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Decision Making Under Risk for Chronic Pancreatitis Using Triangular Fuzzy Number

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Abstract:*Chronic pancreatitis (CP) remain unchanged indefinitely which cause infection in pancreas and will be never cured or enrich by the change in internal organs, structures and their functions. However data on chronic pancreatitis are not well defined and so the difficulty in medical diagnosis developed a new research study for finding the clinical program from acute pancreatitis to chronic pancreatitis. Our research study is based on acute pancreatitis (AP) that affects the patients under our medical diagnostic model among this chronic pancreatitis are found to be in men affected patients. This paper we described here is decision making under risk for triangular fuzzy number in medical diagnostic model. We also analyzed decisions under a state of risk for the acute pancreatitis patients in which output parameter connected with medical evidences are known, which will be concluded once their patient experience.*

Index Terms*:Acute and chronic pancreatitis; Decision under risk; Fuzzy number; Triangular fuzzy number; Saddle point.*

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I. Introduction

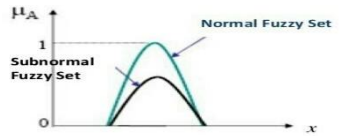
L.A. Zadeh[1] formulated fuzzy set theory and their applications in both mathematical approach and medical knowledge based system. Several authors studied and investigated fuzzy matrices and decision making. In this medical field it is very hard to predict correct decision making under risk but in case of fuzzy it is very much useful for finding decision under fuzzy environment. The history of chronic pancreatitis developed by Elham Afghani [3]. Many authors investigated and extended the field of medical research on chronic pancreatitis studies.

II. Definitions and Preliminaries

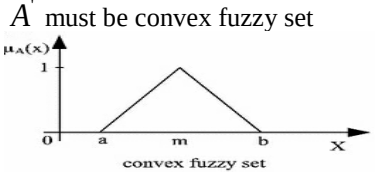
Let S' be a set. A fuzzy set A' on S' is defined to be a function $A': S' \to [0,1]$ or $\mu_{A'}: S' \to [0,1]$. In other words, a fuzzy set A' is defined to be the class of objects having the following representation $A' = \{(s', \mu_{A'}(s')) : s' \in S'\}$ where $\mu_{A'}: S' \to [0,1]$ is a function called the membership function of A'.

Definition 2.1: The fuzzy number A' is a fuzzy set whose membership function $\mu_{A'}(s')$ satisfies the following conditions:

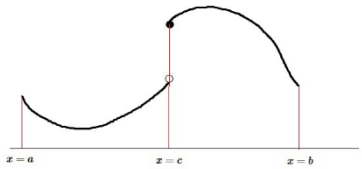
- A' must be a normal fuzzy set



- A' must be convex fuzzy set



- It should be piecewise continuous



Definition 2.2: A triangular fuzzy number is a fuzzy number represented with three points as follows: $A' = (a_1', a_2', a_3')$, this representation is interpreted as a function $\mu_{A'}(s')$.

$$\mu_{A'}(s') = \begin{cases} 0, & s' \le a_1' \\ \dfrac{s' - a_1'}{a_2' - a_1'}, & a_1' < s' \le a_2' \\ 1, & s' = a_2' \\ \dfrac{a_3' - s'}{a_3' - a_2'}, & a_2' < s' \le a_3' \\ 0, & s' \ge a_3' \end{cases}$$

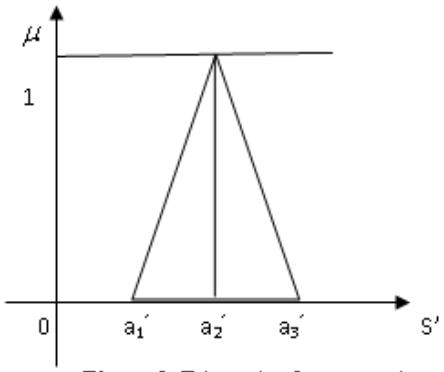


Figure 1. Triangular fuzzy number

Next we will define addition, subtraction and multiplication of two triangular fuzzy numbers

$$(a)\ \ (a_1', a_2', a_3') + (b_1', b_2', b_3') = (a_1' + b_1', a_2' + b_2', a_3' + b_3')$$

$$(b)\ \ (a_1', a_2', a_3') - (b_1', b_2', b_3') = (a_1' - b_3', a_2' - b_2', a_3' - b_1')$$

$$(c)\ \ (a_1', a_2', a_3') \times (b_1', b_2', b_3') = [\min(a_1'b_1', a_1'b_3', a_3'b_1', a_3'b_3'), a_2'b_2', \max(a_1'b_1', a_1'b_3', a_3'b_1', a_3'b_3')]$$

Definition 2.3: Decision making under risk refer to decision situations where the decision maker chooses from among several possible outcomes where output parameters of occurrence can be stated (or determined) objectively from the past data.

Definition 2.3.1: Triangular fuzzy expected monetary value is used for calculating the expected monetary value for each act using the output parameters.

TF_{emv} = $\sum$ [(outcome of each output parameter) × (outcome of each payoff)]

Definition 2.3.2: Triangular fuzzy expected opportunity loss is a method will require calculation of expected opportunity loss for each data using output parameters.

TF_{eol} = $\sum$ [(outcome of each output parameter) × (regret of outcome)]

Note: regret = best payoff - payoff received

Definition 2.3.3: Triangular fuzzy expected value of perfect information is referred as the difference between the expected value with perfect information and the maximum expected value without perfect information computed under uncertainty.

$$TF_{evpi} = TF_{ev_w pi} - TF_{ev_{wo} pi} \text{ where } TF_{ev_{wo} pi} = \max TF_{emv}$$

(or)

$$TF_{evpi} = \min TF_{eol}$$

Definition 2.4:A saddle or equilibrium point in a payoff matrix is that position in the payoff matrices where maximum of row minima coincides with the minimum of column maximum.

III. Algorithm

Step 1 : List the TFN and compute event output parameters

Step 2 : Next we will calculate TF_{emv} which is summarized as below

Step 2.1: List triangular fuzzy number for each event combination along with corresponding event output parameters.
Step 2.2: For each TFN, determine the expected conditional profit
Step 2.3: Determine TF_{emv} for each TFN
Step 2.4: Choose the TFN which corresponds to the optimal TF_{emv}
Step 3 : Further we investigate TF_{eol} in detail
Step 3.1: List the conditional profit table for each TFN event combination along with corresponding event output parameters.
Step 3.2: For each event, determine the TF_{col} values by first locating the most maximum TFN for that event and then taking the difference between the conditional profit value and each conditional profit for that event.
Step 3.3: For each TFN determine the expected TF_{col} values and sum there values to get the expected opportunity loss for that TFN.
Step 3.4: Choose that TFN which corresponds to the minimum TF_{col} value.
Step 4 : Finally we have calculated TF_{evpi}.

$$TF_{evpi} = TF_{ev_w pi} - TF_{ev_{wo} pi} \quad \text{Where } TF_{ev_{wo} pi} = \max TF_{emv}$$

(Or)

$$TF_{evpi} = \min TF_{eol}$$

Step 5 : We conclude the algorithm by finding the saddle point.
The above algorithm can be described further by giving a suitable example based on medical knowledge with triangular fuzzy number.

IV. Numerical Applications

In a hospital we consider 5 Patients whose medical evidences are identified as CP diseased affected people like upper abdominal pain, nausea and vomiting, fever, diarrhea and weight loss which are represented by N_1, N_2, N_3, N_4 and N_5 respectively. Now we shall take patient disease triangular fuzzy number which is determined between 0 and 1.

Medical evidence	Strategic parameters	Output parameters
Upper abdominal pain	$S_1 = (0.001, 0.002, 0.003)$	$N_1 = (0.10, 0.14, 0.18)$
Nausea and vomiting	$S_2 = (0.003, 0.0035, 0.0038)$	$N_2 = (0.2, 0.26, 0.3)$
Fever	$S_3 = (0.004, 0.0043, 0.0048)$	$N_3 = (0.34, 0.36, 0.42)$
Diarrhea	$S_4 = (0.0046, 0.0051, 0.0054)$	$N_4 = (0.45, 0.52, 0.56)$
Weight loss	$S_5 = (0.0063, 0.0067, 0.0072)$	$N_5 = (0.6, 0.64, 0.7)$

Under CP-model at first we consider upper abdominal pain CP affected patients with their respective output parameters and using definition 2.2 (c) we calculated

Step 1

$S_1N_1 = (0.0001, 0.00028, 0.00054)$
$S_1N_2 = (0.0002, 0.00052, 0.0009)$
$S_1N_3 = (0.00034, 0.00072, 0.00126)$
$S_1N_4 = (0.00045, 0.00104, 0.00168)$
$S_1N_5 = (0.0006, 0.00128, 0.0021)$

Next we also observed that 4 more medical evidences affected with chronic pancreatitis like nausea and vomiting, fever, diarrhea and weight loss patients can be evaluated in a similar fashion using definition 2.2 (c) and we represented as

$S_2N_1 = (0.0003, 0.00049, 0.000684)$
$S_2N_2 = (0.0006, 0.00091, 0.00114)$
$S_2N_3 = (0.00102, 0.00126, 0.001596)$
$S_2N_4 = (0.00135, 0.00182, 0.002128)$
$S_2N_5 = (0.0018, 0.00224, 0.00266)$

S_3N_1 = (0.0004, 0.000602, 0.000864)
S_3N_2 = (0.0008, 0.001118, 0.00144)
S_3N_3 = (0.00136, 0.001548, 0.002016)
S_3N_4 = (0.0018, 0.002236, 0.002688)
S_3N_5 = (0.0024, 0.002752, 0.00336)
S_4N_1 = (0.00046, 0.000714, 0.000972)
S_4N_2 = (0.00092, 0.001326, 0.00162)
S_4N_3 = (0.001564, 0.001836, 0.002268)
S_4N_4 = (0.00207, 0.002652, 0.003024)
S_4N_5 = (0.00276, 0.003264, 0.00378)
S_5N_1 = (0.00063, 0.000938, 0.001296)
S_5N_2 = (0.00126, 0.001742, 0.00216)
S_5N_3 = (0.002142, 0.002412, 0.003024)
S_5N_4 = (0.002835, 0.003484, 0.004032)
S_5N_5 = (0.00378, 0.004288, 0.00504)

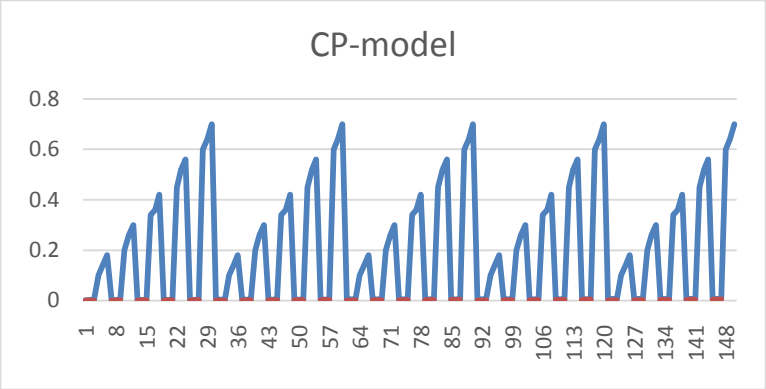


Figure 2. Chronic pancreatitis -triangular fuzzy number

It should be noted that the graph which we described in a more sophisticated way tells us how the patient-disease medical evidence of CP-model are we used under triangular fuzzy number with respect to crisp value.

The table below shows the triangular fuzzy expected monetary value for decision making under risk for the above output parameters and their corresponding their patient-medical evidence triangular fuzzy number.

Table 1: Triangular fuzzy expected monetary value

M/O	N_1	N_2	N_3	N_4	N_5	Output parameters
S_1	(0.0001, 0.00028, 0.00054)	(0.0002, 0.00052, 0.0009)	(0.00034, 0.00072, 0.00126)	(0.00045, 0.00104, 0.00168)	(0.0006, 0.00128, 0.0021)	(0.10, 0.14, 0.18)
S_2	(0.0003, 0.00049, 0.000684)	(0.0006, 0.00091, 0.00114)	(0.00102, 0.00126, 0.001596)	(0.00135, 0.00182, 0.002128)	(0.0018, 0.00224, 0.00266)	(0.2, 0.26, 0.3)
S_3	(0.0004, 0.000602, 0.000864)	(0.0008, 0.001118, 0.00144)	(0.00136, 0.001548, 0.002016)	(0.0018, 0.002236, 0.002688)	(0.0024, 0.002752, 0.00336)	(0.34, 0.36, 0.42)
S_4	(0.00046, 0.000714, 0.000972)	(0.00092, 0.001326, 0.00162)	(0.001564, 0.001836, 0.002268)	(0.00207, 0.002652, 0.003024)	(0.00276, 0.003264, 0.00378)	(0.45, 0.52, 0.56)
S_5	(0.00063, 0.000938, 0.001296)	(0.00126, 0.001742, 0.00216)	(0.002142, 0.002412, 0.003024)	(0.002835, 0.003484, 0.004032)	(0.00378, 0.004288, 0.00504)	(0.6, 0.64, 0.7)

Also the graphical CP disease representation proved clearly that the patient affected with CP that too ACP will be cured but with respect to the above medical evidence we have mentioned and here we come to the conclusion that the patient with weight loss is more affected under output parameter condition we extended our calculation to find triangular fuzzy expected monetary values using definition 2.2 (a) & (c).

From this we conclude from medical knowledge based system that CP diseased patient affected with upper abdominal pain is thoroughly seen in S_1

Step 2

$TF_{emv}(S_1) = (0.001, 0.002, 0.003)$

Also we have analyzed the other medical evidences respectively as follows for nausea and vomiting, fever, diarrhea and weight loss which will be seen in S_2, S_3, S_4& S_5.

$TF_{emv}(S_2) = (0.002, 0.003, 0.004)$

$TF_{emv}(S_3) = (0.003, 0.004, 0.005)$

$TF_{emv}(S_4) = (0.003, 0.005, 0.006)$

$TF_{emv}(S_5) = (0.005, 0.006, 0.008)$

With the above calculations we have produced the ratio how the medical evidence of CP diseased people are more affected due to weight loss which is found to optimal with respect to fuzzy expected monetary values.

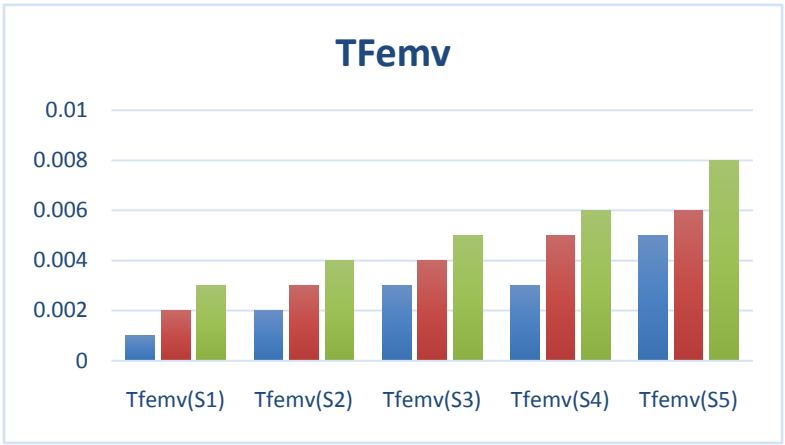


Figure 3. Triangular fuzzy expected monetary value

In this graph chronic pancreatitis disease is affected for the symptoms from S_1 to S_5 but S_5 is highly affected CP disease which is under risk.

The table below shows the triangular fuzzy expected opportunity loss for decision making under risk for the above output parameters and their corresponding patient-medical evidence triangular fuzzy number

Table 2: Triangular fuzzy expected opportunity loss

M/O	N_1	N_2	N_3	N_4	N_5	Output parameters
S_1	(0.00009, 0.000658, 0.001196)	(0.00036, 0.001222, 0.00196)	(0.000882, 0.001692, 0.002684)	(0.001155, 0.002444, 0.003582)	(0.00168, 0.003008, 0.00444)	(0.10, 0.14, 0.18)
S_2	(-0.000054, 0.000448, 0.000996)	(0.00012, 0.000832, 0.00156)	(0.000546, 0.001152, 0.002004)	(0.000707, 0.001664, 0.002682)	(0.00112, 0.002048, 0.00324)	(0.2, 0.26, 0.3)
S_3	(-0.000234, 0.000336, 0.000896)	(-0.00018, 0.000624, 0.00136)	(0.000126, 0.000864, 0.001664)	(0.000147, 0.001248, 0.002232)	(0.00042, 0.001536, 0.00264)	(0.34, 0.36, 0.42)
S_4	(-0.000342, 0.000224, 0.000836)	(-0.00036, 0.000416, 0.00124)	(-0.000126, 0.000576, 0.00146)	(-0.000189, 0.000832, 0.001962)	(0, 0.001024, 0.00228)	(0.45, 0.52, 0.56)
S_5	(-0.000666, 0, 0.000666)	(-0.0009, 0, 0.0009)	(-0.000882, 0, 0.000882)	(-0.001197, 0, 0.001197)	(-0.00126, 0, 0.00126)	(0.6, 0.64, 0.7)

As already calculated in Table 1 here we will demonstrated to find TF_{eol} using definition 2.2 (b) with the same assumptions we have taken the Table 2

If we consider the first medical evidence, where the CP patient will be completely lose their control even though dosage is given thereafter we analyzed the result to continue in our mathematically with the notion of triangular fuzzy number and their output parameters we get the TF_{eol} of the first patient

Step 3

$TF_{eol}(S_1) = (0.002, 0.004, 0.007)$

Similarly, we will look it for other symptoms S_2, S_3, S_4&S_5

$TF_{eol}(S_2) = (0.001, 0.003, 0.005)$

$TF_{eol}(S_3) = (0, 0.002, 0.004)$

$TF_{eol}(S_4) = (0, 0.001, 0.004)$

$TF_{eol}(S_5) = (-0.003, 0, 0.003)$

In the above TF_{eol} calculation we observe that under medical diagnostic model the most affected CP patient in S_5 which comparing with event output parameters it is known that weight loss is in high priority.

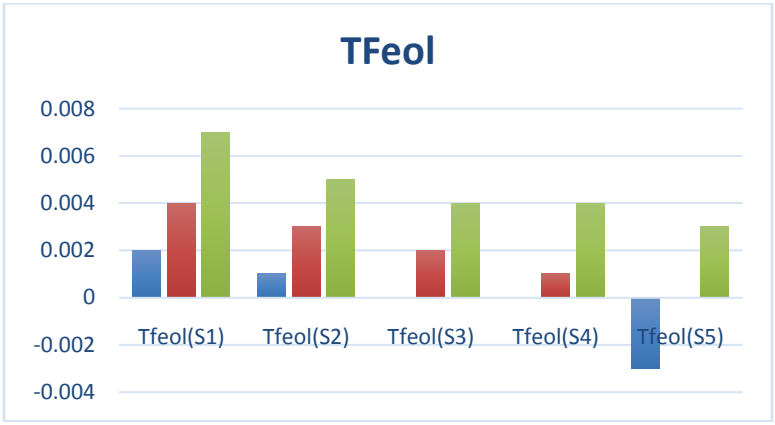


Figure 4. Triangular fuzzy expected opportunity loss

In the above graph representing S_1 to S_4 medical evidence patients can be cured under those who are affected with acute pancreatitis disease but for S_5 diseased patients are affected more in CP and cannot be cured which is weight loss we have concluded.

The table below shows the triangular fuzzy expected value of perfect information for decision making under risk for the above output parameters and their corresponding patient-medical evidence triangular fuzzy number

Table 3: Triangular fuzzy expected value of perfect information

M/O	N_1	N_2	N_3	N_4	N_5	Output parameters	TF_{emvs}
S_1	(0.0001, 0.00028, 0.00054)	(0.0002, 0.00052, 0.0009)	(0.00034, 0.00072, 0.00126)	(0.00045, 0.00104, 0.00168)	(0.0006, 0.00128, 0.0021)	(0.10, 0.14, 0.18)	(0.0007281, 0.0017936, 0.0033072)
S_2	(0.0003, 0.00049, 0.000684)	(0.0006, 0.00091, 0.00114)	(0.00102, 0.00126, 0.001596)	(0.00135, 0.00182, 0.002128)	(0.0018, 0.00224, 0.00266)	(0.2, 0.26, 0.3)	(0.0021843, 0.0031388, 0.00418912)
S_3	(0.0004, 0.000602, 0.000864)	(0.0008, 0.001118, 0.00144)	(0.00136, 0.001548, 0.002016)	(0.0018, 0.002236, 0.002688)	(0.0024, 0.002752, 0.00336)	(0.34, 0.36, 0.42)	(0.0029124, 0.00385624, 0.00529152)
S_4	(0.00046, 0.000714, 0.000972)	(0.00092, 0.001326, 0.00162)	(0.001564, 0.001836, 0.002268)	(0.00207, 0.002652, 0.003024)	(0.00276, 0.003264, 0.00378)	(0.45, 0.52, 0.56)	(0.00334926, 0.00457368, 0.00595296)
S_5	(0.00063, 0.000938, 0.001296)	(0.00126, 0.001742, 0.00216)	(0.002142, 0.002412, 0.003024)	(0.002835, 0.003484, 0.004032)	(0.00378, 0.004288, 0.00504)	(0.6, 0.64, 0.7)	(0.00458703, 0.00600856, 0.00793728)

Same as Table 1 we have calculated here by choosing best value for the medical evidences S_1 to S_5 with the respective output parameters using definition 2.2 (c)
As we formulated in algorithm step 4 we continuing the process

Step 4

$$TF_{ev_w pi} = (0.005, 0.006, 0.008)$$

$$TF_{ev_{wo} pi} = (0.005, 0.006, 0.008) \text{ where } TF_{ev_{wo} pi} = \max TF_{emv}$$

$$TF_{evpi} = (-0.003, 0, 0.003)$$

Under medical diagnose TF_{evpi} denotes the maximum number of patients affected with CP disease and which is found to be the patients no longer alive even though dosage is highly preferable.

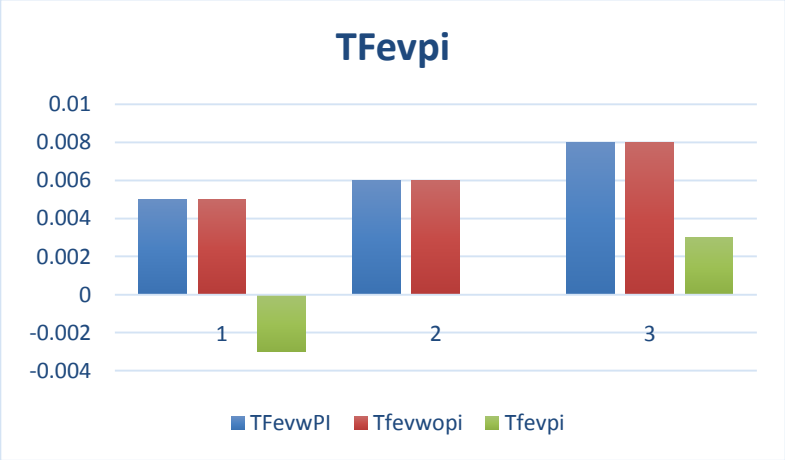


Figure 5. Triangular fuzzy expected value of perfect information

The above graph indicate that there is a opportunity of loss of patients affected with CP-model so that, the medical evidences are widely distributed to all the chronic pancreatitis patients. But it is clearly verified under mathematical model that, we have assumed the medical evidence of CP and shown that weight loss is the only evidence which is affected more in this type of CP-model disease.

Further we extend the work to find the saddle point under output parameter model and using definition 2.4 it describes in a more sophisticated way under triangular fuzzy number for minimum and maximum value.

I. Finding the saddle point for TF_{emv}

	R-Min
0.001 0.002 0.003	0.001
0.002 0.003 0.004	0.002
0.003 0.004 0.005	0.003
0.003 0.005 0.006	0.003
0.005 0.006 0.008	**0.005**
C-Max **0.005** 0.006 0.008	

Maximin = 0.005
Minimax = 0.005
Maximin = Minimax
It has a saddle point 0.005

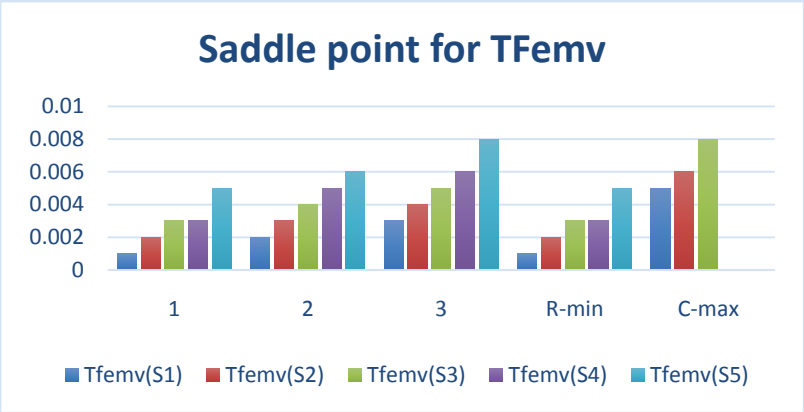


Figure 6. Saddle point for triangular fuzzy expected monetary value

It is clear from the graph that medical evidence which can be cured in an upper abdominal pain affected CP-disease that is the row minimum under output parameter way. Similarly the medical evidences which are either can be cured or not cured in weight loss affected CP diseased patients.
Similarly we can calculate the saddle point of expected loss under fuzzy model using the definition 2.4

II. Finding the saddle point for TF_{eol}

				R-Min
	0.002	0.004	0.007	**0.002**
	0.001	0.003	0.005	0.001
	0	0.002	0.004	0
	0	0.001	0.004	0
	−0.003	0	0.003	-0.003
C-Max	**0.002**	0.004	0.007	

Maximin = 0.002
Minimax = 0.002
Maximin = Minimax
It has a saddle point 0.002

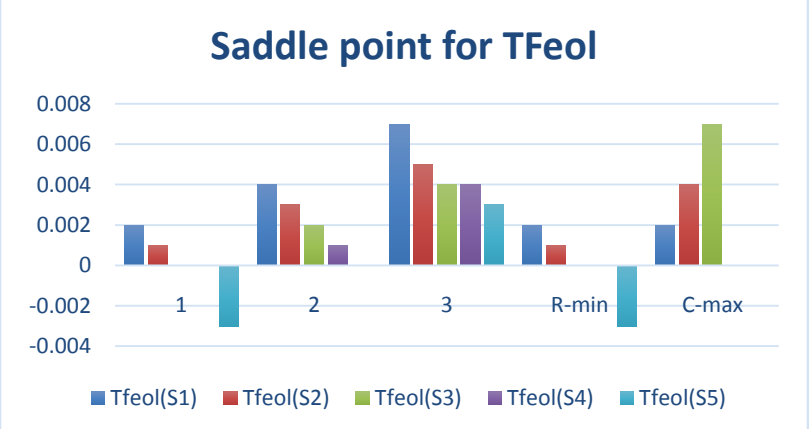


Figure 7. Saddle point for triangular fuzzy expected opportunity loss

The above graph represented that medical evidence which cannot be cured in weight loss affected CP-disease that is the row minimum under output parameter way. Similarly the medical evidence which can be cured in upper abdominal pain affected CP diseased patients.
Below we calculated the saddle point in expected value of perfect information using definition 2.4

III. Finding the saddle point for TF_{evpi}

				R-Min
	0.005	0.006	0.008	**0.005**
	0.005	0.006	0.008	0.005
	−0.003	0	0.003	-0.003
C-Max	**0.005**	0.006	0.008	

Maximin = 0.005
Minimax = 0.005
Maximin = Minimax
It has a saddle point 0.005

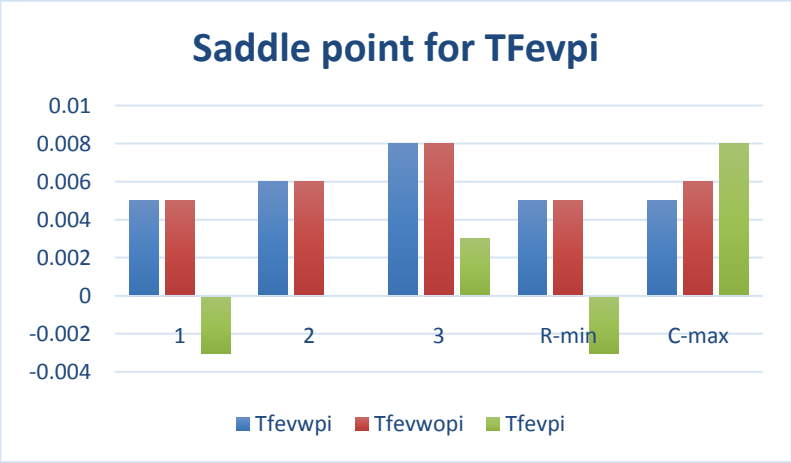


Figure 8. Saddle point for triangular fuzzy expected value of perfect information

The above graph represented that medical evidencewhich cannot be cured in weight loss affected CP-disease that is the row minimum under output parameter way. Similarly the medical evidence which can be cured in upper abdominal pain affected CP diseased patients.

We defined fuzzy membership for the strategic parameters (upper abdominal pain, nausea and vomiting, fever, diarrhea and weight loss) and output parameter that is decision making under risk ratio. For example fuzzy membership function for chronic pancreatitis is given below.

Let x be the chronic pancreatitis patient medical evidences form as

$$\mu_{s-low}(x) = \begin{cases} 1 & x < 0.001 \\ \dfrac{0.004 - x}{0.003} & 0.001 \le x \le 0.004 \end{cases}$$

$$\mu_{s-middle}(x)=\begin{cases}\dfrac{x-0.001}{0.003} & 0.001\le x<0.004\\ 1 & 0.004\le x\le 0.005\\ \dfrac{0.0054-x}{0.0004} & 0.005\le x<0.0054\end{cases}$$

$$\mu_{s-high}(x)=\begin{cases}\dfrac{x-0.0046}{0.0008} & 0.0046\le x\le 0.0054\\ 1 & 0.0054\le x\le 0.0072\end{cases}$$

Let y be the decision making under risk value for CP model membership output expression is given by

$$\mu_{TF_{env}}(y)=\begin{cases}\dfrac{y-0.001}{0.004} & 0.001\le y<0.005\\ 1 & 0.005\le y<0.0054\\ \dfrac{0.008-y}{0.004} & 0.0054\le y<0.008\end{cases}$$

$$\mu_{TF_{eol}}(y)=\begin{cases}\dfrac{y}{0.002} & 0\le y<0.002\\ \dfrac{0.007-y}{0.005} & 0.002\le y<0.007\\ 0 & y<1\end{cases}$$

$$\mu_{TF_{evpi}}(y)=\begin{cases}\dfrac{y-0.005}{0.003} & 0.005\le y<0.008\\ 1 & y\ge 0.008\end{cases}$$

$$\mu_{saddle\ point}(y)=\begin{cases}0 & y<1\\ \dfrac{y-0.001}{0.003} & 0.001\le y\le 0.004\\ 1 & y=0.005\\ \dfrac{0.008-y}{0.003} & 0.005\le y\le 0.008\\ 0 & y\ge 0.008\end{cases}$$

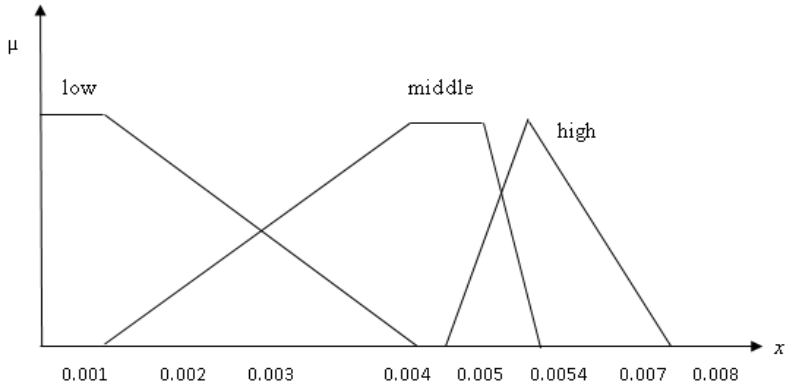


Figure 9. Input expression

In figure 9. The line graph describes for 5 medical evidences are low (upper abdominal pain), middle (fever) and high (weight loss) respectively under CP medical diagnostic model.

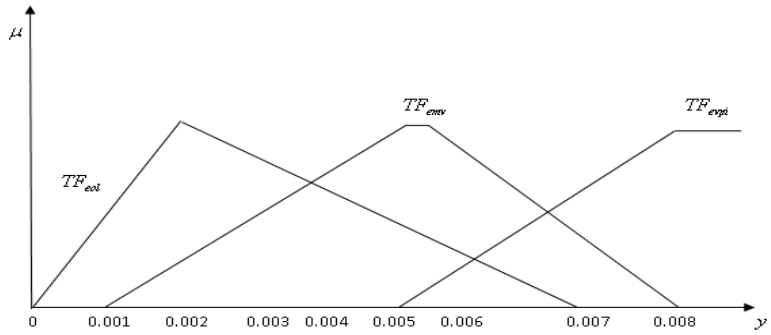


Figure 10. Output expression

In figure 10. The calculation which we have verified in Step 2,3&4 is the extension of the line graph which is in the form of triangular fuzzy number.

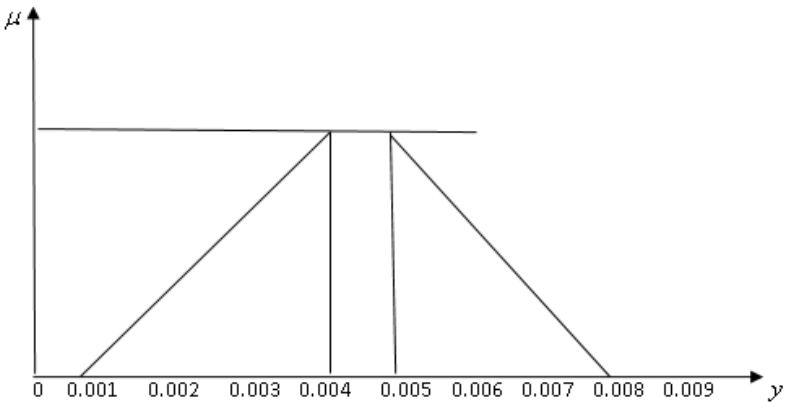


Figure 11. Saddle point

From the above figure (9&10) we infer that all the medical evidence will equalize for the CP-disease which we have shown in the form of line graph as saddle point.

V. Conclusion

Fuzzy set and decision making under risk frame work has been utilized in several different approaches to model the medical diagnostic process. We also infer that is very effective method for which it can help a physician to get a better accuracy when giving a diagnosis to the patient which we described using triangular fuzzy number. Also we developed a new study and which emerges many results concerning triangular fuzzy number. This new research study for decision making under risk designed a result under medical diagnostic model. Also we have shown the fuzzy membership function in the form of graphical representation of CP

diseased patients in comparison with medical evidence for finding how the patients can be cured and not cured with respect to the output parameter model for decision making under risk.

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Authors Profile

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