IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Longitudinal Sustainability Assessment of Tribal Education in India: A Multi-Criteria Decision Making (MCDM) Approach Using TOPSIS

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Abstract: Education is fundamental to the socio-economic advancement of Scheduled Tribes (STs) in India; however, sustainability assessments often rely on isolated indicators such as literacy or enrolment, limiting holistic evaluation. This study introduces the Tribal Education Sustainability Index **(TESI)**, a composite quantitative framework integrating Literacy Performance, Retention Efficiency, and Gender Parity into a unified sustainability metric. The model adopts a deterministic Multi-Criteria Decision Making (MCDM) structure and applies the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to rank longitudinal performance using secondary data from 2013–2016. The study also analyses different case studies to determine their efficacy.

The results classify tribal education as moderately sustainable with gradual improvement, with 2015–16 emerging as the most preferred year. However, retention efficiency is identified as the principal structural constraint, revealing the system's sensitivity to dropout fluctuations despite stable literacy and improving gender parity. The proposed TESI–TOPSIS framework offers a replicable and policy-relevant tool for quantitative sustainability assessment in marginalized educational contexts. Conclusively some policy measures were recommended for enhancement and sustainability of tribal education.

Index Terms **- Tribal Education, Sustainability, MCDM, TOPSIS, TESI, Retention Rate, Gender Parity.**

I. INTRODUCTION

Education serves as the primary instrument for the socio-economic mobility of marginalized Scheduled Tribe (ST) communities in India. It serves as a primary agent of transformation, impacting both the economic development and inner strength of tribal communities. Education empowers these communities to meet new challenges, improve their immediate living conditions, and enhance their potential for future prosperity. The discourse on tribal education in India focuses on the tension between preserving cultural identity and achieving mainstream educational integration. Despite the constitutional mandate for equality, Scheduled Tribes (STs)—comprising over 104 million people—remain among the most marginalized groups, facing distinct socio-economic and pedagogical challenges.

1.1 Socio-Economic and Cultural Barriers Early anthropological studies have long highlighted the alienation of tribal communities from the mainstream education system, which often fails to accommodate their unique socio-cultural context. Verma [1] emphasizes a "cultural disconnect" between tribal students and the standard curriculum, which frequently ignores local dialects and traditions. Economic constraints further exacerbate this exclusion; Dreze and Sen [2] observe that for many tribal families, the direct and indirect costs of schooling are prohibitive, leading to high dropout rates despite a desire for education.

1.2 Institutional Challenges and Infrastructure - While enrollment at the primary level has improved, the Ministry of Tribal Affairs (2018) [3] notes significant attrition at secondary and higher education levels. A critical factor is the inadequate infrastructure in remote tribal areas, as highlighted by NUEPA (2017) [4], which hinder consistent access to quality schooling. Furthermore, Kumar and Patnaik [5] argues that while quantitative enrollment has increased, the quality of education and retention rates remain poor, indicating that access alone does not equate to educational success.

1.3 Policy Interventions and Success Models - Government initiatives like the *Sarva Shiksha Abhiyan* (SSA) and the *Right to Education Act* (2009) have attempted to bridge these gaps. Specific interventions, such as the establishment of Ashram schools and Eklavya Model Residential Schools (EMRS), have shown promise. Joshi [6] found that EMRS students demonstrate better academic performance and retention compared to those in standard state-run schools. Similarly, special scholarship schemes have

been documented as effective tools for financial inclusion. However, a gap remains in quantitatively measuring the sustainability of these interventions over time, a need this study addresses through a proposed mathematical index.

1.4 The Impact of National Education Policy (NEP) 2020 -The introduction of the National Education Policy (NEP) 2020 marked a paradigm shift, emphasizing equity and inclusion. Raj and Tandi [7] noted that while NEP 2020 introduces progressive measures like mother-tongue instruction to bridge the cultural gap, its implementation in tribal belts remains hindered by infrastructural deficits. The policy envisions a "holistic" curriculum, yet critics argue that without addressing the distinct socio-economic realities of tribal families, policy intent may not translate into retention.

1.5 The Digital Divide and Post-Pandemic Challenges - Recent studies indicate that the "digital divide" has emerged as a new form of exclusion. Srivastava [8] highlights that the lack of digital infrastructure in tribal belts has exacerbated marginalization, while Raj and Tandi [7] argue that the implementation of NEP 2020 remains hindered by these infrastructural deficits.

1.6 The Sustainability Gap - While previous studies have focused on access, recent research has shifted towards "educational sustainability." Bindhani [9] argues that geographic isolation continues to be a primary sustainability hurdle, with 44% of primary schools in tribal areas suffering from low enrolment due to distance. This literature underscores a critical gap: while qualitative descriptions of these barriers exist, there is a lack of **quantitative indices** to measure how these factors—policy, digital access, and geography—collectively impact the long-term sustainability of tribal education.

1.7 Research Gap: While agencies like UNESCO monitor standard indicators such as Gross Enrolment Ratio (GER) and Gender Parity Index (GPI), these metrics are often analyzed in isolation. Assessment of educational systems involves conflicting criteria—such as high enrolment versus low quality, or high literacy versus low retention—making it a classic **Multi-Criteria Decision Making (MCDM)** [10] problem. However, existing literature on tribal education is largely descriptive or regression-based (Kumar & Patnaik, [5]). There is a critical paucity of research that applies robust MCDM techniques like **TOPSIS** [11] to synthesize these disjointed indicators into a holistic "Sustainability Score." This study fills that gap by introducing a composite index (**TESI**) and analyzing it through a geometric distance-based MCDM framework.

II. METHODOLOGY

2.1 Research Design - This study adopts a quantitative longitudinal secondary-data design supported by qualitative contextual interpretation, integrating secondary longitudinal data (2013–2016) with a deterministic MCDM framework. The study is longitudinal in nature, analyzing trends over the period of 2013–2016 to assess the sustainability of educational interventions.

2.1.1Data Sources and Study Period - Secondary data was collated from reliable government repositories to ensure national representativeness:

- **Demographic Data:** Census of India (2011) [12] and Ministry of Tribal Affairs Annual Reports [13,14].
- **Educational Statistics:** *Unified District Information System for Education* (U-DISE) and *Educational Statistics at a Glance* (MHRD, 2018) [15].
- **Policy Documents:** Reports on NEP 2020 and SSA implementation.

2.1.2 Data constraints - It is pertinent to note that the longitudinal analysis is restricted to the period **2013–2016**. This selection is driven by two critical factors:

- **Data Homogeneity:** This period offers the most consistent, uninterrupted time-series data for *Retention Rates* and *Gender Parity* in the U-DISE format, which underwent structural changes in subsequent years.
- **Census Unavailability:** The calculation of the Literacy Index ($\boldsymbol{L_P}$) relies on the **Census 2011** dataset, which remains the most recent official demographic enumeration due to the indefinite delay of the Census 2021.

Consequently, this study serves as a quantitative baseline analysis, evaluating the systemic sustainability of tribal education prior to the policy shifts introduced by **NEP 2020.**

2.2 Mathematical Framework: Tribal Education Sustainability Index (TESI) - To move beyond descriptive analysis, this study constructs a composite index, the **Tribal Education Sustainability Index (TESI)**. This deterministic model synthesizes multiple educational indicators into a single quantifiable metric.

2.2.1 Variable Definitions

- **Literacy Performance ($\boldsymbol{L_P}$):** The ratio of ST literacy rate to the National literacy rate,

$$L_P = \frac{L_R(\text{Scheduled Tribes})}{L_R\ (\text{National})} \qquad (1)$$

Where $\boldsymbol{L_R}$ stands for the literacy rates.

- **Retention Efficiency (R_E):** Derived from the annual dropout rates (D_R (%)) at the secondary level, calculated as

$$R_E = 1 - D_R(in\ \%)\ . \quad (2)$$

- **Gender Parity (G_P):** The ratio of female retention to male retention rates, measuring equitable access,

$$G_P = \frac{R_F}{R_M} \quad (3)$$

Where R_F, R_M denotes retention of females and males.

2.2.2 Model Construction While statistical weighting methods like Entropy or PCA are common in MCDM (Shannon, [16]), they require high data variance. Given the stability of demographic data, this study adopts the **Normative Equal Weighting** approach ($w_1 = w_2 = w_3 = 0.33$), aligning with the methodology of the **Human Development Index (HDI)** (UNDP, 2023-24 [17]).The TESI is defined as a weighted linear combination of three critical sub-indices: Literacy Performance **(L_P)**, Retention Efficiency **(R_E)**, and Gender Parity **(G_P)**.

$$\textbf{TESI} = w_1 L_P + w_2 R_E + w_3 G_P = \frac{1}{3}\{L_P + R_E + G_P\} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where, $w_1 = w_2 = w_3 = 0.33$, assigning equal weight to literacy, retention, and gender equity to reflect their equal importance in sustainable development.

2.2.3 MCDM Analysis: Longitudinal assessment using TOPSIS [11] - To provide a robust mathematical assessment of the temporal performance of tribal education, this study employs the **Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)**. Unlike simple additive models, TOPSIS ranks performance based on the geometric distance to an "Ideal Best Solution" (Positive Ideal) and an "Ideal Worst Solution" (Negative Ideal).

Step-1: Construction of decision matrices - Consider a decision matrix $[r_{ij}]_{m\times n}$ containing three alternatives (m=3(Years) : $2013-14,\ 2014-15,\ 2015-16$) for the study period (2013-2016) and three measurable criteria (n=3: L_P, R_E, G_P) based on TESI values.

Step-2: **Normalization** - To ensure comparability across dimensions, the decision matrix is normalized using to obtain a normalized decision matrix$[s_{ij}]_{m\times n}$, where

$$s_{ij} = \frac{r_{ij}}{\sqrt{\sum_i {r_{ij}}^2}} \quad . \quad (5)$$

Step -3: Weighted matrix – We apply weights to all the columns of the normalized matrix to obtain the weighted normalized matrix $[v_{ij}]_{m\times n} = [w_i * s_{ij}]_{m\times n}$ with respect to weights of the criteria ($w_i = \frac{1}{3}$).

Step-4: **Determination of Ideal Solutions** - We define the Positive Ideal Solution (PIS) (A^+) and Negative Ideal Solution (NIS) (A^-), defined as

$$A^+ = \left\{\max_{j=1} s_{ij}, \max_{j=2} s_{ij}, \max_{j=3} s_{ij}\right\} = \{Max(L_P), Max(R_E), Max(G_P)\}, \forall i = 1,2,3 \quad (6)$$

$$A^- = \left\{\min_{j=1} s_{ij}, \min_{j=2} s_{ij}, \min_{j=3} s_{ij}\right\} = \{Min(L_P), Min(R_E), Min(G_P)\}, \forall i = 1,2,3 \quad . \quad (7)$$

Step -5: Distance measure – Computing distance from the ideal solutions using

$${S_i}^+ = \sqrt{(L_P - Max(L_P))^2 + (R_E - Max(R_E))^2 + (G_P - Max(G_P))^2} \quad (8)$$

$${S_i}^- = \sqrt{(L_P - Min(L_P))^2 + (R_E - Min(R_E))^2 + (G_P - Min(G_P))^2} \quad (9)$$

Step-6: Calculation of Closeness Coefficient (CC_i) - The final ranking is determined by the relative closeness to the ideal solution, which is calculated as

$$CC_i = \frac{{S_i}^-}{{S_i}^+ + {S_i}^-}, \forall i = 1,2,3 \quad (10)$$

Where, ${S_i}^+, {S_i}^-$ are distances from positive and negative ideal solutions. A higher CC_i indicates superior educational sustainability.

2.3 Qualitative Validation: Sustainable Models in Practice

To contextualize the TESI findings, this study analyzes four successful educational models that have effectively addressed the "Retention Efficiency" (R_E) and "Gender Parity" (G_P) gaps identified in the mathematical analysis.

2.3.1 Institutional Models

- Kalinga Institute of Social Sciences (KISS), Odisha [18].
- Eklavya Model Residential Schools (EMRS) [6].

2.3.2 Community & NGO Models

- Pratham [19].
- Barefoot College, Rajasthan [20].

III. Data and Sources of Data

The following tables mainly focus on the distribution of tribal communities (Scheduled tribes) across different regions of India. Alongside we also consider their literacy rates as well as dropout rates across different stages of education.

Table 1: Population trends : census 2001

Census Year	Total Population (in millions)	Scheduled Tribes Population (in millions)	Proportion of STs Population
1961	439.2	30.1	6.9
1971	547.9	38.0	6.9
1981 #	665.3	51.6	7.8
1991 @	838.6	67.8	8.1
2001 $	1028.6	84.3	8.2
2011	1210.8	104.3	8.6

Excludes Assam in 1981
@ Excludes Jammu & Kashmir in 1991
$ The figures exclude Mao- Maram, Paomata and Purul sub divisions of Senapati district of Manipur, census 2001.

Table 2: Literacy Rates (in %): Census 2011

COUNTRY	PERSONS			MALE			FEMALE		
INDIA	All	ST	Gap	All	ST	Gap	All	ST	Gap
	73	59	14.0	80.9	68.5	12.4	64.6	49.4	15.2

Table 3: Gross Enrolment Ratio (GER) for ST students (in lakhs)

Level/ Year	Primary (I-V) 6-10 Years			Upper Primary (VI-VIII) 11-13 Years			Elementary (I-VIII) 6-13 Years			Secondary (IX-X) 14-15years			Senior Secondary (XI-XII) 16-17years			Higher Education 18-23 years		
	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total
2013-14	114.4	111.9	113.2	90.5	92.2	91.3	105.9	105.0	105.5	70.3	70.1	70.2	36.7	34.1	35.4	12.5	10.2	11.3
2014-15	110.6	108.2	109.4	93.0	95.2	94.1	104.4	103.7	104.0	71.8	72.6	72.2	39.8	37.8	38.8	15.2	12.3	13.7
2015-16	107.8	105.7	106.7	95.4	98.2	96.7	103.4	103.1	103.3	73.7	75.4	74.5	43.8	42.4	43.1	15.6	12.9	14.2

Table 4: Gender Parity Index (GPI) for Scheduled Tribe Students

Level/ Year	Elementary (I-VIII)	Secondary (IX-X)	Senior Secondary (XI-XII)	Higher Education
2013-14	0.99	1.00	0.93	0.81
2014-15	0.99	1.01	0.95	0.81
2015-16	1.00	1.02	0.97	0.83

Table 5: Annual Average Dropout Rates for Scheduled Tribes (ST) (in %)

Year /Class	Classes I-V			Classes I-VIII			Classes I-X		
	Boys	**Girls**	**Total**	**Boys**	**Girls**	**Total**	**Boys**	**Girls**	**Total**
2013-14	31.9	30.7	31.3	49.8	46.4	48.2	63.2	61.4	62.4
2014-15	33.3	31.2	32.3	50.6	47.5	49.2	63.2	62.2	62.7
2015-16	31.9	30.7	31.3	49.8	46.4	48.2	63.2	61.4	62.4

IV. RESULTS AND ANALYSIS

4.1 TESI - To validate the qualitative trends and statistical data presented in the previous section, the proposed mathematical model: the **Tribal Education Sustainability Index (TESI)** is calculated as shown below.

From Table 2 $\boldsymbol{L_P = 0.808}$ (Eq. (1)), is taken constant for all three years.

$\boldsymbol{G_P = \frac{G_P(Elementary)+G_P(Secondary)}{2}}$ (Eq. (2)) and $\boldsymbol{R_E = 1 - drop\ out}$ % (Eq. (3)) and $\boldsymbol{TESI = \frac{L_P+G_P+R_E}{3}}$ (Eq. (4)), which is provided in the table (Table-6) below.

Table 6: TESI

Year	$\boldsymbol{L_P}$	$\boldsymbol{R_E}$	$\boldsymbol{G_P}$	$\boldsymbol{TESI}$	**Status**
2013-14	0.808	0.376	0.995	0.726	Moderate
2014-15	0.808	0.373	1.000	0.727	Improving
2015-16	0.808	0.376	1.010	0.731	Improving

4.1.2 Conclusion of Mathematical Model

The longitudinal application of TESI (2013–16) classifies the tribal education system as **"Moderately Sustainable and improving."** The results indicate that while literacy remains stable and retention efficiency recovered after a slight dip, gender parity has shown gradual improvement, which justifies the system should be improving in the long run**.**

4.2 TOPSIS

Evaluation by TOPSIS method**.**

Step-1: With reference to the values of TESI (Table 6) we consider this as our initial decision matrix.

Step-2: Using Eq. (5) the normalized matrix is obtained (Table 7).

Table 7: Normalized matrix

Year	$\boldsymbol{L_P}$	$\boldsymbol{R_E}$	$\boldsymbol{G_P}$
2013-14	0.577	0.578	0.573
2014-15	0.577	0.574	0.576
2015-16	0.577	0.578	0.582

Step-3: Computing weighted normalized matrix using $[\boldsymbol{v_{ij}}] = [w_i * s_{ij}]$, where $w_i = \frac{1}{3}$ which is displayed in the table below (Table 8).

Table 8: Weighted normalized matrix

Year	L_P	R_E	G_P
2013-14	0.192	0.193	0.191
2014-15	0.192	0.191	0.192
2015-16	0.192	0.193	0.194

Step-4: **Ideal solutions**

Positive Ideal Solution (PIS) $A^+ = \{0.192, 0.193, 0.194\}$.

Negative Ideal Solution (NIS) $A^- = \{0.192, 0.191, 0.191\}$.

Step- 5: Computing distance using (Eq. (8), (9)) we get $S_i{}^+, S_i{}^-$ as displayed below (Table 9).

Table 9: Distances from ideal solutions

Year	$S^+{}_i$	$S^-{}_i$
2013-14	0.0030	0.0020
2014-15	0.0022	0.0014
2015-16	0.0000	0.0036

Step- 6: Computing the closeness coefficient (using Eq. (10)) as displayed in table below (Table 10) along with ranking.

Table 10: Ranking

Year	CC_i	$RANK$
2013-14	0.400	2
2014-15	0.390	3
2015-16	1.000	1

Ranking: *2015–16 > 2013–14 > 2014–15*

4.2.1 **Analysis of MCDM Results**

The TOPSIS analysis reveals a gradual improvement in sustainability performance, with 2015–16 emerging as the most preferred alternative due to superior gender parity and stable retention efficiency. The dip in year 2014-15 can again be justified due to the low retention efficiency (R_E), which is also aligned with the results of TESI. These two frameworks justify the fact that for sustainability of tribal education, retention is the key. Hence appropriate government initiatives should be launched to reduce drop outs to enhance retention.

4.3 Analysis of case studies

- **Kalinga Institute of Social Sciences (KISS), Odisha:** Addressing the economic barrier to retention, KISS provides a holistic, fully-funded residential model for over 30,000 tribal students. Its integration of vocational training with formal schooling directly tackles the high dropout rate caused by livelihood pressures.
- **Eklavya Model Residential Schools (EMRS):** A government initiative focusing on remote accessibility. Joshi [6], notes that EMRS schools have achieved higher retention rates by incorporating tribal heritage into the curriculum, thereby reducing the "cultural disconnect" that leads to student alienation.
- **Pratham:** Focusing on foundational literacy (L_P), Pratham's "Teaching At the Right Level" (TARL) approach groups students by learning level rather than age. This method has proven effective in improving basic literacy and numeracy skills in rural settings.
- **Barefoot College, Rajasthan:** Addressing the gender parity gap (G_P), this model empowers rural women and grandmothers as "Solar Engineers". Its night schools allow working children to attend classes, offering a flexible schedule that accommodates the agricultural labour demands of tribal families.

4.4 Policy Recommendations

Based on the TESI findings which identify **Retention Efficiency (R_E)** as the critical failure point, this study proposes a three-tiered intervention strategy:

- **Structural Interventions (Addressing R_E):** To arrest the "leaky bucket" at the secondary level, the academic calendar in tribal belts must be synchronized with the agricultural cycle (harvesting seasons) to reduce economic dropouts. Furthermore, the expansion of fully-funded residential models like **KISS** and **EMRS** is statistically proven to isolate students from livelihood pressures, thereby improving retention.

- **Pedagogical Interventions (Addressing L_P):** The curriculum must transition from "imposed literacy" to "cultural integration." Adopting **NEP 2020's** mother-tongue instruction mandate and utilizing tribal folklore in Teaching Learning Materials (TLM) can reduce the "cultural disconnect" cited by Verma [1].
- **Socio-Economic Interventions (Addressing G_P):** While gender parity is stable, it remains fragile. Schemes akin to **Barefoot College's** night schools should be institutionalized to accommodate the time-constraints of the girl child, ensuring that economic contribution does not come at the cost of educational exclusion.

V. CONCLUSION

In conclusion, the education of Scheduled Tribes (STs) in India presents significant challenges. Despite notable progress in enrolment and literacy rates, there remain substantial gaps in educational attainment between tribal and non-tribal populations. The longitudinal application of TESI (2013–16) classifies the tribal education system as **"Moderately Sustainable and improving."** The data proves that while literacy is high (relative to the national average) and gender parity is also favourable (>1.0), but still the system can be **unsustainable in the long run** due to a critically low retention rate (R_E< 0.40). Future policies must target retention specifically, as it is the "leaky bucket" draining the sustainability of the entire framework. Policy recommendations include improving access to quality education, providing culturally relevant curricula, training teachers from tribal backgrounds, and enhancing community involvement in the educational process.

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