Tanzania Journal of Science 45(2): 226-237, 2019 ISSN 0856-1761, e-ISSN 2507-7961


# Decision Rules for Supplier Selection Using Intuitionistic Fuzzy TOPSIS

**Dickson EA Omorogbe[1] and Sunday E Omosigho[2]**
[1]*Institute of Education (Ekehuan Campus), University of Benin, Benin City, Nigeria*
*E-mail: erhaativie.Omorogbe@uniben.edu*
[2]*Department of Mathematics, University of Benin, Benin City, Nigeria*
*E-mail: seomosigho@uniben.edu*

**Abstract**

This paper provides a methodology for addressing contradictions in the ranking of suppliers when more than one metric functions are adopted in intuitionistic fuzzy TOPSIS (Technique for Order Preference by Similarity to the Ideal Solution) for supplier selection. Our literature search revealed contradictions when more than one metric functions are adopted in the method. Two types of contradictions were addressed: (i) contradiction of the best supplier, and (ii) contradiction at the middle of the park. Decision rules algorithms were developed to address the problems.Worked examples were given to illustrate the rules for resolving the contradiction. A major thrust of this paper is the adoption of odd number of metric functions with the use of the ballot strategy. This paper used three metric functions which are Spherical, Euclidean and Hamming metric fuctions. In case of contradiction, the alternatve that gives majority of same rank with respect to the metric fuctions is selected.

**Keywords:** Supplier Selection, Intuitionistic fuzzy TOPSIS, Metric Functions, Contraditions, contradiction of best alternatives, contradiction at the middle of the park.

## Introduction

Supplier selection is an important component of supply chain management in today's global competitive environment. Hence the evaluation and selection of suppliers have received considerable attention in the literature. Many attributes of suppliers other than cost are considered in the evaluation and selection process. Therefore, supplier evaluation and selection is a multi-criteria decision making problem involving many suppliers that have the potential to meet the need of an organisation. But the suppliers are not the same in many respects. For example: one supplier may deliver on time but the items are costly. A supplier requires longer time to deliver but the items are cheaper than those of a supplier that requires a shorter time to deliver. An important issue in the selection of suppliers is the fact that it is almost impossible to find a supplier that excels in all the possible attributes identified by an organization or decision makers. The scores for all suppliers on these attributes are not the same. Nevertheless, the organization must select a specific number of suppliers from the available suppliers. This is the supplier selection problem. Using the Framework of Chai and Liu (2010) the supplier selection problem is presented as follows:

| *Decision factors* | *Mathematical formulation* | |
|---|---|---|
| Suppliers or alternative set | $A = \{A_1, A_2, \cdots A_n\}$ | (1) |
| Decision makers (DM) set | $E = \{e_1, e_2, \cdots e_l\}$ | (2) |
| Criteria or attributes | $C = \{c_1, c_2, \cdots c_m\}$ | (3) |
| Decision maker (DM) weights | $W = \{w_1, w_2, \cdots w_l\}$ | (4) |
| Criterion weights | Ꞷ$= (\omega_1, \omega_2 \cdots \omega_m)$ | (5) |

Aggregating these variables to select the best supplier is the supplier selection problem.

There is a burgeoning literature on supplier selection problem. Mutiple critera decsion making is an important aspect of operations reseach (Fei et al. 2016). Amindoust et al. (2012) and Ho et al. (2010) presented reviews of the methods for solving supplier selection problem. Chen and Tsao (2008) illustrated that contradictory ranking of suppliers may be obtained when more than one metric function is adopted in the calculations of the seperation measure betwen each supplier and the positive ideal solution (PIS) and negative ideal solution (NIS). They did not consider how the issue of contradiction in the ranking of suppliers can be resolved.

Applications of intuitionistic fuzzy TOPSIS have been reported by several authors. Gerogiannis et al. (2011) illustrated the use of Intuitionistic Fuzzy Set-TOPSIS Method for evaluating projects and Portfolio Management Information Systems. Only Euclidean metric was used. Shahroudi and Tonekaboni (2012) proposed the application of TOPSIS method to supplier selection in Iran auto supply chain using only Euclidean distance. Rouyendegh (Babek Erdebilli) and Saputro (2014) also applied integrated fuzzy TOPSIS and multi-choice goal programming (MCGP) to Supplier selection incorporating only Euclidean metric. Omosigho and Omorogbe (2015) argued that for empirical supplier selection problem more than one metric functions should be adopted in order to reveal cases of contradictions in the ranking of supplier and using one metric function as commonly used in literature is misleading.

The supplier selection problem entails selecting a number of suppliers from a list of suppliers using many criteria. TOPSIS (Technique for Order Preference by Similarity to the Ideal Solution) is one of the methodologies for solving the supplier selection problem among other computational methods (Omorogbe and Omosigho 2019). TOPSIS requires the determination of the positive ideal solution (PIS) and the negative ideal solution (NIS). The PIS is a matrix containing the best ratings for all criteria and all suppliers while the NIS is a matrix containing the worst ratings for all criteria and all suppliers. For each supplier, a similarity measure called closeness coefficient is calculated using the distances of each supplier from the PIS and NIS. These distances are calculated using a metric function. The closeness coefficients are used to rank the suppliers. However, when several metric functions are adopted in some supplier selection problems, contradictory recommendations may be obtained. For example, if A3 » A1 means that supplier A3 is preferred to supplier A1, we may obtain A3 » A1 » A4 » A2 » A5 and A3» A1 » A2 » A4 » A5 when five suppliers A1, A2, A3, A4, and A5 are compared using two different metric functions.

The paper considered a final decision matrix $D$ for the supplier selection problem can be written as:

$$D = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix} \qquad (6)$$

for a decision situation with m suppliers and n criteria. Each $x_{ij}$ represents the final score of Supplier $i, (i = 1, 2, \dots, m)$, in criterion $j$, $(j = 1, 2, \dots, n)$. In intuitionistic fuzzy TOPSIS, each $x_{ij}$ in D is an intuitionistic fuzzy number i.e., $x_{ij} = <\mu_{ij}, \ v_{ij}, \ \tau_{ij}>$, where $\mu_{ij} + v_{ij} + \tau_{ij} = 1$, $0< \mu_{ij} <1$, $0< v_{ij} < 1$, $0< \tau_{ij} < 1$. In $x_{ij} = <\mu_{ij}, \ v_{ij}, \ \tau_{ij}>$, $\mu_{ij}$ is the degree of membership, $v_{ij}$ is he degree of non-membership, while $\tau_{ij} = 1 - \mu_{ij} - v_{ij}$ is the hesitation of the decision maker assigning $v_{ij}$ *and* $\mu_{ij}$ to Supplier $i$ with respect to criterion $j$. The process for obtaining the final decision matrix for a supplier selection problem is well established in the literature, see for example

Boran et al. (2009), Jadidi et al. (2010), Izadikhah (2012) and Joshi and Kumar (2014).

The selection process presented in this paper starts from the final decision matrix *D*. Amongst other computations, TOPSIS requires the determination of the positive ideal solution (PIS), the negative ideal solution (NIS) and the closeness coefficients. The PIS is a matrix containing the best ratings for all criteria and all suppliers while the NIS is a matrix containing the worst ratings for all criteria and all suppliers. The closeness coefficient is calculated using a metric function. When two or more metric functions are used for the same supplier selection problem, we may have contradictions in the ranking of suppliers.

The paper proposes how to resolve contradictions in the ranking of suppliers when more than one metric functions are used in intuitionistic fuzzy TOPSIS. Simple and easy to used rules are proposed. The rules are based on simple computations. Examples are given to illustrate applications of the proposed decision rules for the ranking of suppliers using TOPSIS with more than one metric functions.

The use of efficient and reliable suppliers is imperative for the efficient and profitable management of an organization's supply chain. Intuitionistic fuzzy TOPSIS is an established method for solving supplier selection problem. Nevertheless, the use of more than one metric functions in intuitionistic fuzzy TOPSIS may produce contradictory ranking of suppliers. This means that if one metric function is adopted, the wrong supplier can be selected. Hence, it is important to develop a methodology that can be used to resolve the problem associated with intuitionistic fuzzy TOPSIS when more than one metric funtions are adopted. Indeed, the development of decision rules for supplier selection is worthwhile.

## Materials and Methods

Given the final decision matrix *D* as in Equation (6), this section presents the abridged version of the TOPSIS algorithm derived from the standard TOPSIS algorithm (Boran et al. 2009 ). The steps for the abridged version of the TOPSIS algorithm adopted in this paper are provided below.

**Step 1**

Determine the positive ideal solution (PIS) and the negative ideal solution (NIS). Both PIS and NIS are row vectors having the same dimension as the number of criteria. Using *D* in Equation 6, both PIS and NIS have dimension (*1 x n).* If C*j* is a cost criterion (less is better) then the PIS component corresponding to C*j* is obtained as follows:

$pis_j = <\mu^*_{ij} = \min_i \mu_{ij}, v^*_{ij} = \max_i v_{ij}, \tau^*_{ij} = 1 - \mu^*_{ij} - v^*_{ij} >$ (7)

If B*j* is a benefit criterion (more is better) then the PIS component corresponding to B*j* is obtained as follows:

$pis_j = <\mu^*_{ij} = \max_i \mu_{ij}, v^*_{ij} = \min_i v_{ij}, \tau^*_{ij} = 1 - \mu^*_{ij} - v^*_{ij} >$ (8)

If C*j* is a cost criterion (less is better) then the NIS component corresponding to C*j* is obtained as follows:

$nis_j = <\mu^*_{ij} = \max_i \mu_{ij}, v^*_{ij} = \min_i v_{ij}, \tau^*_{ij} = 1 - \mu^*_{ij} - v^*_{ij} >$ (9)

If B*j* is a benefit criterion (more is better) then the NIS component corresponding to B*j* is obtained as follows:

$nis_j = <\mu^*_{ij} = \min_i \mu_{ij}, v^*_{ij} = \max_i v_{ij}, \tau^*_{ij} = 1 - \mu^*_{ij} - v^*_{ij} >$ (10)

**Step 2**

Construct the separation measures (distance from PIS and distance from NIS) for each supplier.

For each supplier the separation measures (distance from PIS and distance from NIS) are calculated using a metric function. Let $S^+$ and $S^-$ be the distances of each supplier from the PIS and NIS respectively. In this work we shall use the following metric functions: Euclidean, Hamming and Spherical metric functions.

Given any set $U = \{u_1, u_2, \ldots, u_n\}$, two intuitionistic fuzzy subsets $A = \{\langle u_i, \mu_A(u_i), \nu_A(u_i), \tau_A(u_i)\rangle\}$ and $B = \{\langle u_i, \mu_B(u_i), \nu_B(u_i), \tau_B(u_i)\rangle\}$ of the universe of discourse and using the 3D representation, the following metric functions are well known (Chen and Tsao 2008, Omorogbe 2014 and Omosigho and Omorogbe 2015).

a. Hamming distance *H(A,B)*

$$H(A,B) = \tfrac{1}{2}\sum_{i=1}^{n}[|\mu_A(u_i) - \mu_B(u_i)| + |\nu_A(u_i) - \nu_B(u_i)| + |\tau_A(u_i) - \tau_B(u_i)|] \quad (11)$$

b. Euclidean distance *E(A, B)*

$$E(A,B) = (\tfrac{1}{2}\sum_{i=1}^{n}[(\mu_A(u_i) - \mu_B(u_i))^2 + (\nu_A(u_i) - \nu_B(u_i))^2 + (\tau_A(u_i) - \tau_B(u_i))^2])^{0.5} \quad (12)$$

*c.* Spherical distance *S(A,B)*

$$S(A,B) = \tfrac{2}{\pi}\sum_{i=1}^{n} ar\cos(\sqrt{\mu_A(u_i)\mu_B(u_i)} + \sqrt{\nu_A(u_i)\nu_B(u_i)} + \sqrt{\tau_A(u_i)\tau_B(u_i)}) \quad (13)$$

There are many other metric functions for intuitionistic fuzzy sets, see Grzegorzewski (2004) and references therein.

**Step 3**

Calculate the closeness coefficient for each supplier using the results obtained in step 2. Using $S^+$ and $S^-$ a similarity measure called closeness coefficient and given by

CC= $S^-/(S^+ + S^-)$ is computed for each supplier. (14)

**Step 4**

The closeness coefficients are used to rank the suppliers in decreasing order of the closeness coefficients.

However, when more than one metric functions are adopted in some supplier selection problems, contradictory recommendation may be obtained. For example, if A3 ≫ A1 means supplier A3 is preferred to supplier A1, we may obtain:

A3 ≫ A1 >> A4 ≫ A2 ≫ A5 and

A3 ≫ A1 ≫ A2 ≫ A4 ≫ A5

when five suppliers A1, A2, A3, A4, and A5 are compared using two different metric functions. Observe that we have A4 ≫ A2 and A2 ≫ A4, i.e. a contradiction in the ranking of suppliers A4 and A2 when two metric functions are used. This type of contradiction we shall refer to as contradiction in the ranking of some suppliers in the middle of the park. In some cases we may also have contradiction in the ranking of the best alternative such as A4 ≫ A2 ≫ A5 and A2 ≫ A4 ≫ A5. Contradictions in the ranking of suppliers can affect single source supplier problem or multiple source supplier problems. The question is how do we resolve such problems in a decision-making situation? The decision rules contained in this paper provides a way out of the problems.

**Decision rules for resolving contradictions in the ranking of suppliers**

We assume that two metric functions are used for the same problem initially. This implies that for each supplier problem, there will be two rankings of the suppliers. We recommend the use of Euclidean and Hamming metric functions. The Euclidean metric function is very popular. With two rankings of the suppliers, there are two cases of contradiction to examine. First, we may have contradiction in the ranking of best alternatives, Chen and Tsao (2008), i.e., the two metric functions will produce two suppliers as the best alternatives. Second, we may have contradictions in the ranking of suppliers in the middle. We shall consider these two cases separately.

**Contradiction in the ranking of best alternative**

In a single source supplier problem, it is important to identify the best supplier. When there is contradiction in the best alternative, the following rule is proposed for resolving the contradiction.

**Rule 1**:

**Step 1:** Identify the two alternatives involved in the contradiction of the best alternative.

**Step 2:** For the two suppliers identified in step 1, use the abridged version of TOPSIS and odd number of metric functions. In this paper, we use three metric functions namely: Hamming, Euclidean and Spherical metrics.

**Step 3**: Use a voting strategy to choose the preferred alternative, i.e, the supplier identified as the preferred alternative by a majority of the metric functions is selected.

When using rule 1, we actually solve a sub problem derived from the original problem. The sub problem involves only two suppliers. We call the PIS and NIS associated with the new problem, relative PIS and relative NIS. The relative PIS and relative NIS, can in some cases, provide sufficient information to choose between the two alternatives since the relative PIS and relative NIS reveal the strength and weakness of both suppliers.

**Contradictions in the ranking in the middle of the park**

Contradiction in the rankings in the middle of the park gives serious concern in a multiple source, supplier selection problem. In a multiple source supplier problem, the main objective is to have the optimum number of required suppliers. Optimum in this case means that none of the suppliers selected is worse than any of the suppliers rejected by the selection process. The ranking of the suppliers selected may not be important. Hence the emphasis is not just on the best supplier but on the best two or more suppliers. If the number of suppliers required by the system can be selected without resolving the contradictions in the ranking of the suppliers then the problem has been completely solved. Otherwise, there are two cases of contradictions in the ranking of suppliers to consider:

1. Two metric functions produce two suppliers for two consecutive positions but the ranking of the suppliers are different.
2. Two metric functions produce three suppliers in two consecutive positions.

**Rule 2**

The next algorithm can be used to resolve problems where two metric functions produce two suppliers for two consecutive positions but the ranking of the suppliers are different.

**Step 1**: Identify the number of suppliers required, k

**Step 2:** Select the number (j) of suppliers that can be selected excluding cases involving contradiction.

**Step 3**: Check the number of suppliers selected. If j = k stop otherwise proceed to the next step.

**Step 4**: If $j + 2 \leq k$, add supplier j + 1 and j + 2 to the list of suppliers already selected. Set j = j + 2 and go to step 3.

**Step 5**: If $j + 2 > k$, identify the two suppliers ranked j + 1 and j + 2 by the two metric functions with contradiction in their ranking. Use rule 1 to obtain suppliers ranked j + 1 and j + 2. Select k suppliers and stop.

**Rule 3**: Two metric functions produce three suppliers in two consecutive positions.

**Step 1**: Identify the number of suppliers required, k

**Step 2**: Select the number (j) of suppliers that can be selected excluding cases involving contradiction.

**Step 3**: Check the number of suppliers selected.. If j = k stop otherwise proceed to the next step.

**Step 4**: If j + 3 $\leq k$, add supplier j + 1, j + 2 and j + 3 to the list of suppliers already selected. Set j = j + 3 and go to step 3.

**Step 5**: If j + 3 $> k$, identify the three suppliers ranked j + 1, j + 2 and j + 3 by the two metric functions with contradiction in their ranking. Use rule 1 to obtain suppliers ranked j + 1, j + 2 and j + 3. Select k suppliers and stop.

However pseudorandom numbers were generated with MATLAB (Omorogbe 2014) to illustrate the implementaion of the decisions rules as contained in this paper for resolving contradictions in the ordering (ranking) of suppliers when more than one metric functions are used. Results and illustative examples of implementing the proposed decision rules are provided below.

## Results

### Contradiction in the ranking of best alternative

Example 1: Table 1 shows a case of contradiction in the ranking of best supplier, a decision matrix for a supplier selection problem with three suppliers and four criteria together with both the Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS). The first criterion is a cost criterion (less is better) while the other three criteria are benefit criteria (more is better).

**Table 1:** Decision matrix for three suppliers and four criteria

| | | Cost B1 | | | Benefit B2 | | | Benefit B3 | | | Beneft B4 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0.441 | 0.4903 | 0.0687 | 0.3202 | 0.0497 | 0.6301 | 0.3291 | 0.3986 | 0.2723 | 0.3218 | 0.5378 | 0.1404 |
| A2 | 0.5558 | 0.3848 | 0.0594 | 0.0484 | 0.4363 | 0.5153 | 0.0196 | 0.4669 | 0.5135 | 0.6957 | 0.0314 | 0.2729 |
| A3 | 0.1562 | 0.3067 | 0.5371 | 0.2857 | 0.3773 | 0.337 | 0.3154 | 0.3476 | 0.3409 | 0.0478 | 0.1005 | 0.8517 |
| PIS | 0.1562 | 0.4903 | 0.3535 | 0.3202 | 0.0497 | 0.6301 | 0.3291 | 0.3476 | 0.3233 | 0.6957 | 0.0314 | 0.2729 |
| NIS | 0.5558 | 0.3067 | 0.1375 | 0.0484 | 0.4363 | 0.5153 | 0.0196 | 0.4669 | 0.5135 | 0.0478 | 0.5378 | 0.4144 |

(Source: Omosigho and Omorogbe 2015)

**Table 2:** Ranking of suppliers in Table 1

| Suppliers | Ranking using Hamming Metric | Ranking using Euclidean Metric |
|---|---|---|
| A1 | 1 | 2 |
| A2 | 3 | 1 |
| A3 | 2 | 3 |

Table 2 shows the ranking of the suppliers in Table 1. Using the Hamming metric function, A1 is the best supplier while A2 is the best supplier according to Euclidean metric function. Thus there is contradiction in the ranking of the best alternative. To resolve the problem we use rule 1.

**Step 1**

The two alternatives involved in the contradiction in the ranking of the best alternative are A1 and A2.

**Step 2**

Table 3 shows the decision matrix for suppliers A1 and A2, augmented with the relative PIS and the relative NIS. B1 remains a cost criterion as in Table 1.

**Table 3:** Decision matrix, PIS, NIS for suppliers A1, A2 taken from Table 1

| | B1 (Cost) | | | B2 (Benefit) | | | B3 (Benefit) | | | B4 (Benefit) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0.4410 | 0.4903 | 0.0687 | 0.3202 | 0.0497 | 0.6301 | 0.3291 | 0.3986 | 0.2723 | 0.3218 | 0.5378 | 0.1404 |
| A2 | 0.5558 | 0.3848 | 0.0594 | 0.0484 | 0.4363 | 0.5153 | 0.0196 | 0.4669 | 0.5135 | 0.6957 | 0.0314 | 0.2729 |
| PIS | 0.4410 | 0.4903 | 0.0687 | 0.3202 | 0.0497 | 0.6301 | 0.3291 | 0.3986 | 0.2723 | 0.6957 | 0.0314 | 0.2729 |
| NIS | 0.5558 | 0.3848 | 0.0594 | 0.0484 | 0.4363 | 0.5153 | 0.0196 | 0.4669 | 0.5135 | 0.3218 | 0.5378 | 0.1404 |

Using the relative PIS and relative NIS, one is tempted to select A1 as the preferred supplier since A1 contributes more to the relative PIS. Table 4 indeed confirms A1 as the preferred supplier.

**Table 4:** Closeness coefficients and ranks for suppliers A1, and A2 in Table 3

| Supplier | Hamming | | Euclidean | | Spherical | |
|---|---|---|---|---|---|---|
| | CC | RANK | CC | RANK | CC | RANK |
| A1 | 0.6156 | 1 | 0.5017 | 1 | 0.6443 | 1 |
| A2 | 0.3844 | 2 | 0.4983 | 2 | 0.3557 | 2 |

**Step 3**

Clearly, from Table 4, it is evident that supplier A1 is better than supplier A2. Now, what about suppliers A2 and A3? There is also contradiction in their rankings as shown in Table 2. Table 5 shows the result of using Rule 1 to rank the two suppliers.

**Table 5:** Ranks for suppliers A2 and A3 in Table 3

| Supplier | Hamming | Euclidean | Spherical |
|---|---|---|---|
| | Rank | Rank | Rank |
| A2 | 2 | 1 | 2 |
| A3 | 1 | 2 | 1 |

By the voting strategy, supplier A3 is preferred to supplier A2. So the complete ranking is
A1 $\gg$ A3 $\gg$ A2. This agrees with the ranking provided by the Hamming metric.
Example 2
Table 6 shows the decision matrix for a supplier selection involving six suppliers and three criteria. Table 7 shows the decision matrix together with the PIS and NIS. The rankings of the suppliers using Hamming and Euclidean metric functions are shown in Table 8.

**Table 6:** Decision matrix for suppliers A1, A2, A3, ..., A6

| | B1 (Cost) | | | B2 (Benefit) | | | B2 (Benefit) | | |
|---|---|---|---|---|---|---|---|---|---|
| A1 | 0.0009 | 0.6318 | 0.3673 | 0.3471 | 0.0707 | 0.5822 | 0.0653 | 0.8601 | 0.0746 |
| A2 | 0.3178 | 0.1052 | 0.5770 | 0.1731 | 0.3963 | 0.4306 | 0.1503 | 0.4753 | 0.3744 |
| A3 | 0.4455 | 0.1047 | 0.4498 | 0.1724 | 0.3070 | 0.5206 | 0.4363 | 0.0484 | 0.5153 |
| A4 | 0.5457 | 0.0181 | 0.4362 | 0.0653 | 0.8601 | 0.0746 | 0.3878 | 0.1609 | 0.4513 |
| A5 | 0.3370 | 0.2857 | 0.3773 | 0.0707 | 0.3471 | 0.5822 | 0.5061 | 0.0550 | 0.4389 |
| A6 | 0.2205 | 0.3271 | 0.4524 | 0.0844 | 0.4252 | 0.4904 | 0.2205 | 0.3271 | 0.4524 |

**Table 7:** Decision matrix, PIS, NIS for suppliers A1, A2, A3, ..., A6

| | B1 (Cost) | | | B2 (Benefit) | | | B2 (Benefit) | | |
|---|---|---|---|---|---|---|---|---|---|
| A1 | 0.0009 | 0.6318 | 0.3673 | 0.3471 | 0.0707 | 0.5822 | 0.0653 | 0.8601 | 0.0746 |
| A2 | 0.3178 | 0.1052 | 0.5770 | 0.1731 | 0.3963 | 0.4306 | 0.1503 | 0.4753 | 0.3744 |
| A3 | 0.4455 | 0.1047 | 0.4498 | 0.1724 | 0.3070 | 0.5206 | 0.4363 | 0.0484 | 0.5153 |
| A4 | 0.5457 | 0.0181 | 0.4362 | 0.0653 | 0.8601 | 0.0746 | 0.3878 | 0.1609 | 0.4513 |
| A5 | 0.3370 | 0.2857 | 0.3773 | 0.0707 | 0.3471 | 0.5822 | 0.5061 | 0.0550 | 0.4389 |
| A6 | 0.2205 | 0.3271 | 0.4524 | 0.0844 | 0.4252 | 0.4904 | 0.2205 | 0.3271 | 0.4524 |
| PIS | 0.0009 | 0.6318 | 0.3673 | 0.3471 | 0.0707 | 0.5822 | 0.5061 | 0.0484 | 0.4455 |
| NIS | 0.5457 | 0.0181 | 0.4362 | 0.0653 | 0.8601 | 0.0746 | 0.0653 | 0.8601 | 0.0746 |

**Table 8**: Ranking of suppliers in Table 6

| Suppliers | Ranking using Hamming distance | Ranking using Euclidean distance |
|---|---|---|
| A1 | 3 | 4 |
| A2 | 5 | 5 |
| A3 | 2 | 2 |
| A4 | 6 | 6 |
| A5 | 1 | 1 |
| A6 | 4 | 3 |

The ranking of the suppliers are as follows:

(a) **A5 ≫ A3**≫ A1≫ A6≫ A2 ≫ A4 using Hamming distance

(b) **A5 ≫ A3** ≫A6 ≫ A1 ≫ A2 ≫ A4 using Eclidean distance.

Here there is inconsistency in the ranking of the suppliers in the middle of the park, namely A1 and A6. A pairwise comparison of A1 and A6 using Hamming, Euclidean and Spherical metric functions in TOPSIS produce Table 9.

**Table 9:** Ranks of suppliers A1 and A6 in Table 6

| Supplier | Hamming | Euclidean | Spherical |
|---|---|---|---|
| | Rank | Rank | Rank |
| A1 | 1 | 2 | 1 |
| A6 | 2 | 1 | 2 |

By the voting strategy we have A1 ≫ A6. Hence the final ranking of the suppliers in Table 6 is:

A5 ≫ A3≫ A1 ≫ A6 ≫ A2 ≫ A4.

This is in concordance with the ranking produced using Hamming metric function.

**Remarks**

1. In this example, if the number of suppliers required is 2 or 4, then the selection can be made without further computation.
2. In this example, if only 3 suppliers are required then using the Euclidean metric function alone would have produced suppliers A5, A3, and A6 instead of suppliers A5, A3 and A1.
3. It is easy to see that Rule 2 can be used to select optimum 3 suppliers in this example.

Example 3: Table 10 is the decision matrix, the PIS and NIS of 12 suppliers with 4 criteria. B1 is cost criteria, while the other attributes are benefit criteia.

Tanzania Journal of Science 45(2): 226-237, 2019 ISSN 0856-1761, e-ISSN 2507-7961


**Table 10:** Decision matrix, PIS and NIS

| | B1 (Cost) | | | B2 (Benefit) | | | B3 (Benefit) | | | B4 (Benefit) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0.8553 | 0.0598 | 0.0849 | 0.3202 | 0.0497 | 0.6301 | 0.2001 | 0.3604 | 0.4395 | 0.4053 | 0.2169 | 0.3778 |
| A2 | 0.3743 | 0.4750 | 0.1507 | 0.0484 | 0.4363 | 0.5153 | 0.4444 | 0.0859 | 0.4697 | 0.2517 | 0.5808 | 0.1675 |
| A3 | 0.5651 | 0.1506 | 0.2843 | 0.2857 | 0.3773 | 0.3370 | 0.1049 | 0.4459 | 0.4492 | 0.4128 | 0.4062 | 0.1810 |
| A4 | 0.1047 | 0.1121 | 0.7832 | 0.3878 | 0.1609 | 0.4513 | 0.3416 | 0.1071 | 0.5513 | 0.2995 | 0.2720 | 0.4285 |
| A5 | 0.6274 | 0.0216 | 0.3510 | 0.2751 | 0.2486 | 0.4763 | 0.4516 | 0.2277 | 0.3206 | 0.1949 | 0.0035 | 0.8016 |
| A6 | 0.0844 | 0.4252 | 0.4904 | 0.5061 | 0.0550 | 0.4389 | 0.3178 | 0.1052 | 0.5770 | 0.2098 | 0.2184 | 0.5718 |
| A7 | 0.4124 | 0.3690 | 0.2186 | 0.3801 | 0.4195 | 0.2004 | 0.1824 | 0.3255 | 0.4921 | 0.1512 | 0.4100 | 0.4388 |
| A8 | 0.2344 | 0.2617 | 0.5040 | 0.4973 | 0.2732 | 0.2295 | 0.3851 | 0.3081 | 0.3068 | 0.4423 | 0.1828 | 0.3749 |
| A9 | 0.3918 | 0.2684 | 0.3398 | 0.1724 | 0.5206 | 0.3070 | 0.1394 | 0.5073 | 0.3533 | 0.1061 | 0.4220 | 0.4719 |
| A10 | 0.4787 | 0.2200 | 0.3013 | 0.4467 | 0.4212 | 0.1321 | 0.0665 | 0.2244 | 0.7091 | 0.0570 | 0.3528 | 0.5902 |
| A11 | 0.4495 | 0.2455 | 0.3050 | 0.5457 | 0.0181 | 0.4362 | 0.0497 | 0.4510 | 0.4993 | 0.1970 | 0.1755 | 0.6275 |
| A12 | 0.2205 | 0.3271 | 0.4524 | 0.3471 | 0.0707 | 0.5822 | 0.0653 | 0.8601 | 0.0746 | 0.5640 | 0.1734 | 0.2626 |
| PIS | 0.0844 | 0.4750 | 0.4406 | 0.5457 | 0.0181 | 0.4362 | 0.4516 | 0.0859 | 0.4625 | 0.5640 | 0.0035 | 0.4325 |
| NIS | 0.8553 | 0.0216 | 0.1231 | 0.0484 | 0.5206 | 0.4310 | 0.0497 | 0.8601 | 0.0902 | 0.0570 | 0.5808 | 0.3622 |

Table 11 shows the ranking of the suppliers in Table 10.

**Table 11:** Ranking of suppliers in Table 10 using the indicated metric functions

| Suppliers | 12 suppliers with 4 criteria instance | |
|---|---|---|
| | Hamming distance | Euclidean distance |
| A1 | 10 | 10 |
| A2 | 7 | 6 |
| A3 | 11 | 11 |
| A4 | 2 | 3 |
| A5 | 5 | 5 |
| A6 | 1 | 1 |
| A7 | 8 | 9 |
| A8 | 3 | 2 |
| A9 | 12 | 12 |
| A10 | 9 | 8 |
| A11 | 4 | 4 |
| A12 | 6 | 7 |

The ranking of the suppliers is as follows:
Hamming: A6 ≫ A4 ≫ A8 ≫ A11 ≫ A5 ≫ A12 ≫ A2 ≫ A7 ≫ A10 ≫ A1 ≫ A3 ≫ A9
Euclidean: A6 ≫ A8 ≫ A4 ≫ A11 ≫ A5 ≫ A2 ≫ A12 ≫ A10 ≫ A7 ≫ A1 ≫ A3 ≫ A9

In this case, there is no problem with the ranking of suppliers A6, A1, A3 and A9. In a scenario of multiple source supplier problems, the number of suppliers required will determine whether to order A4, A8, A2, A12, A7 and A10. Rule 2 can conveniently be used to solve the multiple source suppliers in this case by comparing the two suppliers involved in each case of contradiction. Table 12 shows the decision matrix, the relative PIS and relative NIS of suppliers A4 and A8.

**Table 12:** Decision matrix, PIS and NIS for suppliers A4 and A8 from Table 10

| | B1(cost) | B2(benefit) | B3(benefit) | B4(benefit) |
|---|---|---|---|---|
| A4 | 0.1047 0.1121 0.7832 | 0.3878 0.1609 0.4513 | 0.3416 0.1071 0.5513 | 0.2995 0.2720 0.4285 |
| A8 | 0.2344 0.2617 0.5040 | 0.4973 0.2732 0.2295 | 0.3851 0.3081 0.3068 | 0.4423 0.1828 0.3749 |
| PIS | 0.1047 0.2617 0.6336 | 0.4973 0.1609 0.3418 | 0.3851 0.1071 0.5078 | 0.4423 0.1828 0.3749 |
| NIS | 0.2344 0.1121 0.6535 | 0.3878 0.2732 0.3390 | 0.3416 0.3081 0.3503 | 0.2995 0.2720 0.4285 |

**Table 13**: Ranking of suppliers A4 and A8

| Supplier | Hamming | Euclidean | Spherical |
|---|---|---|---|
| | Rank | Rank | Rank |
| A4 | 1 | 2 | 1 |
| A8 | 2 | 1 | 2 |

Based on the voting strategy, the ordering of suppliers A4 and A8 is A4 ≫ A8. Similarly, by considering the decision matrix for the other pairs and their relative PIS and relative

NIS, we have A12 ≫ A2, and A7 ≫ A10. The combine chain gives a basis for selecting multiple suppliers.
Final ordering is:
A6 ≫ A4 ≫ A8 ≫ A11 ≫ A5 ≫ A12 ≫ A2 ≫ A7 ≫ A10 ≫ A1 ≫ A3 ≫ A9.

**Discussion**

This paper proposed decision rules to resolve the problem of contradictory recommendations in the ranking of suppliers in literature (Chen and Tsao, 2008) when more than one metric functions are adopted in intuitionistic fuzzy TOPSIS for supplier selection. Two types of contradictions were addressed: (i) contradiction of the best supplier (ii) contradiction at the middle of the park. Illustrative examples for implementing the decision rules were provided. Odd number of metric functions with the use of voting or ballot strategy is recommended for the implementation of the decision rules. This paper use three metric functions which are Spherical, Euclidean and Hamming metric fuctions. In case of contradiction, the alternatve that gives majority of same rank with respect to the metric fuctions is selected. Computer generated pseudorandom numbers in MATLAB were used as data throughout this paper (Omorogbe 2014). The literature on supplier selection using intuitionistic TOPSIS is replete with implementation of intuitionistic TOPSIS using only one metric function especially Euclidean metric function. There is increasing evidence that one metric function may not provide optimum ordering of suppliers using TOPSIS (Chen and Tsao 2008, Omosigho and Omorogbe 2015). Two metric functions should be used in the preliminary analysis of supplier selection problem. For single source problem, a third metric function should be used to resolve contradiction in the best alternative. For multiple source supplier problems, the type of contradiction in the ranking of alternatives should dictate what should be done next after the preliminary analysis using two metric functions. Yang and Chiclana (2009) argued that Spherical metric is very suitable for measuring distances between intuitionistic fuzzy sets. The number of metric functions for measuring distances between intuitionistic fuzzy sets is increasing. So it is very expedient that the issue of contradiction in the ranking of suppliers when more than one metric functions are implemented cannot be ignored.

On application of similarity measure, Li et al. (2007) stated that “one may have different results based on different solutions. In other words, this selection procedure is very necessary and important.” It is therefore imperative to formulate fundamental guidelines that can be used to select optimum solution from the different results which this paper provided. But there are other pathological cases of contradictions not covered by the rules presented here. These cases are being studied and will be reported elsewhere.

**Conclusion**

The need for efficient supplier selection methodology to improve the selection process cannot be over-emphasized. The benefit of applying multiple metric functions was demonstrated in literature (Omorogbe 2014 and Omosigho and Omorogbe 2015). Omosigho and Omorogbe (2015) concluded that using one metric function could be misleading in practice. However, this work provided a framework for resolving contradictions when more than one metric functions are adopted in intuitionistic fuzzy TOPSIS for supplier selection using the ballot (voting) strategy. Illustrative examples of how to resolve contradictions in the ranking of the best alternative and contradiction in the ranking of alternatives in the middle of the park were provided.

**Acknowledgement**
We acknowledge the Authority of the University of Benin, Nigeria for the support given in doing this research.

**References**

Amindoust A, Ahmed S, and Saghafinia A 2012 A taxonomy and review on supplier selection methods under uncertainty. *Int. J. Inform. Technol. Bus. Manag.* 7(1): 33-43.

Boran FE, Genc S, Kurt M and Akay D 2009 A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method. *Exp. Syst. Applicat.* 36: 11363-11368.

Chai J and Liu JNK 2010 A Novel Multi-criteria Group Decision Making Approach with Intuitionistic Fuzzy SIR Method. *World Automation Congress* pp. 1-6.

Chen TY, Tsao CY 2008 The interval-valued fuzzy TOPSIS method and experimental analysis. *Fuz. Set. Syst.* 159: 1410-1428.

Gerogiannis VC Fitsilis P and Kameas AD 2011 Using a combined intuitionistic fuzzy set-TOPSIS method for evaluating project and portfolio management information systems. In *Artificial Intelligence, Applications and Innovations* (pp. 67-81). Springer, Berlin, Heidelberg.

Grzegorzewski P 2004 Distances between intuitionistic fuzzy sets and/or interval-valued fuzzy sets based on the Hausdorff & metric. *Fuz. Set. Syst.* 148: 319-328.

Ho W, Xu X and Dey PK 2010 Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. *Eur. J. Operat. Res.* 202(1): 16-24.

Izadikhah M 2012 Group decision making process for supplier selection with TOPSIS method under interval-valued intuitionistic fuzzy numbers. *Advances in Fuzzy Systems* 2012: 2.

Jadidi O, Firouzi F and Bagliery E 2010 TOPSIS method for supplier selection problem. *World Acad. Sci., Engin. Technol.* 47(11): 956-958.

Joshi D, Kumar S 2014 Intuitionistic fuzzy entropy and distance measure based TOPSIS method for multi-criteria decision making. *Egypt. Inform. J.* 15: 97-104.

Fei L, Hu Y, Xiao F, Chen L and Deng Y 2016 A modified TOPSIS method based on numbers and its application in human resources selection. *Mathematical Problems in Engineering* 2016.

Li Y, Olson DL, and Qin Z 2007 Similarity measures between intuitionistic fuzzy (vague) sets: A comparative analysis. *Pattern Recognition Letters* 28: 278-285.

Omorogbe DEA 2014 *Intelligent intuitionistic fuzzy TOPSIS inference rules for supplier selection.* Ph.D. Thesis, Department of Mathematics, University of Benin, Nigeria.

Omorogbe DEA and Omosigho SE 2019 Multi-criteria decision making methods for supplier selection: A state of the arts review. *Trans. Niger. Assoc. Math. Phys.* 8: 85-92.

Omosigho SE and Omorogbe DEA 2015 Supplier selection using different metric functions. *Yugoslav. J. Operat. Res.* 25(3): 413-423.

Rouyendegh (Babek Erdebilli) BD and Saputro TE 2014 Supplier selection using integrated fuzzy TOPSIS and MCGP: A case study. *Procedia–Soc. Behav. Sci.* 116: 3957-3970.

Shahroudi K and Tonekaboni SMS 2012 Application of TOPSIS method to supplier selection in Iran auto supply chain. *J. Glob. Strateg. Managt.* 12: 123-131.

Yang Y and Chiclana F 2009 Intuitionistic fuzzy sets: spherical representation and distances. *Int. J. Intel. Syst.* 24: 399-420.