Analytical Hierarchy Process – Study on its Applicability on Web Based Environment

M. Daya Kanmozhi Rani¹ and Dr. S. Sakthivel²

¹Associate Professor, Department of Information Technology, Adhiyamaan College of Engineering, Hosur, Tamil Nadu, India
²Professor, Department of Computer Science, Sona College of Technology, Salem, Tamil Nadu, India
¹mkanidaya@gmail.com, ²sakthits@rediffmail.com

Abstract

Availability of finite set of alternative solution for any problem tends to make decision making an inevitable part of today’s opportunistic world. Generally Decision making is made based on various perspectives like psychological, cognitive, normative means. In all situations Cost-Benefit analysis forms the key reason for decision making. Multi Criteria Decision Making (MCDM) methods make the analysis of highly complex system much easier. Analytical Hierarchy Process (AHP) is one of the popular MCDM methods which works on priority theory. AHP is modeled in such a way that the experts make pairwise comparison of all available alternatives and rank them accordingly. This study identifies the application of AHP on various fields like web service selection, web development platform, selecting a website for online advertisement, banking and many. And finally this study identifies various methodologies to rank the alternatives in AHP method and try to associate its applicability with various other MCDM methods.

Keywords: Decision making, MCDM, AHP, pair wise comparison

1. Introduction

Complex real time problem requires a varied mean of analysis, to derive the best solution under consideration of various criteria’s. The alternative solutions have to be evaluated and ranked on the basis of their association with these criteria’s. Multi Criteria Decision Making method is supposed to be one of the important tools that support the decision makers to identify the pertinent decision among the available numerous and similar alternatives. A complex real time problem cannot be resolved considering a single criterion. Single dimensional decision making generally don’t deal with high level of complexity and often seems to be biased. The biased nature of the problem solving turns the advancement towards multi criteria decision making. This multi criterion based analysis though seems to be confusing it helps us to analyze the problem on various accords. These criteria’s have to be evaluated for their order of preference and ranked in their order of priority. Different rating methods are available to rate these criteria’s. Computations of weights are done through various methods like Rating Methods, Voting Methods, and Entropy Methods and so on.

Multi Criteria Decision Making (MCDM) [3-6] is the branch of Operation Research where decision making is one of the important tasks of every growing complex business environment where potentially highly conflicting alternatives are involved. Basically MCDM is divided into two categories namely Multi Objective Decision Making (MODM) and Multi Attribute Decision Making (MADM). MODM is the method that involves the decision maker to optimize the multiple set of objectives to determine the appropriate alternative solution. MADM is designed in such a way that using a predefined set of attributes, a group of solutions are analyzed and an optimal alternative is selected.
Among these two varieties it is identified about 70 – 80 MCDM techniques are involved to facilitate the decision making process.

For Quantitative and Qualitative analysis of complex problems Analytical Hierarchical Process (AHP), found by L.Saaty (1980) [1] could be used. This is one of the important MCDM methods. The complex problem is systematically decomposed into a hierarchical model for simple and quick decision making using AHP. Huge volumes of alternate solutions of the complex problem are rated by pairwise comparison method based on the predefined set of criteria’s. These criteria’s are identified based on the requirement goals. The relationship among these criteria’s and alternative solutions is established using the AHP method [7, 8]. Recent research states that AHP has been applied on diverse areas like Management, Information Technology, and Web site evaluation and so on.

This paper details the process methodology and importance of AHP in decision making in Section 2. In Section 3 various application AHP on fields like selection of web sites, web services, open source software, and evaluation of web site quality are discussed. In Section 4 the various ranking methodology used by AHP are discussed in detail. In Section 5 we come to an assertion on what ranking methodology could be adopted. Section 6 finishes the paper with conclusions.

2. Analytical Hierarchy Process

AHP [1, 9, 10] is a powerful methodology for quantifying and ranking the alternative solution by ranking the criterion on subjective scales and also by quantitative scale. The solutions of the complex problems are derived right from the goal of solving the problem. Once the goal is determined the process of identification of factors or criteria that affect the success of the goal can be determined. As the criteria’s are decided the problem is resolved by the construction of hierarchical model. The increased levels of hierarchy mean there is a increased level of complexity.

The AHP model is built in such a way that the goal is represented at the first level and the criteria that affect the goal at the next consecutive levels. The criteria can be further granularized into sub criteria and placed in the next level. The alternative solution tends to be the last level of hierarchy. To compare two criteria’s or alternatives pairwise comparison method proposed by L. Saaty (1980) was used to identify their relative importance. The below Figure 1 depicts the structure of AHP hierarchy.

The components of the hierarchical model are compared with each other by means of pairwise comparison method and they are graded according to the order of preference. The grading continues till the last level and the appropriate alternative is determined. The criteria’s and alternatives of the problem are compared with the help of comparison matrix. The availability of n criteria determines the construction of n x n matrix. Each criterion is compared with other criteria to identify its relative importance.
To quantify the comparison a scale named L.Saaty’s scale is used. Research says around 78 different scales can be used. The scale that holds successive scale value with a difference of

Table 1. Saaty’s Scale

<table>
<thead>
<tr>
<th>Defined Limits</th>
<th>Assigned Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equally Important</td>
<td>1</td>
</tr>
<tr>
<td>Weak Importance</td>
<td>3</td>
</tr>
<tr>
<td>Strong Importance</td>
<td>5</td>
</tr>
<tr>
<td>Demonstrated Importance</td>
<td>7</td>
</tr>
<tr>
<td>Absolute Importance</td>
<td>9</td>
</tr>
<tr>
<td>Intermediate Values</td>
<td>2, 4, 6, 8</td>
</tr>
</tbody>
</table>

one is widely adapted by all researchers. Generally the comparison is based on this set of values \{9, 8, 7, 6, 5, 4, 3, 2, 1, 0, 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9\}. On the subjective application of this Saaty’s scale on the comparison matrix, weightage of each criteria and
sub criteria’s can be identified and quantified. Comparison matrix is constructed and evaluated at each level of hierarchical model. The above specified Table - 1 Saaty’s scale is mostly followed by the researchers.

The mathematical representation of the comparison matrix makes the understandability of the matrix much easier. Suppose there are n criteria’s to be subjected to analysis, each criteria c<sub>i</sub> is compared with other set of criteria’s {c<sub>1</sub>, c<sub>2</sub>… c<sub>n</sub>}. A matrix is plotted against each criteria holding the order of preference of the criteria over the other criteria. It is analyzed that around n (n-1) comparison have to be made to identify the most preferred criteria. The Weightage adapted for the comparison is taken from the Table 1. A positive reciprocal matrix is constructed for the comparison.

![Figure 2. Comparison matrix of Criteria's](image)

The weightage of the criteria can be evaluated using the identification of Eigen Vector or Eigen Values derived basically either through sum of row values or product of row values. Subjective analysis of the criteria’s or alternative through comparison matrix tends to be less precise as it may be subjected due to human errors. To eradicate this discrepancy the Consistency Ratio (CR) of the matrix is identified and applied for reformation. When CR is lower than 1.0 means the comparison is consistent and when CR falls between 1.0 and 2.0 the criteria must be handled with care and if it exceeds 2.0 the comparison matrix must be recomputed till the consistency is achieved. The values of CR may differ based on the levels of hierarchy in the AHP model.

The basic flow of the problem analysis and process of determining the solution is represented as a sequence of steps.

i. Determine the goal to be achieved.
ii. Identify the set of criteria’s that are associated with the identified goal.
iii. Analyze the criteria’s involved and construct a hierarchical tree holding the goal or objective as a root and the criteria, sub criteria, alternative solution at the various levels of the hierarchical tree.
iv. The relative importance of criteria, sub criteria, alternative solutions are determined at various levels of the tree by the comparison matrix.
v. Pairwise comparison matrix at each level is constructed and a consistent Eigen Vector is calculated after n iterations.
vi. Based on the criteria and sub criteria’s the alternative solutions are evaluated and ranked as the same via Comparison matrix.

vii. The Consistency Ratio of the alternative is determined and the alternative solution for the problem is identified.
3. Application of AHP

Application of AHP has an unlimited utility on various domains. This study is basically on the application of AHP on selection of web based application, web based services and evaluation of web sites. Few applications of AHP over these areas are taken into this study.

3.1. Application of AHP for Web Based Software Selection

AHP has its basic application of ranking huge volume of data to be worked on certain set criteria. This nature of AHP can be applied on various selection processes like selection materials, selection of supplier, selection of software and so. Here this discussion is used to projects things about the means of selection of Software Architecture, selection of Business Plan Software and so.

Software architecture is mean to obtain a solution for most recurring problems. A common style of solution retrieval can be ascertained by the promotion of architecture design. Quishi Wang et al., [14] in their research work has considered around 6 software architecture styles. Based on the scope of the applicability of the architecture style it is further represented as 17 styles. The above set of architecture style is evaluated on the grounds of a certain defined set of criteria’s. Quality attributes to define and identify the correct architecture style was selected from both Functional and Non – Functional requirement. Around 16 criteria’s were subjected to the selection process. Fundamental Scale 1-9 scale of Saaty was used for the analysis. The positive reciprocal matrix was used for calculating the weight of the criteria. The weighted criteria will be multiplied with the weight of each style and finally will be summed up to get the highly desired architecture for the desired set of criteria.

The study by Marko Hell et al.,[12] was basically analyzed to identify the business planning software for the utility of the novice users. Business planning software that meets the following needs like uncertain business environment, globalization of business, quick planning to meet business requirement are prioritized and ranked based on the desired criteria. Five business planning software is subjected to study namely Business-in-a-Box Software, Plan Magic Business Software, Plan Ware Software, Plan2Biz Software and Capital Business Plan Software. These software’s are categorized and analyzed based on these set of criteria’s namely Research Tool, Forecasting Tools, Import & Export Option and Help & Support where each of these criteria’s hold 4 sub criteria’s. These sub criteria’s and criteria’s are evaluated by both Business Management students for subjective knowledge and Managers, Entrepreneur’s and Professionals for practical knowledge. Based on these factors the Business plan software is ranked. Saaty’s fundamental scale 1-9 is used here for the evaluation purpose. Sum of weight is used to determine the appropriate Business plan software.

3.2. Application of AHP to Determine Web Site Quality

Humera Khan et al.,[10] by the application of AHP and online web diagnostic tool have tried to evaluate Asian Airline web site quality. The detailed study using AHP has determined the Malaysian Airline to be the best. Four airline portals namely Air Asia, Malaysian Airline, Thai and Singapore Airlines were subjected to study. Around 30 trials were performed to evaluate the web sites. AHP model was subjected to decision making of these web sites by considering various factors like Load time page size, no. of items, response time, page speed, availability, broken links, response time, mark up validation, design optimization, page rank and traffic. Saaty’s scale 1-9 scale is used for the evaluation. Sum of Rows is the method adapted for website evaluation.

E-commerce websites are the important means of business associates to identify and adapt the customers to their business. For designing these websites the most powerful
methodology AHP is selected and applied. Experts identified six quality criteria’s to evaluate the websites for business needs. Six web sites are ranked on the following criteria’s namely search engine optimization, appearance & style of site, Information, website usability, customer service and warranty and return policy. Six international companies are evaluated by Kenan Tas et al., [11] and ranked by the application of these criteria’s by expert members.

Education through websites has received recent success over these decades. The prime success of E-learning websites is determined by a few factors. Many literature surveys performed by Mehrbakhsh Nilashi et al., [16] have helped them to categorize the factors affecting the E-learning websites into four major categories namely course details, integrate learning theories, learning satisfaction, relative website design.10 expert members were subjected for analysis by using the Expert Choice software. The Second level of analysis was performed with the help of 150 IT students. Both the analysis was conducted through questionnaire sessions. It could be noted that the study made the utility of AHP methodology, Expert Choice software and also the application of Fuzzy Logic for the evaluation of E-Learning websites.

Othman Ibrahim et al., [17] has extended his laborious work into the evaluation of Mobile Commerce Websites based on the preferences of customers and vendors. Two means of validation were subjected on these web sites. The criteria’s was evaluated on two means one by the expert’s evaluation and other by data captured from these web sites. AHP was subjected to the analysis by experts while for the data’s collected from the customer utility of web sites was subjected to be analyzed by using k – means clustering algorithm. 27 clusters were constructed from the data set received from the customers of the website. Three criteria’s was opted for expert analysis is Content Factors, Privacy and Security Factors and Design Factors. These factors were further decomposed into 50 sub criteria’s. Eigen vector based analysis was performed along with the evaluation of CR and CI. The combination of AHP and K-Means Clustering makes the process of ranking much more consistent.

Combination of AHP and Grey Clustering Theory has made the process of evaluating the websites for Bindu Madhuri & Ch Et [9] al.’s much easier. The methodology proposed here is to evaluate the web site based on the three prime areas namely Attribute Layer, Target Layer and Indicators Layer. Here the analysis is performed with 4 different criteria’s which are further decomposed into 14 sub criteria’s for further analysis. The AHP process uses Proportional scale 1-9. Later the factors are subjected to grey scale analysis using the following scale: “Very Satisfactory”, “Satisfactory”, “average”, “unsatisfactory”, “very Satisfactory”. By this mean they have identified and rated the website functionality.

4. Various Ranking Methodology Used In AHP

Basically the ranking up of alternatives for making a decision has a direct association between the criteria’s and sub criteria’s involved. The hierarchical structure generated will be subjected to Pairwise Comparison method to rank the alternatives to attain a specific goal. This pairwise comparison method utilizes the following methods and generates the priority weights of the alternatives involved. The methods which are generally used in collaboration with AHP are listed below.

- **Sum Method**

The Weightage of the alternatives available in the positive reciprocal matrix is obtained by calculating the Eigen Vector or Principal Vector. Here initially the values of the columns in the reciprocal matrix are summed up. Next the elements are divided by the summed value to obtain a normalized relative weight. To obtain the normalized Eigen Vector the normalized relative weight available in the row are summed up and divide by
the no of alternatives involved in the comparison. By this the relative weightage of the alternatives is obtained.

- **Product Method**

  The process of obtaining the Eigen Vector for the Positive Reciprocal matrix is much similar to that of the Sum Method. Initially every element in the row is subjected to multiplication and the $n^{th}$ root of the product is calculated, here $n$ is the no of alternatives. Next the $n^{th}$ root values are summed up. Every $n^{th}$ root of the product is divided by the sum of $n^{th}$ root values to obtain the relative weightage of the alternatives.

- **Eigen Vector Method**

  A positive reciprocal matrix is constructed which holds the values of preference, based on Saaty’s scale, for the items involved in pair wise comparison. Here the matrix is squared and normalized using sum method or product method. The Weightage of the alternatives are evaluated and compared iteratively to get a consistent Eigen vector. This generates a Normalized Eigen Vector called as Priority Vector. The consistency of the Eigen Vector is calculated using the Principal Eigen Value ($\lambda_{\text{MAX}}$). The Eigen Vector method increases the accuracy of prediction as more no of iterations are involved.

- **AHP Sort**

  Generally AHP is built on the platform of Pair wise comparison where there are more no of comparisons to be performed to identify and rank the best alternative. When there is large no of alternatives the pairwise comparison takes enormous time and this is simplified using the new alternative of AHP namely AHP Sort. Here the decision makers define a predefined set of classes. Each class falls between two preference levels high and low and the alternatives are fit into these classes. Next the alternatives are ranked within the classes by pairwise comparison method. Finally they are cross compared with the other classes and limiting levels. This method vastly reduces the effort and time required to rank the alternative.

- **AHP (Assigning Weights to the Decision Makers)**

  The process generally employed to analyze the rank of alternatives do not consider the order of priority of the decision makers. The general process is to consider every decision makers equally. Practically this does not support all the situations. Assigning weights to the decision makers improves the decision making process. Here it is noticed that the consistency ratio (CR) and Euclidean Distance (ED) is used to weigh the decision makers. This is later incorporated into the process of selecting the alternatives.

5. **Assertion**

  From the above study on the application of AHP on various web environments, it gives a clear mean of analysis that the multi criterion decision making methodology, AHP, can be subjected to efficient ranking of web sites, web applications and web portals. Increased level hierarchy means higher level of complexity in the problem but also it literates that these levels help to derive a precise decision making. The noted drawback of AHP is that there is a vast amount of comparison has to be made if there is more number of options. To add on there is a chance of bias nature in the judgment of the decision makers. These drawbacks have to be eradicated to provide an optimal solution. When AHP is deployed to work in collaboration with other methodology there is a positive divergence in the means of analysis. To be noted the usage of clustering methodology and assigning
weights to the decision maker will improve the decision making process. A hybrid methodology of combining any of these techniques will provide a varied set of solution.

6. Conclusion

This study has paved means to understand the various utilities of MCDM method, AHP, for decision making under various levels of criteria. Literature survey has confirmed its applicability on various applications like Software selection, Supplier selection, Web site evaluation, Web site selection, Banking, and so. Though this study has restricted its analysis on few works, we are able to ascertain the importance of AHP in Web environment. The scope of the study has claimed the direction of research towards the determination and ranking of quality attributes for building reliable web based applications. It also steers the research towards the combined utility of various decision making methodology like TOPSIS, VIKOR and so in collaboration with Clustering Algorithm.

References


Authors

M. Daya Kanimozhi Rani, received her ME degree in Software Engineering from Anna University, Chennai, 2008 and currently doing her research in Software Reliability and Software Testing. Currently working as an Asst. Professor in the department of Information Technology, Adhiyamaan College of Engineering, Hosur. Her research interests include Software Engineering, Data Mining, and Cloud Computing.

S. Sakthivel, received his ME degree in Computer Science and Engineering from Anna University, Chennai, 2004 and PhD from the Information and Communication Engineering from Anna University, Chennai, India, 2011 and now working as a Professor in the Department of Computer Science and Engineering, Sona College of Technology, Salem. His research interests include Image Processing, Network Security and Cloud Computing.