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An Integer Solution in Intuitionistic Transportation Problem with Application in Agriculture

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ABSTRACT

In this paper, we investigate a Transportation problem which is a special kind of linear programming in which profits; supply and demands are considered as Intuitionistic triangular fuzzy numbers. The crisp values of these Intuitionistic triangular fuzzy numbers are obtained by defuzzifying them and the problem is formulated into linear programming problem. The solution of the formulated problem is obtained through LINGO software. If the obtained solution is non-integer then Branch and Bound method can be used to obtain an integer solution.

Keywords: Transportation Problem, Intuitionistic triangular fuzzy numbers, Maximized profit, Branch and Bound method, optimal allocation and LINGO.

INTRODUCTION

Transportation problem is a spectial kind of linear programming problem in which goods are transported from a set of source to the set of destination subject to the supply and demands of the source and destinations. Hitchcock (1941) firstly introduced the Transportation Problem and after that it presented by Koopmans (1947). The first mathematical formulation of fuzziness was pioneered by Zadeh (1965). Orlovsky (1980) made a numerous attempts to explore the ability of fuzzy set theory to become a useful tool for adequate mathematical analysis of real world problems. Atanassov (1986) introduced Intuitionistic fuzzy sets as an extension of Zadeh's notion of fuzzy set. Intuitionistic fuzzy set is a powerful tool in solving real life problems and has a greater influence in solving Transportation problems to find optimal allocation. A new method for solving Transportation problems with Intuitionistic triangular fuzzy numbers was proposed by Paul *et.al* (2014). A balanced Intuitionistic fuzzy assignment problem was solved by Kumar *et al.*,(2014) . Intuitionistic fuzzy Transportation problem has been studied by many authors and with different approaches have been proposed such as (Ganiand Abbas (2013), Hussainand Kuma (2012), Hakim(2012) and Pramila and Ultra(2014) etc) . Ranking and defuzzification methods based on area compensation fuzzy sets and systems can be found in Fortemps and Roubens (1996). Ranking of trapezoidal Intuitionistic fuzzy numbers was presented De and Das.(2012).In this paper, the transportation problemconsidered in which the profits, availability and requirement are Intuitionistic triangular fuzzy numbers. By defuzzifying, the profits, availability and requirements are converted into crisp values. The problem is formulated into Linear programming problem and solution is obtained through LINGO Software. If the obtained solution is non-integer then we round the non integer value to the nearest integer value. But sometimes in practical situation by rounding, we get a solution which may be infeasible or impractical. Thus instead of rounding the non integer solution to the nearest integer value we use Branch and Bound to obtain integer solution. The assignment costs are converted into crisp values by defuzzifying with the accuracy function and the optimum solution is obtained by using Branch and Bound method

Preliminaries

Fuzzy set

Let A be a classical set, $\mu_{\overline{A}}(x)$ be a function from A to [0, 1]. A fuzzy set $\overline{A}$ with the membership function $\mu_{\overline{A}}(x)$ is defined by $\overline{A} = \{(x, \mu_{\overline{A}}(x)); x \in A, \mu_{\overline{A}}(x) \in [0,1\}$.

IntuitionisticFuzzy set (IFS)

Let X denote universe of discourse, then an Intuitionistic fuzzy set $\overline{A}^I$ in X is given by $\overline{A} = \{(x, \mu_{\overline{A}^I}(x), v_{\overline{A}^I}(x)); x \in X,\}$ where, $\mu_{\overline{A}^I}(x), v_{\overline{A}^I}(x)$: X→[0,1] are functions such that 0 ≤ ($\mu_{\overline{A}^I}(x) + v_{\overline{A}^I}(x)$ ≤ 1 for all x∈X. For each x the member ship function $\mu_{\overline{A}^I}(x)$ and $v_{\overline{A}^I}(x)$ represent thedegree of membership and non-membership of the element x∈X to A⊂X respectively.

Intuitionistic fuzzy number(IFN)

An Intuitionistic fuzzy set of real line R is called an Intuitionistic fuzzy number if the following holds:

(i) There exists $x_o \in R$, $\mu_{\overline{A}^I}(x_o)$ = 1 and $v_{\overline{A}^I}(x_o)$ = 0, x_o is called the mean value of $\overline{A}^I$.

(ii) $\mu_{\overline{A}^I}$ is a continuous mapping from R to the closed interval [0,1] and for all x∈R, the relation $o \leq \mu_{\overline{A}^I} + v_{\overline{A}^I} \leq 1$ holds.

Triangular intuitionistic fuzzy number (TrIFN):

A triangular intuitionistic fuzzy number is an intuitionistic fuzzy subset in R with the following membership function $\mu_{\overline{A}^I}(x)$ and non-membership function $v_{\overline{A}^I}(x)$.

$$\mu_{\overline{A}^I}(x) = \begin{cases} 0 & , x < a_1 \\ \dfrac{(x-a_1)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \dfrac{(a_3 - x)}{a_3 - a_2}, & a_2 \leq x \leq a_3 \\ 0 & x > a_3 \end{cases}$$

$$v_{\overline{A}^I}(x) = \begin{cases} 1 & , x < a_1^{'} \\ \dfrac{(a_2 - x)}{a_2 - a_1^{'}}, & a_1^{'} \leq x \leq a_2 \\ \dfrac{(x - a_2)}{a_3^{'} - a_2}, & a_2 \leq x \leq a_3^{'} \\ 1 & x > a_3^{'} \end{cases}$$

Where $a_1^{'} \leq a_1 \leq a_2 \leq a_3 \leq a_3^{'}$ and $(\mu_{\overline{A}^I}(x), v_{\overline{A}^I}(x) \leq 0.5$, $\mu_{\overline{A}^I}(x) = v_{\overline{A}^I}(x)$ for all x∈R. The ***TrIFN*** is given by

$$\overline{A}^I = (a_1, a_2, a_3; a_1^1 a_2, a_3^1)$$

Defuzzification

We define Accuracy functionto defuzzify a given triangular Intuitionistic fuzzy number is

$$H(\overline{a}^I) = \frac{(a_1 + 2a_2 + a_3) + (a_1^{'} + 2a_2 + a_3^{'})}{8}$$

Intuitionistic Fuzzy Transportation Problem (IFTP):

Consider Transportation with m Intuitionistic fuzzy orginsand n Intuitionistic fuzzy destinations.

Let $\widetilde{C}_{ij}^I$ $(i = 1,2,..,m\ , j = 1,2,..,n)$ be Intuitionistic triangular fuzzy (ITF) profit/cost obtained from transporting one unit of the product from i^{th} origin to the j^{th} job destination. Let $\widetilde{a}_i^I$ and $\widetilde{b}_j^I$ denoted theIntuitionistic triangular fuzzy numbers of the quantity available and required quantity respectively. Let the decision variable X_{ij} denoting the quantity transported a from i^{th} IF orgion to the j^{th} IF destination. Mathematically an IFTP is given below:

Maximize $Z = \sum_{i=1}^{m} \sum_{j=1}^{n} \tilde{C}_j X_j$

Subject to

$\sum_{i=1}^{m} X_{ij} \le \tilde{a}_i^I \qquad for\ i = 1,2,...,m.$

$\sum_{j=1}^{n} X_j \ge \tilde{b}_j^I \qquad for\ j = 1,2,...,n.$

$$\tilde{C}_{ij}^{I} = (C_{ij}^1, C_{ij}^2, C_{ij}^3)(C_{ij}^{1'}, C_{ij}^{2}, C_{ij}^{3'})$$

In tabular form we can write

Origins	source D1	D2	... ... Dn	Availability
O1	$\tilde{C}_{11}$	$\tilde{C}_{12}$	... ... $\tilde{C}_{1n}$	$\tilde{a}_1^I$
O2	$\tilde{C}_{21}$	$\tilde{C}_{22}$	... ... $\tilde{C}_{2n}$	$\tilde{a}_2^I$
⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮
Om	$\tilde{C}_{m1}$	$\tilde{C}_{m2}$	$\tilde{C}_{mn}$	$\tilde{a}_m^I$
Requirement	$\tilde{b}_1^I$	$\tilde{b}_2^I$	... ... $\tilde{b}_n^I$	

Numerical Illustration

Let us assume that O_i, and D_i denotes grounds and crops respectively, and $\tilde{a}_i^I$ and $\tilde{b}_j^I$ denotes the area of groundsand requirement of area for crop sowing with Intuitionistic triangular fuzzy numbers respectively.Let $\tilde{C}_{ij}^I\ (i = 1,2,..,m\ ,\ j = 1,2,..,n)$ be (ITF) profit obtained from one hectare of ground sown by j^th crop. Also, let the decision variable X_{ij} denoting the number of hectares of i^th ground sown by to the crop. The objective is to determine an optimal allocation of land (hectares) used for sowing so that over profit will be maximized. The crop problem can be found in Mitchell(2011)and Thornley and France (2006). The hypothetical data set in tabular form is shown below:

The above problem can be formulated as a linear programming problem (LPP) and the solution can be obtained from the following given program in LINGO software.

MODEL:
SETS:
grounds: area;
crops: mrcsa;
LINKS(grounds ,crops): PROFIT, VOLUME;

ENDSETS
DATA:
grounds = P1 P2 P3 P4 P5;
crops = Rice Maize Wheat ;

Crops

		Rice	Maize	Wheat	Area(hectares)
	O1	(12,14,16)	(3,2,4)	(10,12,14)	(7,9,11)
		(10,12,18)	(2,2,5)	(11,12,17)	(5,9,13)
	O2	(7,10,13)	(4,5,6)	(7,10,12)	(6,8,12)
		(6,10,14)	(3,5,7)	(5,10,14)	(4,8,19)
	O3	(5,7,9)	(8,10,12)	(13,14,17)	(7,11,24)
		(4,7,10)	(7,10,13)	(11,14,20)	(4,11,27)
	O4	(4,5,6)	(4,6,8)	(6,7,8)	(7,9,11)
		(3,5,7)	(2,6,10)	(5,7,9)	(5,9,13)
	O5	(7,10,13)	(12,13,14)	(8,10,12)	(7,8,15)
		(6,10,14)	(11,13,15)	(7,10,16)	(1,8,21)
Availability Of area for sowing		(2,10,24)	(7,9,11)	(5,19,27)	
		(1,10,27)	(5,9,13)	(1,19,32)	

Using[1], the above table can be replaced by their corresponding values as

		Crops			
Grounds		**Rice**	**Maize**	**Wheat**	**Area(hectares)**
	O1	14	2.75	12.5	4.50
	O2	10	5.13	9.75	6.75
	O3	7	10	14.625	17.25
	O4	5.13	6	7	4.50
	O5	10	13	10.37	9
Availability (mrcsa) Of area for sowing		16.25	4.50	21.25	

```
area = 4.50 6.75 17.25 4.50 9.0;
mrcsa = 16.25 4.50 21.25;
  PROFIT = 14.0 02.75 12.50
        10.0 05.13 09.75
        07.0 10.00 14.62
        05.1 06.00 07.00
        10.0 13.00 10.37;
ENDDATA
MAX = @SUM( LINKS( I, J):
PROFIT( I, J) * VOLUME( I, J));
@FOR( crops( J):
@SUM( grounds( I): VOLUME( I, J)) =
mrcsa( J));
@FOR( grounds( I):
@SUM( crops( J): VOLUME( I, J)) <=
area( I));

END
Global optimal solution found.
 Objective value:                516.7450
 Infeasibilities:                0.000000
 Total solver iterations:               8

 Model Class:                          LP

 Total variables:          15
 Nonlinear variables:       0
 Integer variables:         0

 Total constraints:         9
 Nonlinear constraints:     0

 Total nonzeros:           45
 Nonlinear nonzeros:        0
```

Variable	Value	Reduced Cost
AREA(P1)	4.500000	0.000000
AREA(P2)	6.750000	0.000000
AREA(P3)	17.25000	0.000000
AREA(P4)	4.500000	0.000000
AREA(P5)	9.000000	0.000000
MRCSA(RICE)	16.25000	0.000000
MRCSA(MAIZE)	4.500000	0.000000
MRCSA(WHEAT)	21.25000	0.000000
PROFIT(P1, RICE)	14.00000	0.000000
PROFIT(P1, MAIZE)	2.750000	0.000000
PROFIT(P1, WHEAT)	12.50000	0.000000
PROFIT(P2, RICE)	10.00000	0.000000
PROFIT(P2, MAIZE)	5.130000	0.000000
PROFIT(P2, WHEAT)	9.750000	0.000000
PROFIT(P3, RICE)	7.000000	0.000000
PROFIT(P3, MAIZE)	10.00000	0.000000
PROFIT(P3, WHEAT)	14.62000	0.000000
PROFIT(P4, RICE)	5.100000	0.000000
PROFIT(P4, MAIZE)	6.000000	0.000000
PROFIT(P4, WHEAT)	7.000000	0.000000
PROFIT(P5, RICE)	10.00000	0.000000
PROFIT(P5, MAIZE)	13.00000	0.000000
PROFIT(P5, WHEAT)	10.37000	0.000000
VOLUME(P1, RICE)	4.500000	0.000000
VOLUME(P1, MAIZE)	0.000000	14.25000
VOLUME(P1, WHEAT)	0.000000	3.400000
VOLUME(P2, RICE)	6.750000	0.000000
VOLUME(P2, MAIZE)	0.000000	7.870000
VOLUME(P2, WHEAT)	0.000000	2.150000
VOLUME(P3, RICE)	0.000000	5.720000
VOLUME(P3, MAIZE)	0.000000	5.720000
VOLUME(P3, WHEAT)	17.25000	0.000000

VOLUME(P4, RICE)	0.5000000	0.000000
VOLUME(P4, MAIZE)	0.000000	2.100000
VOLUME(P4, WHEAT)	4.000000	0.000000
VOLUME(P5, RICE)	4.500000	0.000000
VOLUME(P5, MAIZE)	4.500000	0.000000
VOLUME(P5, WHEAT)	0.000000	1.530000

Row	Slack or Surplus	Dual Price
1	516.7450	1.000000
2	0.000000	5.100000
3	0.000000	8.100000
4	0.000000	7.000000
5	0.000000	8.900000
6	0.000000	4.900000
7	0.000000	7.620000
8	0.000000	0.000000
9	0.000000	4.900000

Since the optimal allocation is non integer. In real life problems sometime rounding non integer solution to the nearest integer value may give us infeasible or misleading solutions. So instead of rounding non integer solution to the nearest integer value we use Branch and Bound method to get an integer solution. Therefore the integer allocation is

X11=	VOLUME(P1, RICE)	4.000000
X12=	VOLUME(P1, MAIZE)	0.000000
X13=	VOLUME(P1, WHEAT)	0.000000
X21=	VOLUME(P2, RICE)	6.000000
X22=	VOLUME(P2, MAIZE)	0.000000
X23=	VOLUME(P2, WHEAT)	0.000000
X31=	VOLUME(P3, RICE)	0.000000
X32=	VOLUME(P3, MAIZE)	0.000000
X33=	VOLUME(P3, WHEAT)	17.00000
X41=	VOLUME(P4, RICE)	0.0000000
X42=	VOLUME(P4, MAIZE)	0.000000
X43=	VOLUME(P4, WHEAT)	4.000000
X51=	VOLUME(P5, RICE)	3.000000
X52=	VOLUME(P5, MAIZE)	6.000000
X53=	VOLUME(P5, WHEAT)	0.000000

And total maximized profit**=$**493.1450

CONCLUSION

In this paper a well known transportation problem and its application in agriculture have been studied. By defuzzifying, the IF profits, availability and requirement are converted into crisp values and the optimal solution shown above is obtained by formulated programme in LINGO using integer programming technique.

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