GRADING OF FACTORS INFLUENCING CUSTOMERS' SATISFACTION FROM CAR COMPANIES USING FUZZY ANALYTIC HIERARCHY PROCESS

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Abstract :

Nowadays concurrent with globalization of trade marks and services, companies need to pay special attention to customers' satisfaction. The aim of the current study is to classify factors influencing customers' satisfaction of car companies. The factors are determined after study of similar essays on the same subject and interview with customers and managers of car companies and then the resulted factors are compared to together using **Fuzzy Analytic Hierarchy Process**

Key words:

Customer satisfaction, car companies, Fuzzy Analytic Hierarchy Process

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Preface :

What has been current and common among managers and marketing theoreticians is the fact that quality of customer services is the basis of success in any business enterprise . (Kristensenet al.1992.Mccool-kennedy and sch neider2000 zeithaml etal .1996).Companies rendering best services for customers, gain maximum income compared to similar companies (Aaker and) Jacobon.1994.Bolton1998. Customer satisfaction in long term is the most important cause of success in any business and relation between customer satisfaction and customer's behavior are written and registered in the marketing texts (G.Rinald Gilbere et al 2004).

High satisfaction of customer will result in more loyalty of customers and then bring subsequent incomes. Increase of satisfaction leads to reduction of customer complains, and then increases their loyalty. (Anderson and Sullivan Bouldinget al.1993 ft 1990).

Anderson and Fornell believe that the nature of any business existence should be customer satisfaction. Quantity of goods and production services of company no longer bring success and growth, but it is the customers' satisfaction that can maintain a company and bring growth and progress. Nowadays, the success of production and service companies is dependent to a great extent on the way that customers' requirements are met and in the meanwhile, the most important step is to correctly determine importance and value of customers' requirements. Some people have tried to specify the importance of these forces and values or weights using different methods. The simplest way is to prioritize customers' requirements on the basis of the point-scoring (or grading) criteria so that customers give different factors scores between 1 and 5 or 1 and 10 (griffij and havser.1993). However, these methods fail to effectively meet the customers' realizations of product (G.K kwong). Many of methods for solving problems and decision makings have been complicated and can not be simply quantified. The Fuzzy theory uses estimated and ambiguous data like human for decision making. This method is intended for conditions with lack of high reliability.

Review of Fuzzy AHP

Many methods by different writers are provided for solving problems that presented through Fuzzy AHP. The first step was taken by Van lahron Vepidech that Fuzzy proportions compared with triangular membership function, have been described. Biokley (1985) specified the compared proportions of fuzzy priorities using trapezoid membership function. Stam and his friends (1996) determined or estimated the importance proportions in AHP using artificial intelligence. Chang (1996) introduced a new method for solving fuzzy AHP using triangular fuzzy numbers for paired comparisons. Ghahreman together with his friends (1998) introduced a method to obtain AHP weights and to provide evaluation of fuzzy weights using objective and abstract variations. Chang (1999) provided a new method for evaluation of an armament system using hierarchy analysis process based on oral variables. The Chang's method has been used in this study as Extent Analysis Method. The number (1) indicates the factors influencing customers satisfactions compared in pairs.

Triangular fuzzy numbers

The F fuzzy set defined as below:

$F=\{(x, m_f(x), x \in r)\}, m_f(x): R \rightarrow [0,1]$

The M fuzzy number is given as M=(L.M.U) that its membership function equals:

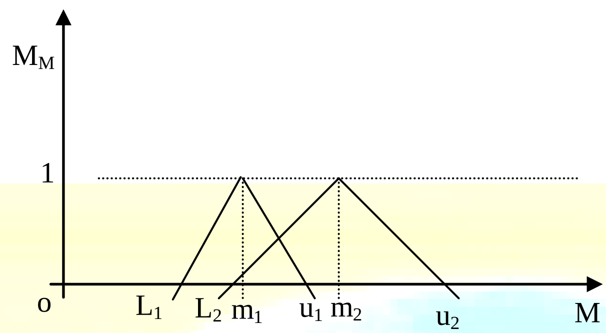
$M_m(x)=R \rightarrow [0,1]$

$$\mu_m(x) = \begin{cases} \frac{x}{m-L} - \frac{L}{m-L} & xE\,[L, m] \\ \frac{x}{m-u} - \frac{u}{m-u} & xE\,[m, u] \end{cases}$$

When L=M=U, in this case M is no longer a fuzzy number, but it is a normal number. The main functional rules for two triangular numbers of M.m2 are as below, Kafman(199):

$$M_1 = (L_1, m_1, u_1), M_2 = (L_2, m_2, u_2)$$
$$M_1 + M_2 = (L_1 + L_2, m_1 + m_2, u_1 + u_2)$$
$$M_1 \times M_2 = (L_1 L_2, m_1 m_2, u_1 u_2)$$
$$\lambda \times M_1 = (\lambda l_1, \lambda m_1, \lambda u_1)$$
$$M_1^{-1} = (\frac{1}{u_1)}, \frac{1}{m_1}, \frac{1}{\lambda_1})$$

The triangular fuzzy numbers of M_1, M_2 are shown on the following diagram:



The paired comparisons of customers' requirements

Questionnaire is devised so that customer can easily compare factors to each other and explain importance of his preferences. If responder marks right side of term 'same', it means that right side factor is of greater importance compared to left side action. When left side of term 'same' is marked, it is meant that left side factor is of grater importance compared to right side action. Assumed that a person realizes factor 'I' compared to factor 'j' based on very specific important criteria, its corresponding triangular fuzzy number is equals to aij= (2.33,3 &3.67). In this case, factor j compared to I is of very low importance, and paired comparison between I and j using fuzzy numbers is shown as below:

$$\frac{1}{3/67},\frac{1}{3},\frac{1}{2/33}$$

Assume that calculation of single weight vector of hierarchy levels $X = \{x_1,....x_n\}$, is the reference set $U = \{u_1,....u_m\}$, it is possible to obtain m extent analysis value for each Xi according to Chang EA method as below: $Mg_i^1, Mg_i^2,...., Mg_i^m$ i=1,2…….n so that all triangular fuzzy numbers $(j = 1,...., m_1, Mg^j$ of extent analysis process can be written as below:

1st Process:

Value of extent fuzzy combination according to I of x can be defined as:

$$S= \sum_{j=1}^{m} Mg_i^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} mg_i^j \right]$$

To obtain $\sum_{j=1}^{m} mg_i^j$, fuzzy addition operations as regards m value (EA) is done for matrixes so:

$$\sum_{j=1}^{m} mg_i^j = (\sum_{j=1}^{m} li, \sum_{j=1}^{m} mj, \sum_{j=1}^{m} uj)$$

To obtain $\left[\sum_{i=1}^{m}\sum_{j=1}^{m} mg_i^j\right]$, first do the fuzzy addition operation:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} mg_i^j \quad \left(\sum_{i=1}^{n} li, \sum_{i=1}^{n} mi, \sum_{i=1}^{n} ui\right)$$

And then inversion obtained:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} Mg_i^j\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} ui}, \frac{1}{\sum_{i=1}^{n} mi}, \frac{1}{\sum_{i=1}^{n} Li}\right)$$

2nd process

In general, if M (L_1, m, u) and M (L.m,u) are two triangular fuzzy numbers, the extensiveness rate of m1 and m2 is defined as:

$$V(M_2 \geq M_1) = \sup_{y \geq x}[\min(\mu_{m_1}(x), \mu_{m_2}(y))]$$

$$V = (m_2 \geq m_1) = hot(m_1 \cap m_2)$$

if $M_2 > M_1$

if $L_1 > U_2$

$$= \begin{cases} 1 \\ 0 \\ \dfrac{L_1 - U_2}{(m_2 - U_2) - (m_1 - L_1)} \end{cases}$$

So that d is the maximum L of cross point between m_1 and m_2 (number2).

It is needed to calculate v (m1≥m2) and v ($m_2 \geq m_1$) for comparison of m1 and m2.

3rd process:

The greatness rate of a convex fuzzy number than k convex fuzzy number M1(i=1,2,….k), is defined as below:

$$V(M \geq m_1, m_2, \ldots m_k)$$
$$= V[(m \geq m_1), (m \geq m_2), \ldots, (m \geq m_k)]$$
$$= \min V(m \geq m_i), i = 1,2,\ldots,k$$

Assuming that $d'(A_i) = \min V(S_i \geq S_k)$ for $k = 1,2.....n, k \neq i$, then the weight vector is obtained as:

$$W' = (d'(A_1), d(A'), \ldots\ldots d'(A_n))T$$

So that there are nAi element, n…, ., =2,1 i

$$V(M_2 \geq M_1)$$

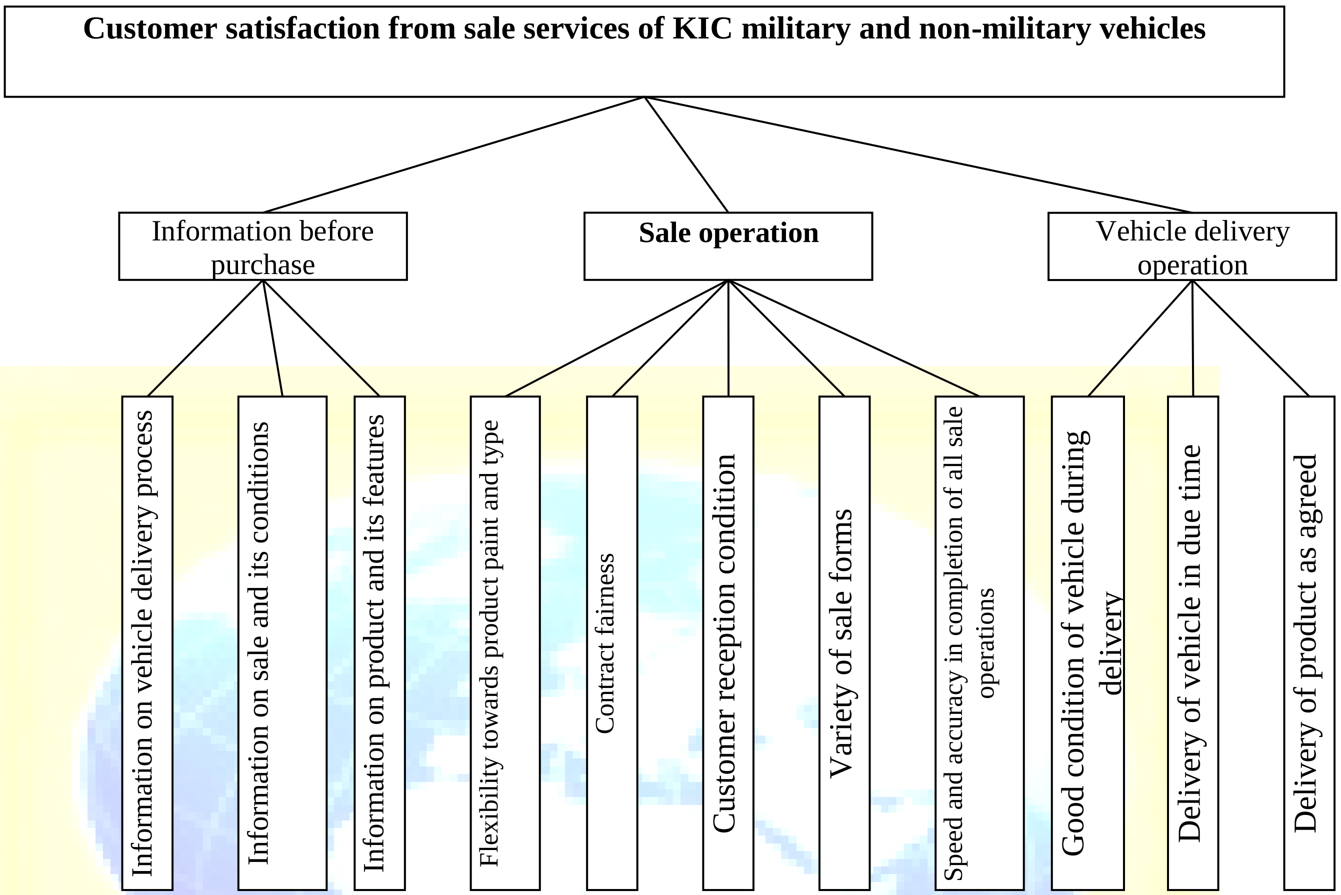
4th process:

Now the weight vector can be normalized**;**

$$W = (d_1 A_1) \cdot d\ (A_2), \ldots. d(A_n)T$$

So that W is a non fuzzy number.

In order to make sure that the questionnaire frame is clear, 30 people of military and non military vehicles owners, purchased from sale department, were used to complete the primary questionnaire and existing structural difficulties were eliminated based on difficulties people faced during completing the questionnaire.



A questionnaire is devised for prioritizing customers requirements, 30 customers are wanted to complete the questionnaire. The customers are asked to compare specified factors in pairs and determine the importance extent of each pair of the factors. The results of field analysis indicates that three factors of information before purchase, sale operation and product delivery operation are main factors forming the customers satisfaction from sale services (table 1-4 and 2-4).

Table (4-1) the ultimate value or weight of main criteria influencing customer satisfaction from non-military sale services

Title	Name of critera	Value obtained from analysis AHP	Value obtained from analysis FAHP
Customer satisfaction	Information before purchase	0/466	0/385
	Sale operation	0/163	0/24
	Product delivery operation	0/370	0/375

Table (4-2) the ultimate value or weight of main criteria influencing customer satisfaction from military sale services

Title	Name of critera	Value obtained from analysis AHP	Value obtained from analysis FAHP
Customer satisfaction	Information before purchase	0/38	0/36
	Sale operation	0/216	0/27
	Product delivery operation	0/405	0/37

According to available data in above table, it can be resulted that 3 criteria of information before purchase, sale operation and product delivery operation are of main criteria influencing customers' satisfaction from KIC products and matrix compatibility rate of criteria paired comparisons in AHP method for the non-military is 0.03 and also incompatibility rate of the whole model for the non-military is 0.03 and incompatibility rate of these criteria for military is 0.02 and incompatibility rate of the whole model for the military is 0.01. These criteria are compatible and reliable and the main theory 1 is confirmed.

Theory 2: Factors influencing customers' satisfaction from KIC product sale and delivery services based on Fuzzy Analytic Hierarchy Process (FAHP) are in different grades.

After that data relevant to judgments of KIC products owners collected, the relative weights of criteria and sub criteria as well as priority of these criteria in each level of decision tree hierarchy are calculated that date provided and summary of calculations are given as below.

{What has been given below is only related to the calculations of Fuzzy Analytic Hierarchy Process data. Analysis of corresponding hierarchy process data is done using **Expert choice** software, which are also given in the enclosure 2}.

Table (4-3) ultimate matrix of non-military main criteria data

Data ultimate matrix AHP			Data ultimate matrix FAHP			
Information before purchase	Product delivery operation	Sale operation	Information before purchase	Product delivery operation	Sale operation	
0/41	0/37	1	0/76 , 1/3) (0/55,	0/73, 1/18) (0/55,	(1, 1, 1)	Sale operation
0/66	1	2/7	0/92, 1/54) (0/62,	(1, 1, 1)	1/36, 1/8) (0/84,	Product delivery operation
1	1/5	4/2	(1, 1, 1)	1/08, 1/75) (0/64,	1/3, 1/8) (0/76,	Information before purchase

$$S_k = \sum M_{kj} \left[\sum\sum M_{ij}\right]^{-1}$$

$$\sum\sum M_{ij} = (6/96\ ,\ 9/15\ ,\ 12/37)$$

$$\left[\sum\sum M_{ij}\right]^{-1} = (0/8\ ,\ 0/109\ \ 0/14)$$

$$\sum_{j=1}^{3} M_{1j} = (/2\ ,\ 2/49\ ,\ 3/48) \rightarrow S_1 = (0/168\ ,\ 0/27\ ,\ 0/49)$$

$$\sum_{j=1}^{3} M_{2j} = (/46\ ,\ 3/28\ ,\ 4/34) \rightarrow S_1 = (0/197\ ,\ 0/36\ ,\ 0/6)$$

$$\sum_{j=1}^{3} M_{3j} = (/4\ ,\ 3/38\ ,\ 4/55) \rightarrow S_3 = (0/19\ ,\ 0/37\ ,\ 0/64)$$

In general, if $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$, degree of M_1 and M_2 greatness is defined as below:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M2}(d) = \begin{cases} 1 & m_2 \geq m_1 \\ 0 & l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & otherwise \end{cases}$$

Amount of a fuzzy number greatness than K fuzzy number $M_i\ (i = 1, 2, \ldots, K)$ is defined as below:

$$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1), \ldots, (M \geq M_k)]$$
$$= \min V(M \geq M_i) \quad , \quad i = 1, 2, \ldots, K$$

Sale operation $S_1 = (0/168\ ,\ 0/27\ ,\ 0/49)$

Product delivery operation $S_2 = (0/197\ ,\ 0/36\ ,\ 0/6)$

Information before purchase $S_3 = (0/19\ ,\ 0/37\ ,\ 0/64)$

$V(S_1 \geq S_2) = 0/62$	$V(S_1 \geq S_3) = 0/75$	$V(S_1 \geq S_2, S_3) = \min(0/62, 0/75) = 0/62$
$V(S_2 \geq S_1) = 1$	$V(S_2 \geq S_3) = 0/97$	$V(S_2 \geq S_1, S_3) = \min(1, 0/97) = 0/97$
$V(S_3 \geq S_1) = 1$	$V(S_3 \geq S_2) = 1$	$V(S_3 \geq S_2, S_3) = \min(1, 1) = 1$

Where, these figures indicate not normalized value or weights of indexes for sale operation, product delivery operation and information before a non-military purchase.

$$W' = (0/62\ ,\ 0/97\ ,\ 1)$$

Here, based on $W_i = \frac{w_i'}{\sum W_i'}$ relation, amount of mentioned normalized values is obtained:

$$W = (0/24\ ,\ 0/375\ ,\ 0/385)$$

The ultimate matrix of sale operation sub criteria (nonmilitary)

Date ultimate matrix FAHP

	A	B	C	D	E
A	(1, 1 , 1)	(0/83, 1/2, 1/7)	(0/48, 0/71, 1/2)	(0/68, 1/02, 1/5)	0/79, 1/27) (0/56,
B	0/82, 1/2) (0/57,	(1, 1, 1)	0/77, 1/28) (0/54,	0/96, 1/4) (0/657,	(0/54, 0/71, 1/2)
C	(0/82, 1/4, 2)	(0/78, 1/3, 1/8)	(1, 1, 1)	(0/97, 1/47, 1/9)	1/15, 1/56) (0/85,
D	0/98, 1/4) (0/64,	1/03, 1/5) (0/69,	(0/5, 0/68, 1/02)	(1, 1, 1)	(0/5, 0/76, 1/35)
E	1/26, 1/8) (0/78,	(83, 1/4, 1/8)	0/87, 1/17) (0/64,	(0/74, 1/3, 1/9)	(1, 1, 1)

Date ultimate matrix AHP

A	B	C	D	E
1	1/7	/42 0	1/2	0/5
0/58	1	/43 0	/83 0	/41 0
2/4	2/3	1	2/6	1/3
0/83	1/2	/38 0	1	/41 0
2	2/4	/77 0	2/4	1

A: Speed and accuracy
B: Variety of sale forms
C: Customer reception condition
D: Fairness of contract
E: Flexibility towards product paint and type

$$S_k = \sum M_{kj} \left[\sum\sum M_{ij}\right]^{-1}$$

$$\sum\sum M_{ij} = (8/597\ ,\ 25/58\ ,\ 34/95)$$

$$\left[\sum\sum M_{ij}\right]^{-1} = (0/028\ ,\ 0/04\ ,\ 0/054)$$

Speed and accuracy in completion of sale operation $S_1 = (0/099\ ,\ 0/18\ ,\ 0/36)$

Variety of sale forms $S_2 = (0/092\ ,\ 0/17\ ,\ 0/33)$

Customer reception condition $S_3 = (0/12\ ,\ 0/25\ ,\ 0/45)$

Fairness of contract $S_4 = (0/093\ ,\ 0/18\ ,\ 0/34)$

Flexibility towards product paint and type $S_5 = (0/11\ ,\ 0/23\ ,\ 0/41)$

$V(S_1 \geq S_2) = 1$, $V(S_1 \geq S_3) = 0/77$, $V(S_1 \geq S_4) = 1$, $V(S_1 \geq S_5) = 0/83$

$V(S_2 \geq S_1) = 0/96$, $V(S_2 \geq S_3) = 0/72$, $V(S_2 \geq S_4) = 0/96$, $V(S_2 \geq S_5) = 0/78$

$V(S_3 \geq S_1) = 1$, $V(S_3 \geq S_2) = 1$, $V(S_3 \geq S_4) = 1$, $V(S_3 \geq S_5) = 1$

$V(S_4 \geq S_1) = 1$, $V(S_4 \geq S_2) = 1$, $V(S_4 \geq S_3) = 0/76$, $V(S_4 \geq S_5) = 0/76$

$V(S_5 \geq S_1) = 1$, $V(S_5 \geq S_2) = 1$, $V(S_5 \geq S_3) = 0/935$, $V(S_5 \geq S_4) = 1$

$$V(S_1 \geq S_2 , S_3 , S_4 , S_5) = \min \{1 , 0/77 , 1 , 0/83\} = 0/77$$

$$V(S_2 \geq S_1 , S_3 , S_4 , S_5) = \min \{0/96 , 0/72 , 0/96 , 0/78\} = 0/72$$

$$V(S_3 \geq S_1 , S_2 , S_4 , S_5) = \min \{1 , 1 , 1 , 1\} = 1$$

$$V(S_4 \geq S_1 , S_2 , S_3 , S_5) = \min \{1 , 1 , 0/76 , 0/76\} = 0/76$$

$$V(S_5 \geq S_1 , S_2 , S_3 , S_4) = \min \{1 , 1 , 0/935 , 1\} = 0/935$$

Abnormal values:

$$M' = (0/77 , 0/72 , 1 , 0/76 , 0/935)$$

Normalized values of indexes:

$$M = (0/19 , 0/17 , 0/24 , 0/18 , 0/22)$$

$$W = (0/27 , 0/37 , 0/36)$$

The data ultimate matrix of sale operation sub criteria (military)

Date ultimate matrix FAHP

	A	B	C	D	E
A	**(1 , 1 , 1)**	**(1/76 , 1/09 , 1/54)**	**(0/64 , 0/9 , 1/28)**	**(0/52 , 1/74 , 1/08)**	**(0/55 , 0/7 , 1/09)**
B	**(0/64 , 0/9 , 1/3)**	**(1 , 1 , 1)**	**(0/58 , 0/86 , 1/24)**	**(0/58 , 0/84 , 1/2)**	**(0/53 , 0/75 , 1/07)**
C	**(0/78 , 1/09 , 1/5)**	**(0/8 , 1/15 , 1/7)**	**(1 , 1 , 1)**	**(0/68 , 0/93 , 1/3)**	**(0/64 , 0/86 , 1/2)**
D	**(0/92 , 1/35 , 1/9)**	**(0/82 , 1/18 , 1/7)**	**(0/77 , 1/07 , 1/47)**	**(1 , 1 , 1)**	**(0/77 , 1/09 , 1/5)**
E	**(0/91 , 1/3 , 1/8)**	**(0/92 , 1/3 , 1/87)**	**(0/82 , 1/16 , 1/56)**	**(0/65 , 0/9 , 1/3)**	**(1 , 1 , 1)**

Date ultimate matrix AHP

A	B	C	D	E
1	**1/2**	**0/9**	**0/5**	**0/58**
0/83	**1**	**0/82**	**0/7**	**//55 0**
1/1	**1/2**	**1**	**1/83**	**0/65**
2	**1/4**	**1/2**	**1**	**1/2**
1/7	**1/8**	**1/5**	**0/82**	**1**

A: Speed and accuracy
B: Variety of sale forms
C: Customer reception condition
D: Fairness of contract
E: Flexibility towards product paint and type

$$W = (0/175 , 0/175 , 0/2 , 0/23 , 0/22)$$

The information received after analysis of data in fuzzy analytic hirarchy process are given in the following tables including relative value of criteria and sub criteria and also priority of the criteria in each hirarchy level of decision tree is calculated.

Table (4-6) Comparison of priority order of nonmilitary criteria and sub criteria in two methods of fuzzy analytic hierarchy process and classic analytic hierarchy process.

Group title	Name of criteria	Ultimate value in FAHP method	Ultimate value in AHP method	Priority based on FAHP	Priority based on AHP
Main criteria (goal)	Sale operations	0/24	0/163	3	3
	Product delivery operation	0/375	0/370	2	**2**
	Information before purchase	0/385	0/466	1	1
Sub-criteria	Speed and accuracy in completing all sale operations	0/0456	0/033	9	9
	Variety of sale forms	0/0408	0/024	11	11
	Customer reception condition	0/0576	0/070	6	6
	Fairness of contract	0/0432	0/027	10	10
	Flexibility towards product paint and type	0/0582	0/060	8	8
	Delivery of product in due time	0/0975	0/064	7	7
	Delivery of product as agreed	0/1125	0/090	5	5
	Safety of product parts during delivery	0/165	0/159	1	2
	Information on the product and its features	0/12705	0/126	3	4
	Information on sale, time to enroll and sale conditions	0/11935	0/145	4	3
	Information on product delivery condition	0/1386	0/201	2	1

Table (4-7) Comparison of priority order of military criteria and sub criteria in two methods of fuzzy analytic hierarchy process and classic analytic hierarchy process.

Group title	Name of criteria	Ultimate value in FAHP method	Ultimate value in AHP method	Priority based on FAHP	Priority based on AHP
Main criteria (goal)	Sale operations	0/27	0/216	3	3
	Product delivery operation	0/37	0/405	1	1
	Information before purchase	0/36	0/38	2	2
Sub-criteria	Speed and accuracy in completing all sale	0/04725	0/051	10	10
	Variety of sale forms	0/04725	0/049	11	11
	Customer reception condition	0/054	0/06	9	7
	Fairness of contract	0/0621	0/085	7	5
	Flexibility towards product paint and type	0/0594	0/083	8	6
	Delivery of product in due time	0/0962	0/06	5	8
	Delivery of product as agreed	0/0814	0/058	6	9
	Safety of product parts during delivery	0/1924	0/159	1	1
	Information on the product and its features	0/1008	0/097	4	4
	Information on sale, time to enroll and sale conditions	0/1296	0/149	2	2
	Information on product delivery condition	0/1296	0/149	3	3

As it is noted, the ultimate value obtained in two methods differ from each other so that the ultimate value of nonmilitary main criteria in fuzzy analytic hierarchy process method are 0.27, 0.37 and 0.36 respectively, but its corresponding ultimate value or weights in analytic hierarchy process method is 0.216, 0.405 and 0.38. Also, the ultimate values or weights of military main criteria in fuzzy analytic hierarchy process method are 0.24, 0.375 and 0.385 respectively. While their corresponding ultimate values or weights in analytic hierarchy process method are 0.163, 0.37 and 0.466. Accordingly, the ultimate weights or values of sub-criteria are also different in two products, but priority of main criteria both in nonmilitary and military are the same, yet priority of sub-criteria for two products are different from one another in two methods.

Conclusion:

Nowadays, taking decision is made in a very complicated environment. In many of decisions, taken in such a complicated environment, fuzzy decision making can also overcome problems resulting from complexity of environment. The current essay covers grading of factors influencing customers' satisfaction from vehicles. 9-point criteria are used in classic AHP paired comparisons to indicate importance of factors. Despite its easy and simple use, but it can not show the uncertainty found in human judgments. Because, a person's evaluation is always unclear and subjective. Fuzzy AHP can also overcome such problem. There are many methods for comparison of factors influencing customers' satisfaction such as TOPSIS and ELECTRE. Such methods are recently used more in the fuzzy environments. In coming studies, such methods can be used for grading and comparison of factors influencing customers' satisfaction from car companies.