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ENRICHING PROCESS OF ICE-CREAM RECOMMENDATION USING COMBINATORIAL RANKING OF AHP AND MONTE CARLO AHP

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ABSTRACT

Diabetes disease is the curse to human life and it is one of the worst nightmares of everyone's life. The patient needs to keep count on the sugar level each time when he/she consumes food, sugar free ice-creams are not spared from this and are favorite dessert of every one. Very less systems exist which can guide diabetic and non-diabetic persons about the contents of sugar free ice-creams. Many methodologies exist to recommend the ice-creams which are based on some traditional techniques like collaborative filtering and content recommendations. But most of the time their results are not up to the mark and they may wrongly recommend the ice-cream which may adversely disturb blood sugar level of the person. So, proposed methods put forward an idea of recommending sugar free ice-creams based on its ingredients like carbohydrates, fats, proteins and dietary fibers, which play a vital role in affecting blood glucose levels of diabetics and non-diabetics. The proposed system uses advanced techniques like Analytic Hierarchy Process (AHP) and Monte Carlo AHP (MCAHP) which can be powered with Goal programming and classification process. It is observed that rankings obtained from these two techniques are same for ice creams under consideration. This paper mainly focuses on the techniques of AHP and MCAHP for the ranking of considered sugar free ice-creams.
Keywords: *Analytic Hierarchy Process (AHP), Sugar Free, Ice-creams, Monte Carlo AHP (MCAHP), Ranking etc.*

1. INTRODUCTION

The first part of the paper presents how traditional AHP can be formulated for ranking and recommending the sugar free ice-cream or a combination of those sugar free products to diabetic as well as non-diabetic persons. In the later part, Monte Carlo AHP is used to apply to same multi-criteria problem. Thus, the paper culminates development and a comparative study between traditional Analytic Hierarchy Process (AHP) and Monte Carlo Analytic Hierarchy Process (MCAHP). The paper reveals the obtained results to encourage selection process in multi-criteria decision problem (MCDP).

2. ANALYTIC HIERARCHY PROCESS (AHP)

2.1 Introduction to Analytic Hierarchy Process (AHP)

Decisions made using intelligence, creativity and wisdom tend to satisfy the needs and desires. Analytic Hierarchy Process (AHP) is one of the modern popular multi-criteria analytical techniques used to get best suitable solution for the problem or goal under consideration from available alternatives considering multiple impactful criteria and choices. AHP is used to get out of the complex decisions which are merely impossible to overcome using standard methods [1]. This modern method of AHP is developed by Thomas Saaty in order to efficiently optimize decision making from qualitative, quantitative, conflicting factors under consideration. It helps in deriving or selecting the solution or alternative that proves to be best to satisfy the desired goal among available different

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alternatives considering multiple criteria (such as costs, risks involved, benefits derived, losses from decision made) [2]. Recently, AHP is used to rank state IT policy documents in India by considering a particular perspective [3]. In AHP, the criteria or factors considered to affect decision making have competing priorities and rankings against each other. Thomas Saaty designed the technique of AHP to evaluate decision made from available choices by prioritizing the measures (criteria). Characteristics of Analytic Hierarchy Process (AHP) make it efficient to use in solving multi-criteria decision problems. AHP can be efficiently used in operation research, engineering, design for six sigma (DFSS) situations. The research elaborates the novel approach for recommending the ice-creams to the patients who are suffering from the diabetes disease [4]. For detection of true or false condition i.e. whether ice-cream should be recommended to the patient or not, four important ingredients are considered which are normally observed in the ice-cream viz. sugar, cholesterol, dietary fiber and protein. For understanding purpose a clear graph is given by the author who precisely shows the percentage of each of these ingredients in the ice-cream. The experimental evaluation is done through MATALAB simulation tool.

Another good use of the AHP is in vehicle routing system [5]. Presents a study which makes use of AHP and fuzzy logic remote guidance system on vehicle. The said system is also synonym as Dynamic Route Guidance System (DRGS). It observes the traffic pattern and the traffic information to accomplish the task. The main advantage of the AHP-Fuzzy combination is that it greatly clarifies the problem statement of the decision strategy and the multiple criterions. The main motto behind the use of fuzzy is that it effectively deals with the uncertainty of the input data and solves the situation.

Today's industry highly suffers the problem of project complexity, day by day complexity of project is increasing and it highly requires the skilled person to manage the huge projects [6]. Many systems were proposed to get out of these scenarios. AHP is one of the best techniques to solve the given problem. AHP can be used to get best suitable solution from a range of alternatives and situations that involve subjective judgments, multiple decision making. It also deals efficiently with finite objective as well as subjective attributes [7].AHP represents the problem (decision situation) along with its attributes into hierarchy of distinct levels as level 0, level 1, and level 2 and so on and sub-levels as required. These levels consist of problem definition, criteria, and options available. AHP can be viewed to have 4 steps. First step clearly defines the goal or objective. Second step presents the criteria (factors) that influence the decision made. These criteria can be further arranged into levels and sublevels. Third step involves making paired comparisons of all the criteria with each other. AHP uses weighted matrix algebra to calculate Eigen values, Eigen vectors, consistency measures i.e. consistency index (CI), consistency ratio (CR). The fourth and last step is to rank the alternatives available to reach the final choice. AHP is mainly based on the use of Saaty scale of relative importance.

2.2 SAATY Scale of Relative Importance

AHP Scale of Importance for comparison pair (aij)	Numeric Rating	Reciprocal (decimal)
Extreme Importance	9	1/9 (0.111)
Very strong to extremely	8	1/8 (0.125)
Very strong Importance	7	1/7 (0.143)
Strongly to to very strong	6	1/6(0.167)
Strong Importance	5	1/5(0.200)
Moderately to Strong	4	1/4(0.250)
Moderate Importance	3	1/3(0.333)
Equally to Moderately	2	1/2(0.500)
Equal Importance	1	1 (1.000)

Fig 1: Saaty scale for factor ranking

Figure 1 describes the different factor ranking based on Saaty scale of relative importance. On the basis of respective importance of the entities in AHP and Saaty scale, the measures (criteria) are ranked against each other. AHP allows calculating consistent weights and evaluating composite performance score of alternatives to get the rank of considered alternatives. Rank depends on performance score. Higher is rank if higher is the performance. Consider two items 'i' and 'j'. Comparing 'i' and 'j' i.e. 'aij' would range from values 9(max) to 1/9(0.111).

(Item 'i') 9-8-7-6-5-4-3-2-1-2-3-4-5-6-7-8-9 (Item 'j')

If item 'i' is strongly important than that of 'j', we have 'aij'=5 i.e. (1/aij)=aji=1/5=0.2.

2.3 Priority and Ranking Using Weighted Comparison Matrices

AHP ensures comparisons between all possible pairs of criteria using weighted matrix algebra and

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constructs comparison matrices. The comparison matrices represent importance of criteria with respect to each other. Weights of criteria are inputs to matrix to calculate Eigen values and Eigen vectors to compute consistency measures. However, outputs obtained by matrix operations may be inconsistent. Consider three items say A, B and C. Let item A be preferable and important than item B. whereas, item B is important than item C. This implies that, item A must be important and preferable than item C, the transitive property. If this does not hold good, comparisons made are inconsistent.

2.4 Mathematical Model for AHP

$$C_s = \sum mat_i \qquad (1)$$

Where, c_s represents sum of elements in each column,
mat stands for weighted matrix,
'i' is number of rows.
.

$$d(mat) = \sum \frac{mat_{[i,j]}}{Cs} \qquad (2)$$

Where, $d(mat)$ is division matrix,
$mat_{[i,j]}$ represents each matrix element.

$$E_{vector} = \sum d_j \qquad (3)$$

Where, E_{vector} is the matrix of Eigen vector,
'j' is column number.

$$E_{value}(\lambda_{\max}) = \sum \left(C_{s(i)} * E_{vector(i)} \right) \qquad (4)$$

Where, $E_{value}(\lambda_{\max})$ stands for Eigen value proposed methodology.

2.5 Pseudo Code for AHP

The pseudo code for AHP is designed as in the below figure 2[8]:

```
Step 1: Calculate column sum of weighted values as CS1, CS2... CSn where 'n'
        is the number of elements.
Step 2: Divide each weight in column by its column sum
        i.e. divide every weighted value in nth column by CSn and store as tempn
        to get n*n temp values
Step 3: Calculate normalised Principal Eigen Vector matrix (Priority Vector
        Matrix)
        1/n * [temp1+temp2+...+temp n]
Step 4: Calculate Eigen value i.e. λmax which is a single value
        for i=1 to n
            do addition of
            (CSi * value of Principal Eigen Vector from ith row of Eigen Vector
            matrix)
Step 5: Calculate Consistency Index (C.I.)
        C.I. = (λmax-n) / (n-1)
Step 6: Random Consistency Index (RI)
        if n=4 RI=0.9
Step 7: Calculate Consistency Ratio (CR)
        CR= CI/RI where CR<=0.1
          = CI/0.9
```

Fig 2: Pseudo code for AHP

3. APPLYING AHP FOR SUGAR FREE ICE-CREAMS

This paper deliberates three different sugar free ice-creams viz. Breyers Sugar Free Vanilla, Butterscotch Ripple and Blue Bunny and four ingredients of sugar free ice-creams as multiple criteria. Carbohydrate content of the sugar free ice-cream is the most important and impactful criteria on person's blood sugar level, which is followed by fats. Proteins and dietary fibers present in sugar free ice-creams have very less impact as compared to carbohydrates and fats. Analytic Hierarchy Process is used to get the best suitable sugar free ice-cream or combination of sugar free ice-creams, based on nutritional information, to recommend for diabetics and non-diabetics. Patient's details are not considered as criterion, to make analysis of the ice-creams easier.

The following table 3.1 lists out the nutritional values of the ice-creams considered as alternatives.

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Table 3.1: Criteria And Alternatives For Recommending Sugar Free Ice-Cream(S)

Attributes (in milligrams)	Breyers Vanilla	Butterscotch Ripple	Blue Bunny
Carbohydrates	13	16	15.086
Fats	4	6	4.526
Proteins	2	1	3.017
Dietary Fibers	4	0	2.011

Accordingly, third step is to have paired comparisons of all the criteria with each other and the ice-cream alternatives. For every weighted matrix, normalized Principal Eigen vector (Priority vector) is computed. For Eigen vector, every element in matrix is divided by sum of all elements in its column followed by adding resultant elements in rows. From the obtained results, Principal Eigen value (λ_{max}) is computed. Obtained Eigen value is used to get Consistency Index (C.I.). C.I. is used to compute Consistency Ratio (C.R.). Hierarchical structure of levels consisting of criteria and alternatives in analytic hierarchy process is given in figure 3 as below:

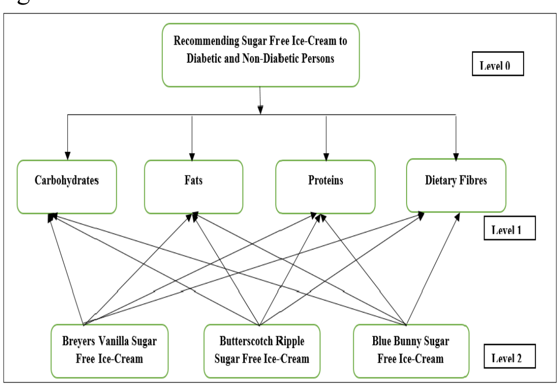

Fig.3: Hierarchical structure of proposed AHP model

Along with the expert advice, the scale of relative importance mentioned in section 2.2 and by considering compositions of sugar free ice- creams to be ranked, the following tables 3.2 to 3.6 represent relative weights assigned to criteria and alternatives considered. Following are the paired comparisons for each criteria and alternatives for every individual criteria separately.

Table 3.2: AHP For Considered Sugar Free Ice-Creams (Alternatives)

Criteria Preferences	Carbohydrate -s	Fats	Prot eins	Dietary Fibres
Carbohydrates	1	3	7	9
Fats	1/3	1	5	7
Proteins	1/7	1/5	1	3
Dietary Fibres	1/9	1/7	1/3	1

CI: 0.0549 CR: 0.0617 λ: 4.1648

Table 3.3: AHP For Carbohydrates

	Breyers Vanilla	Butterscotch Ripple	Blue Bunny
Breyers Vanilla	1	5	3
Butterscotch Ripple	1/5	1	¼
Blue Bunny	1/3	4	1

CI: 0.0428 CR: 0.0824 λ: 3.085

Table 3.4: AHP For Fats

	Breyers Vanilla	Butterscotch Ripple	Blue Bunny
Breyers Vanilla	1	7	3
Butterscotch Ripple	1/7	1	¼
Blue Bunny	1/3	4	1

CI: 0.0162 CR: 0.0311 λ: 3.0323

Table 3.5: AHP For Proteins

	Breyers Vanilla	Butterscotch Ripple	Blue Bunny
Breyers Vanilla	1	2	¼
Butterscotch Ripple	½	1	1/5
Blue Bunny	4	5	1

CI: 0.0120 CR: 0.0232 λ: 3.0241

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Table 3.6: AHP For Dietary Fibers

	Breyers Vanilla	Butterscotch Ripple	Blue Bunny
Breyers Vanilla	1	½	3
Butterscotch Ripple	2	1	3
Blue Bunny	1/3	1/3	1

CI: 0.0266 CR: 0.0511 λ: 3.0532

4. RESULTS OBTAINED AND ANALYSIS

Analytic Hierarchy Process model can be effectively used to recommend the sugar free ice-creams to diabetics as well as non-diabetic persons. AHP ranks the alternatives and criteria (i.e. sugar free ice-creams considered and their nutritional components). On the basis of Saaty scale and weighted matrix computations, the following results are obtained.

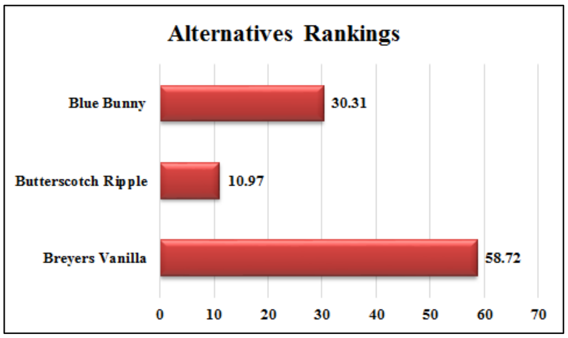

Fig.4: Ranking Of Alternatives

Fig.4 shows the rankings obtained from AHP model. Since, Breyers Vanilla has less carb content than others, it is preferred and recommended the most, and hence its rank is obtained as 58.72. This is followed by Blue Bunny sugar free ice-cream with rank of 30.31 i.e. the second most recommended sugar free product. Sugar-free Butterscotch Ripple is the highest to contain carbohydrates and hence AHP ranks it as 10.97 to be least preferred among those sugar free products.

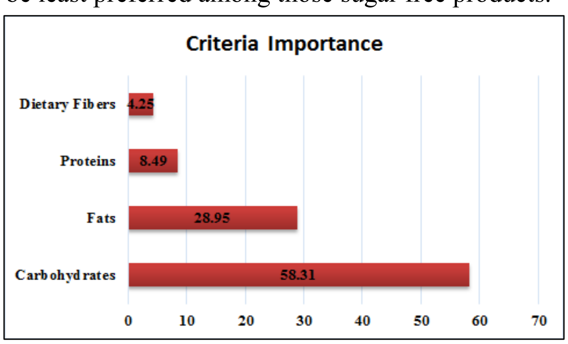

Fig5:AHP Ranking Of Criteria

Fig.5 reveals the importance of multiple criteria considered in AHP model. It is clear that recommendation of sugar free ice-creams mainly depends on carbohydrates content of the products. Carbs play a vital role in affecting persons' blood sugar level and hence the most important criteria. AHP ranked carbohydrates as 58.31 to be most important in all criteria, followed by fats with rank of 28.95, proteins to have 8.49 with dietary fibers having least impact on persons' blood glucose level and hence, AHP method ranked dietary fibers to just 4.25 .

AHP can be used to evaluate the benefit/cost ratio so as to decide the benefits of alternatives chosen on the basis of cost.

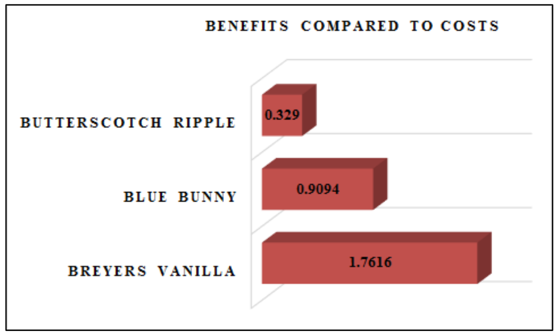

Fig. 6: Benefits-Cost Analysis

Fig.6 depicts the benefit-cost analysis obtained using AHP for sugar free ice-creams.

5. MONTE CARLO ANALYTIC HIERARCHY PROCESS

5.1 Introduction to Monte Carlo AHP

Traditional AHP lacks of using probability distribution in ranking the alternatives. Rosenbloom(1997) suggested to use the values for paired comparisons a(j,i)=1/a(i,j) and a(i,i)=1 by using Saaty's scale of importance, as random variables. Monte Carlo AHP (MCAHP) uses probability distributions to convert value of every paired comparison a (i, j) to a discrete random variable by replicating ranges for the given values for 'n' times [9]. Using traditional AHP, one can make judgements and get decisions using single numeric preferences by making pair wise comparisons of all the alternatives and criteria in AHP. The rankings of alternatives obtained can't be tested against the statistical significance and variations (Paulson & Zahir 1995, Rosenbloom 1996, Scott 2002). To overcome the limitations of traditional AHP, MCAHP incorporates probabilistic distributions to focus on uncertainty in derived judgements. Thus, MCAHP incorporates analysis

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of rankings. It can efficiently deal with managerial (soft) aspects of multi-dimensional problems. MCAHP's effective dealings with managerial aspects lead to have:

i. More clear understanding of the context of problem.
ii. Clear structure of the problem.
iii. Enhanced results.
iv. Generation of new insights in results obtained.

To figure out the quality of the dental service, research [10] presents an AHP-Monte Carlo AHP (MCAHP) based approach for detecting the quality of dental service. Here MCAHP is used for analyzing and prioritizing the attributes from the huge set of attributes. For showing the experimental evaluation the system is compared with the real world dental clinic. After comparison it had been observed that the system effectively finds the attributes having high quality. Paper [11] also presents the effective use of Monte Carlo AHP to find the associated sampling methods.

5.2 Flowchart of Monte Carlo AHP

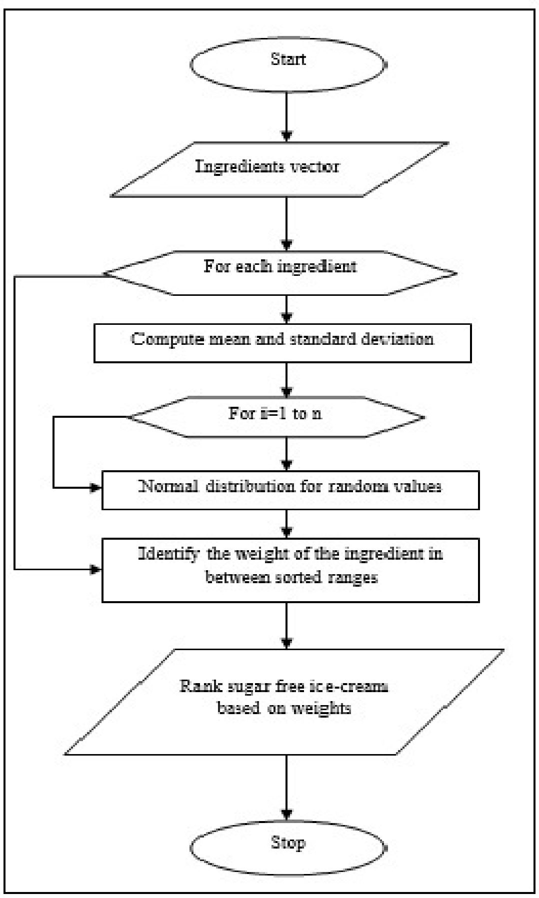

Fig 6: Flow Chart Depicting Steps In Monte Carlo AHP For 'N' Number Of Iterations

5.3 Mathematical Model of MCAHP

$$\mu = \left(\sum_{i=1}^{n} \left(Ch_i / F_i / P_i / DF_i \right) \right) / n \qquad (1)$$

Where, μ = mean for carbohydrates, fats, proteins and dietary fibers,

n = number of sugar free ice-creams,

Ch_i = value of carbohydrate content for ith sugar free ice-cream,

F_i = value of fat content in ith sugar free ice-cream,

P_i = protein content of ith ice-cream,

DF_i = dietary fiber content in ith sugar free ice-cream.

$$\sigma = \sqrt{\left[\sum_{i=1}^{n} \left(\mu - Ch_i / F_i / P_i / DF_i \right)^2 / n \right]} \qquad (2)$$

Where, σ =standard deviation for carbohydrates, fats, proteins, dietary fibers.

$$f(x \mid \mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{(x-\mu)^2}{2\sigma^2}} \qquad (3)$$

Where, x = random possible value of the nutrition factors in between their respective minimum and maximum limits.

6. APPLYING MONTE CARLO AHP FOR SUGAR FREE ICE-CREAMS

Selecting a single nutritional factor at any given instance and then arrange them in ascending order. Then, for every sugar free ice-cream two ranges have been set within past and current values. Starting from zero and ends at last ice-cream that is sorted in ascending order. The weight of their respective possibilities is being identified and counted and then based on this weight, the final sugar free products are ranked.

7. RESULTS OBTAINED

Table 7.1: Results of AHP and MCAHP

Traditional AHP Simulation Results (based on benefit-cost)	Monte Carlo AHP Simulation Results (based on probability weights)
Breyers Vanilla (1.7616)	Breyers Vanilla (56)
Blue Bunny (0.9094)	Blue Bunny (47)
Butterscotch Ripple (0.3290)	Butterscotch Ripple (0)

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Table 7.1 represents ranking of considered sugar free ice- creams and they are ranked on the basis of their weights obtained for methodologies under consideration. The ice- cream that has more priority is ranked higher followed by those that are having less priorities.

The above table depicts the fact that both AHP and Monte Carlo AHP yield the same result for different ice-creams. AHP uses the benefit cost as the major constraint to measure the ranking of the ice-creams. On the other hand Monte Carlo AHP uses the probability weights to measure the ranking.

Above obtained results clearly indicate that the ranking parameters of traditional AHP are having a minute difference which eventually makes tough to take decisions about ranking. Whereas, Monte Carlo AHP ranking parameters are clear and distinct which help us to take better ranking decisions for the sugar free ice-creams.

8. CONCLUSION

The proposed method of recommendation for ice-creams to the diabetic patients clearly provides best result due to successful incorporation of the AHP for the given criterions. Whereas the proposed system generates distribution of the ingredient values is been calculated successful random probabilities through which normal using Gaussian function.

Due to usage of the combinatorial values of the both AHP and Monte Carlo AHP systems, it leads to decrease in the possibilities of the improper recommendation to its low level and increase the better chances to the recommendation seekers.

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