Analytic Hierarchy Process for Product Selection

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Abstract

This paper intends to implement the decision supporting tool which uses the AHP method. The decision support system is flexible decision supporting tool in which we can add any case with any criterias and any alternatives. Firstly, the criterias must be considered and alternatives of any problems must be entered into this system. And then the best alternative among a set of alternatives will be chosen from this system using Multi Criteria Decision Making (MCDM). Finally, any problem with multi-criteria will be easily solved by this system. In product development problems, a decision maker is to select the best alternative among a set of alternatives with respect to the selection criteria of case which user adds. The system is implemented by using visual studio 2017 and Microsoft SQL server 2017 that is used for the data storage.

Keywords: Decision Supporting; AHP method; Criteria; Alternative

1. Introduction

To buy something and to choose something when making a decision, a decision maker has to think a lot. It is also important to anticipate all the possible consequences and make the right decisions. When making decisions, it needed to think about the criterias such as the product, quality, price, etc. No needs to consider the emotion.

So, decision making is the heart of management. The decision- making process may involve three basic stages: intelligence, decision, and choice. In the intelligence stage, data are gathered and analyzed. In the decision stage, the problem is studied, and solutions are generated and tested. In the choice state, a solution is selected.

The Analytic Hierarchy Process (AHP) is a decision support method designed to select the best from a number of alternatives evaluated with respect to several criteria. The general principle of AHP methodology involves the pair-wise comparison of various alternatives of which the best decision to be chosen.

1.1. Related Work

The Analytic Hierarchy Process (AHP) is a structured technique for dealing with complex decisions. The AHP provides a comprehensive and rational framework for structuring a problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. It is used throughout the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education and so on [8].

The following applications illustrate the wide breath of areas to which AHP has been applied. Choice decisions involve the selection of one alternative from a set of alternatives under consideration. Typical choice problems include product selection, vendor selection, organizational structure decisions and policy decisions.

2. What is Analytic Hierarchy Process?

AHP is developed by Thomas Saaty. AHP provides a proven, effective means to deal with complex decision making and can assist with identifying and weighting selection criteria, analyzing the data collected for the criteria and expediting the decision-making process [7].

AHP helps capture both subjective and objective evaluation measures, providing a useful mechanism for checking the consistency of the evaluation measures and alternatives suggested by the team thus reducing bias in decision making.

AHP should be used when making complex decisions involving multiple criteria. The top level is develop a hierarchical structure with a goal, the attributes/ criteria at the second level and alternatives at the third level. The input can be obtained from actual measurement such as price, quality, etc, or from subjective opinion such as satisfaction feelings and preference. AHP allows some small inconsistency in judgment because human is not always consistent. The ratio scales are derived from the principal Eigen vectors and the consistency index is derived from the principal Eigen value. The aim of the analytic hierarchy process is not to provide just one unique, correct decision [5].

3. Fundamental Scale for Pairwise Comparisons

Table 1 describes basic comparison scale [1]. The determination will be based on the judgment / experience of the decision maker.

1-A has the equal importance as B with respect to decision maker.

3-A has moderate importance than B with respect to decision maker.

Table 1. Scale for pairwise comparisons

Intensity of Importance	Definition
1	Equal importance
3	Moderate importance
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values between the two adjacent judgments

5-A has essential or strong importance than B with respect to decision maker.
7-A has very strong importance than B with respect to decision maker.
9-A has extreme importance B with respect to decision maker.
1/3-B has moderate importance than A with respect to decision maker.
1/5-B has essential or strong importance than A with respect to decision maker.
1/7-B has very strong importance than A with respect to decision maker.
1/9-B has extreme A with respect to decision maker.
2,4,6,8 - Intermediate numbers are used for finer resolution.
There, A is the former one and B is the latter.

Table 2. Number of comparison

Number of things	1	2	3	4	5	6	7	n
Number of comparisons	0	1	3	6	10	15	21	$\frac{n(n-1)}{2}$

Table 2 shows the number of the comparison when using AHP method [3].

3.1. Elements Pairwise Comparisons

In using AHP method, comparing criteria must be firstly made as shown in Figure 1.

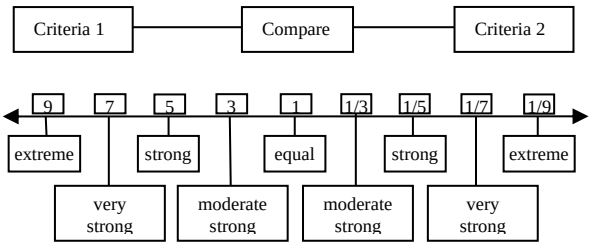

Figure 1. Compare two criterias

The comparison of strength is always an activity appearing in the row on the left against an activity appearing in the column on top. The following table is pairwise comparison matrix with four rows and four columns (a 4 × 4 matrix).

Table 3. Pairwise comparison matrix

Criteria	A	B	C	D
A	1	3	5	7
B	1/3	1	9	5
C	1/5	1/9	1	7
D	1/7	1/5	1/7	1

The diagonal elements of the matrix are always 1 and only need to fill up the upper triangular matrix. The user must fill up the upper triangular matrix by using Table 1, comparison scale 1 to 9 as described in section 4. To fill lower triangular matrix, the reciprocal values of the upper diagonal must be used. If a_{ij} is the element of row i column j of the matrix, then the lower diagonal is filled using this formula $a_{ij}=\frac{1}{a_{ji}}$. The entire elements in the comparison matrix are positive or $a_{ij}>0$.

4. Steps in AHP Methodology

Three steps are used to solve a problem with the AHP methodology [2]. In the first step, the user must build a decision "hierarchy" by breaking the general problem into individual criteria (user/ analyst modeling phrase). The user can gather relational data for the decision criteria and alternatives and encode using the AHP relational scale (user / analyst pairwise compa-rison input).

In the second step, the user can estimate the relative priorities (weights) of the decision criteria and alternatives. In the third step, the user can perform a composition of priorities for the criteria which gives the rank of the alternatives (usually lowest level of hierarchy) relative to the top-most objective.

The AHP steps described above can be best understood through an example application. The decision problem is to determine the best contractor for the procurement of a particular system. The user must assume that the associated cost proposals were judged to be equal. The non-quantitative considerations are safety, performance and reliability / maintainability.

The AHP is a method for formalizing decision making where there are a limited number of choices but each has a number of attributes and it is difficult to formalize some of those attributes. The AHP has been used in a large number of applications to provide some structure on a decision making process [4].

4.1. AHP Process Step 1

Given i = 1,…,n criteria, determine their relative weights, W_i with respect to the objective.

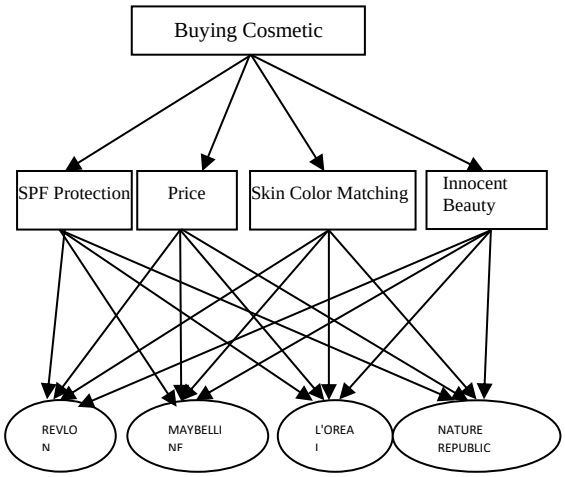

Figure 2. MCDM problem in AHP

This paper intends to develop the alternative product selection during product development process is an iterative process and to select the best cosmetic. Figure 2 gives a typical example of buying cosmetic decision whether Revlon, Maybelline, L'oreal and Nature Republic problem. Suppose that there are four cosmetic brands: Revlon, Maybelline, L'oreal and Nature Republic. We want to come up with priorities among the concepts with respect to four factors: SPF Protection, Price, Skin Color Matching and Innocent Beauty.

Table 4. Criteria metric

Best choices buying cosmetic	SPF Protection	Price	Skin Color Matching	Innocent Beauty	Priority(W_i)
SPF Protection	1	5	5	9	0.60
Price	1/5	1	7	7	0.27
Skin Color Matching	1/5	1/7	1	5	0.09
Innocent Beauty	1/9	1/7	1/5	1	0.04

Table 4 illustrates whether Revlon, L'oreal, Maybelline and Nature Republic problem (four alternatives compare four criteria) can be computed as normalized geometric means (M) of the rows, which are very close to the eigenvector corresponding to the largest eigen value of the matrix according to the use of table 3.

The geometric means of 'SPF Protection- M1', 'Price- M2', ' Skin Color Matching- M3', ' Innocent Beauty- M4' are computed as:

$$M1 = \sqrt[4]{(1 \times 5 \times 5 \times 9)} = 3.87$$

$$M2 = \sqrt[4]{((\tfrac{1}{5}) \times 1 \times 7 \times 7)} = 1.77$$

$$M3 = \sqrt[4]{((\tfrac{1}{5}) \times (\tfrac{1}{7}) \times 1 \times 5)} = 0.61$$

$$M4 = \sqrt[4]{((\tfrac{1}{9}) \times (\tfrac{1}{7}) \times (\tfrac{1}{5}) \times 1)} = 0.24$$

So, the relative weight (priority P1) of the criterion 'SPF Protection' is :

$$Pi = \frac{M_i}{M_1+M_2+\cdots+M_i}$$

$$P1 = \frac{M_1}{M_1+M_2+M_3+M_4} = \frac{3.87}{3.87+1.77+0.61+0.24} = 0.60$$

So, the relative's weight (priority P_2) of the criterion 'Price' is :

$$P_2 = \frac{M_2}{M_1+M_2+M_3+M_4} = \frac{1.77}{3.87+1.77+0.61+0.24} = 0.27$$

So, the relative weight (priority P_3) of the criterion 'Skin Color Matching' is :

$$P_3 = \frac{M_3}{M_1+M_2+M_3+M_4} = \frac{0.61}{3.87+1.77+0.61+0.24} = 0.09$$

So, the relative weight (priority P_4) of the criterion 'Innocent Beauty' is :

$$P_4 = \frac{M_4}{M_1+M_2+M_3+M_4} = \frac{0.24}{3.87+1.77+0.61+0.24} = 0.04$$

4.2. AHP Process Step 2

For each criteria i, compare the j=1,…,m alternatives and determine their weights W_{ij} with respect to criteria i; and based on an expert knowledge the relative weight of criteria can be described on the overall objective. The corresponding consistent pairwise comparison matrices based on the above information are: we compare the alternatives on each of the criteria as shown in Table 5,6,7,8 by using as described in section 4.

Table 5. Alternatives metric respect to SPF Protection

SPF Protection	Revlon	Maybelline	L'oreal	Nature Republic	Priority(Wij)
Revlon	1	1/3	3	1/5	0.14
Maybelline	3	1	5	1/7	0.25
L'oreal	1/3	1/5	1	1	0.11
Nature Republic	5	7	1	1	0.50

Table 6. Alternatives metric respect to Price

Price	Revlon	Maybelline	L'oreal	Nature Republic	Priority(Wij)
Revlon	1	5	9	3	0.59
Maybelline	1/5	1	9	3	0.20
L'oreal	1/9	1/3	1	1/7	0.05
Nature Republic	1/3	1/3	7	1	0.16

Table 7. Alternatives metric respect to Skin Color Matching

Skin Color Matching	Revlon	Maybelline	L'oreal	Nature Republic	Priority(Wij)
Revlon	1	5	5	1	0.42
Maybelline	1/5	1	1	1/5	0.08
L'oreal	1/5	1	1	1/5	0.08
Nature Republic	1	5	5	1	0.42

Table 8. Alternatives metric respect to Innocent Beauty

Innocent Beauty	Revlon	Maybelline	L'oreal	Nature Republic	Priority(Wij)
Revlon	1	3	1	1/3	0.20
Maybelline	1/3	1	1/3	1/5	0.08
L'oreal	1	3	1	1/5	0.20
Nature Republic	3	5	3	1	0.52

4.3. AHP Process Step 3

Determine the final alternative weights Wj with respect to all the criteria by Wj = W1jW1 + W2jW2 + ... + Wnj Wn. The most preferred alternative is the one having the largest Wj. The following results can be obtained [6].

$$\begin{bmatrix} \text{Revlon} \\ \text{Maybelline} \\ \text{L}\prime\text{oreal} \\ \text{Nature Republic} \end{bmatrix} = \begin{bmatrix} 0.14 \\ 0.25 \\ 0.11 \\ 0.50 \end{bmatrix} \times 0.60 + \begin{bmatrix} 0.59 \\ 0.20 \\ 0.05 \\ 0.16 \end{bmatrix} \times 0.27 + \begin{bmatrix} 0.42 \\ 0.08 \\ 0.08 \\ 0.42 \end{bmatrix} \times 0.09 + \begin{bmatrix} 0.20 \\ 0.08 \\ 0.20 \\ 0.52 \end{bmatrix} \times 0.04$$

$$\begin{bmatrix} \text{Revlon} \\ \text{Maybelline} \\ \text{L}\prime\text{oreal} \\ \text{Nature Republic} \end{bmatrix} = \begin{bmatrix} 0.084 \\ 0.150 \\ 0.066 \\ 0.300 \end{bmatrix} + \begin{bmatrix} 0.159 \\ 0.054 \\ 0.014 \\ 0.043 \end{bmatrix} + \begin{bmatrix} 0.038 \\ 0.007 \\ 0.007 \\ 0.038 \end{bmatrix} + \begin{bmatrix} 0.008 \\ 0.003 \\ 0.008 \\ 0.021 \end{bmatrix}$$

$$\begin{bmatrix} \text{Revlon} \\ \text{Maybelline} \\ \text{L}\prime\text{oreal} \\ \text{Nature Republic} \end{bmatrix} = \begin{bmatrix} 0.289 \\ 0.214 \\ 0.095 \\ 0.402 \end{bmatrix}$$

Using the above information we can calculate the priorities. It is obtained that Nature Republic cosmetic foundation has the highest priority followed by Revlon and Maybelline and L'oreal. So, Nature Republic cosmetic foundation should be selected as the best alternative. For other users, the more different the value of comparison scale, the more different the result of the alternative.

5. Implementation of the system

For product selection problem, suppose we are having four concepts: (Revlon, Maybelline, L'oreal and Nature Republic) and we want to come up with priorities among the products with respects to four factors :(SPF protection, Price, Skin Color Matching and Innocent beauty.

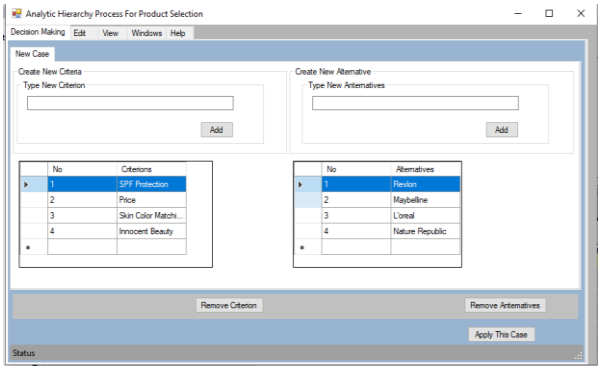

Figure 3. Create criterias and alternatives form

After defining the criteria and alternatives, the user must choose the comparison scale of criteria to decide the decision of the applicant. A relational scale of real numbers from 1 to 9 is used to systematically assign preference when comparing the attitudes. The diagonal elements of the matrix are always 1 and only need to fill up the upper triangular matrix. The system fills up the upper triangular matrix from the user's choice scale.

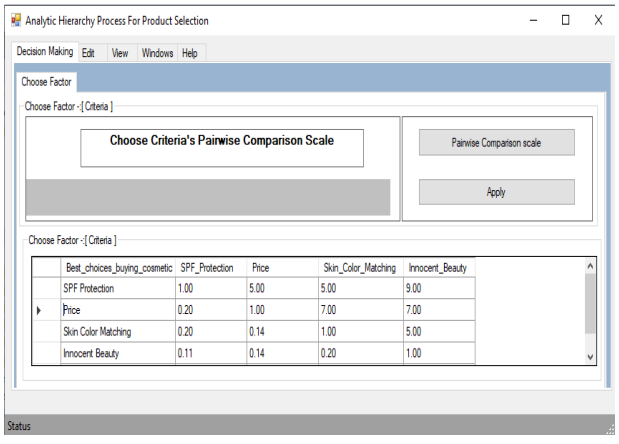

Figure 4. Criteria scales form

After that system fills up the diagonal elements and the reciprocal value for lower triangular matrix. After filling the criteria comparison, user need to fill the pairwise comparison scale of alternatives with respect with each criteria. This system is processed until the last choice of the factor. And then the system calculates the

priorities of alternative respect of each criterion. The system will also display the ranking the alternatives and the most preferred largest alternative.

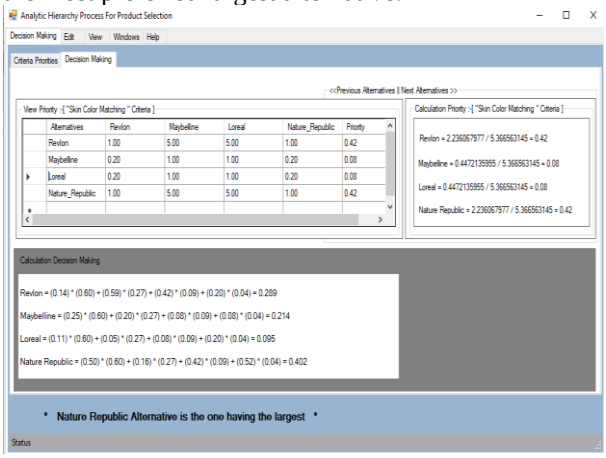

Figure 5. Alternatives priorities and decision form

6. Conclusion

The user can see how easy and powerful the technique is when used to monitor build quality. Furthermore, the user can use the technique in other areas. This is used for competitive analysis to assess the overall quality of the system relative to major competing systems. As the software development environment continues to mature, techniques like the analytic hierarchy process will become increasingly important components of user's software engineering skill set.

This system presents the framework of product (alternative) selection analytic hierarchy process (AHP). The AHP function is employed in performing "pairwise comparison" between competing alternatives and a "reference" on each of the criteria. The comparisons are also used to obtain the relative importance of criteria with respect to the overall objective.

6.1. Limitation And Further Extension

This paper intends to use for any domain in multi criteria decision making (MCDM) problems and it is suggested to use scale 1 to 9. The use of references is necessary due to the difficulty in consistently comparing concepts to one another. The system can determine sub-criteria but it is implemented criteria level 1 [9].

Making decisions at this stage becomes very difficult due to imprecise and uncertain product requirements. This system will extend the product concept selection that integrates the other methods (i.e. Fuzzy-set, Bayesian and so on) related with the analytic hierarchy process (AHP). Also, a further investigation needs to be done to see whether or not using different methods will give the same result as the original AHP does. The analytic hierarchy process (AHP) includes both the rating and comparison methods. In this paper, we made the best choice using comparison method.

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