



# An Integrated Multi-Criteria Decision-Making Approach for Identification and Ranking Solar Drying Barriers under Single-Valued Triangular Neutrosophic Sets (SVTNSs)

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## Abstract

Solar dryers utilized in agriculture for the drying of food and crops are also utilized for drying operations in industrial settings. They have the potential to be shown as a very helpful tool in terms of the management of energy saving. It not only helps conserve energy, but it also helps save a lot of time, consumes less space, makes the procedure more effective, enhances the standard of the product, and safeguards the surroundings. Due to the many associated potential barriers, the acceptance of solar dryers has not yet reached a benchmark, although this was an expectation. In this body of work, a methodical framework that makes use of the MCDM tools has been proposed to identify and rank several obstacles in descending order of importance. The AHP can identify both quantitative and qualitative aspects by using comparison matrices to assign weights to them and rank them in order of importance. The AHP technique is used to calculate the weights and relationship of the solar drying barrier. To account for the lack of clarity and coherence in the data that is available in the actual world, we tested the suggested model in a neutrosophic set. We used the single-valued triangular neutrosophic sets (SVTNSs). SVTNSs are a type of neutrosophic set, integrated into triangular neutrosophic sets and SVNSs. The application of applying the SVNSs-AHP is performed.

**Keywords:** Neutrosophic Sets; Food Supply; MCDM; Solar Drying; Ranking

## 1. Introduction

According to the findings of recent research, about 15% of the population of the globe today is malnourished. The current mismatch between the number of people and the amount of food available will get much worse as the global population continues to rise. In addition to expanding the available food supply and putting a cap on population growth, one additional strategy that seems to have promise is cutting food waste across the board throughout the stages of food production, harvesting, post-harvest processing, and marketing. Minor farmers in poor nations, who produce more than 80 percent of the food, have a unique challenge when it comes to reducing the amount of food that is wasted. To preserve food and agricultural goods, the process of solar drying has been used from the beginning of time. This was accomplished in particular by sun drying in the open air under clear skies [1], [2]. Because the traditional technique of sun drying involves a comparatively slow procedure, significant losses are possible. Insect infestation, enzymatic reactions, the growth of microorganisms, and the creation of mycotoxins are all factors that contribute to a decline in the overall quality of the product. This method has several drawbacks, such as the possibility of product spoiling as a result of unfavorable weather conditions such as rain, wind, dampness, and dust; the possibility of material loss as a result of birds and animals; and the possibility of material degradation as a result of decomposition, insect infestation, and fungal development. In addition, the procedure involves a substantial amount of human labor, a significant amount

of time, and a wide area[3], [4]. As a result of advances in culture and industry, artificial drying by mechanical means became common practice. Because of the large amount of energy required and the high cost of the process, the final price of the product is higher[5]. Therefore, solar drying is the greatest substitute available as a solution to all of the problems associated with natural drying and artificial mechanical drying[6], [7].

Solar dryers employed in farming for the drying of food and crops are also utilized for drying operations in industrial settings. They have the potential to be shown as a very helpful tool in terms of the management of energy saving[8], [9]. It not only helps conserve energy, but it also helps save a lot of time, consumes less space, helps the process better, enhances the standard of the product, and safeguards the surroundings. Solar dryers get beyond some of the most significant challenges that are inherent in traditional drying methods. Solar drying may be utilized for the whole of the drying process, or it can be used as a complement to artificial drying systems; either way, the total quantity of fuel energy that is needed is reduced. But the solar drying has multiple barriers[10]–[12]. So, the idea of MCDM is used[13], [14].

The analytic hierarchy process, more often referred to by the acronym AHP, is an instance of the MCDM technique that is employed to deal with complex problems and conduct in-depth analyses of problematic scenarios. When it concerns the creation of computational and mathematical techniques for assessing which choice is superior to others, provided several specific demands, the MCDM sector performs an important part in the subject of operations research [15], [16].

The AHP is disassembled into its component pieces. For you to have a better understanding of the problem at hand, the initial thing that needs to be performed is to construct a hierarchy for it. The starting point of the AHP's hierarchy is a goal (objective), which continues with decision factors, sub-factors, and finally all of the available options[17], [18]. After the AHP hierarchy has been established, supervisors will develop pair-wise comparison matrices to fit Saaty's measure to the achieving of the specifications. After everything is said and done, the final value of every choice is determined, and then the choices are ordered in order of preference. After that, the AHP will be able to evaluate the issue by taking into account both qualitative and quantitative factors. As a consequence of this, it is one of the approaches to decision-making that takes into account several different aspects that is the most realistically useful[19], [20].

In real-world situations, the requirements for making decisions are often inaccurate, complicated, and fundamentally conflicting. Furthermore, the employing of crisp values inside a matrix of comparisons is not necessarily appropriate due to the uncertainty and the unclear facts that are available to individuals who are in charge of making judgments. The use of fuzzy set theory is expanding among academics, and this trend is expected to continue. On the other hand, the fuzzy set theory just considers the truth membership degree when making its predictions. Atanassov is associated with establishing the intuitionistic fuzzy set theory, because it takes responsibility for changing degrees of truth and falsity but does not take into consideration indeterminacy. This theory was named after him. Smarandache came up with the idea of neutrosophic sets as a potential answer to the issues that had been brought up by fuzzy and intuitionistic fuzzy sets[21], [22]. These sets properly depict ambiguous and inaccurate information because they take into consideration varying degrees of truth, indeterminacy, and falsehood all at the same time. As a direct result of this, neutrosophic sets give a representation of reality that is more faithful. Because of this, during each phase of our research, we took advantage of the AHP whenever it was positioned inside a neutrosophic environment[23], [24].

In this paper, we extended the AHP method with the single-valued triangular neutrosophic sets (SVTNSs) to show the weights and relationships between the barriers of solar drying.

The remaining parts of this work are structured as described below. In Section 2, you can find the introductory definitions as well as the preliminary information on SVTNS. In Section 3, we present our SVTN AHP method, which is a suggested approach for the MCDM. Section 5 applies the SVTNSs-AHP approach to show the weights of barriers in solar drying. The last part of the report presents the findings and conclusions of the investigation.

**2. The Single-Valued Triangular Neutrosophic Sets (SVTNSs)**

The term "neutrosophic sets" refers to a generalization of the terms "classical sets," "fuzzy sets," and "intuitionistically fuzzy sets." Smarandach was the one who originated the idea for them. Classical fuzzy sets aren't as good as these sets when it comes to reflecting ambiguity, inconsistency, and real-world difficulties. The SVTNSs can be organized as  $t = \langle (t_1, t_2, t_3); t_4, t_5, t_6 \rangle$  where  $(t_1, t_2, t_3)$  refers to the triangular neutrosophic number (TNNs) and  $t_1, t_2,$  and  $t_3$  refers to the lower, middle, and upper neutrosophic numbers. The  $t_4, t_5, t_6$  refers to the single-valued neutrosophic numbers (SVNNS) and represents the truth, indeterminacy, and falsity membership degrees[25], [26].

**Definition 1**

The two single-valued triangular neutrosophic numbers (SVTNNs)  $e = \langle (T_1, I_1, F_1); e_1, e_2, e_3 \rangle$  and  $h = \langle (T_2, I_2, F_2); h_1, h_2, h_3 \rangle$  can be added as:

$$e + h = \langle (T_1 + T_2, I_1 + I_2, F_1 + F_2); e_1 \wedge h_1, e_2 \vee h_2, e_3 \vee h_3 \rangle \tag{1}$$

The subtraction of these numbers can be determined as:

$$e - h = \langle (T_1 - T_2, I_1 - I_2, F_1 - F_2); e_1 \wedge h_1, e_2 \vee h_2, e_3 \vee h_3 \rangle \tag{2}$$

**Definition 2**

The inverse and division of SVTNNs can be computed as:

$$e^{-1} = \langle (\frac{1}{T_1}, \frac{1}{I_1}, \frac{1}{F_1}); e_1, e_2, e_3 \rangle \tag{3}$$

$$\frac{e}{h} = \begin{cases} \langle (\frac{T_1}{F_2}, \frac{I_1}{I_2}, \frac{F_1}{T_2}); e_1 \wedge h_1, e_2 \vee h_2, e_3 \wedge h_3 \rangle & \text{if } F_1 > 0, F_2 > 0 \\ \langle (\frac{F_1}{F_2}, \frac{I_1}{I_2}, \frac{T_1}{T_2}); e_1 \wedge h_1, e_2 \vee h_2, e_3 \wedge h_3 \rangle & \text{if } F_1 < 0, F_2 > 0 \\ \langle (\frac{F_1}{T_2}, \frac{I_1}{I_2}, \frac{T_1}{F_2}); e_1 \wedge h_1, e_2 \vee h_2, e_3 \wedge h_3 \rangle & \text{if } F_1 < 0, F_2 < 0 \end{cases} \tag{4}$$

**Definition 3**

In this definition, we define the equation of multiplication of two SVTNNs as:

$$e * h = \begin{cases} \langle (T_1 * T_2, I_1 * T_2, F_1 * F_2); e_1 \wedge h_1, e_2 \vee h_2, e_3 \wedge h_3 \rangle & \text{if } r_3 > 0, t_3 > 0 \\ \langle (T_1 * F_2, I_1 * T_2, F_1 * T_2); e_1 \wedge h_1, e_2 \vee h_2, e_3 \wedge h_3 \rangle & \text{if } r_3 < 0, t_3 > 0 \\ \langle (F_1 * F_2, I_1 * I_2, T_1 * T_2); e_1 \wedge h_1, e_2 \vee h_2, e_3 \wedge h_3 \rangle & \text{if } r_3 < 0, t_3 < 0 \end{cases} \tag{5}$$

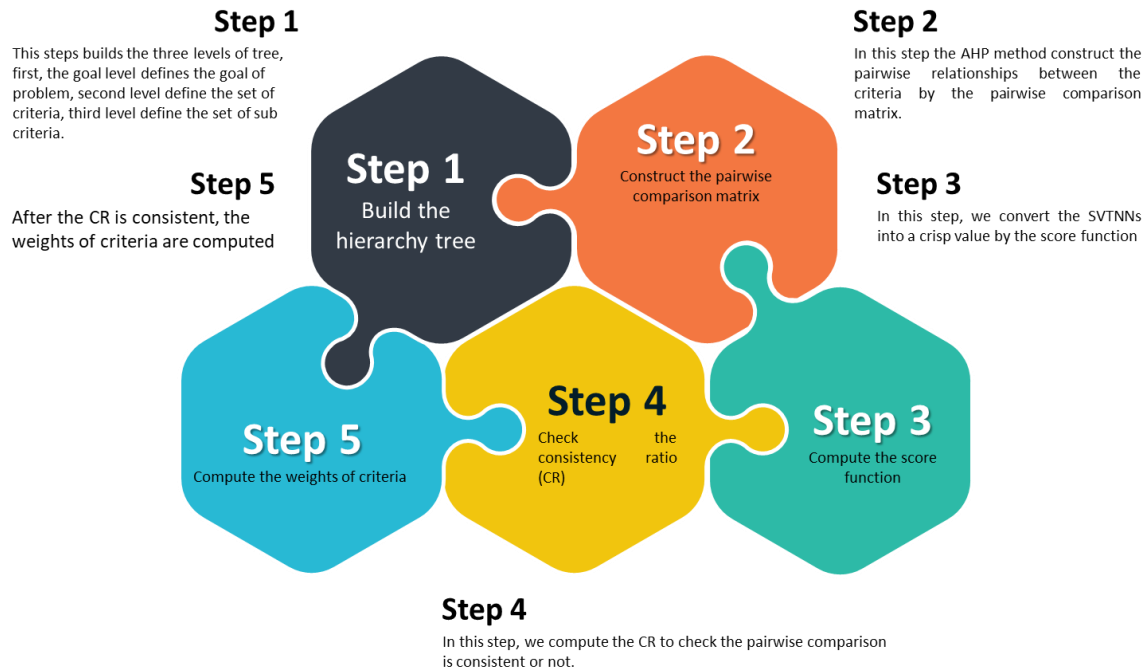


Figure 1: The steps of the neutrosophic AHP.

### 3. The SVTNNs AHP Method

The AHP is an MCDM method. The AHP computes the relationship between criteria and computes the weights of principles. Figure 1 displays the steps of the proposed model. The AHP method is defined below in the next phases:

#### Step 1: Build the hierarchy tree

This stage builds the three levels of the tree, first, the goal level defines the goal of the problem, the second level defines the set of principles, and the third level defines the set of sub-principles.

#### Step 2: Construct the pairwise comparison matrix

In this step, the AHP method constructs the pairwise relationships between the criteria by the pairwise comparison matrix. The experts and decision makers use the linguistic terms of the SVTNNs scale. Then replace these terms with the numbers of neutrosophic (SVTNNs). The pairwise comparison matrix can be built as:

$$r = \begin{pmatrix} 1 & r_{12} & r_{13} & \dots & r_{14} & r_{15} & r_{1m} \\ \frac{1}{r_{12}} & 1 & r_{23} & \dots & r_{24} & r_{25} & r_{2m} \\ \frac{1}{r_{13}} & \frac{1}{r_{23}} & 1 & \dots & r_{34} & r_{35} & r_{3m} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ r_{m1} & 1/r_{m2} & 1/r_{m3} & \dots & 1/r_{m4} & 1/r_{m5} & 1 \end{pmatrix} \tag{6}$$

#### Step 3: Compute the score function

In this step, we convert the SVTNNs into a crisp value by the score function in [[26]].

**Step 4: Check the consistency ratio (CR)**

In this step, we compute the CR to check whether the pairwise comparison is reliable or not. If the CR is less than 0.1, the pairwise is consistent if not the pairwise is not consistent.

$$CR = \frac{CI}{RI} \quad (7)$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (8)$$

Where the CI denotes the consistency index, the RI refers to the random index, and n refers to the number of criteria.

**Step 5: Compute the weights of the principles**

After the CR is consistent, the weights of the principles are computed by normalizing the pairwise comparison matrix and then normalizing the weights of the principles.

**4. The Application**

This section presented the works in the identification of the obstacles to solar drying. In the first step, we collect the principles and sub- principles from the literature works [27]–[29]. Figure 2 shows the list of criteria and sub-criteria. First, the specialists and decision-makers built the pairwise comparison matrix by the linguistic terms. Then replace these terms with the SVTNNs as shown in Table 1. Table 1 displays the SVTNNs for the main criteria. Then normalize the pairwise matrix as shown in Table 2. Then check the CR by using Eqs. (7,8). The CR is less than 0.1, so the pairwise matrix is consistent. Then calculate the weights of the principles. Figure 3 shows the weights of the main principles.



Figure 2: The list of criteria and sub-criteria.

Table 1: The pairwise comparison matrix.

	$BSOC_1$	$BSOC_2$	$BSOC_3$	$BSOC_4$	$BSOC_5$	$BSOC_6$
$BSOC_1$	1	$\langle(2, 3, 4); 0.30, 0.75, 0.70\rangle$	$\langle(9, 9, 9); 1.00, 0.00, 0.00\rangle$	$\langle(1, 2, 3); 0.40, 0.65, 0.60\rangle$	$\langle(3, 4, 5); 0.60, 0.35, 0.40\rangle$	$\langle(5, 6, 7); 0.70, 0.25, 0.30\rangle$
$BSOC_2$	$1/\langle(2, 3, 4); 0.30, 0.75, 0.70\rangle$	1	$\langle(5, 6, 7); 0.70, 0.25, 0.30\rangle$	$\langle(9, 9, 9); 1.00, 0.00, 0.00\rangle$	$\langle(2, 3, 4); 0.30, 0.75, 0.70\rangle$	$\langle(2, 3, 4); 0.30, 0.75, 0.70\rangle$
$BSOC_3$	$1/\langle(9, 9, 9); 1.00, 0.00, 0.00\rangle$	$1/\langle(5, 6, 7); 0.70, 0.25, 0.30\rangle$	1	$\langle(4, 5, 6); 0.80, 0.15, 0.20\rangle$	$\langle(1, 2, 3); 0.40, 0.65, 0.60\rangle$	$\langle(5, 6, 7); 0.70, 0.25, 0.30\rangle$

BS OC <sub>4</sub>	1/⟨(1, 2, 3);0.4 0,0.65, 0.60⟩	1/⟨(9, 9, 9);1.0 0,0.00, 0.00⟩	1/⟨(4, 5, 6);0.8 0,0.15, 0.20⟩		⟨(5, 6, 7);0.70,0 .25, 0.30⟩	⟨(7, 8, 9);0.85, 0.10, 0.15⟩
BS OC <sub>5</sub>	1/⟨(3, 4, 5);0.6 0,0.35, 0.40⟩	1/⟨(2, 3, 4);0.3 0,0.75, 0.70⟩	1/⟨(1, 2, 3);0.4 0,0.65, 0.60⟩	1/⟨(5, 6, 7);0.7 0,0.25, 0.30⟩		⟨(7, 8, 9);0.85, 0.10, 0.15⟩
BS OC <sub>6</sub>	1/⟨(5, 6, 7);0.7 0,0.25, 0.30⟩	1/⟨(2, 3, 4);0.3 0,0.75, 0.70⟩	1/⟨(5, 6, 7);0.7 0,0.25, 0.30⟩	1/⟨(7, 8, 9);0.8 5,0.10, 0.15⟩	1/⟨(7, 8, 9);0.8 5,0.10, 0.15⟩	

Table 2: The normalization pairwise comparison matrix.

	<i>BSOC<sub>1</sub></i>	<i>BSOC<sub>2</sub></i>	<i>BSOC<sub>3</sub></i>	<i>BSOC<sub>4</sub></i>	<i>BSOC<sub>5</sub></i>	<i>BSOC<sub>6</sub></i>
<i>BSOC<sub>1</sub></i>	0.134044	0.062333	0.401284	0.04417	0.22501	0.169848
<i>BSOC<sub>2</sub></i>	0.315398	0.146666	0.191725	0.51856	0.077558	0.033575
<i>BSOC<sub>3</sub></i>	0.029788	0.068217	0.089174	0.235196	0.069948	0.169848
<i>BSOC<sub>4</sub></i>	0.349711	0.032592	0.043691	0.115236	0.392353	0.273866
<i>BSOC<sub>5</sub></i>	0.108714	0.345096	0.232649	0.053598	0.18249	0.273866
<i>BSOC<sub>6</sub></i>	0.062346	0.345096	0.041476	0.033241	0.052641	0.078999

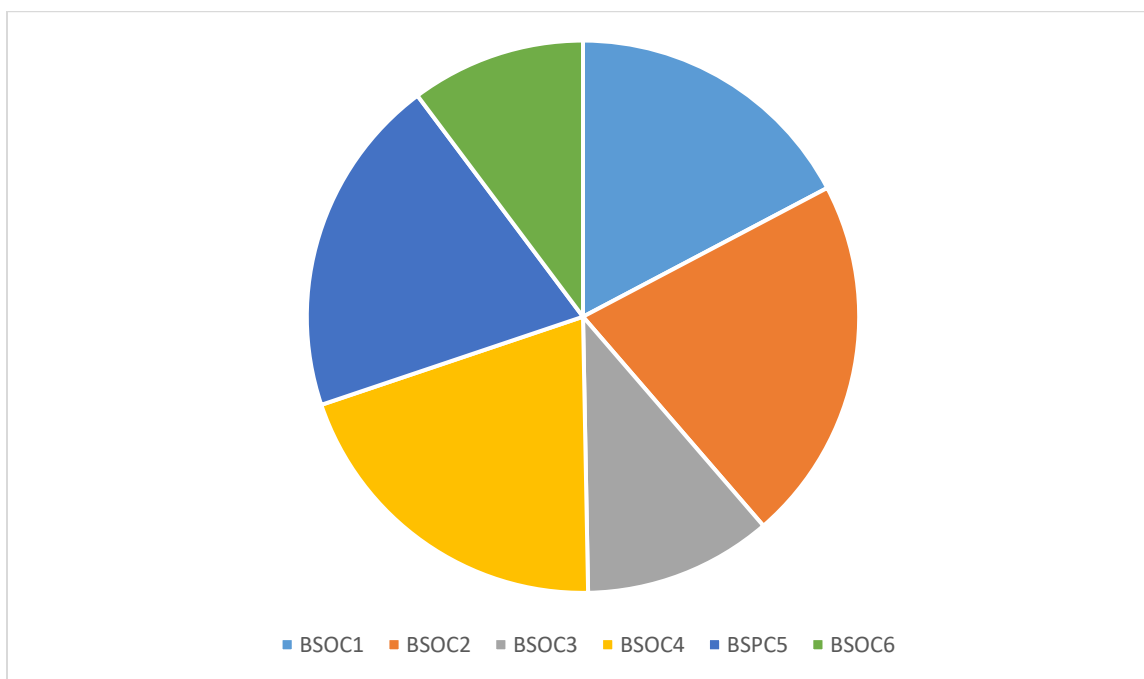


Figure 3: The weights of the main principles.

Then apply the previous steps to all sub-criteria. The first sub-criteria has four elements. Then build the pairwise comparison matrix and normalize the pairwise comparison matrix in Table 3. Then calculate the weights of the principles in Figure 4.

Table 3: The normalization pairwise comparison matrix for the first sub-criteria.

	<i>BSOC<sub>1,1</sub></i>	<i>BSOC<sub>2</sub></i>	<i>BSOC<sub>1,3</sub></i>	<i>BSOC<sub>1,4</sub></i>
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BSOC <sub>1,1</sub>	0.523681	0.521551	0.563972	0.378521
BSOC <sub>1,2</sub>	0.116373	0.1159	0.252409	0.066901
BSOC <sub>1,3</sub>	0.116373	0.057547	0.125327	0.378521
BSOC <sub>1,4</sub>	0.243572	0.305001	0.058292	0.176056

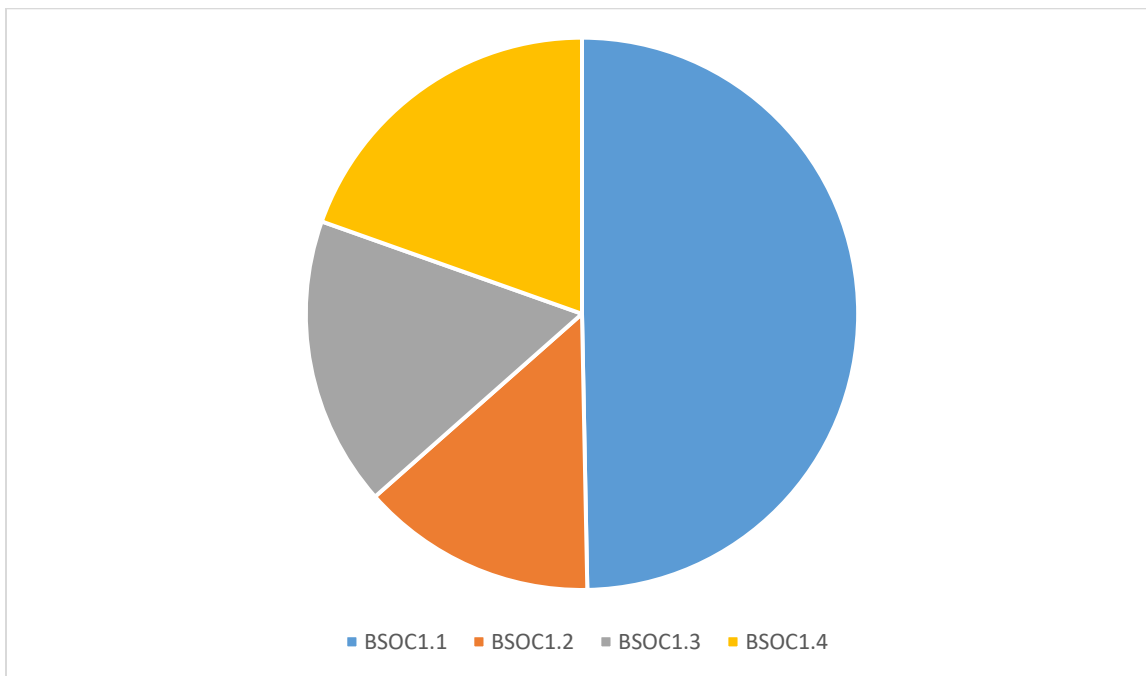


Figure 4: The weights of the first sub- principles.

The second sub-principle has four elements. Then build the pairwise comparison matrix and normalize the pairwise comparison matrix in Table 4. Then compute the weights of the principles in Figure 5.

Table 4: The normalization pairwise comparison matrix for the second sub-principle.

	BSOC <sub>2,1</sub>	BSOC <sub>2,2</sub>	BSOC <sub>2,3</sub>	BSOC <sub>2,4</sub>
BSOC <sub>2,1</sub>	0.215325	0.252201	0.463296	0.126156
BSOC <sub>2,2</sub>	0.175061	0.205042	0.350046	0.139881
BSOC <sub>2,3</sub>	0.04785	0.060306	0.102955	0.404832
BSOC <sub>2,4</sub>	0.561765	0.482451	0.083703	0.329131

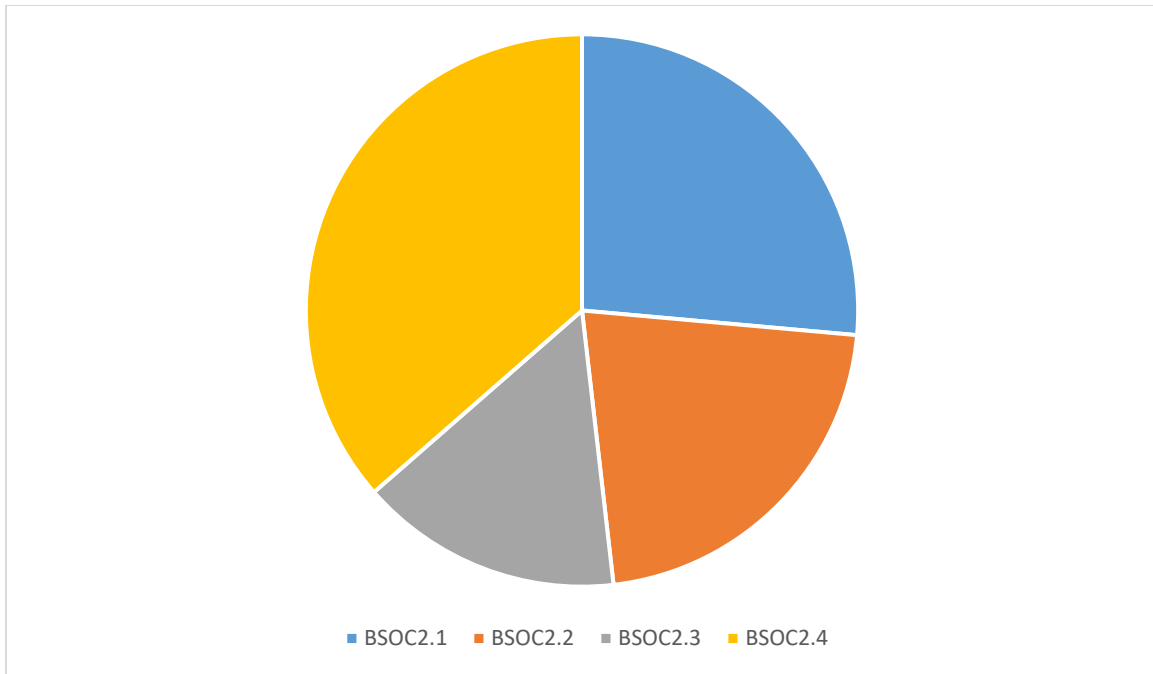


Figure 5: The weights of the second sub-principle.

The third sub-principle has three elements. Then build the pairwise comparison matrix and normalize the pairwise comparison matrix in Table 5. Then compute the weights of the principles in Figure 6.

Table 5: The normalization pairwise comparison matrix for the third sub-criteria.

	BSOC <sub>3.1</sub>	BSOC <sub>3.2</sub>	BSOC <sub>3.3</sub>
BSOC <sub>3.1</sub>	0.279707	0.224854	0.588235
BSOC <sub>3.2</sub>	0.658135	0.529068	0.281046
BSOC <sub>3.3</sub>	0.062157	0.246078	0.130719

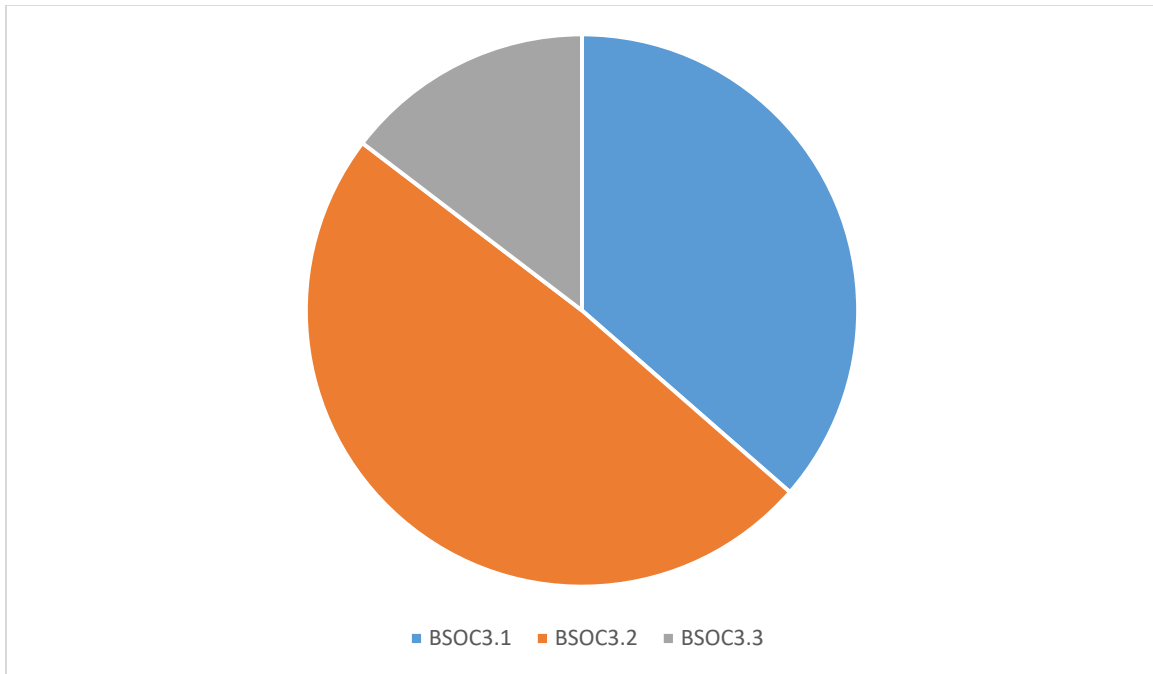


Figure 6: The weights of the third sub-principle.

The fourth sub-principle has three elements. Then build the pairwise comparison matrix and normalize the pairwise comparison matrix in Table 6. Then compute the weights of the principles in Figure 7.

Table 6: The normalization pairwise comparison matrix for the fourth criterion.

	BSOC <sub>4.1</sub>	BSOC <sub>4.2</sub>	BSOC <sub>4.3</sub>
BSOC <sub>4.1</sub>	0.491823	0.268865	0.759494
BSOC <sub>4.2</sub>	0.398883	0.218058	0.07173
BSOC <sub>4.3</sub>	0.109294	0.513077	0.168776

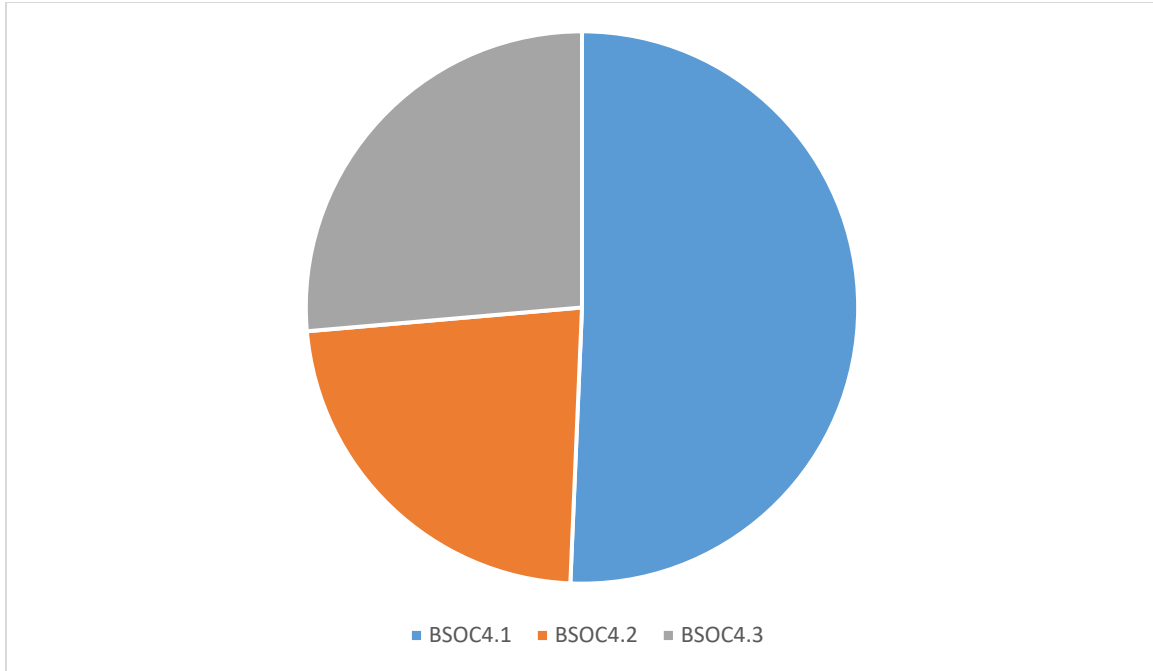


Figure 7: The weights of the fourth sub-principle.

The fifth sub-principle has four elements. Then build the pairwise comparison matrix and normalize the pairwise comparison matrix in Table 7. Then compute the weights of the principles in Figure 8.

Table 7: The normalization pairwise comparison matrix for the fifth and fourth principles.

	BSOC <sub>5,1</sub>	BSOC <sub>5,2</sub>	BSOC <sub>5,3</sub>	BSOC <sub>5,4</sub>
BSOC <sub>5,1</sub>	0.242709	0.663581	0.53185	0.063081
BSOC <sub>5,2</sub>	0.070147	0.191786	0.254106	0.569425
BSOC <sub>5,3</sub>	0.053935	0.089203	0.118189	0.20292
BSOC <sub>5,4</sub>	0.633209	0.05543	0.095855	0.164574

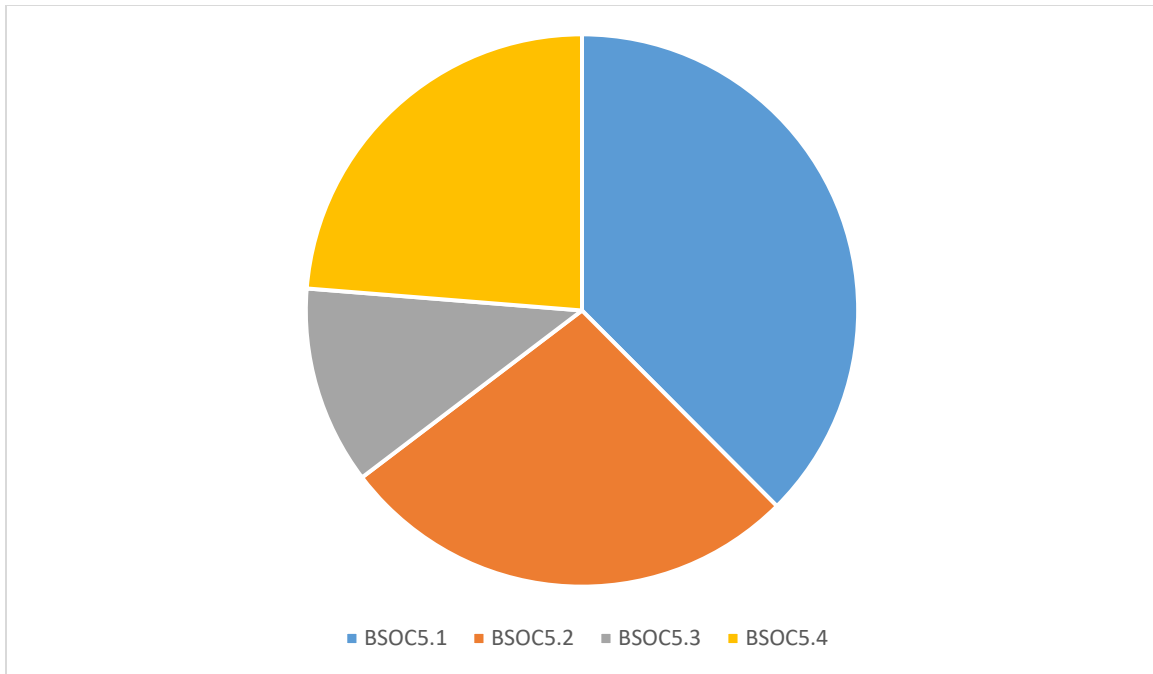


Figure 8: The weights of the fifth sub-principle.

The sixth sub-principle has four elements. Then build the pairwise comparison matrix and normalize the pairwise comparison matrix in Table 8. Then compute the weights of the principles in Figure 9.

Table 8: The normalization pairwise comparison matrix for the sixth fourth criterion.

	BSOC <sub>6.1</sub>	BSOC <sub>6.2</sub>	BSOC <sub>6.3</sub>	BSOC <sub>6.4</sub>
BSOC <sub>6.1</sub>	0.256896	0.616241	0.564797	0.064501
BSOC <sub>6.2</sub>	0.081554	0.195632	0.269848	0.305661
BSOC <sub>6.3</sub>	0.057088	0.090992	0.125511	0.47807
BSOC <sub>6.4</sub>	0.604462	0.097136	0.039845	0.151768

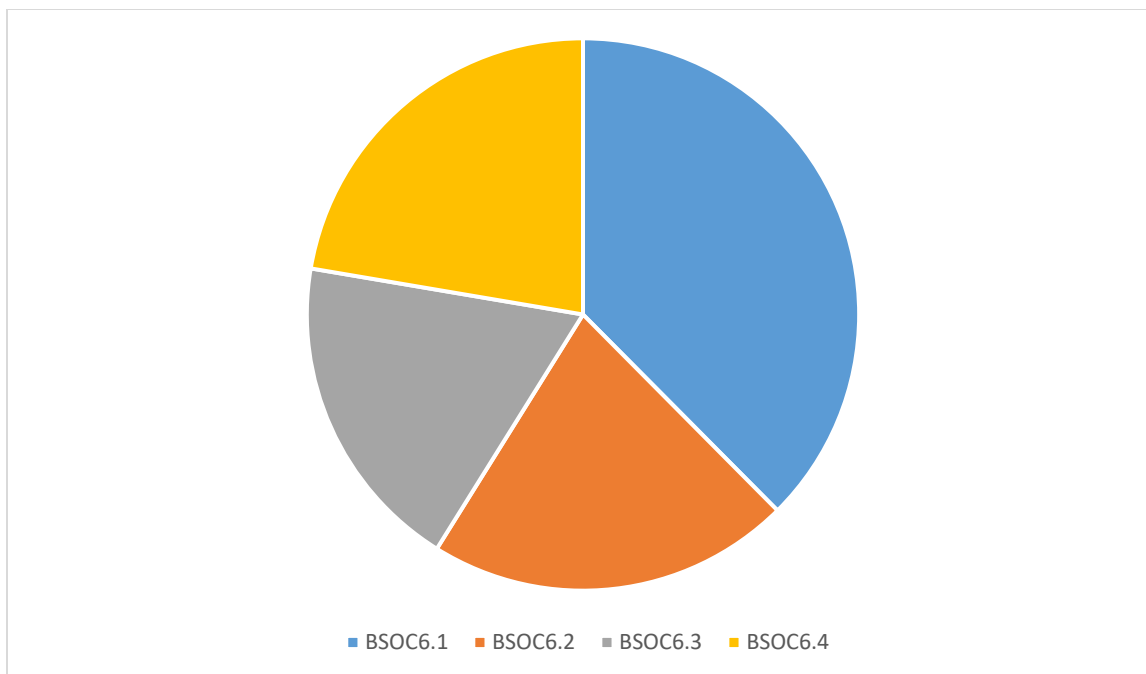


Figure 9: The weights of the sixth sub-principle.

## 5. Conclusions

The current study exhibits the use of the AHP system to identify and prioritize several possible obstacles to the deployment of solar drying. This work makes a contribution to the existing body of knowledge in the following ways: (A) This is the first time that neutrosophic sets have been linked with AHP and used to the identification and rank the barriers of solar drying. (B) The second contribution that the research has made is in proposing a new integrated risk assessment approach to rank the risks of solar drying. The use of the SVTNSs-AHP, which is an essential multi-criteria technique using neutrosophic sets, is a fundamental component of the risk assessment process. By carrying out these steps, an enhanced strategy that combines linguistic words and neutrosophic sets has been put into effect. During the procedure of subjective judgment, this integration was able to effectively handle the ambiguity and inconsistency of the perceptions held by the expert teams. (C) Integration of the triangular neutrosophic sets and single-valued neutrosophic sets to give more effectiveness in the ranking process. (D) The technique that was used provides a clear knowledge of the relationships among the identified obstacles that were grouped as cause and effect. Nevertheless, the results got are restricted to the subjectivity of several professionals who took part in the conversations and conversations in groups; as a result, the results should not be taken too seriously.

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