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Novel Method for Sensitivity Analysis of Fully Fuzzy Linear Programming Problem by Tabular Method

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Abstract- In the literature, there are various methods that deals with the sensitivity analysis of such linear programming problem in which some or all parameters are represented by triangular or trapezoidal fuzzy numbers by converting the whole problem into crisp linear programming problem. But till now, there is no method that deals with the sensitivity analysis of fully fuzzy linear programming problem (FFLPP) by tabular method. In this paper, a new method is proposed for the same.
Keywords: Fuzzy arithmetic, Fuzzy Set, Fully fuzzy linear programming problem, Triangular fuzzy number, Sensitivity analysis.

I. INTRODUCTION

The fuzzy set theory is being applied massively in many fields these days. One of these is linear programming problems. Sensitivity analysis is well-explored area in classical linear programming. Sensitivity analysis is a basic tool for studying perturbations in optimization problems. There is considerable research on sensitivity analysis for some operations research and management science models such as linear programming and investment analysis.

In most practical applications of mathematical programming the possible values of the parameters required in the modeling of the problem are provided either by a decision maker subjectively or a statistical inference from the past data due to which there exists some uncertainty. In order to reflect this uncertainty, the model of the problem is often constructed with fuzzy data [21].

Fuzzy linear programming provides the flexibility in values. But even after formulating the problem as fuzzy linear programming problem, one cannot stick to all the values for a long time or it is quite possible that the wrong values got entered. With time the factors like cost, required time or availability of product etc. changes widely. Sensitivity analysis for fuzzy linear programming problems needs to be applied in that case. Sensitivity analysis is one of the interesting researches in fuzzy linear programming problems.

Zimmermann [22] attempted to fuzzify a linear program for the first time, fuzzy numbers being the source of flexibility. Zimmermann also presented a fuzzy approach to multi-objective linear programming problems and its sensitivity analysis. Sensitivity analysis in fuzzy linear programming problem with crisp parameters and soft constraints was first considered by Hamacher et al. [7].

Tanaka and Asai [18] proposed a method for allocating the given investigation cost to each fuzzy coefficients by using sensitivity analysis. Tanaka et al. [19] formulated a fuzzy linear programming problem with fuzzy coefficients and the value of information was discussed via sensitivity analysis. Sakawa and Yano [16] presented a fuzzy approach for solving multi-objective linear fractional programming problems via sensitivity analysis.

Fuller [5] proposed that the solution to fuzzy linear programming problems with symmetrical triangular fuzzy numbers is stable with respect to small changes of centers of fuzzy numbers. Perturbations occur due to calculation errors or just to answer managerial questions ‘‘What if . . .’’. Such questions propose after the simplex method and the related research area refers to as basis invariance sensitivity analysis.

Dutta et al. [3] studied sensitivity analysis for fuzzy linear fractional programming problem. Verdegay and Aguado [20] proposed that in the case of fuzzy linear programming problems, whether or not a fuzzy optimal solution has been found by using linear membership functions modeling the constraints, possible further changes of those membership functions do not affect the former optimal solution. The sensitivity analysis performed for those membership functions and the corresponding solutions shows the convenience of using linear functions instead of other more complicated ones.

Kumar et al. [13] pointed out the shortcomings of the existing method [14] and proposed a method to find the fuzzy optimal solution of fully fuzzy linear programming problems with equality constraints. Kheirfam and Hasani [8] studied the basis invariance sensitivity analysis for fuzzy linear programming problems. Ebrahimnejad [4] generalized the concept of sensitivity analysis in fuzzy number linear programming problems by applying fuzzy simplex algorithms and using the general linear ranking function on fuzzy numbers.

Nasseri and Ebrahimnejad [15] proposed a method for sensitivity analysis on linear programming problem with trapezoidal fuzzy variables. Kumar and Bhatia [12] proposed a method that deals with the sensitivity analysis of such fuzzy linear programming problem in which the decision variables are represented by real numbers and rest of the parameters are represented by interval-valued fuzzy numbers. Bhatia and Kumar [2] proposed a method that deals with the sensitivity analysis of such linear programming problem in which all the parameters are represented by interval-valued fuzzy numbers. Gani and Assarudeen [6] proposed a new operation on triangular fuzzy number for solving FFLPP.

In this paper, using operations proposed by [6] a new method is proposed that deals with the sensitivity analysis for FFLPP by tabular method.

II. PRELIMINARIES

A. *Fuzzy set [10:*

A fuzzy set $\tilde{A}$ in X (set of real number) is a set of ordered pairs:

$\tilde{A}$= {(x, $\mu_{\tilde{A}}$(x)) / x ∈ X} $\mu_{\tilde{A}}$(x) is called membership function of x in $\tilde{A}$ which maps X to [0,1].

B. *Fuzzy Number [17]*

A fuzzy set Ã defined on the set of real numbers R is said to be a fuzzy number if its membership function $\mu_{\tilde{A}}$: R→[0,1] has the following characteristics

1) Ã is normal. It means that there exists an x ∈ R such that $\mu_{\tilde{A}}(x) = 1$
2) Ã is convex. It means that for every x_1, x_2 ∈ R, $\mu_{\tilde{A}}(\lambda x_1 + (1-\lambda)x_2) \geq \min.\{ \mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)\}, \lambda \in [0,1]$
3) $\mu_{\tilde{A}}$ is upper semi-continuous.
4) supp (Ã) is bounded in R

C. *Triangular Fuzzy Number [6]:*

It is a fuzzy number represented with three points as follows: $\tilde{A} = (a_1, a_2, a_3)$

This representation is interpreted as membership functions and holds the following conditions

(i) a_1 to a_2 is increasing function

(ii) a_2 to a_3 is decreasing function

(iii) $a_1 \leq a_2 \leq a_3$.

$$\mu_{\tilde{A}}(x) = \begin{cases} 0 & \text{for } x < a_1 \\ \dfrac{x - a_1}{a_2 - a_1} & \text{for } a_1 \leq x \leq a_2 \\ \dfrac{a_3 - x}{a_3 - a_2} & \text{for } a_2 \leq x \leq a_3 \\ 0 & \text{for } x > a_3 \end{cases}$$

D. *Positive triangular fuzzy number [6]:*

A positive triangular fuzzy number $\tilde{A}$ is denoted as $\tilde{A}= (a_1, a_2, a_3)$ where all a_i's > 0 for all i=1, 2, 3.

E. *Negative triangular fuzzy number [6]*

A negative triangular fuzzy number $\tilde{A}$ is denoted as $\tilde{A}= (a_1, a_2, a_3)$ where all a_i's < 0 for all i=1, 2, 3.

Note: A negative Triangular fuzzy number can be written as the negative multiplication of a positive Triangular fuzzy number. Example: $\tilde{A}=(-3, -2, -1)$ is a negative triangular fuzzy number this can be written as $\tilde{A} = -(1,2,3)$.

F. *Operation of Triangular Fuzzy Number Using Function Principle [6]:*

The following are the four operations that can be performed on triangular fuzzy numbers: Let $\tilde{A} = (a_1, a_2, a_3)$ and $\tilde{B}= (b_1, b_2, b_3)$ then,

1) *Addition:* $\tilde{A} + \tilde{B} = (a_1+ b_1, a_2+ b_2, a_3+ b_3)$.

2) *Subtraction:* $\tilde{A}-\tilde{B} = (a_1- b_3, a_2- b_2, a_3- b_1)$.

3) *Multiplication:* $\tilde{A}x\tilde{B}$ = (min $(a_1 b_1, a_1 b_3, a_3 b_1, a_3 b_3)$, $a_2 b_2$, max $(a_1 b_1, a_1 b_3, a_3 b_1, a_3 b_3)$).

4) *Division:* $\tilde{A}/\tilde{B}$ = (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)).

G. *Operations for Subtraction and Division on Triangular Fuzzy Number [6]:*

1) *Subtraction:*

Let $\tilde{A}$ = (a_1, a_2, a_3) and $\tilde{B}$= (b_1, b_2, b_3) then, $\tilde{A}$-$\tilde{B}$ = (a_1- b_1, a_2- b_2, a_3- b_3)

The new subtraction operation exist only if the following condition is satisfied DP($\tilde{A}$) ≥ DP($\tilde{B}$) where DP($\tilde{A}$)= $\frac{a_3-a_1}{2}$, DP($\tilde{B}$)= $\frac{b_3-b_1}{2}$ and DP denotes Difference point of a Triangular fuzzy number.

2) *Division:*

Let $\tilde{A}$ = (a_1, a_2, a_3) and $\tilde{B}$= (b_1, b_2, b_3) then, $\tilde{A}/\tilde{B}$= (a_1/b_1, a_2/b_2, a_3/b_3)

The new Division operation exists only if the following conditions are satisfied $\left|\frac{DP(\tilde{A})}{MP(\tilde{A})}\right| \geq \left|\frac{DP(\tilde{B})}{MP(\tilde{B})}\right|$ and the negative triangular fuzzy number should be changed into negative multiplication of positive number as per note in definition 2.5 where MP($\tilde{A}$) = $\frac{a_3+a_1}{2}$, DP($\tilde{A}$) = $\frac{a_3-c_1}{2}$, MP($\tilde{B}$) = $\frac{b_3+b_1}{2}$, DP($\tilde{B}$) = $\frac{b_3-b_1}{2}$ and MP denotes Midpoint of a Triangular fuzzy number.

III. PROPOSED METHOD

In the literature, there are various methods [1,4,8,9,10,11] that deal with the sensitivity analysis of such linear programming problem in which some or all parameters are represented by triangular or trapezoidal fuzzy numbers by converting the whole problem into crisp linear programming problem. Gani and Assarudeen [6] had solved FFLPP by simplex algorithm by tabular method. But till now, there is no method that deals with the sensitivity analysis of FFLPP by tabular method. In this section, a new method is proposed for the same using the operations proposed by Gani and Assarudeen [6]. The following cases will be discussed in the proposed method:

A. *Change in the fuzzy cost vector*

There arise two cases under this category:

1) Suppose $\tilde{x}_k$ is a nonbasic fuzzy variable and its fuzzy cost $\tilde{c}_k$ is changed to $\tilde{c}_k+\Delta\tilde{c}_k$. Then, the fuzzy optimal solution remains same if $\tilde{c}_B\tilde{B}^{-1}\tilde{A}_k$-($\tilde{c}_k+\Delta\tilde{c}_k$) ≥ $\tilde{0}$. Otherwise the optimality is disturbed, which can be restored by simplex method to find new fuzzy optimal solution.
2) Now, suppose $\tilde{x}_k$ is a basic fuzzy variable and its fuzzy cost $\tilde{c}_k$ is changed to $\tilde{c}_k+\Delta\tilde{c}_k$. Then relative cost of each nonbasic fuzzy variable is changed to $\tilde{c}_B\tilde{\alpha}^k$-$\tilde{c}_k$+$\Delta\tilde{c}_k\tilde{\alpha}_j^k$ where $\tilde{\alpha}^k$ is the coordinate vector. The fuzzy optimal solution remains same if $\tilde{c}_B\tilde{\alpha}^k$-$\tilde{c}_k$+$\Delta\tilde{c}_k\tilde{\alpha}_j^k$ ≥ $\tilde{0}$ or $\tilde{z}_k$-$\tilde{c}_k$+$\Delta\tilde{c}_k\tilde{\alpha}_j^k$ ≥ $\tilde{0}$ or $\Delta\tilde{c}_k \geq -\frac{\tilde{z}_k-\tilde{c}_k}{\tilde{\alpha}_j^k}$ if $\tilde{\alpha}_j^k$≥ $\tilde{0}$ and $\Delta\tilde{c}_k \leq -\frac{\tilde{z}_k-\tilde{c}_k}{\tilde{\alpha}_j^k}$ if $\tilde{\alpha}_j^k$≤ $\tilde{0}$

Thus, if $\Delta\tilde{c}_k$ satisfies

Max.$\left\{\Delta\tilde{c}_k \geq -\frac{\tilde{z}_k-\tilde{c}_k}{\tilde{\alpha}_j^k}\ for\ \tilde{\alpha}_j^k \geq \tilde{0}\right\}$ ≤ $\Delta\tilde{c}_k$ ≤ Min. $\left\{\Delta\tilde{c}_k \leq -\frac{\tilde{z}_k-\tilde{c}_k}{\tilde{\alpha}_j^k}\ for\ \tilde{\alpha}_j^k \leq \tilde{0}\right\}$ the current fuzzy solution remains feasible.

If $\Delta\tilde{c}_k$ is assigned beyond the above limits then feasibility is disturbed. Restore the feasibility using the dual simplex method.

B. *Change in the fuzzy requirement vector*

This change corresponds to two cases:

1) If all the values of the new solution column are non-negative then the existing table remains optimal with the new fuzzy solution and new fuzzy optimal value.

Let the FFLPP be Max $\tilde{z}$ = $\tilde{C}^T\tilde{x}$, subject to $\tilde{A}\tilde{x} = \tilde{b}$, $\tilde{x} \geq \tilde{0}$. Any change in the right hand entry of the fuzzy constraints does not effect the optimality conditions. It may affect the feasibility conditions and the fuzzy optimum value.

So, if $\tilde{b}_k$ is changed to $\tilde{b}_k$ + $\Delta\tilde{b}_k$, the new basic fuzzy feasible solution is given by: $\tilde{x}'_{Bi}$=$\tilde{x}_{Bi}$ + $\tilde{\beta}_{ik}\Delta\tilde{b}_k$, where $\tilde{\beta}_{ik}$ is the

$(i,k)^{th}$ element of $\tilde{B}^{-1}$.

For to maintain the feasibility of the solution at each iteration, $\tilde{x}'_{Bi}$ must be non-negative. i.e. $\tilde{x}_{Bi} + \tilde{\beta}_{ik}\Delta\tilde{b}_k \geq \tilde{0}$

or $\Delta\tilde{b}_k \geq -\frac{\tilde{x}_{Bi}}{\tilde{\beta}_{ik}}$ for $\tilde{\beta}_{ik} \geq \tilde{0}$ and $\Delta\tilde{b}_k \leq -\frac{\tilde{x}_{Bi}}{\tilde{\beta}_{ik}}$ for $\tilde{\beta}_{ik} \leq \tilde{0}$

Thus if $\Delta\tilde{b}_k$ satisfies Max. $\left\{-\frac{\tilde{x}_{Bi}}{\tilde{\beta}_{ik}}\ for\ \tilde{\beta}_{ik} \geq \tilde{0}\right\} \leq \Delta\tilde{b}_k \leq$ Min. $\left\{-\frac{\tilde{x}_{Bi}}{\tilde{\beta}_{ik}}\ for\ \tilde{\beta}_{ik} \leq \tilde{0}\right\}$ the current fuzzy solution remain feasible.

2) If $\Delta\tilde{b}_k$ is assigned beyond the above limits then feasibility is disturbed. Restore the feasibility using the dual simplex method.

C. Change in the coefficient matrix of the fuzzy constraints

There arise two cases:

1) First, when $\tilde{A}_k$ is associated with a nonbasic fuzzy variable. Suppose $\tilde{A}_k$ is changed to $\tilde{A}'_k$, this will affect the relative cost of $\tilde{x}_k$. The fuzzy optimal table remains same if $\tilde{z}_k - \tilde{c}_k + \tilde{\delta}_{ik}\tilde{c}_B\tilde{\beta}_i \geq \tilde{0}$. Hence, $\tilde{\delta}_{ik} \geq -\frac{\tilde{z}_k - \tilde{c}_k}{\tilde{c}_B\tilde{\beta}_i}$.

This gives the variation in element $\tilde{a}_{ik}$ of the column $\tilde{A}_k$ in fuzzy constraint matrix so that the fuzzy optimal solution remains same. If it is violated then restore the optimal criteria by the simplex method to get the new fuzzy optimal solution.

2) Let the column $\tilde{A}_k$ associated with basic fuzzy variable $\tilde{x}_k$ is changed to $\tilde{A}'_k$. Then compute $\tilde{z}'_k$-$\tilde{c}_k$= $\tilde{c}_B\tilde{B}^{-1}\tilde{A}'_k$-$\tilde{c}_k$. If $\tilde{z}'_k$-$\tilde{c}_k \geq \tilde{0}$, there is no effect of such change, otherwise the optimality is disturbed, which can be restored by simplex method to find new fuzzy optimal solution.

D. Addition of new fuzzy variable

When we add a new fuzzy variable $\tilde{x}_{n+1}$ with a cost $\tilde{c}_{n+1}$ and $\tilde{A}_{n+1}$ is the associated column in the new fuzzy constraint matrix, then there arise two cases:

1) If $\tilde{z}_{n+1}$-$\tilde{c}_{n+1} \leq \tilde{0}$, then $\tilde{x}_{n+1}$ enter the basis and continue with the simplex method or dual simplex method.
2) If $\tilde{z}_{n+1}$-$\tilde{c}_{n+1} > \tilde{0}$, then fuzzy optimal solution does not change.

E. Addition of new fuzzy constraint

When we add a new fuzzy constraint to a FFLPP, then we have to make two observations:

1) If the fuzzy constraint to be added is satisfied by the given fuzzy optimal solution, then there will be no effect on adding this constraint.
2) If this fuzzy constraint is not satisfied by the given fuzzy optimal solution, then addition will affect the fuzzy optimal solution. For this restore the feasibility use dual simplex method to find new fuzzy optimal solution.

F. Deletion of fuzzy variable

There arise two cases under this category:

1) If a nonbasic fuzzy variable or a basic fuzzy variable at zero level (i.e. its rank is zero) is deleted, then there will be no change in the fuzzy optimal solution.
2) However, deletion of positive basic fuzzy variable (i.e. its rank is positive) will affect the optimal solution.

Considering (2) note that deleting a fuzzy variable at positive level is equivalent to convert it into non basic fuzzy variable .For the same, first remove the entire column associated with the basic fuzzy variable to be deleted from the optimal table and then multiply the entire row corresponding to this variable by -1 so that feasibility gets disturbed. Now, applying fuzzy dual simplex method for FVLP, restore feasibility, which will include the removal of variable to be deleted.

G. Deletion of fuzzy constraint

While deleting a fuzzy constraint we observe two solutions:

1) If any fuzzy constraint is satisfied on the boundary, i.e., rank of slack or surplus variable corresponding to this fuzzy constraint is at zero level then deletion of such a fuzzy constraint may cause change in the fuzzy optimal solution.
2) If any fuzzy constraint is satisfied in the interior of feasible region P_F i.e., rank of slack or surplus variable corresponding to

this fuzzy constraint are positive then deletion of such a constraint will not affect the fuzzy optimal solution.

In other words, situation (1) is a binding on the fuzzy optimal solution, while situation (2) is a nonbinding on the fuzzy optimal solution.

IV. NUMERICAL EXAMPLE

In this section, FFLPP [6] is solved by using proposed method:

Max $\tilde{z}$ = (5, 7, 9)$\tilde{x}_1$ + (6, 8, 10) $\tilde{x}_2$

Subject to constraint

(1,2,3) $\tilde{x}_1$ + (2,3,4) $\tilde{x}_2$ $\leq$ (4,6,8) (1)

(4,5,6)$\tilde{x}_1$ +(3,4,5) $\tilde{x}_2$ $\leq$ (8,10,12)

Rewrite as

Max $\tilde{z}$ = (5, 7, 9)$\tilde{x}_1$ + (6, 8, 10) $\tilde{x}_2$ +(0,0,0) $\tilde{x}_3$ +(0,0,0) $\tilde{x}_4$

Subject to constraint

(1,2,3)$\tilde{x}_1$ + (2,3,4) $\tilde{x}_2$ +(1,1,1) $\tilde{x}_3$ = (4,6,8)

(4,5,6)$\tilde{x}_1$ +(3,4,5) $\tilde{x}_2$ +(1,1,1) $\tilde{x}_4$ = (8,10,12)

Optimal table:

		$\tilde{x}_2$	$\tilde{x}_3$	$\tilde{x}_4$	**RHS**
$\tilde{x}_1$	(1,1,1)	(1.33,1.52,2)	(.5,.5,.66)	(0,0,0)	(1.33,3.03,8)
$\tilde{x}_4$	(0,0,0)	-(.33,3.59,9)	-(.88,2.5,5.47)	(1,1,1)	(-48,-5.15,8.67)
$\tilde{z}$	(0,0,0)	(1.99,2.61,4)	(2.25,3.5,18.86)	(0,0,0)	(7.99,21.21,56)

Hence $\tilde{x}_1$=(1.33,3.03,8) & $\tilde{x}_2$=(0,0,0) then $\tilde{z}$=(7.99,21.21,56)

(a) Suppose the fuzzy cost coefficients (5,7,9) of the fuzzy decision variable $\tilde{x}_1$ is changes to (6,10,12) in FFLPP (1). Then, by applying proposed method as discussed in section 4 the final iteration is

	$\tilde{x}_1$	$\tilde{x}_2$	$\tilde{x}_3$	$\tilde{x}_4$	**RHS**
$\tilde{x}_1$	(1,1,1)	(1.33,1.52,2)	(.5,.5,.66)	(0,0,0)	(1.33,3.03,8)
$\tilde{x}_4$	(0,0,0)	-(.33,3.59,9)	-(.88,2.5,5.47)	(1,1,1)	(-48,-5.15,8.67)
$\tilde{z}$	(0,0,0)	(1.98,7.2,14)	(3,5,7.92)	(0,0,0)	(7.98,30.3,96)

Hence, $\tilde{x}_1$= (1.33,3.03,8), $\tilde{x}_2$= (0,0,0) and $\tilde{z}$ = (7.98,30.3,96)

(b) Suppose the fuzzy requirement vector b=[(4,6,8) (8,10,12)]^T is changes to b'=[(4,6,8) (10,18,52)]^T in FFLPP (1). Then, by applying proposed method as discussed in section 4 the final iteration is

	$\tilde{x}_1$	$\tilde{x}_2$	$\tilde{x}_3$	$\tilde{x}_4$	**RHS**
$\tilde{x}_1$	(1,1,1)	(1.33,1.52,2)	(.5,.5,.66)	(0,0,0)	(2,3,5.28)
$\tilde{x}_4$	(0,0,0)	-(.33,3.59,9)	-(.88,2.5,5.47)	(1,1,1)	(6.48,3,8.24)
$\tilde{z}$	(0,0,0)	(1.99,2.61,4)	(2.25,3.5,18.86)	(0,0,0)	(9,21,150.88)

Hence, the fuzzy optimal solution of changed problem is

$\tilde{x}_1$= (2,3,5.28), $\tilde{x}_2$= (0,0,0) and $\tilde{z}$ = (9,21,150.88)

(c) Suppose column of the coefficient matrix of the constraints [(1,2,3) (4,5,6)]^T corresponding to the fuzzy variable $\tilde{x}_1$ is changes to [(4,5,6) (1,2,3)]^T in FFLPP (1). Then by applying the proposed method as discussed in section 4 the final iteration is

	$\tilde{x}_1$	$\tilde{x}_2$	$\tilde{x}_3$	$\tilde{x}_4$	**RHS**
$\tilde{x}_1$	(3,3.5,4.96)	(1.33,1.52,2)	(.5,.5,.66)	(0,0,0)	(1.33,3.03,8)
$\tilde{x}_4$	-(.52,10.5,31.82)	-(.33,3.59,9)	-(.88,2.5,5.47)	(1,1,1)	(-48,-5.15,8.67)
$\tilde{z}$	(9,17.5,113.16)	(1.99,2.61,4)	(2.25,3.5,18.86)	(0,0,0)	(7.99,21.21,56)

Hence $\tilde{x}_1$=(1.33,3.03,8), $\tilde{x}_2$=(0,0,0) and $\tilde{z}$=(7.99,21.21,56)

(d) Suppose a new fuzzy variable $\tilde{x}_5$ with fuzzy cost (17,18,19) and column $\tilde{A}_5$= [(1,1,1) (1,2,3)]^T is added in the FFLPP (1). Then by applying the proposed method as discussed in section 4 the final iteration is

	$\tilde{x}_1$	$\tilde{x}_2$	$\tilde{x}_3$	$\tilde{x}_4$	$\tilde{x}_5$	RHS
$\tilde{x}_5$	(1.51,2.03,2.0)	(2.7,3.13,3.13)	(1,1,1)	(0,0,0)	(1,1,1)	(3.12,6.21,10.75)
$\tilde{x}_4$	(-29.13,3.68, 24.19)	(-17.84,2.06,15.33)	(-3,-2,-1)	(1,1,1)	(0,0,0)	(-73.67,2.07,63.14)
$\tilde{z}$	(20.67,29.54,29.57)	(39.9,48.34,49.47)	(17,18,19)	(0,0,0)	(0,0,0)	(53.04,111.78, 204.25)

Hence, $\tilde{x}_1$=(0,0,0), $\tilde{x}_2$=(0,0,0), $\tilde{x}_5$=(3.12,6.21,10.75) & $\tilde{z}$ = (53.04,111.78,204.25).

Remark 4.1 The other cases i.e. addition of new fuzzy constraint, deletion of fuzzy variables and deletion of fuzzy constraints can also be solved by using proposed method as discussed in section 4.

V. CONCLUSION

Gani and Assarudeen [6] introduced a new operation for subtraction and division. The advantage of these operations is to undergo the inverse operations of addition and multiplication. In this paper, a new method that deals with sensitivity analysis of FFLPP by tabular method is proposed using the operations proposed by Gani and Assarudeen [6]. The proposed method is illustrated with the help of a numerical example.

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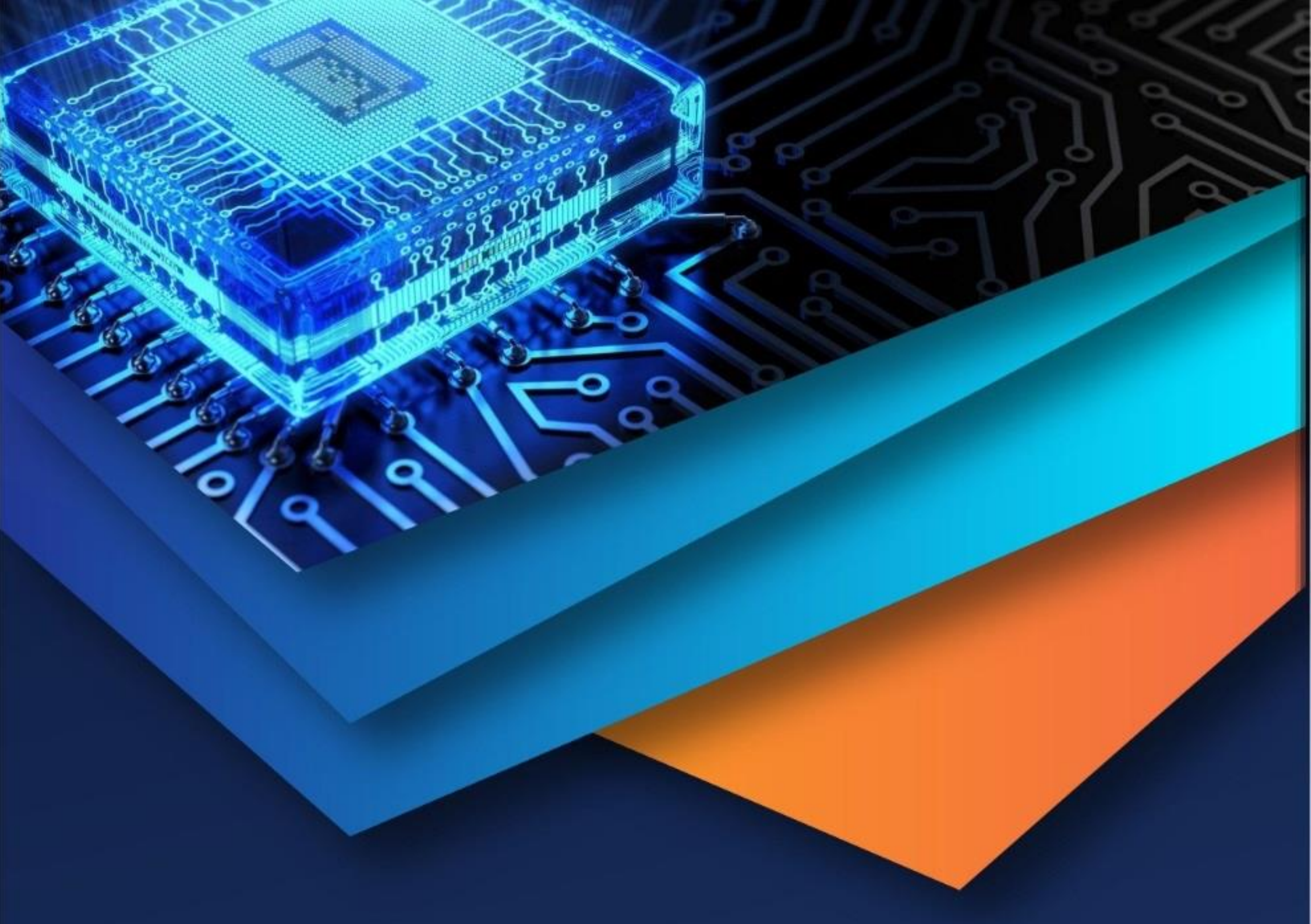

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ISRA JIF IMPACT FACTOR: 7.129

SJIFactor TOGETHER WE REACH THE GOAL IMPACT FACTOR: 7.429

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