



# Applying Fuzzy Analytic Hierarchy Process to Evaluate the Motive of Healthcare Towards Patients

Research Article\*

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**Abstract:** Humans and other living organisms are infected by many diseases due to intensive pollution in this world. Medicine is the vital importance to cure living organisms from most of these diseases. At present there are different healthcare and hospitals, which administer different medical practices and medications to patients. In this research paper, the Fuzzy AHP technique is used to find the motive of these healthcare and hospitals towards the patients.

**Keywords:** Fuzzy Analytical Hierarchy Process (FAHP), Multi Criteria Decision Making (MCDM).

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## 1. Introduction

Disease is the disorder of the regular function or abnormal condition in all of the living organism. It is interpreted with symptoms and signs specific to the particular medical condition. Medicine is a field of science which is utilized to prevent disease. Generally referred as Medical Science, it analyses the symptoms and signs of the disease to diagnose, treat and prevent the disease. Typically the drugs are administered for the treatment of the particular disease. Surgeries are performed to treat the abnormal condition, which is usually caused by a disease. Some medical conditions are also treated using diet, exercise or some nonsurgical methods.

The History of Medicine emerged way back during the Prehistoric Period. During those period, people used medicinal plants as herbs, animal parts and minerals to treat diseases. The archaeologists have discovered early records on medicine from ancient Babylonian medicine, Ayurvedic medicine, Egyptian medicine, ancient Chinese medicine and Greek medicine. The oldest medical record from the Egyptian was written around 2000BC which is the Kahun Gynaecological Papyrus. The origin of Ayurveda is dated back around 5000BC. The ancient surgeon, Sushruta written numerous surgical procedures in his texts. Ayurveda is one of the medical practices which is still followed in modern medicine. In Greek medicine, Hippocrates, also known as 'father of western medicine' founded different rational approach in medicine. During the middle ages, the Islamic physicians translated the works of ancient physicians like Hippocrates and Sushruta into Arabic and engaged in significant medical researches. They have also written notable texts that was much influential in medieval Islamic and medieval Western medicine. In Europe, the Catholic churches were incorporated to provide health care as one of the prime activities. The church also established schools and universities where medicine was taught. The study of medicine improved and there were

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notable researches carried out in different fields. Bacteria and microorganisms initiated the field of microbiology when they were first observed with microscope, during 1676.

Modern scientific research replaced the early western medical traditions which was not only based on Herbalism, but also animal and human body parts and fluids as medicine. During the late 18th century, Pharmacology was developed from Herbalism. Pharmacology is the study of interaction between the chemicals and living organisms and the chemicals which have proved to make positive effect are considered pharmaceuticals. The modern medical era began with the discovery of the smallpox vaccine during the 18th century, followed by the discovery of the antibiotics by 1900. Pharmacology has become much sophisticated through the modern Biotechnology, where new drugs were developed corresponding to specific disease and also reducing the side effects from the drugs. The knowledge of human genetics, lead to the study of Genomics, where the causes of genetic disorders are studied and drugs being developed from those knowledge. At present the field of medicine has increased vastly, where most of the hospitals and small healthcare clinics employ modern medical practices and implement modern medications.

In 1980's Prof. Thomas L Saaty [1] developed the Fuzzy Analytical hierarchy Process (FAHP). It is one of the Multi Criteria Decision Making method that employs qualitative and quantitative techniques to solve complex decisions based on several criteria and alternatives. To provide a solution to this problem various decision making (MCDM) methods have been proposed[2]. In this paper we use the FAHP and the opinions of the objective and subjective attributes from the experts to find the motive of healthcare towards the patients.

## 2. Description Of Healthcare

Healthcare is classified into five major divisions. Primary care, Secondary care, Tertiary care, Quaternary care and Home and Community care.

### 2.1. Primary Care

Primary care is the first place for consultation for all the patients. Such a place is where you can find general practitioners and physiotherapists. Depending on their health condition they may visit different practitioners, who may advice them for Secondary or Tertiary care. They provide services on the same day with appointment or walk in basis. The scope of primary care is wide which includes patients of all ages, different geographic origins and patients with acute and chronic illness, mental and social health issues. The Primary care practitioner usually possesses broad knowledge to treat these patients. Common illness which are treated here are diabetes, asthma, depression, back pain, arthritis and thyroid dysfunction. In 2013, the National Health Interview Survey found the disorders of lipid metabolism (22.4%), back problems (23.9%), osteoarthritis and joint disorders (33.6%), skin disorders (42.7%) were most common disorders for consulting physicians. The number of primary care grows at a rapid rate as there are numerous new diseases which make the patients to visit primary care a first priority.

### 2.2. Secondary Care

Once the Patients have been advised to consult a specialist by the primary care, they come to visit the Secondary Care. These cares are handled by medical specialists, dental specialists and other medical professional who does not have the first contact with the patients, until advised by primary care. Some of these professionals include cardiologists, neurologists, urologists, etc. Some of the serious illnesses, injury and other health conditions are treated in Hospital Emergency Departments. This includes immense care during child birth, and intensive care unit for emergency conditions and medical imaging services.

Hospital is the general term which is given for secondary care. However some of the professionals work outside from the hospital like, psychiatrists , psychologists, dental therapists, physiotherapists, etc. Some secondary care also includes primary care inside them to diagnose and treat the patients all in one place. Some countries restrict the patients from consulting a secondary care without a referral from the primary care and it is considered a necessity.

### 2.3. Tertiary Care

Tertiary Care is a specialized health care for inpatients who come to cure a disease on a referral from the primary and secondary healthcare. It has facilities for advanced medical investigation and treatment. Some of the care includes cancer treatment, neurosurgery, cardiac surgery, plastic surgery and other complex medical surgeries.

### 2.4. Quaternary Care

Some of the treatments which are not specialized by tertiary care and are not widely treated are handled by the Quaternary Care. They also administer some of the uncommon surgeries and diagnosis. These services are offered in limited national and regional health care centres.

### 2.5. Home and Community Care

Some of the health care interventions are offered outside the health care facilities. These includes interventions on Home and Community Care. Community care generally involves diagnosis for primary diseases, but on the community level. Such cares are usually a team of doctors who camp at remote villages or other public places to diagnose people and provide medicine to treat them. Also they may have a central place to diagnose and treat most of the prime diseases all in one place and provide rapid medical support to the whole community when the necessity arises. Home care involves in taking care of aged and senior people. They help in transporting them to the different health care when needed, provide them proper medication and help them in their day to day activities. They also take care of people who cannot visit the necessary care often or could not travel due to severe health conditions and need the help of some health professionals. Mostly they visit the patient's home to treat or take care of them.



Figure 1. Description of Healthcare

### 3. Fuzzy Analytic Hierarchy Process (F-Ahp)

Fuzzy Analytic Hierarchy Process is based on Analytic Hierarchy Process and Fuzzy Theory, which was developed by Saaty. It is one of the widely used multi criteria decision making tool. A pairwise comparisons is made between different alternatives and with various related criteria and the final decision is made. In AHP, the hierarchical structure is classified into the objective in the first level, the criteria in the second level, the sub criteria in the third level and finally the alternatives in the fourth level [3].

In F-AHP, based on the criteria and alternatives a pairwise comparison is made using the linguistic variables, which are represented using triangular numbers. [4] Laarhoven and Pedrycz performed the first fuzzy AHP application, for the pairwise comparison to define the triangular membership function. Later,[5]Buckley has determined the fuzzy priorities of comparison ratios having triangular membership function. Even though there are some more techniques to evaluate the complex decision using triangular numbers in pairwise comparison, we are implementing Buckley’s method to assess the priority weights for both the criteria and alternatives.

#### 3.1. Procedure for F-AHP Using Triangular Numbers

The following steps are used to find the best motive of Health Care using the alternatives with the relative criteria.

**Step 1:** A pairwise comparison is made between the alternatives and criteria using the linguistic terms and apt relative triangular scale is taken from the following table.1.

Saaty Scale	Linguistic Variable	Fuzzy Triangular Scale
1	Equally Important	(1,1,1)
3	Weakly Important	(2,3,4)
5	Fairly Important	(4,5,6)
7	Strongly Important	(6,7,8)
9	Absolutely Important	(9,9,9)
2		(1,2,3)
4		(3,4,5)
6	The intermittent values between two adjacent scales	(5,6,7)
8		(7,8,9)

**Table 1.** Linguistic Variable and the Corresponding Triangular fuzzy Values.

For ex. If the decision maker chooses the value for Criterion 1 (C1) as Fairly moreImportant than Criterion 2 (C2) then it takes the fuzzy triangular scale as (4,5,6). The comparison of C2 to C1 in the pair wise comparison matrix will take the fuzzy triangular scale as (1/6,1/5,1/4). Using the fuzzy triangular scale the matrix is formed from the opinion of the decision maker, where  $\widetilde{v}_{ij}^k$  indicates the preference of  $i^{th}$  criterion over  $j^{th}$  criterion by the  $v^{th}$  decision maker using fuzzy triangular numbers. Here the triangular number demonstration is represented by the “tilde” and  $\widetilde{v}_{12}^1$  represents the first decision maker’s preference of the first criterion over third criterion and equals to  $\widetilde{v}_{12}^1 = (4,5,6)$ .

$$\widetilde{A}^k = \begin{bmatrix} \widetilde{v}_{11}^k & \widetilde{v}_{12}^k & \dots & \widetilde{v}_{1n}^k \\ \widetilde{v}_{21}^k & \dots & \dots & \widetilde{v}_{2n}^k \\ \dots & \dots & \dots & \dots \\ \widetilde{v}_{n1}^k & \widetilde{v}_{n2}^k & \dots & \widetilde{v}_{nn}^k \end{bmatrix} \tag{1}$$

**Step 2:** If the number of decision maker is more than one, the preference is calculated by evaluating the average  $\widetilde{v}_{ij}$  of each decision maker’s preferences  $\widetilde{v}_{ij}^k$ .

$$\widetilde{v}_{ij} = \frac{\sum_{k=1}^K \widetilde{v}_{ij}^k}{K} \tag{2}$$

**Step 3:** Pair-wise contribution matrix is updated according to the averaged preferences as shown in Eq.3.

$$\tilde{A} = \begin{bmatrix} \widetilde{v}_{11} & \dots & \widetilde{v}_{1n} \\ \vdots & \ddots & \vdots \\ \widetilde{v}_{n1} & \dots & \widetilde{v}_{nn} \end{bmatrix} \tag{3}$$

**Step 4:** According to Buckley, the geometric mean is calculated from the fuzzy comparison values of each criterion as shown in Eq.4. Here  $\widetilde{r}_i$ , represents triangular values.

$$\widetilde{r}_i = \left( \prod_{j=1}^n \widetilde{v}_{ij} \right)^{1/n}, \quad i = 1, 2, \dots, n \tag{4}$$

**Step 5:** From Eq.5 the fuzzy weights for each criterion can be evaluated, by incorporating next 3 sub steps.

**Step 5a:** Each  $\widetilde{r}_i$  is taken and the vector summation is Determined.

**Step 5b:** The (-1) power of summation vector is found and the fuzzy triangular number is replaced to make it in an increasing order.

**Step 5c:** The fuzzy weight of criterion  $i(\widetilde{w}_i)$  is found by multiplying each  $\widetilde{r}_i$  with this reverse vector.

$$\begin{aligned} \widetilde{w}_i &= \widetilde{r}_i \otimes (\widetilde{r}_1 \oplus \widetilde{r}_2 \oplus \dots \oplus \widetilde{r}_n)^{-1} \\ &= (xw_i, yw_i, zw_i) \end{aligned} \tag{5}$$

**Step 6:** Since  $\widetilde{w}_i$  are still a fuzzy triangular numbers, they are de-fuzzied by [6] Chou and Chang’s Centre of area method, after applying Eq.6.

$$M_i = \frac{xw_i + yw_i + zw_i}{3} \tag{6}$$

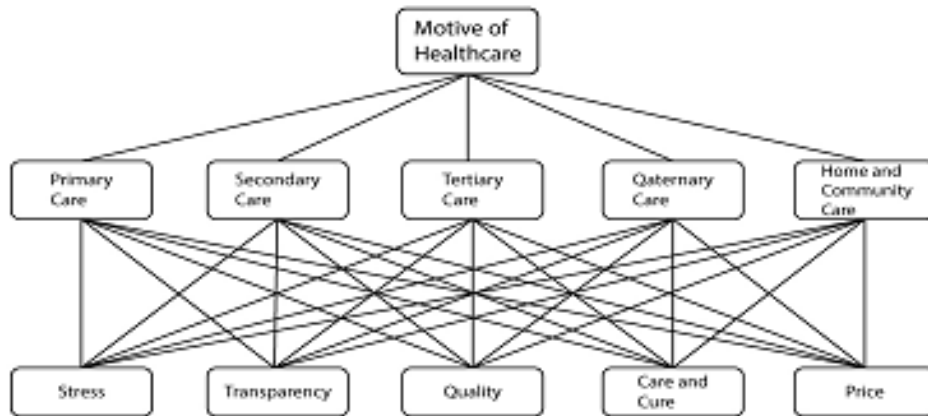
**Step 7:**  $M_i$  is normalized by Eq.7 as it is a non fuzzy number.

$$N_i = \frac{M_i}{\sum_{i=1}^n M_i} \tag{7}$$

By following the given 7 steps the normalized weights of both the alternatives and criteria are found. The scores of each alternative is evaluated by multiplying each alternative weight with related criteria. The alternative with the highest score is suggested to the decision maker from the obtained results.

## 4. Application to evaluate the best Motive of Health Care

The F-AHP methodology is applied to find the motive of the healthcare towards the patients. Based on 5 alternatives and 5 criteria a pairwise comparison is made and the final motive of the healthcare is found. The different alternatives and criteria used are shown in Figure 2.



### 4.1. Evaluating the Weights of Criteria

In order to evaluate the motive of health care a discussion was between the experts and the pair-wise comparison is determined. As per the experts opinion a pair-wise comparison is tabled in Figure 3.

(9,9,9)	(6,7,8)	(4,5,6)	(2,3,4)		(1,1,1)		(2,3,4)	(4,5,6)	(6,7,8)	(9,9,9)
A Imp	S Imp	F Imp	W Imp	Criteria	Eq Imp	Criteria	W Imp	F Imp	S Imp	A Imp
	(4,5,6)			P.C	—	S.C				
	(2,3,4)			P.C	—	T.C				
				P.C	—	Q.C			(1/6,1/5,1/4)	
	(6,7,8)			P.C	—	H.C.C				
	(1,1,1)			S.C	—	T.C				
				S.C	—	Q.C			(1/4,1/3,1/2)	
	(4,5,6)			S.C	—	H.C.C				
	(6,7,8)			T.C	—	Q.C				
	(2,3,4)			T.C	—	H.C.C				
	(1,1,1)			Q.C	—	H.C.C				

Figure 2. Pair wise Comparisons of Criteria

A pair-wise comparison matrix is determined by following the first 3 steps from the Procedure and is tabulated in Table 2.

CRITERIA	PC	SC	TC	QC	HCC
PC	(1,1,1)	(4,5,6)	(2,3,4)	(1/6,1/5,1/4)	(6,7,8)
SC	(1/6,1/5,1/4)	(1,1,1)	(1,1,1)	(1/4,1/3,1/2)	(4,5,6)
TC	(1/4,1/3,1/2)	(1,1,1)	(1,1,1)	(6,7,8)	(2,3,4)
QC	(4,5,6)	(2,3,4)	(1/8,1/7,1/6)	(1,1,1)	(2,3,4)
HCC	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1,1,1)

**Table 2. Comparison Matrix for Criteria**

The geometric mean of fuzzy comparison values of each criteria is calculated from step 4 of the procedure. For example

$$\tilde{r}_i = \left( \prod_{j=1}^n \tilde{v}_{ij} \right)^{1/n} = \left[ (1*4*2*\frac{1}{6}*6)^{\frac{1}{5}} ; (1*5*3*\frac{1}{5}*7)^{\frac{1}{5}} ; (1*6*4*\frac{1}{4}*8)^{\frac{1}{5}} \right]$$

$$= [1.56; 1.83; 2.16]$$

The geometric mean of fuzzy comparison values for all criteria are shown in Table 3. The final total is made in addition to the criteria and from the total the reverse values are also presented. The order of the numbers are changed, since the fuzzy triangular number should be in increasing order.

CRITERIA	$(\tilde{r}_i)$		
PC	1.56	1.83	2.16
SC	0.698	0.802	0.944
TC	1.245	1.475	1.741
QC	1.148	1.451	1.741
HCC	0.264	0.316	0.401
Total	4.915	5.874	6.987
Reverse power of -1	0.203	0.170	0.143
Increasing Order	0.14	0.17	0.20

**Table 3. Geometric Mean of Fuzzy Comparison Values**

From step 5 the fuzzy weights of ‘Primary Care’ criterion ( $\tilde{w}_1$ ) is calculated as.

$$\tilde{w}_1 = [(1.56 * 0.14) ; (1.83 * 0.17) ; (2.16 * 0.20)]$$

$$= [0.218; 0.311; 0.432]$$

Further criteria are also evaluated and tabulated in Table 4.

CRITERIA	$(\tilde{w}_i)$		
PC	0.218	0.311	0.432
SC	0.097	0.136	0.188
TC	0.174	0.250	0.348
QC	0.160	0.246	0.348
HCC	0.036	0.053	0.080

**Table 4. Relative Fuzzy Weights of Each Criterion**

The average of relative fuzzy weights of each criterion ( $M_i$ ) is calculated by following Step 6 and the normalized weights of each criterion is calculated using non fuzzy  $M_i$ ’s by following step 7 and it is tabulated in Table 5.

CRITERIA	$M_i$	$N_i$
PC	0.320	0.313
SC	0.140	0.137
TC	0.257	0.251
QC	0.251	0.246
HCC	0.056	0.054

**Table 5.** Average and Normalized relative weights of Criterion

## 5. Evaluating Weights of Alternatives with Respective Criteria

By following the same methodology that we used to obtain the normalized non-fuzzy relative weights for criteria is applied to calculate the respective values for alternatives. Now a pair-wise comparison is made from the alternatives with the respective criterion in Table 6.

ALTERNATIVES	STRESS	TRANSPRENCY	QUALITY	CARE & CURE	PRICE
STRESS	(1,1,1)	(2,3,4)	(1/9,1/9,1/9)	(1/6,1/5,1/4)	(6,7,8)
TRANSPRENCY	(1/4,1/3,1/2)	(1,1,1)	(1/4,1/3,1/2)	(2,3,4)	(1/4,1/3,1/2)
QUALITY	(9,9,9)	(2,3,4)	(1,1,1)	(6,7,8)	(1/6,1/5,1/4)
CARE & CURE	(4,5,6)	(1/4,1/3,1/2)	(1/8,1/7,1/6)	(1,1,1)	(1/4,1/3,1/2)
PRICE	(1/8,1/7,1/6)	(2,3,4)	(4,5,6)	(2,3,4)	(1,1,1)

**Table 6.** Comparison Matrix of alternatives with respect to “Primary care” Criterion.

Following the above steps the Geometric Mean ( $\tilde{r}_i$ ) and Fuzzy Weights ( $\tilde{w}_i$ ) of alternatives with respect to ‘Primary Care’ criteria is calculated in the Table 7, 8.

ALTERNATIVES	$(\tilde{r}_i)$		
STRESS	0.740	0.859	0.977
TRANSPRENCY	0.500	0.577	0.871
QUALITY	1.783	2.068	2.352
CARE & CURE	0.500	0.602	0.758
PRICE	1.149	1.451	1.741
Total	4.672	5.557	6.699
Reverse power of -1	0.21	0.18	0.15
Increasing Order	0.15	0.18	0.21

**Table 7.** Geometric Mean of Fuzzy Comparison Values

ALTERNATIVES	$(\tilde{w}_i)$		
STRESS	0.111	0.155	0.205
TRANSPRENCY	0.075	0.104	0.183
QUALITY	0.267	0.372	0.494
CARE & CURE	0.075	0.108	0.159
PRICE	0.172	0.261	0.366

**Table 8.** Fuzzy Weights ( $\tilde{w}_i$ ) of alternatives with respective to “Primary care” Criterion

By following the centre of area method the non fuzzy  $M_i$  and normalized  $N_i$  values are obtained and are shown in Table 9.



ALTERNATIVES	$M_i$	$N_i$
STRESS	0.157	0.152
TRANSPRENCY	0.121	0.117
QUALITY	0.377	0.364
CARE & CURE	0.144	0.110
PRICE	0.266	0.257

**Table 9.** Average and Normalized relative weights of each alternative with respect to “Primary care” Criterion

Similarly by following the same procedure the calculations for other criteria is calculated and tabulated below. From our above explanation, the normalized non-fuzzy relative weights of each alternative for each criterion are determined and tabulated in Table 10.

ALTERNATIVES	PC	SC	TC	QC	HCC
STRESS	0.152	0.104	0.079	0.118	0.039
TRANSPRENCY	0.117	0.069	0.081	0.157	0.151
QUALITY	0.364	0.188	0.222	0.296	0.364
CARE & CURE	0.114	0.491	0.559	0.318	0.325
PRICE	0.266	0.149	0.060	0.112	0.121

**Table 10.** Normalized non-fuzzy relative weights of each alternative for each Criterion

## 6. Aggregated Result

Finally based on the evolution the final judgment of each alternative for each criterion are tabulated in Table 11.

CRITERIA		Scores of Alternatives with respect to related Criterion				
	Weights	STRESS	TRANSPRENCY	QUALITY	CARE & CURE	PRICE
PC	0.313	0.152	0.117	0.364	0.110	0.257
SC	0.137	0.104	0.069	0.188	0.491	0.149
TC	0.251	0.079	0.081	0.222	0.559	0.060
QC	0.246	0.118	0.157	0.296	0.318	0.112
HCC	0.054	0.039	0.151	0.364	0.325	0.121
<b>TOTAL</b>		0.098	0.115	0.287	<b>0.360</b>	0.140

**Table 11.** Aggregated result for each alternative according to each Criterion

## 7. Conclusion

Good health is one of the vital need for living organisms. Whenever health is affected by a disease, we visit the relevant health care to cure the disease and sustain good health. Different health cares diagnose and cure prime diseases as well as diseases which are difficult to treat. In this paper we used the FAHP methodology to evaluate the motive of health cares towards the patients. From our evaluation we find that the motive of the health cares at first is to care and cure the disease.

## References

[1] T.L.Saaty, *The Analytic Hierarchy Process*, McGraw-Hill, New York, USA, (1980).  
 [2] H.S.Kilic, *An integrated approach for supplier selection in Multi item environment*, Applied Mathematical Modelling, 37(14-15)(2013).

- [3] O.Kilincci and S.A.Onal, *Fuzzy AHP approach for supplier selection in a washing machine company*, Expert Systems with Application, (2011).
- [4] P.J.M.Van Laarhoven and W.Pedrycz, *A Fuzzy extension of saaty's priority Theory*, Fuzzy sets and Systems, 11(1-3)(1983), 199-227.
- [5] J.J.Buckley, *Fuzzy Hierarchical analysis*, Fuzzy Sets Systems, 17(1)(1985), 233-247.
- [6] S.W.Chou and Y.C.Chang, *The implementation factors that influence the ERP Benefits*, Decisions support systems, 4(1)(2008), 149-157.