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The New Ranking Method using Octagonal Intuitionistic Fuzzy Unbalanced Transportation Problem

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ABSTRACT

In this paper a new ranking method is proposed for finding an optimal solution for intuitionistic fuzzy unbalanced transportation problem, in which the costs, supplies and demands are octagonal intuitionistic fuzzy numbers. The procedure is illustrated with a numerical example.

KEYWORDS: *Unbalanced transportation problems, Octagonal Intuitionistic fuzzy numbers, Ranking method, Modi method, Initial Basic Feasible Solution, Optimal Solution*

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1. INTRODUCTION

In general, Unbalanced transportation problems are solved with assumptions that the cost, supply and demand are specified in precise manner. However, in many cases the decision maker has no precise information about the coefficient belonging to the unbalanced transportation problem. Intuitionistic fuzzy set is a powerful tool to deal with such vagueness.

L. A. Zadeh introduced fuzzy set theory in 1965. Different types of fuzzy sets are defined in order to clear the vagueness of the existing problems.

The concept of Intuitionistic Fuzzy Sets (IFSs), proposed by Atanassov in [1] and [2], has been found to be highly useful to deal with vagueness. Many authors discussed the solutions of Fuzzy Transportation Problem (FTP) using various techniques. In 2016, Mrs. Kasthuri. B introduced Pentagonal intuitionistic fuzzy. In 2015, A. Thamaraiselvi and R. Santhi [3] introduced Hexagonal Intuitionistic Fuzzy Numbers. In 2015, Thangaraj Beaula – M. Priyadharshini [4] proposed A New Algorithm for Finding a Fuzzy Optimal Solution. K. Prasanna Devi, M. Devi Durga [5] and G. Gokila, Juno Saju [6] introduced Octagonal Fuzzy Number.

In this paper, a new method is proposed for finding an optimal solution for intuitionistic fuzzy Unbalanced transportation problem, in which the costs, supplies and Demands are octagonal intuitionistic fuzzy numbers. Using Octagonal Intuitionistic fuzzy unbalanced transportation problem we get best minimum value of optimal solution.

The paper is organized as follows, In section 2 introduction with some basic concepts of fuzzy and Intuitionistic fuzzy definitions, In section 3 introduced Octagonal Intuitionistic Fuzzy Definition and proposed algorithm followed by a Numerical example using Modi method and finally the paper is concluded in section 4.

2. PRELIMINARIES

2.1. Definition (Fuzzy set$[FS]$)[3]

Let X be a nonempty set. A fuzzy set $\bar{A}$ of Xis defined as$\bar{A}$=$\{< x, \mu_{\bar{A}}(x) >/x \in X\}$. Where $\mu_{\bar{A}}(x)$ is called membership function, which maps each element of X to a value between 0 and 1.

2.2. Definition (Fuzzy Number$[FN]$) [3]

A fuzzy number is a generalization of a regular real number and which does not refer to a single value but rather to a connected a set of possible values, where each possible value has its weight between 0 and 1. The weight is called the membership function.

A fuzzy number $\bar{A}$ is a convex normalized fuzzy set on the real line R such that

There exists at least one x ∈R with $\mu_{\bar{A}}$ (x) = 1.
$\mu_{\bar{A}}$ (x)$\mu_{\bar{A}}$ (x) is piecewise continuous.

2.3. Definition (Intuitionistic Fuzzy Set [IFS]) [3]

Let X be a non-empty set. An Intuitionistic fuzzy set $\bar{A}^I$ of X is defined as
$\bar{A}^I$ = {<x,$\mu_{\bar{A}^I}(x), \vartheta_{\bar{A}^I}$(x) > / x∈ X}. Where $\mu_{\bar{A}^I}(x)$ and $\vartheta_{\bar{A}^I}$(x) are membership and non-membership function. Such that $\mu_{\bar{A}^I}(x), \vartheta_{\bar{A}^I}$(x): X→ [0, 1] and 0≤ $\mu_{\bar{A}^I}(x) + \vartheta_{\bar{A}^I}$(x) ≤ 1 for all x∈ X.

2.4. Definition (Intuitionistic Fuzzy Number [IFN]) [3]

An Intuitionistic Fuzzy Subset $\bar{A}^I$ = {< x, $\mu_{\bar{A}^I}(x), \vartheta_{\bar{A}^I}$(x) > / x∈ X} of the real line R is called an Intuitionistic Fuzzy Number, if the following conditions hold,

There exists m ∈ R suct that $\mu_{\bar{A}^I}(m) = 1$ and $\vartheta_{\bar{A}^I}$(m) = 0.
$\mu_{\bar{A}^I}\mu_{\bar{A}^I}(x)$ is a continuous function from R → [0,1] such that 0≤ $\mu_{\bar{A}^I}(x) + \vartheta_{\bar{A}^I}$(x) ≤1 for all x∈ X.

The membership and non- membership functions of $\bar{A}^I$ are in the following form

$$\mu_{\bar{A}^I}(x) = \begin{cases} 0 \; for -\infty < x \le a_1 \\ f(x) \; for \; a_1 \le x \le a_2 \\ 1 \; for \; x = a_2 \\ g(x) \; for \; a_2 \le x \le a_3 \\ 0 \; for \; a_3 \le x < \infty \end{cases}$$

$$\vartheta_{\bar{A}^I}(x) = \begin{cases} 1 \; for -\infty < x \le a_1' \\ f'(x) \; for \; a_1' \le x \le a_2 \\ 0 \; for \; x = a_2 \\ g'(x) \; for \; a_2 \le x \le a_3' \\ 1 \; for \; a_3' \le x < \infty \end{cases}$$

Wheref, f', g, g' are functions from R → [0,1] . f and g' are strictly increasing functions and g and f' are strictly decreasing functions with the conditions $0 \le f(x) + f'(x) \le 1$ and $0 \le g(x) + g'(x) \le 1$.

3. OCTAGONAL INTUITIONISTIC FUZZY NUMBER

3.1. Definition (Octagonal Intuitionistic Fuzzy Number [OIFN])

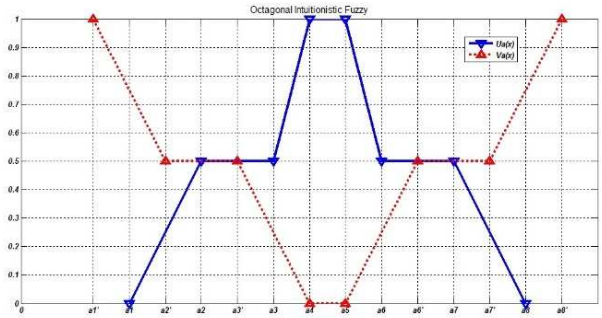
An Octagonal Intuitionistic Fuzzy Number is specified by $\bar{A}_{oc}{}^{I}$=$(a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8)$, $(a_1', a_2', a_3', a_4, a_5, a_6', a_7', a_8')$.

Where$a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_1', a_2', a_3', a_6', a_7'$ and a_8' and its membership and non-membership functions are given below

$$\mu_{\bar{A}}(x) = \begin{cases} 0 \; for \; x < a_1 \\ k\left(\frac{x - a_1}{a_2 - a_1}\right) for \; a_1 \le x \le a_2 \\ k \; for \; a_2 \le x \le a_3 \\ k + (1-k)\left(\frac{x - a_3}{a_4 - a_3}\right) for \; a_3 \le x \le a_4 \\ 1 \; for \; a_4 \le x \le a_5 \\ k + (1-k)\left(\frac{a_6 - x}{a_6 - a_5}\right) for \; a_5 \le x \le a_6 \\ k \; for \; a_6 \le x \le a_7 \\ k\left(\frac{a_8 - x}{a_8 - a_7}\right) for \; a_7 \le x \le a_8 \\ 0 \; for \; x > a_8 \end{cases}$$

$$\vartheta_{\bar{A}^I}(x) = \begin{cases} 1 \; for \; a_1' < x \\ k + (1-k)\left(\frac{a_2' - x}{a_2' - a_1'}\right) for \; a_1' \le x \le a_2' \\ k \; for \; a_2' \le x \le a_3' \\ k\left(\frac{a_4 - x}{a_4 - a_3}\right) for \; a_3' \le x \le a_4 \\ 0 \; for \; a_4 \le x \le a_5 \\ k\left(\frac{x - a_5}{a_6' - a_5}\right) for \; a_5 \le x \le a_6' \\ k \; for \; a_6' \le x \le a_7' \\ k + (1-k)\left(\frac{x - a_7'}{a_8' - a_7}\right) for \; a_7' \le x \le a_8' \\ 1 \; for \; x > a_8' \end{cases}$$

Graphical representation of Octagonal Intuitionistic Fuzzy Numbers



__ Membership Function$\mu_{\bar{A}}$ (x)
---- Non-Membership Function$\vartheta_{\bar{A}^I}$(x)

3.2. Arithmetic operations on Octagonal Intuitionistic Fuzzy Numbers

Let $\bar{A}_{oc}{}^{I}$ =$(a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8)$ $(a_1', a_2', a_3', a_4', a_5', a_6', a_7', a_8')$ and $\bar{B}_{oc}{}^{I}$ = $(b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8)$ $(b_1', b_2', b_3', b_4', b_5', b_6', b_7', b_8')$ be two Octagonal Intuitionistic Fuzzy Numbers, then the arithmetic operations are as follows.

3.2.1. Addition:

$$\bar{A}_{oc}{}^{I} + \bar{B}_{oc}{}^{I} = (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4, a_5 + b_5, a_6 + b_6, a_7 + b_7, a_8 + b_8)$$
$$(a_1' + b_1', a_2' + b_2', a_3' + b_3', a_4' + b_4', a_5' + b_5', a_6' + b_6', a_7' + b_7', a_8' + b_8')$$

3.2.2. Subtraction:

$$\bar{A}_{oc}{}^{I} - \bar{B}_{oc}{}^{I} = (a_1 - b_8, a_2 - b_7, a_3 - b_6, a_4 - b_5, a_5 - b_4, a_6 - b_3, a_7 - b_2, a_8 - b_1)$$

$(a_1' - b_8', a_2' - b_7', a_3' - b_6', a_4' - b_5', a_5' - b_4', a_6'$-$b_3', a_7' - b_2', a_8' - b_1')$

3.2.3. Multiplication:

$\bar{A}_{oc}{}^{I} * \bar{B}_{oc}{}^{I} = (a_1 * b_1, a_2 * b_2, a_3 * b_3, a_4 * b_4, a_5 * b_5, a_6 * b_6, a_7 * b_7, a_8 * b_8)$
$(a_1' * b_1', a_2' * b_2', a_3' * b_3', a_4' * b_4', a_5' * b_5', a_6' * b_6', a_7' * b_7', a_8' * b_8')$

3.3. RANKING OF OCTAGONAL INTUITIONISTIC FUZZY NUMBERS

The ranking function of Octagonal Intuitionistic Fuzzy Number (OIFN)
$\bar{A}_{oc}{}^{I} = (a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8)$ $(a_1', a_2', a_3', a_4', a_5', a_6', a_7', a_8')$ maps the set of all Fuzzy numbers to a set of real numbers defined as

$$R[\bar{A}_{oc}{}^{I}] = \text{Max}\,[\,Mag_{\mu}(\bar{A}_{oc}{}^{I}), Mag_{\vartheta}(\bar{A}_{oc}{}^{I})]$$

And similarly

$$R[\bar{B}_{oc}{}^{I}] = Max\,[\,Mag_{\mu}(\bar{B}_{oc}{}^{I}), Mag_{\vartheta}(\bar{B}_{oc}{}^{I})],$$

Where

$$Mag_{\mu}(\bar{A}_{oc}{}^{I}) = \frac{2a_1+3a_2+4a_3+5a_4+5a_5+4a_6+3a_7+2a_8}{28}$$

$$Mag_{\vartheta}(\bar{A}_{oc}{}^{I}) = \frac{2a_1'+3a_2'+4a_3'+5a_4'+5a_5'+4a_6'+3a_7'+2a_8'}{28}$$

And similarly

$$Mag_{\mu}(\bar{B}_{oc}{}^{I}) = \frac{2b_1+3b_2+4b_3+5b_4+5b_5+4b_6+3b_7+2b_8}{28}$$

$$Mag_{\vartheta}(\bar{B}_{oc}{}^{I}) = \frac{2b_1'+3b_2'+4b_3'+5b_4'+5b_5'+4b_6'+3b_7'+2b_8'}{28}$$

3.4. MODI METHOD

There are many methods to find the basic feasible solution, Modi method is heuristic method. The advantage of this method is that it gives an initial solution which is nearer to an optimal solution. Here in this paper Modi method is suitably modified and used to solving Intuitionistic Fuzzy transportation problem.

PROPOSED ALGORITHM

Step –1: In Octagonal Intuitionistic Fuzzy transportation problem (OIFN) the quantities are reduced into an integer using the ranking method called accuracy function.

Step – 2: For an initial basic feasible solution with m + n -1 occupied cells, calculate u_i and v_j for rows and columns. The initial solution can be obtained by any of the three methods discussed earlier.

To start with, any ofu_i's orv_j'sis assigned the value zero. It is better to assign zero for a particular u_i or v_j. Where there are maximum numbers of allocations in a row or column respectively, as it will reduce arithmetic work considerably. Then complete the calculation of u_i's andv_j's for other rows and columns by using the relation.$C_{ij} = u_i + v_J$ for all occupied cells (i,j).

Step – 3: For unoccupied cells, calculate opportunity cost by using the relationship
$d_{ij} = C_{ij}$ - $(u_i + v_J)$ for all i and j.

Step – 4: Examine sign of each d_{ij}.
If d_{ij} >0, then current basic feasible solution is optimal.
If d_{ij} = 0, then current basic feasible solution will remain unaffected but an alternative solution exists.
If one or more d_{ij} <0, then an improved solutions can be obtained by entering unoccupied cell (i,j) in the basis. An unoccupied cell having the largest negative value of d_{ij} is chosen for entering into the solution mix (new transportation schedule).

Step – 5: Construct a closed path (or loop) for the unoccupied cell with largest negative opportunity cost. Start the closed path with the selected unoccupied cell and mark a plus sign (+) in this cell, trace a path along the rows (or columns) to an occupied cell, mark the corner with minus sign (-) and continue down the column (or row) to an occupied cell and mark the corner with plus sign (+) and minus sign (-) alternatively, close the path back to the selected unoccupied cell.

Step – 6: Select the smallest quantity amongst the cells marked with minus sign on the corners of closed loop. Allocate this value to the selected unoccupied cell and add it to other occupied cells marked with plus signs and subtract it from the occupied cells marked with minus signs.

Step – 7: Obtain a new improved solution by allocating units to the unoccupied cell according to step – 6 and calculate the new total transportation cost.

Step – 8: Test the revised solution further for optimality. The procedure terminates when all $d_{ij} \geq 0$, for unoccupied cells.

3.5. Numerical Example:

Consider a 3×3 Octagonal Intuitionistic Fuzzy Number.

	D1	D2	D3	Supply
S1	(1,2,3,4,5,6,7,8) (0,1,2,3,4,5,6,7)	(3,4,5,6,7,8,9,10) (1,2,3,4,5,6,7,8)	(6,7,8,9,10,11,12,13) (3,4,5,6,7,8,9,10)	(3,4,5,6,7,8,9,10) (8,9,10,11,12,13,14,15)
S2	(4,5,6,7,8,9,10,11) (1,2,3,4,5,6,7,10)	(8,9,10,11,12,13,14,15) (3,4,5,6,7,8,9,10)	(3,6,7,8,9,10,12,13) (2,3,4,5,6,7,8,9)	(3,4,5,6,7,8,9,10) (6,7,8,9,10,11,12,13)
S3	(5,6,7,8,9,10,11,12) (0,1,2,3,4,5,6,7)	(7,8,9,10,11,12,13,14) (3,6,7,8,9,10,12,13)	(4,5,6,7,8,9,10,11) (1,2,3,5,6,7,8,10)	(1,2,3,5,6,7,8,13) (0,1,2,3,4,7,9,10)
Demand	(7,8,9,10,11,12,13,14) (3,6,7,8,9,10,12,13)	(2,4,6,7,8,9,10,11) (1,2,3,4,5,6,7,10)	(1,2,3,5,6,7,8,10) (4,5,6,7,8,9,10,11)	

ΣDemand = Σ Supply

The problem is a balanced transportation problem. Using the proposed algorithm, the solution of the problem is as follows. Applying accuracy function on Octagonal Intuitionistic Fuzzy Number [(1,2,3,4,5,6,7,8) (0,1,2,3,4,5,6,7)], we have

R $(\bar{A}_{oc}{}^{I})$ = Max [$Mag_{\mu}(\bar{A}_{oc}{}^{I})$,$Mag_{\vartheta}(\bar{A}_{oc}{}^{I})$]
= Max [$\frac{2+6+12+20+25+24+21+16}{28}$,$\frac{0+3+8+15+20+20+18+14}{28}$]
= Max [4.5, 3.5]
R $(\bar{A}_{oc}{}^{I})$ = 4.5

Similarly applying for all the values, we have the following table after ranking

Table 1 - Reduced Table

	B_1	B_2	B_3	Supply
A_1	4.5	6.5	9.5	11.5
A_2	7.5	11.5	8.5	9.5
A_3	8.5	10.5	7.5	5.25
Demand	10.5	7.25	8.5	26.25

Applying VAM method, Table corresponding to initial basic feasible solution is

Table 2 - Reduced Table of VAM Method

	B_1	B_2	B_3	Supply
A_1	[4.25] 4.5	[7.25] 6.5	9.5	11.5
A_2	[6.25] 7.5	11.5	[3.25] 8.5	9.5
A_3	8.5	10.5	[5.25] 7.5	5.25
Demand	10.5	7.25	8.5	26.25

Since the number of occupied cell m+n-1=5 and are also independent. There exists a non-negative basic feasible solution.

The initial transportation cost is
[(4.25 ×4.5) + (7.25×6.5) + (6.25×7.5) + (3.25×8.5) + (5.25×7.5)] = 180.125

Applying MODI method, table corresponding to optimal solution is

Table 3 – Reduced Table Modi Method

	B_1	B_2	B_3	Supply
A_1	[4.25] 4.5	[7.25] 6.5	(4) 9.5	11.5
A_2	[6.25] 7.5	(2) 11.5	[3.25] 8.5	9.5
A_3	(2) 8.5	(0.5) 10.5	[5.25] 7.5	5.25
Demand	10.5	7.25	8.5	26.25

Since all $d_{ij} \geq 0$ the solution in optimum and unique. The solution is given by x_{11}= 4.25,
x_{12} = 7.25 , x_{21}= 6.25, x_{23}= 3.25, x_{33}= 5.25

The problem is a unbalanced transportation problem. Using the proposed algorithm, the solution of the problem is as follows. Applying accuracy function on Octagonal Intuitionistic Fuzzy Number [(1,2,3,4,5,6,7,9)(3,4,5,6,7,8,10,12)], we have

R $(\bar{A}_{oc}{}^{I})$ = Max [$Mag_{\mu}(\bar{A}_{oc}{}^{I})$,$Mag_{\vartheta}(\bar{A}_{oc}{}^{I})$]
= Max [$\frac{2+6+12+20+25+24+21+18}{28}$,$\frac{6+12+20+30+35+32+30+24}{28}$]
= Max [4.5, 6.75]
R $(\bar{A}_{oc}{}^{I})$ = 6.75

The optimal solution is
= [(4.25 × 4.5) +(7.25×6.5)+(6.25×7.5)+(3.25×8.5)+(5.25×7.5)]
= 180.125

Using Octagonal Intuitionistic Fuzzy Numbers, Cost values are same but Supply and Demand values are not equal. Hence this is considered as Unbalanced Transportation Problem. The values are compared to find the minimum transportation cost.

	D1	D2	D3	Dummy	Supply
S1	(1,2,3,4,5,6,7,8) (0,1,2,3,4,5,6,7)	(3,4,5,6,7,8,9,10) (1,2,3,4,5,6,7,8)	(6,7,8,9,10,11,12,13) (3,4,5,6,7,8,9,10)	(0,0,0,0,0,0,0,0) (0,0,0,0,0,0,0,0)	(3,4,5,6,7,8,9,10) (8,9,10,11,12,13,14,15)
S2	(4,5,6,7,8,9,10,11) (1,2,3,4,5,6,7,10)	(8,9,10,11,12,13,14,15) (3,4,5,6,7,8,9,10)	(3,6,7,8,9,10,12,13) (2,3,4,5,6,7,8,9)	(0,0,0,0,0,0,0,0) (0,0,0,0,0,0,0,0)	(3,4,5,6,7,8,9,10) (6,7,8,9,10,11,12,13)
S3	(5,6,7,8,9,10,11,12) (0,1,2,3,4,5,6,7)	(7,8,9,10,11,12,13,14) (3,6,7,8,9,10,12,13)	(4,5,6,7,8,9,10,11) (1,2,3,5,6,7,8,10)	(0,0,0,0,0,0,0,0) (0,0,0,0,0,0,0,0)	(1,2,3,5,6,7,8,9,10) (0,1,2,3,4,5,6,7,8,13)
Demand	(1,2,3,4,5,6,7,9) (3,4,5,6,7,8,10,12)	(4,5,6,7,8,9,10,11) (0,1,2,3,4,5,6,7)	(1,2,3,4,5,6,7,8) (-1,0,1,2,3,4,5,6)	(1,2,3,5,6,7,8,10) (4,5,6,7,8,9,10,11)	

Σ Demand ≠ Σ Supply

Similarly applying for all the values, we have the following table after ranking

Table 4 - Reduced Table

	B_1	B_2	B_3	Dummy	Supply
A_1	4.5	6.5	9.5	0	11.5
A_2	7.5	11.5	8.5	0	9.5
A_3	8.5	10.5	7.5	0	5.25
Demand	6.75	7.5	3.5	8.5	26.25

Applying VAM method, Table corresponding to initial basic feasible solution is

Table 5- Reduced Table of VAM Method

	B_1	B_2	B_3	Dummy	Supply
A_1	[4] 4.5	[7.5] 6.5	9.5	0	11.5
A_2	[2.75] 7.5	11.5	[3.5] 8.5	[3.25] 0	9.5
A_3	8.5	10.5	7.5	[5.25] 0	5.25
Demand	6.75	7.5	3.5	8.5	26.25

Since the number of occupied cell m+n-1=5 and are also independent. There exists a non-negative basic feasible solution.

The initial transportation cost is
[(4 ×4.5) + (7.5×6.5) + (2.75×7.5) + (3.5×8.5) + (3.25×0)+(5.25× 0)] = 117.125

Applying MODI method, table corresponding to optimal solution is

Table 6 - Reduced Table of MODI Method

	B_1	B_2	B_3	Dummy	Supply
A_1	[4] 4.5	[7.5] 6.5	(4) 9.5	(3) 0	11.5
A_2	[2.75] 7.5	(2) 11.5	[3.5] 8.5 ↓	[3.25] ← 0	9.5
A_3	(1) 8.5	(1) 10.5	(-1) 7.5 →	[5.25] 0 ↑	5.25
Demand	6.75	7.5	3.5	8.5	26.25

Table 7 - Reduced Table of MODI Method

	B_1	B_2	B_3	Dummy	Supply
A_1	[4] 4.5	[7.5] 6.5	9.5	0	11.5
A_2	[2.75] 7.5	11.5	8.5	[6.75] 0	9.5
A_3	8.5	10.5	[3.5] 7.5	[8.75] 0	5.25
Demand	6.75	7.5	3.5	8.5	26.25

Since all $d_{ij} \geq 0$ the solution in optimum and unique. The solution is given by x_{11}= 4,
$x_{12} =$ 7.5 , x_{21}= 2.75, x_{24}= 6.75, x_{33}= 3.5, x_{34}= 8.75

The optimal solution is
= [(4 × 4.5) +(7.5×6.5) +(2.75×7.5) +(6.75×0)+(3.75×7.5)+ (8.75×0)]
= 113.625

4. CONCLUSION:

In this paper, we discussed finding optimal solution for Octagonal Intuitionistic Fuzzy Balanced Transportation problem and Unbalanced Transportation problem. It is concluded that Unbalanced Transportation method proves to be cost effective.

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