Selection of Air Lines by the Fuzzy Analytic Hierarchy Process

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Abstract

Air lines users are constantly in search of regular, on time service, reasonable cost, high safety with physical and psychological comfort. This study and the presented evaluation method for the analysis of the current situation along with the comparison of the airlines can help to improvise their services. The data have been analyzed by using Fuzzy Analytic Hierarchy Process, which was proposed by Saaty. The Analytic Hierarchy Process (AHP) is one of the Fuzzy Multiple Criteria Decision Making methods for complicated and unstructured problems. Fuzzy decision making is observed to be a very significant tool. AHP methodology with the Fuzzy Linear Programming Model is found to make complex decisions with ease. Fuzziness and vagueness involved in the problem may contribute to poor judgment in AHP, but AHP-FLP model allows decision makers to consider the uncertain conditions. Thus AHP-FLP model is more relevant than AHP method for the selection of Airlines.

Keywords — *Fuzzy Analytic Hierarchy Process, Multiple Criteria Decision Making method, unstructured problems.*

I. INTRODUCTION

Air lines Passengers are in search of regular, on time services, reasonable costs, high safety with physical and psychological comfort. This paper seeks to provide air lines passengers with a logical and scientific tool to support the decisions made in hope of achieving a higher quality services.

Analytic Hierarchy Process i.e. AHP is one of the most convenient methodology in order to evaluate transportation issues. Basically AHP, which was proposed by proposed by Saaty in 1985 [5] is a method of breaking down a complex, unstructured situation into its components parts, arranging these parts, or variables into a hierarchic order and to synthesize the judgments to determine which variables have the highest priority. This paper is comprised of two main parts. First part is consists of the literature survey regarding the AHP and its application areas. Second part is mainly focused on a sample application of AHP technique. The process of multi-level hierarchical structure uses both the linguistic assessments and numerical values for the alternative selection problem. It uses the concepts of fuzzy set theory and hierarchical structure analysis for the selection of the most appropriate alternative among a set of feasible alternatives. It is easy and useful methodology to be able to provide pair wise comparisons in each area of expertise. The aim of this paper is, how to select the better air transportation according to passengers' expectations.

A. Overview of Multi-Criteria Decision Making

Multi Criteria Decision Making (MCDM) deals with the problems that involve multiple and conflicting objectives. It is obvious that when more objective exists in the problem, then taking a decision becomes more complex. MCDM is both an approach and a set of techniques, with the aim of providing an overall ordering of options, from the most preferred to the least preferred option [The London School of Economics and Political Science 2007][7]. MCDM approaches provide a systematic procedure to help decision makers to choose the most desirable and satisfactory alternative under uncertain situation (Cheng,Y.K. 2000). [1]. It further provides a framework to evaluate different transport options on several criteria. The MCDM approaches are classified into two groups. This classification makes distinction between Multi Objective Decision Making (MODM) and Multi Attribute Decision Making (MADM). The main distinction between the two methods is based on the number of alternatives under evaluation. In MCDM problems, there exist a relatively small number of alternatives and these alternatives are denoted in terms of attributes. MODM problems have a very large number of feasible alternative and the objectives and the constraints depend on the decision variables (Mollaghasemi, M., 1997) [4]. MADM methods are designed for selecting discrete alternatives while MODM are more adequate to deal with multi objective planning problems, when a theoretically infinite number of continuous alternatives are defined by a set of constraints on a vector of decision variables (Mendoza, Martins, 2006) [3].

B. Multi-Attribute Decision Making (MADM)

MADM methods provide a simple and intuitive tools for making decisions on problems that involve uncertain and subjective information [Cheng, Y.K] [1]. These methods have the advantage that they can assess a variety of options according to a variety of criteria that have different units. This is a very important advantage over traditional decision aiding methods where all criteria need to be converted to the same unit. Another significant advantage of MADM methods is that they have the capacity to analyze both quantitative and qualitative evaluation criteria together. MADM describes each alternative by using multiple attributes. For a given set of alternatives, MADM models try to choose the best alternative among them, rank the alternatives from the best to the worst or classify them into classes. Although the MADM methods are generally used to solve discrete problems, some of them can also be used within the context of continuous decision problems (Doumpos and Zopounidis, 2002) [2].

To resolve this difficulty, fuzzy set theory, first introduced by Zadeh, L. A., 1965 [9], has been used and is adopted herein. Fuzzy set theory attempts to select, prioritize or rank a finite number of courses of action by evaluating a group of predetermined criteria. Solving this problem thus requires constructing an evaluation procedure to rate and rank, in order of preference, the set of alternatives. Among the MADM methods developed in the literature, AHP, multi-attribute utility theory and outranking methods are more frequently applied to discrete decision problems than all other methods.

C. Analytic Hierarchy Process

The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then.

Users of the AHP first decompose their decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analysed independently. The elements of the hierarchy can relate to any aspect of the decision problem tangible or intangible, carefully measured or roughly estimated, well or poorly understood anything at all that applies to the decision at hand.

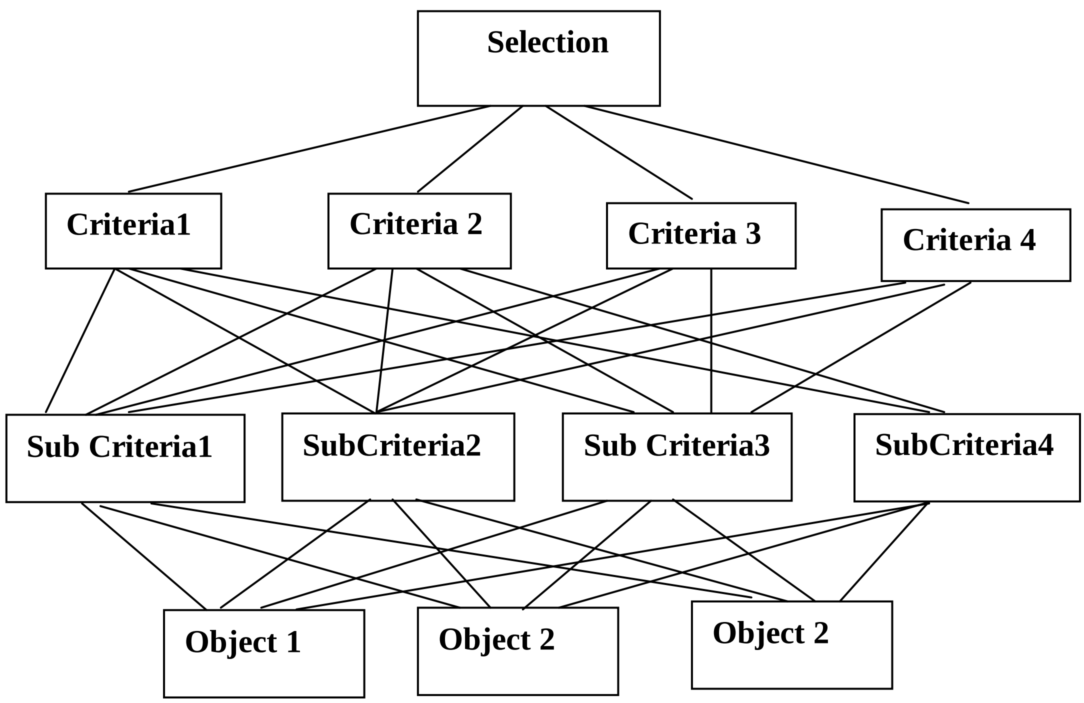

Figure 1: Hierarchical Structure of Selection Criteria

Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to each other two at a time, with respect to their impact on an element above them in the hierarchy. In making the comparisons, the decision makers can use concrete data about the elements, but they typically use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations. Wikipedia [8]

The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other decision making techniques.

In the final step of the process, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternatives' relative ability to achieve the decision goal, so they allow a straight forward consideration of the various courses of action. The pair wise comparisons using fuzzy scale was given by Satty in the Table I.

Table I: The Pair Wise Comparisons Using Fuzzy Scale

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two factors contribute equally to the objective.
3	Somewhat more Important	Experience and judgment slightly favor one over the other
5	Much more Important	Experience and judgment strongly favor one over the other
7	Very much more Important	Experience and judgment very strongly favor one over the other
9	Absolutely more Important	The evidence favoring one over the other is of the highest possible validity.
2, 4, 6, 8	Intermediate values	When compromise is needed.

Through this comparison matrix of the elements is formed and then consistency ratio (CR) is calculated to check the consistency of responses. The reliability of responses is maintained if CR is less or equal to 0.10. This CR is given by CR=CI/RI where CI is consistency index and RI is random index. If CR is greater than 0.10 then judgment in the matrix would be considered as inconsistent and in that case we shall have to revise the matrix. There is computer software to assist in using the process.

II. Application

A. Analytic Hierarchy Process for selection of Airlines

Air lines users are constantly in search of regular, on time service, reasonable cost, high safety with physical and psychological comfort. We made an attempt to use AHP-FLP model in the selection of airline which should be match perfect according to our need.

In this paper, we have selected three airlines A1, A2 and A3. For selection, various criteria and sub-criteria are considered after the discussion with various customers of different category, airline personals and reviews available on the websites. Today's world is competitive and everyone wants to reach on time to their destination hence timing is the most important factor for the customers to travel. Price is also one of the important criteria for passengers and organizations to decide the journey as money matters a lot for loss or profit. Costumers also prefer to have a comfortable journey, hence this is one of the important criteria. Customer services plays a very important role in the selection of airlines. Hence the criteria and sub criteria are decided as given in Table II.

Table II: Criteria and Sub Criteria for Selection of Airlines

S. No.	Criteria	Sub criteria
1	Time (TI)	Check in Start (CIS)
		Check in Closed (CIC)
		Luggage Pickup Time (LPT)
		Arrival on Time (AT)
2	Pricing (PR)	Price (PR)
		Discount/Group Booking (DIS/GB)
		Negotiation/Seat Preference (NE/SP)
		Cancellation /Date Change (CAN/RS)
3	Comfort (CO)	Hospitality (HO)
		Catering Services (CS)
		Delay/Flight Cancelled (D/FC)
4	Customer Care (CC)	Luggage Allowed (LA)
		Luggage Handling (LH)
		Insurance Protection (IP)

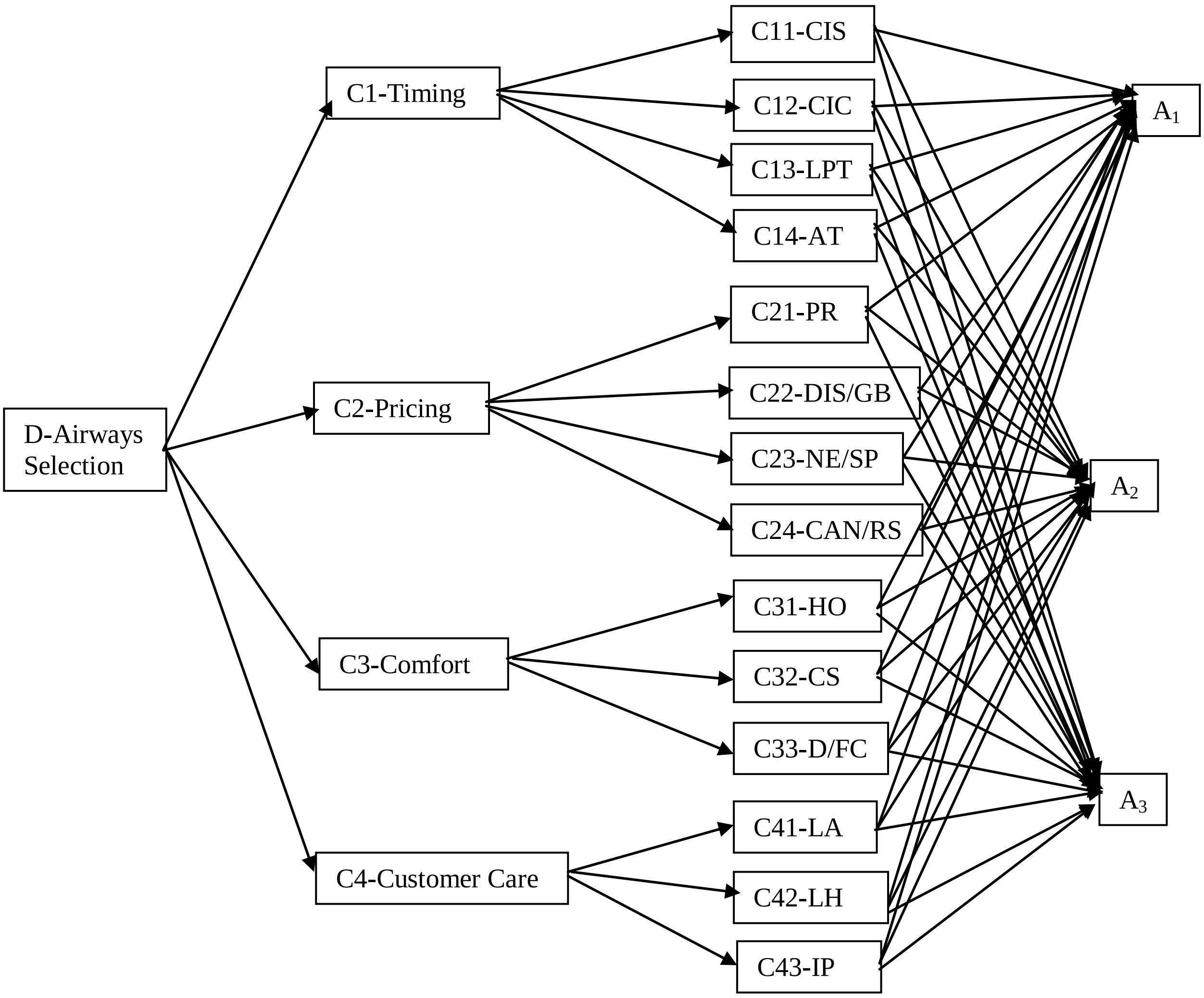

Figure 2: Criteria and Sub Criteria for Selection of Airline

B. Calculation of weights of the criteria

In this paper, three airlines are compared on various criteria and sub-criteria for the selection of proper airline to travel with comfort as per the passengers need. For this pairwise comparison of main selection criteria, comparison of criteria over sub-criteria comparison of sub-criteria over alternatives for selection of airline have been done to know the weights of each airline using Satty's scale.

Pairwise comparison of main selection criteria is given in Table III.

Table III: Inter Comparison of Main Criteria

Criteria	TI	PR	CO	CC	Priority
TI	1	3	1/5	2	0.2305
PR	1/3	1	1	3	0.2079
CO	5	1	1	7	0.4932
CC	1/2	1/3	1/7	1	0.0684
CI:	0.2428	CR:	0.2754	Sum:	1

Table IV to Table VII show pair wise comparison of criteria over sub-criteria for the selection of airline

Table IV: Inter Comparison of Sub-Criteria with Respect to Main Criteria TI

TI	CIS	CIC	LPT	AT	Priority
CIS	1	1/3	2	1/5	0.1087
CIC	3	1	3	1/7	0.1994
LPT	1/2	1/3	1	1/2	0.1107
AT	5	7	2	1	0.5812
CI:	0.239086	CR:	0.271227	Sum:	1

Table V: Inter Comparison of Sub-Criteria with Respect to Main Criteria PR

PR	PR	DIS/GB	NE/SP	CAN/RS	Priority
PR	1	3	2	1	0.32369
DIS/GB	1/3	1	1/5	1/2	0.09727
NE/SP	1/2	5	1	1/3	0.226013
CAN/RS	1	2	3	1	0.353026
CI:	0.12954	CR:	0.146954	Sum:	1

Table VI: Inter Comparison of Sub-Criteria with Respect to Main Criteria CO

CO	HO	CS	D/FC	Priority
HO	1	5	1/7	0.220582
CS	1/5	1	1/3	0.099867
D/FC	7	3	1	0.679551
CI:	0.354473	CR:	0.675829	1

Table VII: Inter Comparison of Sub-Criteria with Respect to Main Criteria CC

CC	LA	LH	IP	Priority
LA	1	7	1/3	0.37309
LH	1/7	1	1/2	0.116582
IP	3	2	1	0.510328
CI:	0.323216	CR:	0.616237	1

Table VIII to Table XI show pair wise comparison of sub-criteria with respect to alternatives for the selection of airline

Table VIII: Timing

CIS	A1	A2	A3	Priority		CIC	A1	A2	A3	Priority
A1	1	2	3	0.531631		A1	1	5	1/3	0.342083
A2	1/2	1	1/4	0.146297		A2	1/5	1	1/2	0.133885
A3	1/3	4	1	0.322072		A3	3	2	1	0.524032
CI: 0.183721		CR: 0.350278		1		CI: 0.234153		CR: 0.446432		1

LPT	A1	A2	A3	Priority		AT	A1	A2	A3	Priority
A1	1	3	1/5	0.211144		A1	1	1/5	3	0.211144
A2	1/3	1	1/4	0.109345		A2	5	1	4	0.679511
A3	5	4	1	0.679511		A3	1/3	1/4	1	0.109345
CI: 0.098638		CR: 0.188061		1		CI: 0.098638		CR: 0.188061		1

Table IX: Pricing

PR	A1	A2	A3	Priority		DIS/GB	A1	A2	A3	Priority
A1	1	3	5	0.65707		A1	1	1/7	1/5	0.075057
A2	1/3	1	1/2	0.146622		A2	7	1	2	0.591727
A3	1/5	2	1	0.196308		A3	5	1/2	1	0.333216
CI: 0.081617		CR: 0.15561		1		CI:0.007076		CR:0.013491		1

NE/SP	A1	A2	A3	Priority		CAN/RS	A1	A2	A3	Priority
A1	1	1/5	1/3	0.109452		A1	1	1/3	1/4	0.121957
A2	5	1	2	0.581552		A2	3	1	1/2	0.319618
A3	3	1/2	1	0.308996		A3	4	2	1	0.558425
CI:0.001847		CR:0.003522		1		CI:0.009147		CR:0.01744		1

Table X: Comfort

HO	A1	A2	A3	Priority		CS	A1	A2	A3	Priority
A1	1	1/5	1/3	0.109452		A1	1	1/2	1/3	0.163424
A2	5	1	2	0.581552		A2	2	1	1/2	0.296961
A3	3	1/2	1	0.308996		A3	3	2	1	0.539615
CI: 0.001847		CR:0.003522		1		CI: 0.004601		CR:0.008773		1

D/FC	A1	A2	A3	Priority
A1	1	1/3	1/5	0.100654
A2	3	1	1/4	0.225536
A3	5	4	1	0.67381
CI: 0.042883		CR: 0.08176		1

Table XI: Customer Care

LA	A1	A2	A3	Priority		LH	A1	A2	A3	Priority
A1	1	2	1/7	0.149899		A1	1	1/4	1/5	0.093616
A2	1/2	1	1/5	0.105638		A2	4	1	1/3	0.279688
A3	7	5	1	0.744463		A3	5	3	1	0.626696
CI:0.059476		CR:0.113395		1		CI:0.042883		CR:0.08176		1

IP	A1	A2	A3	Priority
A1	1	1/2	1/3	0.163424
A2	2	1	1/2	0.296961
A3	3	2	1	0.539615
CI: 0.004601		CR:0.008773		1

Pairwise comparison of airlines with criteria and sub-criteria has been done to find out the weights of airlines and given in Table XII

Table XII: Pairwise Comparison of Airlines with Criteria and Sub-Criteria

Sub-criteria	Weight	Wt of A1	Wt of A2	Wt of A3
CIS	0.1087	0.53163	0.14630	0.32207
CIC	0.1994	0.34208	0.13388	0.52403
LPT	0.1107	0.21114	0.10934	0.67951
AT	0.5812	0.21114	0.67951	0.10934
PR	0.32369	0.65707	0.14662	0.19631
DIS/GB	0.09727	0.07506	0.59173	0.33322
NE/SP	0.226013	0.10945	0.58155	0.30900
CAN/RS	0.353026	0.12196	0.31962	0.55842
HO	0.220582	0.10945	0.58155	0.30900
CS	0.099867	0.16342	0.29696	0.53961
D/FC	0.679551	0.10065	0.22554	0.67381
LA	0.37309	0.14990	0.10564	0.74446
LH	0.116582	0.09362	0.27969	0.62670
IP	0.510328	0.16342	0.29696	0.53961

According to the main selection criteria, Time (TI), Pricing (PR), Comfort (CO) and Customer Care (CC) the final weights of each of the airlines to select the best one is given in Table XIII.

Table XIII: Final Weights of Airlines

Criteria	Weight	Wt of A1	Wt of A2	Wt of A3
TI	0.23	0.272	0.450	0.278
PR	0.21	0.288	0.349	0.363
CO	0.49	0.109	0.311	0.580
CC	0.07	0.150	0.224	0.626
FINAL WEIGHT		0.187	0.345	0.468

C. Multi-objective Linear Programming Problem

In this application we can select four objective functions O_1 to O_4 corresponding to four main selection criteria Time (TI), Pricing (PR), Comfort (CO) and Customer Care (CC).

For the selection of suitable airline multi-objective linear programming model can be written as

$$Maximize \begin{Bmatrix} O_1 = 0.272a_1 + 0.450a_2 + 0.278a_3 \\ O_2 = 0.288a_1 + 0.349a_2 + 0.363a_3 \\ O_3 = 0.109a_1 + 0.311a_2 + 0.580a_3 \\ O_4 = 0.150a_1 + 0.224a_2 + 0.626a_3 \end{Bmatrix} ....(M1)$$

D. Limitations of main criteria

Table 14 gives limitations for each of the main criteria i.e. bounds for them. Minimum value O_K^* & maximum value O_K^0 for each of the main criteria are given in the Table XIV.

Table XIV: Upper & Lower Bounds for Each Criterion

Bounds	O_1	O_2	O_3	O_4
O_K^* (Min)	0.272	0.288	0.109	0.150
O_K^0 (Max)	0.450	0.363	0.580	0.626

E. Fuzzy Multi-objective Linear Programming Problem

From M1, the fuzzy multi-objective linear programming problem for the selection of airline is given below -

$$Find \ \ A$$

$$Maximize \begin{Bmatrix} \tilde{O}_1 = 0.272a_1 + 0.450a_2 + 0.278a_3 \geq O_1^0 \\ \tilde{O}_2 = 0.288a_1 + 0.349a_2 + 0.363a_3 \geq O_2^0 \\ \tilde{O}_3 = 0.109a_1 + 0.311a_2 + 0.580a_3 \geq O_3^0 \\ \tilde{O}_4 = 0.150a_1 + 0.224a_2 + 0.626a_3 \geq O_4^0 \end{Bmatrix} ....(M2)$$

$$Subject \ \ to$$
$$a_1 + a_2 + a_3 = 1;$$
$$a_1, a_2, a_3 \in \{0,1\}$$

For above four objective functions, membership functions can be written as follows:

$$\mu_{O_1}(A) = \begin{Bmatrix} 1 & ; O_1(A) \geq 0.450 \\ \frac{0.450 - O_1(A)}{0.450 - 0.272} & ; 0.272 < O_1(A) < 0.450 \\ 0 & ; O_1(A) \leq 0.272 \end{Bmatrix} ....(M3)$$

$$\mu_{O_2}(A) = \begin{Bmatrix} 1 & ; O_2(A) \geq 0.363 \\ \frac{0.363 - O_2(A)}{0.363 - 0.288} & ; 0.288 < O_2(A) < 0.363 \\ 0 & ; O_2(A) \leq 0.288 \end{Bmatrix} ....(M4)$$

$$\mu_{O_3}(A) = \begin{Bmatrix} 1 & ; O_3(A) \geq 0.580 \\ \frac{0.580 - O_3(A)}{0.580 - 0.109} & ; 0.109 < O_3(A) < 0.580 \\ 0 & ; O_3(A) \leq 0.109 \end{Bmatrix} ....(M5)$$

$$\mu_{O_4}(A) = \begin{cases} 1 & ; O_4(A) \geq 0.626 \\ \dfrac{0.626 - O_4(A)}{0.626 - 0.150} & ; 0.150 < O_4(A) < 0.626 \\ 0 & ; O_4(A) \leq 0.150 \end{cases} \quad \text{.....................} (M6)$$

F. AHP-FLP model construction

From M2, we can write crisp single objective programming model equivalent to Fuzzy multi-objective models M7 for the selection of airline.

$$\begin{aligned} & Maximize \\ & 0.23w_1 + 0.21w_2 + 0.49w_3 + 0.07w_4 \\ & Subject\ to \\ & w_1 \leq \frac{0.450 - (0..272a_1 + 0.450a_2 + 0.278a_3)}{0.450 - 0.272} \\ & w_2 \leq \frac{0.363 - (0..288a_1 + 0.349a_2 + 0.363a_3)}{0.363 - 0.288} \\ & w_3 \leq \frac{0.580 - (0..109a_1 + 0.311a_2 + 0.580a_3)}{0.580 - 0.109} \text{.................} (M7) \\ & w_4 \leq \frac{0.626 - (0..150a_1 + 0.224a_2 + 0.626a_3)}{0.626 - 0.150} \\ & w_1, w_2, w_3, w_4 \in [0,1] \\ & a_1 + a_2 + a_3 = 1; \\ & a_1, a_2, a_3 \in \{0,1\} \end{aligned}$$

It is important to note that weights taken with all w_K, k = 1, 2, 3, 4 are taken as weights of each of the main criteria calculated using AHP in comparison matrix.

Model M7 is solved to get optimal solution for the selection of airline.

We get, a1= 0, a2= 1, a3= 0 which indicates that airline A2 is the best selection for the satisfaction of the passenger on the basis of criteria & sub criteria considered. Hence the values of objective functions and membership functions from this preference can be as follows

O_1= 0.450, O_2= 0.349, O_3= 0.311, O_4=0.224

$\mu_{O_1}(A) = 0$, $\mu_{O_2}(A) = 0.19$, $\mu_{O_3}(A) = 0.57$, $\mu_{O_4}(A) = 0.85$

From this we can say that the achievement levels of the O3 & O4 are better than the achievement levels of O1 & O2

III. RESULTS AND DISCUSSION

Table XV shows comparison of AHP and AHP-FLP results for the selection of airlines. It shows that through AHP-FLP approach, airline A2 is the best choice for the selection of airline with score of one as compare to the AHP approach which suggests that the airline A3 is the best choice with overall score of 0.468. So, the sensitivity of AHP-FLP method is analyzed by considering various criterion and sub criterions used in the model. According to the views of experts and passengers, travelling frequently through air, the comfort and the customer care are considered as the most important as compared to the other two factors namely timing and pricing, for the selection of the suitable airline.

Table XV: Comparison of AHP and AHP-FLP for Selection of Airline

Approach	A_1	A_2	A_3
AHP	**0.187**	**0.345**	**0.468**
AHP-FLP	**0**	1	0

This hybrid model 'AHP-FLP' is applied in an integrated approach of Analytic Hierarchy Process and Fuzzy Linear Programming for selection of airline of suitable choice.

IV. CONCLUSION

Selection of airlines with complex expectations of the decision maker has become very tough due to the overwhelming competition amongst the airlines. Fuzzy decision making is observed to be a very significant tool. AHP methodology with the Fuzzy Linear Programming Model is found to make complex decisions with ease.

Fuzziness and vagueness involved in the problem may contribute to poor judgment in AHP, but AHP-FLP model allows decision makers to consider the uncertain conditions. Thus AHP-FLP model is more relevant than AHP method for the selection of Airlines.

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