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# A Comparative Study of Similarity Measures: Socio-Economic Decision Making in India using Neutrosophic Binary Sets

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**ABSTRACT.** This paper focuses on the unemployment crisis across the southern states of India using neutrosophic binary sets and various similarity measures. The Euclidean and Hamming distance measures for neutrosophic binary sets is validated. Moreover, The cosine similarity measures and correlation coefficient based similarity measure are formulated for neutrosophic binary sets to forecast the decision making process. Finally, a comparitive analysis is made between these measures using the unemployment data and enhance the measure which provide the highest accuracy in forecasting state with low unemployment rates to high unemployment rates.

**Keywords:** Neutrosophic set, Binary set, Neutrosophic binary set, similarity measure based on distance, real life application.

## 1. Introduction

The neutrosophic set was introduced by smarandache in which the set consists of the truth, indeterminancy and false membership functions. These neutrosophic sets have been applied in various fields like medical diagnosis [3, 4], image processing [15–17], decision making problems [5–8] and so on [9–13]. It is seen that the similarity measure plays a vital role in the application of all research fields. Wang et al. [1] introduced the concept of single valued neutrosophic set (SVNS) that is the subclass of a neutrosophic set. SVNS can be applied in real scientific and engineering fields. It offers us additional possibility to represent uncertainty information that manifest the real world. Wang et al. [2] further studied interval neutrosophic sets (IVNSs) in which the truth-membership, indeterminacy-membership, and false-membership were extended to interval numbers. Similarity measures for neutrosophic sets and single valued neutrosophic sets have been addressed in [5, 18–22, 26, 27]. Ye [5] in 2013 defined the similarity measure of SVNSs based on distance and applied it to the decision making problems. Ye [7] also defined three vector similarity measure for Single valued neutrosophiv sets (SVNS) and interval valued neutrosophic set (IVNS) with simplified neutrosophic information. Recently, Jun [28] proposed similarity measures based on Hamming distance and Euclidean distance on interval valued neutrosophic set(IVNS) and applied in decision making problems. The real life cannot be contained in a single universal set. It may contains one or many. The set which contains two universal sets are named as binary sets. Similarly, neutrosophic binary set consists of two universal sets and each universal set has its own truth, indeterminancy and false membership values. The neutrosophic binary topological space was introduced by S.S.Surekha, J.Elekiah and G.Sindhu [22] in 2022. In this article, the similarity measures of neutrosophic binary sets have been introduced and is applied in the statistical data of the unemployed people over southern states of India to determine the southern state which is facing the highest unemployment crisis.

## 2. Preliminaries

**Definition 2.1.** [22] A Neutrosophic binary topology from X to Y is a binary structure $\mathscr{M}_{\mathcal{N}} \subseteq P(X) \times P(Y)$ that satisfies the following conditions:

(1) $(0_X, 0_Y) \in \mathscr{M}_{\mathcal{N}}$ and $1_X, 1_Y \in \mathscr{M}_{\mathcal{N}}$.
(2) $(A_1 \cap A_2, B_1 \cap B_2) \in \mathscr{M}_{\mathcal{N}}$ whenever $(A_1, B_1) \in \mathscr{M}_{\mathcal{N}}$ and $(A_2, B_2) \in \mathscr{M}_{\mathcal{N}}$.
(3) If $(A_\alpha, B_\alpha)_{\alpha \in A}$ is a family of members of $\mathscr{M}_{\mathcal{N}}$, then $(\cup_{\alpha \in A} A_\alpha, \cup_{\alpha \in A} B_\alpha) \in \mathscr{M}_{\mathcal{N}}$.

The triplet $(\mathcal{X}, \mathcal{Y}, \mathscr{M}_{\mathcal{N}})$ is called Neutrosophic Binary Topological space. The members of $\mathscr{M}_{\mathcal{N}}$ are called the neutrosophic binary open sets and the complement of neutrosophic binary open sets are called the neutrosophic binary closed sets in the binary topological space $(\mathcal{X}, \mathcal{Y}, \mathscr{M}_{\mathcal{N}})$.

**Definition 2.2.** [22] $(0_X, 0_Y)$ can be defined as
$(0_1)$ $0_X = \{< x, 0, 0, 1 >: x \in X\}, 0_Y = \{< y, 0, 0, 1 >: y \in Y\}$
$(0_2)$ $0_X = \{< x, 0, 1, 1 >: x \in X\}, 0_Y = \{< y, 0, 1, 1 >: y \in Y\}$
$(0_3)$ $0_X = \{< x, 0, 1, 0 >: x \in X\}, 0_Y = \{< y, 0, 1, 0 >: y \in Y\}$
$(0_4)$ $0_X = \{< x, 0, 0, 1 >: x \in X\}, 0_Y = \{< y, 0, 0, 0 >: y \in Y\}$

$(1_X, 1_Y)$ can be defined as
$(1_1)$ $1_X = \{< x, 1, 0, 0 >: x \in X\}, 1_Y = \{< y, 1, 0, 0 >: y \in Y\}$
$(1_2)$ $1_X = \{< x, 1, 0, 1 >: x \in X\}, 1_Y = \{< y, 1, 0, 1 >: y \in Y\}$
$(1_3)$ $1_X = \{< x, 1, 1, 0 >: x \in X\}, 1_Y = \{< y, 1, 1, 0 >: y \in Y\}$
$(1_4)$ $1_X = \{< x, 1, 1, 1 >: x \in X\}, 1_Y = \{< y, 1, 1, 1 >: y \in Y\}$

**Definition 2.3.** [22] Let $(A,B)=\{<\mu_A,\sigma_A,\gamma_A>,<\mu_B,\sigma_B,\gamma_B>\}$ be a neutrosophic binary set on $(\mathcal{X},\mathcal{Y},\mathscr{M}_{\mathcal{N}})$, then the complement of the set $C(A,B)$ may be defined as

$$(C_1)\quad C(A,B)=\{x,<1-\mu_A(x),\sigma_A(x),1-\gamma_A(x)>: x\in X,$$
$$<y,1-\mu_B(y),\sigma_B(y),1-\gamma_B(y)>: y\in Y\}$$
$$(C_2)\quad C(A,B)=\{x,<\gamma_A(x),\sigma_A(x),\mu_A(x)>: x\in X,$$
$$<y,\gamma_B(y),\sigma_B(y),\mu_B(y)>: y\in Y\}$$
$$(C_3)\quad C(A,B)=\{x,<\gamma_A(x),1-\sigma_A(x),\mu_A(x)>: x\in X,$$
$$<y,\gamma_B(y),1-\sigma_B(y),\mu_B(y)>: y\in Y\}$$

**Definition 2.4.** [22] Let $(A,B)$ and $(C,D)$ be two neutrosophic binary sets which is in the form
$(A,B)=\{<\mu_A,\sigma_A,\gamma_A>,<\mu_B,\sigma_B,\gamma_B>\}$ and
$(C,D)=\{<\mu_C,\sigma_C,\gamma_C>,<\mu_D,\sigma_D,\gamma_D>\}$.
Then $(A,B)\subseteq(C,D)$ can be defined as

(1) $(A,B)\subseteq(C,D) \iff \mu_A(x)\le\mu_C(x),\sigma_A(x)\le\sigma_C(x),\gamma_A(x)\ge\gamma_C(x)\forall x\in X$
$\mu_B(X)\le\mu_D(x),\sigma_B(x)\le\sigma_D(x),\gamma_B(x)\ge\gamma_D(x)\forall y\in Y$

(2) $(A,B)\subseteq(C,D) \iff \mu_A(X)\le\mu_C(x),\sigma_A(x)\ge\sigma_C(x),\gamma_A(x)\ge\gamma_C(x)\forall x\in X$
$\mu_B(X)\le\mu_D(x),\sigma_B(x)\ge\sigma_D(x),\gamma_B(x)\ge\gamma_D(x)\forall y\in Y$

**Definition 2.5.** [22] Let $(A,B)$ and $(C,D)$ be two neutrosophic binary sets which is in the form
$(A,B)=\{<\mu_A,\sigma_A,\gamma_A>,<\mu_B,\sigma_B,\gamma_B>\}$ and
$(C,D)=\{<\mu_C,\sigma_C,\gamma_C>,<\mu_D,\sigma_D,\gamma_D>\}$.
(1) $(A,B)\cap(C,D)$ can be defined as

$$(A,B)\cap(C,D)=\{<x,\mu_A(x)\wedge\mu_C(x),\sigma_A(x)\wedge\sigma_C(x),\gamma_A(x)\vee\gamma_A(x)>$$
$$<x,\mu_A(x)\wedge\mu_C(x),\sigma_A(x)\wedge\sigma_C(x),\gamma_A(x)\vee\gamma_A(x)>\}$$

$$(A,B)\cap(C,D)=\{<x,\mu_A(x)\wedge\mu_C(x),\sigma_A(x)\vee\sigma_C(x),\gamma_A(x)\vee\gamma_A(x)>$$
$$<x,\mu_A(x)\wedge\mu_C(x),\sigma_A(x)\vee\sigma_C(x),\gamma_A(x)\vee\gamma_A(x)>\}$$

(2) $(A,B)\cup(C,D)$ can be defined as

$$(A,B)\cup(C,D)=\{<x,\mu_A(x)\vee\mu_C(x),\sigma_A(x)\vee\sigma_C(x),\gamma_A(x)\wedge\gamma_A(x)>$$
$$<x,\mu_A(x)\vee\mu_C(x),\sigma_A(x)\vee\sigma_C(x),\gamma_A(x)\wedge\gamma_A(x)>\}$$

$$(A,B)\cap(C,D)=\{<x,\mu_A(x)\vee\mu_C(x),\sigma_A(x)\wedge\sigma_C(x),\gamma_A(x)\wedge\gamma_A(x)>$$
$$<x,\mu_A(x)\vee\mu_C(x),\sigma_A(x)\wedge\sigma_C(x),\gamma_A(x)\wedge\gamma_A(x)>\}$$

**Definition 2.6.** [5] Let X be a space of points (objects) with generic elements in X denoted by x. A SVNS P in X is characterized by a truth-membership function, an indeterminacy-membership function, and a falsity membership function. The Euclidean distance between them is described by

$$d^E(A,B) = \sqrt{\frac{1}{6}\left[\sum_{j=1}^{n}(|T_A(x_j) - T_B(x_j)|^2 + |I_A(x_j) - I_B(x_j)|^2 + |F_A(x_j) - F_B(x_j)|^2)\right]}$$

**Definition 2.7.** [19] Let X be a space of points (objects) with generic elements in X denoted by x. A SVNS P in X is characterized by a truth-membership function, an indeterminacy-membership function, and a falsity membership function. The Hamming distance between them is described by

$$d^H(A,B) = \sqrt{\frac{1}{6}\left[\sum_{j=1}^{n}(|T_A(x_j) - T_B(x_j)| + |I_A(x_j) - I_B(x_j)| + |F_A(x_j) - F_B(x_j)|)\right]}$$

**Definition 2.8.** Let $(A, B)$ and $(C, D)$ be two neutrosophic binary sets defined on universal sets $U$ and $V$, respectively. The **Cosine Similarity Measure** between $(A, B)$ and $(C, D)$ is defined as:

$$\text{CosSim}((A,B),(C,D)) = \frac{\sum_{i=1}^{n}(\mu_A(x_i)\mu_C(x_i) + \sigma_A(x_i)\sigma_C(x_i) + \gamma_A(x_i)\gamma_C(x_i))}{\sqrt{\sum_{i=1}^{n}\left(\mu_A^2(x_i) + \sigma_A^2(x_i) + \gamma_A^2(x_i)\right)}}$$

$$\times \frac{1}{\sqrt{\sum_{i=1}^{n}\left(\mu_C^2(x_i) + \sigma_C^2(x_i) + \gamma_C^2(x_i)\right)}}.$$

**Definition 2.9.** Let $(A, B)$ and $(C, D)$ be two neutrosophic binary sets defined over universal sets $U$ and $V$, respectively. Flatten the truth, indeterminacy, and falsity components into vectors $u_k$ and $v_k$, respectively. The **Correlation Coefficient Similarity Measure** between $(A, B)$ and $(C, D)$ is defined as:

$$\text{CorrSim}((A,B),(C,D)) = \frac{\sum_{k=1}^{n+m}(u_k - \bar{u})(v_k - \bar{v})}{\sqrt{\sum_{k=1}^{n+m}(u_k - \bar{u})^2} \cdot \sqrt{\sum_{k=1}^{n+m}(v_k - \bar{v})^2}},$$

where $\bar{u}$ and $\bar{v}$ are the arithmetic means of the vectors $u_k$ and $v_k$, respectively.

## 3. Distance measures on Neutrosophic Binary sets

**Euclidean distance between Neutrosophic Binary Sets:**

Let $\mathcal{S}_{\mathcal{U}} = \{u_1, u_2, ..., u_n\}$ and $\mathcal{S}_{\mathcal{V}} = \{v_1, v_2, ..., v_n\}$ be the universal sets. Let $\mathcal{N}_{U_{B_1}}$ and $\mathcal{N}_{V_{B_2}}$ be the two neutrosophic binary sets. The Euclidean distance between them is described by

$$d^{ED}_{N_B}(\mathcal{N}_{U_{B_1}}, \mathcal{N}_{V_{B_2}}) =$$

$$\sqrt{\frac{1}{6}[\sum_{j=1}^{n} |\mu_{\mathcal{N}_{U_{B_1}}}(x^\star_j) - \mu_{\mathcal{N}_{V_{B_2}}}(x^\star_j)|^2 + |\sigma_{\mathcal{N}_{U_{B_1}}}(x^\star_j) - \sigma_{\mathcal{N}_{V_{B_2}}}(x^\star_j)|^2 + |\gamma_{\mathcal{N}_{U_{B_1}}}(x^\star_j) - \gamma_{\mathcal{N}_{V_{B_2}}}(x^\star_j)|^2]} +$$
$$\sqrt{\frac{1}{6}[\sum_{k=1}^{n} |\mu_{\mathcal{N}_{U_{B_1}}}(y^\star_k) - \mu_{\mathcal{N}_{V_{B_2}}}(y^\star_k)|^2 + |\sigma_{\mathcal{N}_{U_{B_1}}}(y^\star_k) - \sigma_{\mathcal{N}_{V_{B_2}}}(y^\star_k)|^2 + |\gamma_{\mathcal{N}_{U_{B_1}}}(y^\star_k) - \gamma_{\mathcal{N}_{V_{B_2}}}(y^\star_k)|^2]}$$

**Hamming distance between Neutrosophic Binary Sets:**

Let $\mathcal{S}_{\mathcal{U}} = \{u_1, u_2, ..., u_n\}$ and $\mathcal{S}_{\mathcal{V}} = \{v_1, v_2, ..., v_n\}$ be the universal sets. Let $\mathcal{N}_{U_{B_1}}$ and $\mathcal{N}_{V_{B_2}}$ be the two neutrosophic binary sets. The Hamming distance between them is described by

$$d^{HD}_{N_B}(\mathcal{N}_{U_{B_1}}, \mathcal{N}_{V_{B_2}}) =$$

$$\sqrt{\frac{1}{6}[\sum_{j=1}^{n} |\mu_{\mathcal{N}_{U_{B_1}}}(x^\star_j) - \mu_{\mathcal{N}_{V_{B_2}}}(x^\star_j)| + |\sigma_{\mathcal{N}_{U_{B_1}}}(x^\star_j) - \sigma_{\mathcal{N}_{V_{B_2}}}(x^\star_j)| + |\gamma_{\mathcal{N}_{U_{B_1}}}(x^\star_j) - \gamma_{\mathcal{N}_{V_{B_2}}}(x^\star_j)|]} +$$
$$\sqrt{\frac{1}{6}[\sum_{k=1}^{n} |\mu_{\mathcal{N}_{U_{B_1}}}(y^\star_k) - \mu_{\mathcal{N}_{V_{B_2}}}(y^\star_k)| + |\sigma_{\mathcal{N}_{U_{B_1}}}(y^\star_k) - \sigma_{\mathcal{N}_{V_{B_2}}}(y^\star_k)| + |\gamma_{\mathcal{N}_{U_{B_1}}}(y^\star_k) - \gamma_{\mathcal{N}_{V_{B_2}}}(y^\star_k)|]}$$

**Definition 3.1.** Let $\mathcal{S}_{\mathcal{U}} = \{u_1, u_2, ..., u_n\}$ and $\mathcal{S}_{\mathcal{V}} = \{v_1, v_2, ..., v_n\}$ be the universal sets. Let $(S, T)$ and $(U, V)$ be the two neutrosophic binary sets. The Cosine Similarity Measure between them is described by

$$\text{CosSim}((S,T),(U,V)) = \frac{\sum_{i=1}^{n} (\mu_S(x_i)\mu_U(x_i) + \sigma_S(x_i)\sigma_U(x_i) + \gamma_S(x_i)\gamma_U(x_i))}{\sqrt{\sum_{i=1}^{n} \left(\mu_S^2(x_i) + \sigma_S^2(x_i) + \gamma_S^2(x_i)\right) + \sum_{j=1}^{m} \left(\mu_T^2(y_j) + \sigma_T^2(y_j) + \gamma_T^2(y_j)\right)}} +$$
$$\frac{\sum_{j=1}^{m} (\mu_T(y_j)\mu_V(y_j) + \sigma_T(y_j)\sigma_V(y_j) + \gamma_T(y_j)\gamma_V(y_j))}{\sqrt{\sum_{i=1}^{n} \left(\mu_U^2(x_i) + \sigma_U^2(x_i) + \gamma_U^2(x_i)\right) + \sum_{j=1}^{m} \left(\mu_V^2(y_j) + \sigma_V^2(y_j) + \gamma_V^2(y_j)\right)}}.$$

**Theorem 3.2.** *The defined Cosine Similarity Measure CosSim$((S,T),(U,V))$ between two neutrosophic binary sets satisfies the following properties:*

*(1)* $0 \leq \textit{CosSim}((S,T),(U,V)) \leq 1$

*(2)* $\textit{CosSim}((S,T),(U,V)) = 1 \iff (S,T) = (U,V)$

*(3)* $\textit{CosSim}((S,T),(U,V)) = \textit{CosSim}((U,V),(S,T))$

*Proof.* Let $(S, T)$ and $(U, V)$ be two neutrosophic binary sets.

(i) The proof is obvious.

**(ii)** CosSim $= 1$ if and only if the angle between $u$ and $v$ is 0

$u = v$ implies:

$$\mu_S(x_i) = \mu_U(x_i), \quad \sigma_S(x_i) = \sigma_U(x_i), \quad \gamma_S(x_i) = \gamma_U(x_i),$$

$$\mu_T(y_j) = \mu_V(y_j), \quad \sigma_T(y_j) = \sigma_V(y_j), \quad \gamma_T(y_j) = \gamma_V(y_j).$$

Therefore, CosSim $= 1 \iff (S, T) = (U, V)$.

**(iii)** CosSim$((S, T), (U, V))$ = CosSim$((U, V), (S, T))$ because the dot product is commutative.

Hence, the cosine similarity satisfies the axioms of similarity. □

**Definition 3.3.** Let $(S, T)$ and $(U, V)$ be two neutrosophic binary sets defined on universal sets $P$ and $Q$, respectively. $\mu$, $\sigma$ and $\gamma$ from $(S, T)$ and $(U, V)$ are converted into vectors $u_k$ and $v_k$, respectively. The **Correlation Coefficient Similarity Measure** between $(S, T)$ and $(U, V)$ is given by:

$$\text{CorrSim}((S, T), (U, V)) = \frac{\sum_{k=1}^{n+m} (u_k - \bar{u})(v_k - \bar{v})}{\sqrt{\sum_{k=1}^{n+m} (u_k - \bar{u})^2} \cdot \sqrt{\sum_{k=1}^{n+m} (v_k - \bar{v})^2}}, \tag{1}$$

where $\bar{u}$ and $\bar{v}$ are the arithmetic means of the vectors $u_k$ and $v_k$, respectively.

**Theorem 3.4.** *The defined Correlation Coefficient Similarity Measure CorrSim$((S, T), (U, V))$ between two neutrosophic binary sets satisfies the following properties:*

*(1)* $-1 \leq$ *CorrSim*$((S, T), (U, V)) \leq 1$

*(2) CorrSim*$((S, T), (U, V)) = 1 \iff (S, T)$ *and* $(U, V)$ *are perfectly positively correlated*

*(3) CorrSim*$((S, T), (U, V))$ = *CorrSim*$((U, V), (S, T))$

*Proof.* The proof follows from the definition 3.3 □

## 4. Live Coverage application of Neutrosophic Binary Set

Let $\mathcal{S}_{\mathcal{U}}$ represents the universal set over the year 2020 and $\mathcal{S}_{\mathcal{V}}$ represents the universal set over the year 2021. Let $\mathcal{N}_{S_{B_1}}$, $\mathcal{N}_{S_{B_2}}$, $\mathcal{N}_{S_{B_3}}$, $\mathcal{N}_{S_{B_4}}$ and $\mathcal{N}_{S_{B_5}}$ be the southern states via neutrosophic Binary sets.

### 4.1. *Methodology*

**Step 1**: The unemployed datum of educated and uneducated people over the southern states of India for the year 2020 and 2021 are taken from the Centre for Monitoring Indian Economy Pvt. Ltd (CPIM).
**Step 2**: The linguistic values are allocated for the collected datum and converted it into neutrosophic numbers. The defined neutrosophic numbers will be written in the form of neutrosophic binary set.

| Range | Neutrosophic Binary set | Unemployed people |
|---|---|---|
| $1-10$ | $0.01-0.10$ | Extremelly low |
| $11-20$ | $0.11-0.20$ | Very low |
| $21-30$ | $0.21-0.30$ | Very low |
| $31-40$ | $0.31-0.40$ | low |
| $41-50$ | $0.41-0.50$ | Satisfactory |
| $51-60$ | $0.51-0.60$ | Average |
| $61-70$ | $0.61-0.70$ | High |
| $71-80$ | $0.71-0.80$ | Very high |
| $81-90$ | $0.81-0.90$ | Very High |
| $91-100$ | $0.91->1$ | Extremely high |

**Step 3**: The unemployed people are aggregated into five stages.
**Step 4**: The neutrosophic binary weighted average operator is used to get the information from those five stages.

**Definition 4.1.** Let $(P_A, P_B)$ be the collection of neutrosophic binary values, then

$$D^{NB}_{WA}(P_A, P_B) =$$

$$([1-\Pi_{i=1}^{n}(1-\mu_{P_A}(x_i^\star))_i^w], [1-\Pi_{i=1}^{n}(1-\gamma_{P_A}(x_i^\star))_i^w]),$$
$$([1-\Pi_{j=1}^{n}(1-\mu_{P_B}(y_j^\star))_i^w], [1-\Pi_{j=1}^{n}(1-\gamma_{P_B}(y_j^\star))_i^w])$$

where $w=(w_1, w_2, ..., w_n)^T$ are the weighted vectors of $(P_A, P_B)$. Also, $w_i > 0$ and $\sum_{i=1}^{n} w_i = 1$.

**Step 5**: Apply the proposed neutrosophic binary euclidean distance, neutrosophic binary hamming distance, neutrosophic bianry cosine similarity measure and neutrosophic binary correlation similarity measure to the neutosophic binary sets. The obtained result suggests the southern state which has the highest unemployment rate.

### 4.2. *Example: Real World Problem on Neutrosophic Binary Sets*

Consider two universal sets $\mathcal{S}_{\mathcal{U}} = \{u_1, u_2, ..., u_n\}$ and $\mathcal{S}_{\mathcal{V}} = \{v_1, v_2, ..., v_n\}$. This universal sets represent the year 2020 and 2021.

Consider the neutrosophic binary sets $\mathcal{N}_{S_{B_1}}, \mathcal{N}_{S_{B_2}}, \mathcal{N}_{S_{B_3}}, \mathcal{N}_{S_{B_4}}$ and $\mathcal{N}_{S_{B_5}}$ which indicates the southern states: Andhra Pradhesh, Karnataka, Kerala, Tamilnadu and Telangana.

The below table gives the information collected from Centre for monitoring economy (CPIM) pvt. ltd. with the simplified neutrosophic information.

| 2020 | No education | Upto 5th std | 6th - 9th | 10th - 12th | Graduated |
| --- | --- | --- | --- | --- | --- |
| $AP$ | $< 0.11, 0.89, 0.89 >$ | $< 0.41, 0.59, 0.59 >$ | $< 0, 0, 0 >$ | $< 0.03, 0.97, 0.97 >$ | $< 0.33, 0.67, 0.67 >$ |
| $KA$ | $< 0, 0, 0 >$ | $< 0.39, 0.61, 0.61 >$ | $< 0.01, 0.99, 0.99 >$ | $< 0.02, 0.98, 0.98 >$ | $< 0.06, 0.94, 0.94 >$ |
| $KL$ | $< 0, 0, 0 >$ | $< 0.7, 0.3, 0.3 >$ | $< 0.16, 0.84, 0.84 >$ | $< 0.03, 0.97, 0.97 >$ | $< 0.23, 0.77, 0.77 >$ |
| $TN$ | $< 0, 0, 0 >$ | $< 0.33, 0.67, 0.67 >$ | $< 0.64, 0.36, 0.36 >$ | $< 0.04, 0.96, 0.96 >$ | $< 0.10, 0.9, 0.9 >$ |
| $TE$ | $< 0, 0, 0 >$ | $< 0.06, 0.94, 0.94 >$ | $< 0.05, 0.95, 0.95 >$ | $< 0.05, 0.95, 0.95 >$ | $< 0.23, 0.77, 0.77 >$ |

TABLE 1. Values for the year 2020

| 2021 | No education | Upto 5th std | 6th - 9th | 10th - 12th | Graduated |
| --- | --- | --- | --- | --- | --- |
| $AP$ | $< 0, 0, 0 >$ | $< 0.02, 0.98, 0.98 >$ | $< 0.02, 0.98, 0.98 >$ | $< 0.02, 0.98, 0.98 >$ | $< 0.37, 0.63, 0.63 >$ |
| $KA$ | $< 0, 0, 0 >$ | $< 0.99, 0.01, 0.01 >$ | $< 0.01, 0.99, 0.99 >$ | $< 0.02, 0.98, 0.98 >$ | $< 0.06, 0.94, 0.94 >$ |
| $KL$ | $< 0, 0, 0 >$ | $< 0.01, 0.99, 0.99 >$ | $< 0.01, 0.99, 0.99 >$ | $< 0.03, 0.97, 0.97 >$ | $< 0.24, 0.76, 0.76 >$ |
| $TN$ | $< 0, 0, 0 >$ | $< 0.23, 0.77, 0.77 >$ | $< 0.69, 0.31, 0.31 >$ | $< 0.05, 0.95, 0.95 >$ | $< 0.09, 0.91, 0.91 >$ |
| $TE$ | $< 0, 0, 0 >$ | $< 0.01, 0.99, 0.99 >$ | $< 0.67, 0.33, 0.33 >$ | $< 0.80, 0.2, 0.2 >$ | $< 0.26, 0.74, 0.74 >$ |

TABLE 2. Values for the year 2021

These values are written in the form of neutrosophic binary sets:

$$\mathcal{N}_{S_{B_1}} = \{< u_1, (0.11, 0.89, 0.89) >, < u_2, (0.41, 0.59, 0.59) >< u_3, (0, 0, 0) >,$$
$$< u_4, (0.03, 0.97, 0.97) >, < u_5, (0.33, 0.67, 0.67) >; u_1, u_2, u_3, u_4, u_5 \in \mathcal{S}_{\mathcal{U}}\},$$
$$\{< v_1, (0, 0, 0) >, < v_2, (0.02, 0.98, 0.98) >, < v_3, (0.02, 0.98, 0.98) >,$$
$$< v_4, (0.02, 0.98, 0.98) >, < v_5, (0.37, 0.63, 0.63) >: v_1, v_2, v_3, v_4, v_5 \in \mathcal{S}_{\mathcal{V}}\}$$

$$\mathcal{N}_{S_{B_2}} = \{< u_1, (0, 0, 0) >, < u_2, (0.39, 0.61, 0.61) >< u_3, (0.01, 0.99, 0.99) >,$$
$$< u_4, (0.02, 0.98, 0.98) >, < u_5, (0.06, 0.94, 0.94) >; u_1, u_2, u_3, u_4, u_5 \in \mathcal{S}_{\mathcal{U}}\},$$
$$\{< v_1, (0, 0, 0) >, < v_2, (0.99, 0.01, 0.01) >, < v_3, (0.01, 0.99, 0.99) >,$$
$$< v_4, (0.02, 0.98, 0.98) >, < v_5, (0.06, 0.94, 0.94) >: v_1, v_2, v_3, v_4, v_5 \in \mathcal{S}_{\mathcal{V}}\}$$

$$\mathcal{N}_{S_{B_3}} = \{< u_1, (0, 0, 0) >, < u_2, (0.7, 0.3, 0.3) >< u_3, (0.16, 0.84, 0.84) >,$$
$$< u_4, (0.03, 0.97, 0.97) >, < u_5, (0.23, 0.77, 0.77) >; u_1, u_2, u_3, u_4, u_5 \in \mathcal{S}_{\mathcal{U}}\},$$
$$\{< v_1, (0, 0, 0) >, < v_2, (0.01, 0.99, 0.99) >, < v_3, (0.01, 0.99, 0.99) >,$$
$$< v_4, (0.03, 0.97, 0.97) >, < v_5, (0.24, 0.76, 0.76) >: v_1, v_2, v_3, v_4, v_5 \in \mathcal{S}_{\mathcal{V}}\}$$

$$\mathcal{N}_{S_{B_4}} = \{< u_1, (0, 0, 0) >, < u_2, (0.33, 0.67, 0.67) >< u_3, (0.64, 0.36, 0.36) >,$$
$$< u_4, (0.04, 0.96, 0.96) >, < u_5, (0.10, 0.9, 0.9) >; u_1, u_2, u_3, u_4, u_5 \in \mathcal{S}_{\mathcal{U}}\},$$
$$\{< v_1, (0, 0, 0) >, < v_2, (0.23, 0.77, 0.77) >, < v_3, (0.69, 0.31, 0.31) >,$$
$$< v_4, (0.05, 0.95, 0.95) >, < v_5, (0.09, 0.91, 0.91) >: v_1, v_2, v_3, v_4, v_5 \in \mathcal{S}_{\mathcal{V}}\}$$

$$\mathcal{N}_{S_{B_5}} = \{< u_1, (0, 0, 0) >, < u_2, (0.06, 0.94, 0.94) >< u_3, (0.05, 0.95, 0.95) >,$$
$$< u_4, (0.05, 0.95, 0.95) >, < u_5, (0.23, 0.77, 0.77) >; u_1, u_2, u_3, u_4, u_5 \in \mathcal{S}_{\mathcal{U}}\},$$
$$\{< v_1, (0, 0, 0) >, < v_2, (0.01, 0.99, 0.99) >, < v_3, (0.67, 0.33, 0.33) >,$$
$$< v_4, (0.80, 0.2, 0.2) >, < v_5, (0.26, 0.74, 0.74) >: v_1, v_2, v_3, v_4, v_5 \in \mathcal{S}_{\mathcal{V}}\}$$

The neutrosophic binary weighted average operator is given by

$$D^{NB}_{WA} = \{< u_1, (0.03, 0, 0) >, < u_2, (0.53, 0.47, 0.47) >< u_3, (0.07, 0, 0) >,$$
$$< u_4, (0.04, 0.96, 0.96) >, < u_5, (0.19, 0.81, 0.81) >; u_1, u_2, u_3, u_4, u_5 \in \mathcal{S}_{\mathcal{U}}\},$$
$$\{< v_1, (0, 0, 0) >, < v_2, (0.91, 0.09, 0.09) >, < v_3, (0.03, 0.97, 0.97) >,$$
$$< v_4, (0.04, 0.96, 0.96) >, < v_5, (0.2, 0.8, 0.8) >: v_1, v_2, v_3, v_4, v_5 \in \mathcal{S}_{\mathcal{V}}\}$$

TABLE 3. Comparative Analysis of Similarity Measures for Southern States

| State | Euclidean Distance | Hamming Distance | Cosine Similarity | Correlation Coefficient |
|---|---|---|---|---|
| Andhra Pradesh | 1.1816 | 1.2345 | 0.82 | 0.78 |
| Karnataka | 0.7049 | 0.8349 | 0.89 | 0.85 |
| Kerala | 1.2250 | 1.3250 | 0.75 | 0.73 |
| Tamil Nadu | 1.0232 | 1.1340 | 0.79 | 0.76 |
| Telangana | 1.5909 | 1.6585 | 0.71 | 0.69 |

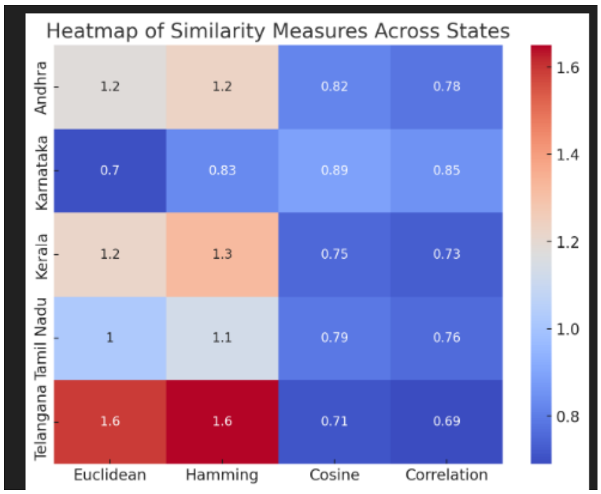


FIGURE 1

The heatmap gives the detailed view of the modulation in similarity measures across the states. The color gradient makes it visually apparent that Telangana exhibits the highest distance values across Euclidean and Hamming measures, indicating severe unemployment levels. In contrast, Karnataka consistently appears with lower distance values, reinforcing its comparatively stable employment scenario. The heatmap helps in identifying extreme and moderate cases at a glance, enhancing the interpretability of the numerical data.

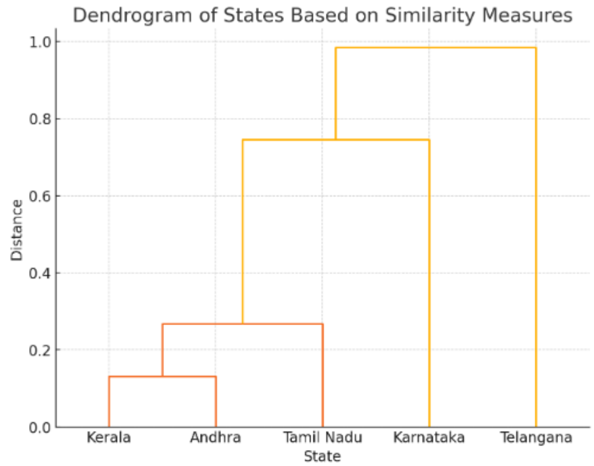


FIGURE 2

The dendrogram illustrates the hierarchical clustering of the states based on their similarity profiles. This clustering method visually separates Telangana from the other states, highlighting its distinct unemployment condition relative to the group. The dendrogram also shows how states like Andhra Pradesh and Kerala form closer clusters, suggesting similarities in their unemployment trends. This hierarchical grouping validates the reliability of the similarity measures in capturing real-world socio-economic distinctions. The radar chart provides a state-wise visualization of the similarity measures, with a specific focus on Telangana. This chart clearly demonstrates how Telangana consistently exhibits the most extreme values across all measures, particularly in Euclidean and Hamming distances.

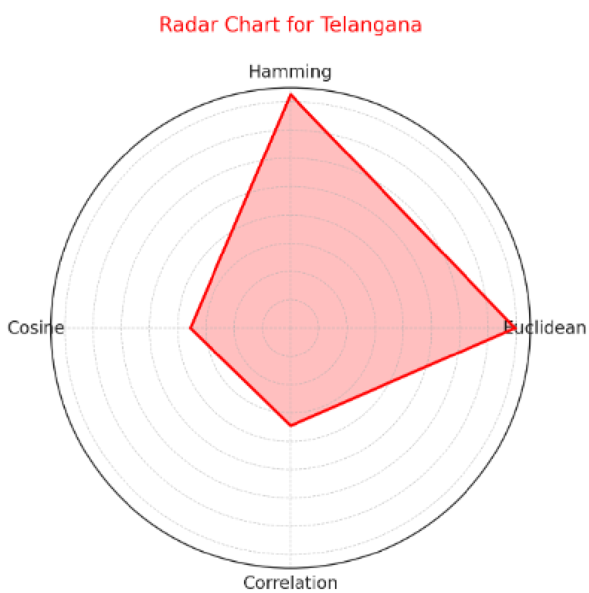


FIGURE 3

By mapping these values on a common scale, the radar chart highlights the disparity between Telangana and other states, supporting the observation that Telangana faces the highest unemployment impact. Similarly, the relatively smaller spread for Karnataka further confirms its lower unemployment concern.

These visual tools allow for a deeper understanding of how the states differ with respect to their unemployment severity. Hence, it is observed that the people of the state Telugana experiences high level unemployment crisis followed by Andhra Pradesh, Kerala, Tamilnadu and Karnataka.

## 5. Conclusion

In this study, multiple similarity measures — Euclidean distance, Hamming distance, cosine similarity, and correlation coefficient — were applied to analyze unemployment trends across the southern states of India using neutrosophic binary sets. Upon comparative evaluation, it is observed that the Euclidean distance measure yields the most accurate and reliable results in capturing the severity and magnitude of differences between the unemployment data of the states. This measure effectively distinguishes between states with varying levels of unemployment, providing clear discrimination, particularly highlighting Telangana as experiencing the highest unemployment crisis, followed by Andhra Pradesh, Kerala, Tamil Nadu, and Karnataka. While the Hamming distance produced similar results, it was less sensitive to the scale of variations. Cosine similarity and correlation coefficient measures, although useful for identifying directional or linear patterns, were found to be less effective in contexts where the magnitude of unemployment differences is critical for decision-making. Therefore, the Euclidean distance-based similarity measure is recommended for future studies involving neutrosophic binary sets in socio-economic decision-making problems.

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## 7. Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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