et al. [5] used AHP method to improve the quantitative basis of strategic forest planning. They applied the AHP-SWOT to aid the decision making in a Finnish forest management. The AHP used to quantify the relative preference weightings of the SWOT group (i.e., Strengths, Weaknesses, Opportunities and Threats) and the weightings of the SWOT indicators with respect to the four group (criteria) in the SWOT group. Based on the weightings, the global priority of the factors obtained. Ananda and Herath [6] described how the AHP method can be used to quantify forest plans using a small sample of forest stakeholders. Mendoza and Prabhu [7] examined 3 methods of Pairwise comparisons (PCs), ranking and rating. The results showed that ratings and ranking methods have a high ease of use but the method of PC method is a more demanding method compared to these methods and require professional evaluation. At the same time, PCs method provides more complete information of evaluation. Kajanus, et al. [8] applied the AHP method to whether culture can be identifying as a successful factor in rural ecotourism. The approach was the same as that described previously in [5]. Wolfslehner, et al. [9] examined AHP and ANP (Analytic Network Process) for measuring the sustainability of four strategies estimated according to 6 criteria and 43 indicators in an Austrian forest. They used AHP and ANP methods to assess Sustainable Forest Management (SFM). ANP has a large potential in the evaluation of complex decisions. These researchers suggested that because of ANP’s ability in evaluation of loops and feedbacks between elements, this approach is a suitable method for the evaluation of criteria and indexes for SFM. Wolfslehner and Vacik [10] examined the application of AHP and ANP methods and DPSIR (Driving Forces-Pressures-State-Impacts-Responses) framework in examination of indicators’ adjustment in SFM in combination with cognitive mapping. The results showed that ANP method has higher correlation compared to AHP method in analyzing the cause and effect relations in assessment of the SFM indicators. Zandebasiri, et al. [11] compared analysis was used. The result showed that the local resident FMU is preferable. By increasing the Forest Management Unit (FMU) of Forest and Rangeland Organization (FRO) with FMU of local residents. They applied stakeholder analysis and AHP. For evaluating the uncertainty effect in decision making, dynamic sensitive element preferences the result of decision making is the same as the first alternatives. In other words, the result of this research is sustainable.

Review of sources indicates that there is no comprehensive assessment about MCDM in forest management in order to compare them from different aspects. Each of these MCDM methods has strengths and weaknesses. In this article, we tried to carry out a comparison among different methods of MCDM in forest management in order to determine strengths and weaknesses and the status of using any of these methods. In this research we evaluate the

MCDM methods with planning of planning and study of the power of MCDM methods. Primary purpose of this study is to examine the status of MCDM methods in forest management. The study also aims to evaluate the strengths and weaknesses of each of MCM methods. We must study the total forest functions in specific decision making. In selecting a Skidders, one machine may have maneuverability and good speed but it may cause severe the forest soil compaction in environmental terms. Or one skidder may have less soil compaction effects but not be cost effective in economic terms and have high cost. Thus it is essential that all criteria be considered and a selection be done based on all criteria (compaction, maneuverability, cost). A variety of methods of MCDM has been used in the forest management until now but few studies have been conducted for comparing different methods.

2 Method

Methods of the research was combined from planning of planning, description of methods and formulations, determining the criteria and alternatives and calculating of Power Index that described below;

2.1 Planning of Planning

The select of optimal method in decision making relates to ability of MCDM methods. The discussion is also called planning of planning [12] which in fact is the selection of proper decision making method. After the initial examinations, record study of literature in MCDM and forest management and with expert team opinions, it was found 10 methods of MCDM that have extensive usage in forest management. These methods are AHP (Analytical Hierarchy Process), FAHP (Fuzzy Analytical Hierarchy Process), ANP (Analytical Network Process), WSM (Weighted Sum Method), DEA (Data Envelopment Analysis), Voting methods, PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation), ELECTRE (Elimination and Choice Translating Reality) ,TOPSIS (Technique for Order Preference by Similarity to Ideal) and VIKOR (Vlse Kriterijumsk Optimizacija kompromisno Resenje). These methods have been widely used in recent year’s articles in forest management field.

2.2 Description of Methods and Formulations

In this section, abstract of formulations of the methods are described. AHP is basic method in MCDM methods. Hierarchy building and pair-wise comparisons matrix (PCM) are the joint operation in many methods. A PCM is illustrated in equation 1.

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & 1 \end{bmatrix}, \quad (1)$$

In A PCM has existed reciprocal condition and the number of Pair wises calculates from $\frac{n(n-1)}{2}$ that n is a dimension of PCM. Global priorities will calculate after normalization of local priorities. Consistency Index (CI) of Pair wises calculates based on $\frac{\lambda_{\max} - n}{n-1}$ that $\lambda_{\max}$ is eigenvalue for PCM. In ANP hierarchy is replaced with network and System with Feedback. ANP calculations are based on Super Matrix. Super Matrix is a portioned matrix. Equation 2 shows a Super Matrix that has 4 dimensions.

$$W = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ A_1 \\ A_2 \\ A_3 \\ A_4 \end{array} \begin{array}{c} \begin{array}{cccccccc} C_1 & C_2 & C_3 & C_4 & A_1 & A_2 & A_3 & A_4 \end{array} \\ \begin{bmatrix} \circ & \circ & \circ & \circ & w_{11} & w_{12} & w_{13} & w_{14} \\ \circ & \circ & \circ & \circ & w_{21} & w_{22} & w_{23} & w_{24} \\ \circ & \circ & \circ & \circ & w_{31} & w_{32} & w_{33} & w_{34} \\ \circ & \circ & \circ & \circ & w_{41} & w_{42} & w_{43} & w_{44} \\ w'_{11} & w'_{12} & w'_{13} & w'_{14} & \circ & \circ & \circ & \circ \\ w'_{21} & w'_{22} & w'_{23} & w'_{24} & \circ & \circ & \circ & \circ \\ w'_{31} & w'_{32} & w'_{33} & w'_{34} & \circ & \circ & \circ & \circ \\ w'_{41} & w'_{42} & w'_{43} & w'_{44} & \circ & \circ & \circ & \circ \end{bmatrix} \end{array}, \tag{2}$$

In Super Matrix is existed the combination alternatives (Ai) and criteria (Cj). Global weights will calculated from $\lim_{K \to \infty} W^{2K+1}$.

In TOPSIS Evaluation Matrix to be comprised of actual values or expert opinions. Then Ideal solutions and Negative ideal solution are described based on equations 3 & 4.

$$A^* = \{U_1^*, \ldots, U_n^*\} = \{\max V_{i1}, \max V_{i2}, \ldots, \max V_{in}\} \tag{3}$$

$$A^- = \{U_1^-, \ldots, U_n^-\} = \{\min V_{i1}, \min V_{i2}, \ldots, \min V_{in}\} \tag{4}$$

For each alternative distance of Ideal solutions and Negative ideal solution are described based on equations 5 & 6.

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}, \tag{5}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, \tag{6}$$

Finally ranking index calculus from Equations 7.

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-} \tag{7}$$

In VIKOR, ranking index calculus from Equations 8.

$$Q_i = V \left[\frac{S_i - S^*}{S^- - S^*} \right] + (1 - V) \left[\frac{R_i - R^*}{R^- - R^*} \right], \tag{8}$$

Usually that is supposed $V = \circ/5$ and Si & Ri are distance of ideal solution and negative ideal solution accordingly and S* & R* are ideal solution and negative ideal solution accordingly. In ELECTRE Concordance and Discordance Matrixes establish from Equations 9.

$$C_{ab} = \{ j \mid X_{aj} > X_{bj} \}, \tag{9}$$

Discordance Matrix is complementary for Concordance Matrix. Then calculate Concordance and Discordance Index to Equations 10 & 11.

$$\overline{C} = \sum_{a=1}^{n}\sum_{b=1}^{n}\frac{c_{ab}}{n(n-1)} \qquad (10)$$

$$\overline{D} = \sum_{a=1}^{n}\sum_{b=1}^{n}\frac{d_{ab}}{n(n-1)} \qquad (11)$$

Finally superior and inferior values calculus from Equations 12 & 13.

$$c_a = \sum_{b=1}^{n} c_{ab} - \sum_{b=1}^{n} c_{ba}, \qquad (12)$$

$$d_a = \sum_{b=1}^{n} d_{ab} - \sum_{b=1}^{n} d_{ba} \qquad (13)$$

The ELECTR method has not ranking and is used the outranking method [2]. In PROMETHEE Preference functions is used by means of Quasi-Criterion, Criterion with Linear Preference, Criterion with Linear Preference and Indifference Area, Level Criterion, Criterion Usual and Gaussian Criterion that accordingly described below in Equations 14-19.

$$P_1(X) = \begin{cases} \circ, & x \le L \\ 1, & x > L \end{cases} \qquad (14)$$

$$P_2(X) = \begin{cases} \frac{x}{m}, & x \le m \\ 1, & x \ge m \end{cases} \qquad (15)$$

$$P_3(X) = \begin{cases} \circ, & x \le s \\ \frac{x-s}{r}, & s \le x \le s+r \\ 1, & x \ge s+r \end{cases} \qquad (16)$$

$$P_4(X) = \begin{cases} \circ, & x \le q \\ \frac{1}{2}, & q \le x \le q+p \\ 1, & x > q+p \end{cases} \qquad (17)$$

$$P_5(X) = \begin{cases} \circ, & x \le \circ \\ 1, & x > \circ \end{cases} \qquad (18)$$

$$P_6(X) = \begin{cases} \circ, & x \le \circ \\ 1-e^{-\frac{x^2}{2\sigma^2}}, & x \ge \circ \end{cases} \qquad (19)$$

In WSM decision making method belonging to scoring methods and will calculus Utility function from $\max \sum_{j=1}^{n} w_j r_{ij}$ that w_i are weight vector for criteria and r_{ij} are elements from evaluating matrix. In DEA evaluate the Efficiency with Linear Programming. In FAHP, AHP is used in combination of fuzzy numbers and in voting methods are used simple methods for voting similar to Approval voting, Borda Count Method and Cumulative rule [2].

2.3 Determining the Criteria and Alternatives

In this step 10 above methods were evaluated as 10 alternatives for decision-making. Then the specialist team were selected for evaluating MCDM processes. The specialist team select criteria for decision making about the optimal solutions in MCDM processes. 9 criteria for evaluating of MCDM processes in forest management were selected by carrying out 2 group sessions with MCDM specialist's team. Ease of using the method, easily interpreted parameters, ease of understanding the results, ability of having detailed sensitivity analysis, ability of using graphical design model, ability of the team decision support, ability of considering various constraints, accuracy in determining the results and velocity in the use of decision making method were determined as criteria for evaluation of MCDM methods. According to this criteria MCDM methods were evaluated. We designed the 12 Questionnaires for forest management specialists. Questionnaires were dispersed for 12 expert related to MCDM methods in forest management. In questionnaire design, the alternatives were assumed MCDM methods and 9 criteria in this study were replaced for criteria in decision making system. The evaluation criterion for different alternatives were used with the Likert scale. Likert scale one of the most usage scales in evaluation of the expert attitudes in forest management [13]. Likert scale has either 5 or 7 items. In this research the 5-part scale was used as follow:

Table 1 Likert scale and its items

Numerical value	1	2	3	4	5
Response items	Completely weak	Weak	Indifferent	Strong	Completely Strong

Based on the above table, if an expert evaluates one MCDM method such as ANP in a criterion such as "Ease of use" as completely strong, (He) will give it (5) and if she evaluates a MCDM method as completely weak, she will give it (1). Numbers (4), (3) and (2) are applied for intermediate advantages. This means that experts were asked to determine value of 1 to 5 for each MCDM method depending on different criteria. The higher numerical values indicate more preference of a method in related criterion and the smaller numerical values indicate less preference of a method in related criterion. Analyst team were designed the lack of recognition response item along with 5 items of Likert scale for the questions that experts had no knowledge about discussed method and relation of criterion and alternative. This item was considered with score of zero. For the evaluating the questions about the importance of each alternative relative to each criterion were designed in the questionnaires.

2.4 Calculating of Power Index (PI)

For data analysis the alternatives scores (MCDM method scores) were calculated from the sum of the scores of different criteria. Then the average of 12 questionnaire scores were calculated. In other words, for each of alternative, criterion scores were calculated with average of total scores of expert's scores. Finally, analyst team defined a PI for MCDM methods. PI were calculated from average for scores of each method in criteria. This average was called the Power Index of MCDM methods. PI causes MCDM methods have been ability to compare to all methods.

3 Result

The results of evaluation of various MCDM methods have been show in figures 1 to 9.

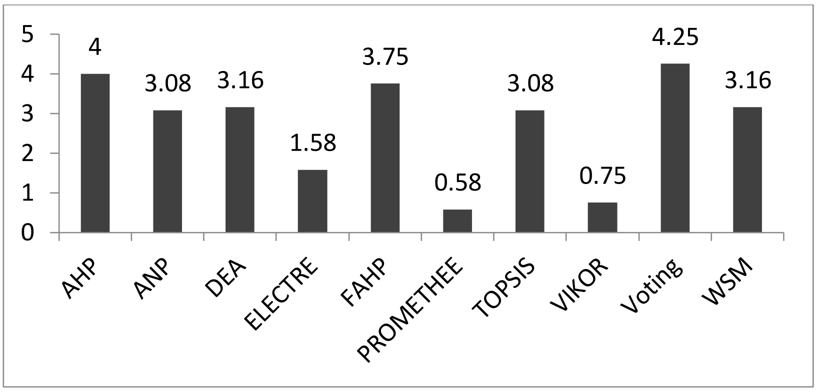

Fig. 1 Evaluation of MCDM methods based on the criterion of "Ease of use"

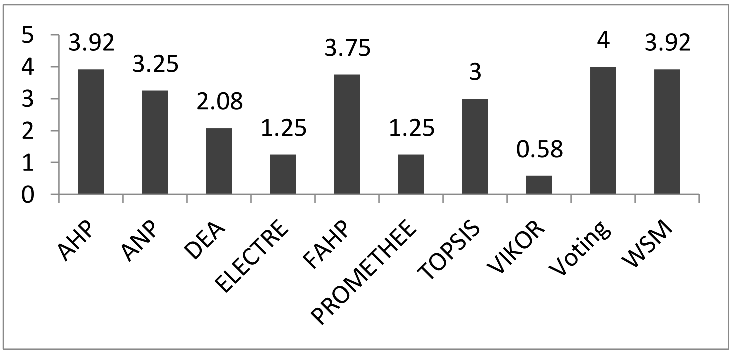

Fig. 2 Evaluation of MCDM methods based on the criterion of "Easily interpreted parameters"

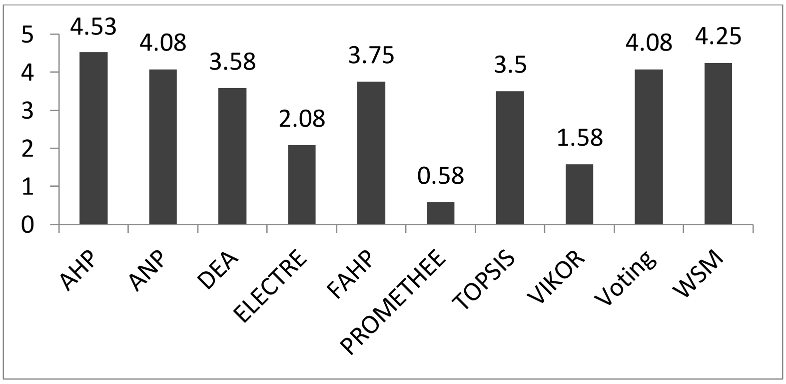

Fig. 3 Evaluation of MCDM methods based on the criterion of "Ease of understanding the results"

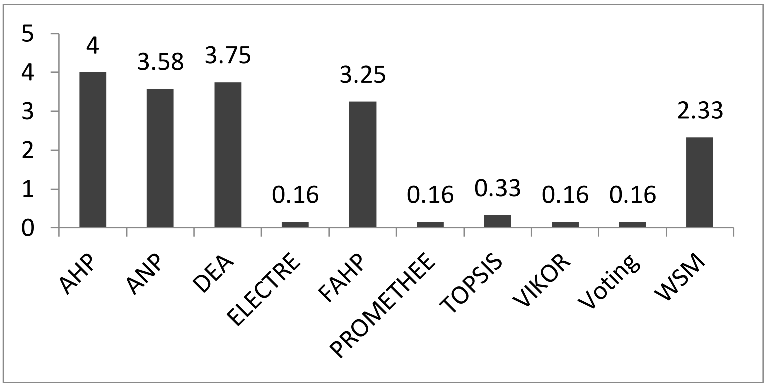

Fig. 4 Evaluation of MCDM methods based on the criterion of "The ability of having detailed sensitivity analysis"

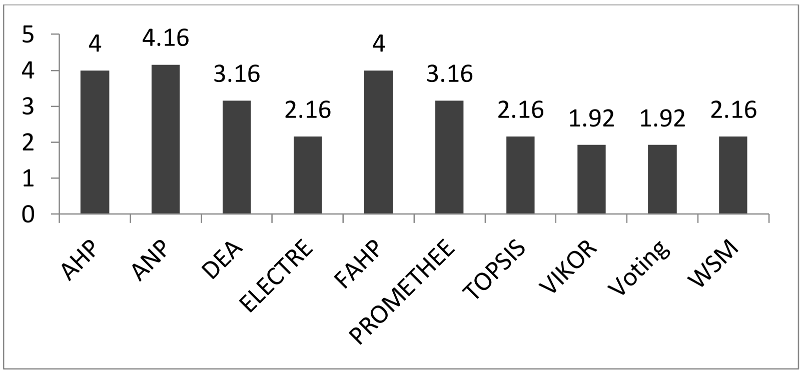

Fig. 5 Evaluation of MCDM methods based on the criterion of "The ability of using graphical design model"

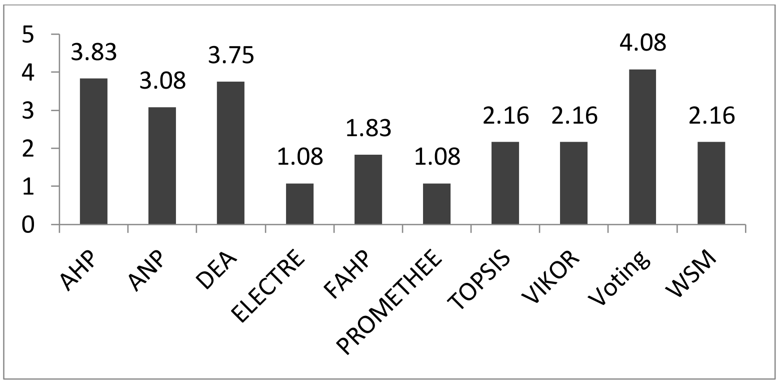

Fig. 6 Evaluation of MCDM methods based on the criterion of "The ability of the team decision support"

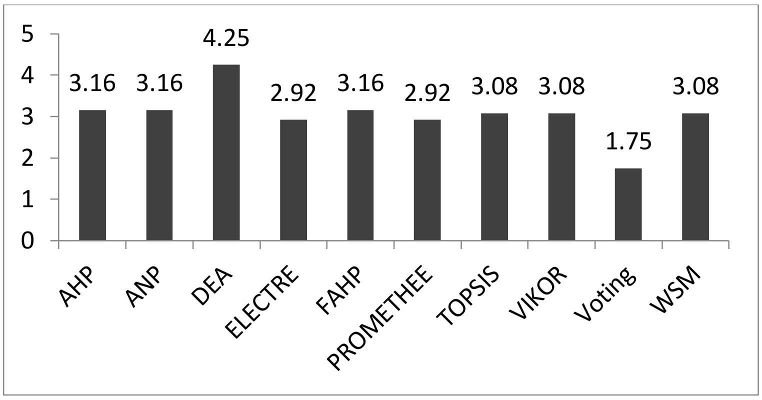

Fig. 7 Evaluation of MCDM methods based on the criterion of "The ability of considering various constraints"

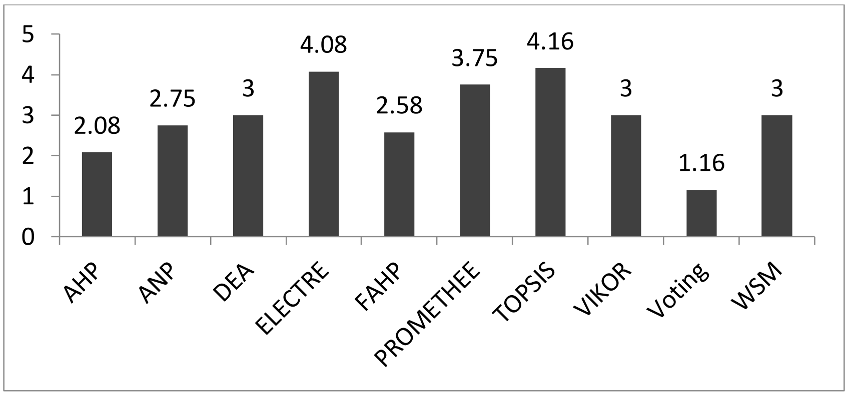

Fig. 8 Evaluation of MCDM methods based on the criterion of "Accuracy"

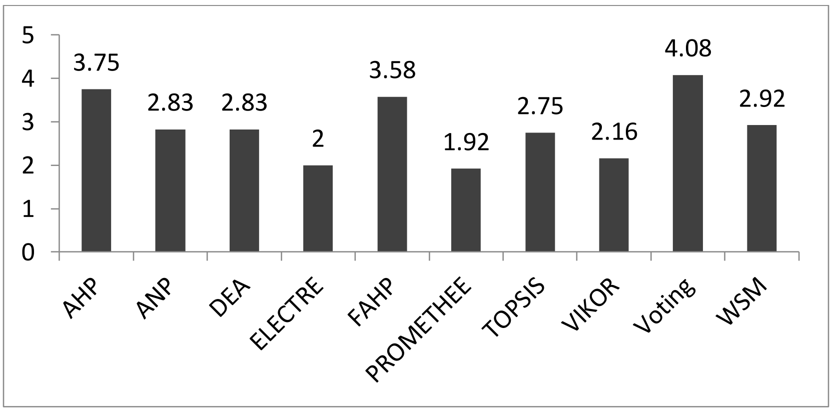

Fig. 9 Evaluation of MCDM methods based on the criterion of "Velocity"

The result PI index of MCDM methods based on all criteria is as shown in figure 10.

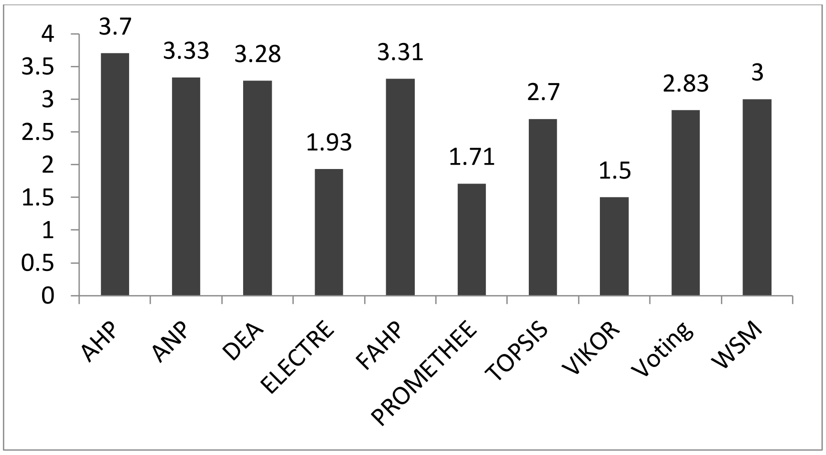

Fig. 10 PI index of MCDM methods based on all criteria

5 Discussion and Conclusions

5.1 AHP Method

Evaluating result of the PI index of MCDM methods in figure 10 shows that AHP method has greater PI compared to all methods (Fig. 10). AHP method breaks down problem to 3 parts of objective, criteria and alternatives and then designs a hierarchical plan for it. Each level of this hierarchy is evaluated using Pairwise Comparisons (PCs) compared to a higher level in order to determine local weight of each element. Ultimately, the global weight of each alternative compared to objective of the problem is determined by a linear combination of weights [14]. This method has strong logical and is adaptable with the human mind. This matter leads to high values for this method in different criteria (Figure 1-9). With regard to all criteria, AHP is the optimal solution in the forest management among of 10 studied methods. It should be noted that AHP is an optimal MCDM method and not an ideal method [12]. This means that the ideal method is superior in all criteria compared to other methods but the optimal method is superior in some criteria compared to other methods and in some criteria has shortcomings compared to other alternatives. But in general the optimal method is the best alternative according to all criteria. AHP has significant importance in "Ease of understanding the results" (Fig.3) and "The ability of having detailed sensitivity analysis" (Fig. 4) criteria and this method is the best criteria in this criteria. Also in other criteria AHP has suitable weights among the other methods. Therefore, on the whole in all criteria AHP is the suitable for forest management but we need to pay attention that the problem and its characteristics determine MCDM method for the problem. If the problem is very simple Voting method will prefer among the alternatives because of ease of use (Fig. 1) but if the problem needs to sensitivity analysis Voting method is not preferable (Fig. 4) and AHP and DEA are suitable for this situation. Each method has strengths and weaknesses points that causes the method will apply for special situation. We need to analysis these strengths and weaknesses points. SWOT analysis (Strengths, Weaknesses, Opportunities and Threats analysis) is one of the most powerful tools for evaluating results. In this evaluation, strengths, weaknesses, opportunities and threats of research result are examined [5]. A SWOT analysis is provided for the application of AHP method for better understanding of applications and limitations of AHP Method:

Table 2 The SWOT analysis for AHP method selection

Strengths	**Opportunities**
Ease of use	Group decision making
Adaptable with the human mind	Experts convenience in PCs due to adaptability with Logic
Adaptable of complex problems	Basis of other methods in criteria weight
Existence of strong mathematical logic	Extensive application in various fields of the forest management
Using measurement based on ratio-scale	Providing high-quality results using ratio-scale data
Weaknesses	**Threats**
simple model and removing some facts	Dependence on experience, expertise and spending time in PCs
Dependence on the analyst team in problem-planning	The need for additional methods such as interviews as well as questionnaire
A lot of criteria or alternatives in the problem	The longtime of questionnaire completion by experts
The lack of application in network and stochastic status	Using in decisions that are not related to AHP application

AHP due to its simplicity, comprehensibility and logic adaptable with the minds of experts has more application compared to other methods. Also this method can be a basis for other methods in part of criteria weight. AHP in forest management is a widely used and accepted method. This method is most widely used among various methods in forest management [15]. AHP simplifies complicated problems by analyzing them. The strengths and opportunities of this method are ease of use and ability to be combined with other methods such as Linear Programming (LP), Goal Programming (GP), Integer Programming (IP), SWOT analysis [5,16] and DEA [17]. AHP is a set of judgments and valuations of experts in a logical method. This method depends on the experience for planning of hierarchy and depends on logic, understanding and knowledge appropriate for the final judgment and decision making [18]. To close the points of weakness of AHP method, it is necessary to pay attention to the fact that AHP requires the use of certified experts for weighting and PCs. PCs will be extremely difficult in the case of using non-expert in the process of weighting the factors. Professional and specialist experts in order to perform PCs to improve the quality of comparisons and reduce superficiality in data exchange of PCs. Other weakness of AHP method is weakness in designing hierarchy by analyst team or Decision Makers (DM). One of the common mistakes in designing hierarchy is that DM sometimes provides standards at the same level which are not comparable. Thus AHP requires a specialist expert analyst team [11,16]. Another shortcoming is that AHP method is not suitable for all problems and in various models such as turning to network model, or tuning to stochastic models, specific methods should be used. It is true that simple methods such as AHP provide very nature of understanding about the problems; however, in some states the use of more sophisticated methods such as ANP becomes inevitable. Many problems in forest management in designing hierarchy are displayed in the best way [19]. The reason for this matter is existence of a set of economic, ecological, cultural and social criteria in the forest which can be categorized in suitable sub criteria in designing hierarchy [11].

5.2 ANP method

ANP is generally obtained from AHP in which elements can have feedback and loop while there may be Internal and bilateral dependencies in the process of the decision issue. Network is a set of nodes or points of linkage that some or all of them are connected by branches or loops [10]. Super Matrix is the foundation of calculations in the process of network analysis. Super Matrix is a set of Matrixes which provides the effect of alternatives on criteria, criteria on alternatives and bilateral effects in form of weighted results of paired comparisons. For the formation of Super Matrix weights, criteria compare to alternatives and Matrix weight of alternatives compared to criteria. Observing bilateral dependencies and loops is the main advantage of ANP compared to the AHP. At the same time increased paired comparisons in Super Matrix is the main weakness of ANP compared to the AHP. Also need to specialized experts and being bored by comparisons is the other weakness of ANP compared to the AHP. But bilateral relation of social and economic factors, cultural and economic factors, ecological and social factors of the forests are examples of this bilateral relation in the forest management due to major role of humans on the ecological issues in the forests. For these reasons ANP has the significant PI (Score 3.33 in Fig. 10).

5.3 FAHP method

FAHP application is covering linguistic ambiguities in order to express advantages in AHP. In forest management fuzzy concepts are very important because of uncertainty cases in forest management plans. The most important cases of uncertainty in the forestry projects are as table 3.

Table 3 The most important cases of uncertainty in the forestry projects [11]

Case of uncertainty	Description
Unpredictability of natural factors	Natural and climatic conditions of the forest makes repetition and probability of occurrence of events in the forest difficult
High volume of data	The forestry plans have larger work level compared to agricultural and industrial projects
Long service life plans	Duration of strategy and approach plans of the forest is 5 years or more
Long exploitation periods in the forest	Erratic price fluctuations will lead to economic uncertainty in long time periods
Prediction of Human factors of the forest ecosystem	The social demands will change with the passage of time, hence Prediction of Human factors of the forest ecosystem will be difficult

The above uncertainties have major effect on the accuracy of criterion of decision making process and these issues can increase the further application of FAHP method in the forest management [15]. Fuzzy numbers can be used instead of absolute numbers by using FAHP. In spite of this advantage, volume of calculation is much more in FAHP. Criterion of "Ease of use" in this method will have less advantage compared to AHP (score 3.75 compared with 4 in Fig. 1). Interpreting the results of this method is not complicated. Also this method has ability for sensitivity analysis similar to AHP. FAHP is also noticeable about criteria for process's velocity with regard to raising the issue by paired comparison (score 3.58 in Fig.9). One of the weaknesses of FAHP method is reduction in usability in the team decisions (score 1.83 in Fig.6). The process of calculating in fuzzy methods is very broad and combining various experts' opinions requires a lot of calculations in FAHP method.

5.4 DEA Method

DEA method is based on linear programming and this method rank alternatives with the concept of efficiency [20]. Efficiency is determined by the ratio of system output to system input. In other words, efficiency is the ratio of outputs or products compared to resources that are consumed. Efficiency is simple concept and has a high acceptance for the human mind. The most important strength of this method is the ability of considering constraints based on mathematical formulas and this leads to the highest rating among all methods for this method in criteria of considering constraints (score of 3.16 in Fig.7). The ability of using graphical design model also has a significant score (score of 3.16 in Fig. 5). It may be due to study of feasible area in linear programming and its effect on the ability of using graphical design model. Due to the need of this method for defining math expressions, interpretation of parameters will be slightly more complex but it is easy to understand in its results because numbers of the results are based on efficiency and lack of efficiency. Overall score of 3.28 (Fig. 10) indicates the high capacity of this decision making method in the forest management.

5.5 Other Methods

WSM method is very similar to the AHP method in the calculation of linear combination but it uses evaluation matrix instead of PCs. This issue reduces the ease of use, velocity and ability of group decision making and also reduces the ability of group sensitivity analysis compared to AHP. It seems that score of 3 for this method (Fig. 10) is also due to similarity with AHP method.

Voting method has the extensive applications in the forest management [21] in criteria of the "Ease of use". Score of 4.25 for this method (Fig. 10) indicates that. This method has not complexity in execution and has a high execution ability. Also interpretation of parameters, understanding the results, group decision making and velocity of this method are strengths of this method. Low accuracy (score 1.16 in Fig.8) due to simple style, lack of accuracy, lack of sensitivity analysis and lack of ability of considering various constraints, reduce the efficacy of this method in complex forest management issues. It seems that this method is extremely useful in simple decision-making processes which have not much complexity but are not useful in cases that have extremely complexity.

TOPSIS method have great accuracy. It seems due to defining positive and negative ideal options that causes the accuracy of the method has the highest score among methods (score 4.16 in Fig8). Low sensitivity of analysis and team decision making are disadvantages of this method.

In ELECTRE method, the outranking concept is used instead of ranking options. In this method, alternatives are evaluated using outranking methods [2,15]. In ELECTREI method interpretation of the parameters is very difficult (score 1.25 in Fig.2). It seems due to defining indicators of Concordance and Discordance Matrixes. Decision making process will have less velocity and ease of using method will be difficult due to mathematical calculations. Score of 1.58 in criteria of "Ease of use" (Fig. 1) can be due to above reason. At the same time, it seems that the analysis of coordination in ELECTREI leads to increase accuracy of decision making. ELECTREI theory is a theory of deletion and selection. According to this theory, unparalleled comparisons are done and there is no direct rating.

In PROMETHEE method ease of use is lower than other methods (Fig.1). Using 6 Preference functions leads to the complexity of the method for experts. This issue along with high volume of calculations leads to increasing computation time in the decision-making process. But score of 3.75 in criteria of accuracy (Fig 8.) indicates the efficacy of this method in decision makings that require accuracy.

TOPSIS and VIKOR methods which search for optimal combination of positive and negative responses are called compromise methods. This means that they try to find an alternative which is the closest response to positive ideal and farthest response to negative ideal. VIKOR method is very similar to TOPSIS method with theses difference that this method need to define Regret indicator that reduce the ease of use this method. This method has the lowest efficiency compared to other methods of multi criteria decision making in forest management (Fig. 10).

Nowadays, MCDM methods are widely used in forest management. Different methods each have different applications. In most cases analyzers of MCDM do not have enough information for selecting the appropriate method for the problem. Nowadays, AHP method is used in most problems. This this method has a high PI index in MCDM in forest management. But it should be noted that this method is not suitable for all problems. It also has weaknesses that most of them are related to the use of experts. If non-professional experts are used PCs, weaknesses of AHP method will be highlighted. Finally, it should be noted that the results of this research has been collected from 12 experts in forest management. Having more experts in case of selecting professional experts and using group sessions for dynamic assessment process as richness of evaluation will be more helpful.

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