








Community Role, Geo-Creative Clusters, and Sustainable Tourism in the Toba Caldera

Ellyta Tambunan¹, Zulkifli Nasution¹, Satia Negara Lubis^{1*}, Femmy Indriany Dalimunthe²,
Arga Abdi Rafiud Darajat Lubis³

¹ Rural Development Planning, Post Graduate School, Universitas Sumatera Utara, Medan 20155, Indonesia

² Postgraduate Program, Politeknik Pariwisata Medan, Medan 20371, Indonesia

³ Postgraduate Graduate School, Universitas Sumatera Utara, Medan 20155, Indonesia

Corresponding Author Email: satia.negara@usu.ac.id

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ABSTRACT

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Geopark destinations require governance arrangements that can translate community participation into measurable sustainability outcomes. This study examines the relationships among community role (X), geo-creative cluster (Z), and sustainable tourism (Y) in the UNESCO Global Geopark Toba Caldera (n = 386). Using Partial Least Squares-Structural Equation Modeling (PLS-SEM), the final measurement model retained original questionnaire items—12 for X, 8 for Z, and 6 for Y—with all retained constructs estimated reflectively after indicator purification. Reliability and convergent validity were satisfactory (Cronbach's $\alpha = 0.947\text{--}0.968$; AVE = 0.682–0.818), while HTMT values supported discriminant validity. Structurally, community role had a strong positive effect on sustainable tourism ($\beta = 0.520$, $p < 0.001$) and a smaller positive effect on geo-creative cluster ($\beta = 0.125$, $p = 0.025$). However, the effect of geo-creative cluster on sustainable tourism was positive but not statistically significant ($\beta = 0.090$, $p = 0.057$), and the indirect effect $X \rightarrow Z \rightarrow Y$ was also not significant ($\beta = 0.011$, $p = 0.178$). The model explained 29.0% of the variance in sustainable tourism and 1.6% of the variance in geo-creative cluster. These findings indicate that community capability remains the principal driver of sustainability in the Toba Caldera, while geo-creative clusters are better understood as an emerging organizational condition than as an effective mediating mechanism in the present dataset.

1. INTRODUCTION

Sustainable tourism is widely recognized as a strategic approach to balancing economic benefit, cultural preservation, and environmental stewardship in fragile and high-value destinations such as geoparks [1, 2]. At the global level, UNESCO defines geoparks as internationally significant landscapes where geological heritage, biodiversity, and culture are managed within an educational and community-based development framework [3, 4]. This orientation encourages forms of geotourism that emphasize learning, authenticity, and conservation while remaining attentive to ecological carrying capacity [5, 6]. In practical terms, such destinations require governance arrangements that position local communities not as peripheral beneficiaries, but as central actors in sustaining long-term tourism outcomes [7].

In Indonesia, policy agendas increasingly connect sustainable tourism, the creative economy, and community empowerment within national development planning [8]. The creative economy is viewed as a source of added value rooted in local creativity, knowledge, and cultural heritage [9]. When linked effectively with tourism, it can strengthen product differentiation, reinforce local supply chains, and expand community-based economic opportunity [10]. Yet these

expected gains do not arise automatically. They depend on organizational arrangements capable of translating community participation into measurable destination performance [11].

The UNESCO Global Geopark Toba Caldera (UGGKT) offers a particularly relevant setting for this discussion. Its geoheritage is embedded in a social and cultural landscape shaped by four major ethnic groups—Toba, Karo, Simalungun, and Pakpak—whose motifs, architecture, cuisine, rituals, and storytelling traditions enrich the region's creative economy potential [12]. This diversity opens opportunities to develop geo-products that are educational, distinctive, and marketable [13]. At the same time, the geological narratives of the caldera can be converted into visitor learning experiences that enhance destination image and length of stay [7]. Without effective governance and sustained community capacity, however, this potential is likely to remain fragmented and unevenly translated into durable sustainability outcomes [14].

A cluster perspective helps explain how dispersed local resources might be coordinated more effectively. In this study, community role is understood as a reservoir of place-based intangible resources, including local knowledge, cultural narratives, trust-based collaboration, co-management capability, and product curation capacity [15, 16]. These

resources are important, but they do not automatically produce destination-level sustainability when they remain scattered across individual actors [17]. Cluster theory offers a meso-level explanation by showing how shared branding, quality standardization, market coordination, cooperative platforms, and learning networks can organize dispersed capabilities into collective action [18]. Accordingly, community role (X) is positioned here as the micro-level resource base, geo-creative cluster (Z) as the coordinating mechanism, and sustainable tourism (Y) as the destination-level outcome. Conceptually, stronger community role is expected to strengthen the local capacity that supports cluster development, while better organized clusters may contribute to more coherent economic, socio-cultural, and environmental tourism outcomes [19].

This framing addresses an important gap in the literature. Previous studies have commonly examined either the direct relationship between community participation and tourism sustainability or the contribution of clusters to innovation and destination competitiveness. Much less attention has been given, particularly in geopark settings, to whether cluster capability adds explanatory value in linking community-based resources with measurable sustainability outcomes in culturally differentiated destinations [20, 21].

Against this background, the present study contributes to the sustainable tourism literature by examining geo-creative clusters as a potential intervening organizational mechanism in the relationship between community role and sustainable tourism in the Toba Caldera [22-25]. Rather than presuming mediation in advance, the study tests whether cluster capability meaningfully extends the direct contribution of community role to sustainability outcomes within a geopark context marked by socio-cultural diversity.

Methodologically, Partial Least Squares-Structural Equation Modeling (PLS-SEM) is employed because it is suitable for latent-variable models that involve measurement refinement, structural-path estimation, and mediation testing [26]. Model evaluation therefore covers loading adequacy, reliability and convergent validity, discriminant validity, selected multicollinearity diagnostics, and structural-model assessment [27, 28].

Within a sustainability framework, the outcome construct must still be grounded in observable dimensions. Economic aspects can be reflected in local income generation, employment, and supply-chain linkages [29, 30]. Socio-cultural aspects concern tradition preservation, community participation, and the quality of visitors' learning experiences [31]. Environmental aspects, in turn, relate to geosite conservation, visitor education, and carrying-capacity management [32].

The Toba Caldera context also presents opportunities for cultural fusion in which ideas, motifs, and practices can be curated into distinctive creative-product narratives [33]. An umbrella brand architecture centered on "Toba Caldera Geopark," complemented by endorsed identities for each ethnic group, may strengthen differentiation while preserving geoheritage integrity [34]. Such an approach is consistent with the need for quality standards, certification, and storytelling to increase willingness to pay among environmentally conscious visitors [35]. More broadly, better coordinated cluster development may help transform cultural value into sustainable economic value while remaining aligned with geosite conservation, spatial planning, and place-sensitive development priorities [36].

The theoretical contribution of this study lies in positioning

community role (X) as the micro-level resource base, geo-creative cluster (Z) as the organizational mechanism through which local resources may be coordinated, and sustainable tourism (Y) as the destination-level outcome. The analysis is situated in a culturally differentiated geopark context, but its primary purpose is to assess whether cluster capability contributes explanatory value beyond the direct role of community participation (Table 1).

Table 1. Conceptual positioning of the study

Main Construct	Brief Definition	Theoretical Sources	Construct Role in the Model
Community Role (X)	Participation, co-management, geo-product production & curation, narrative-based marketing	[3, 7]	Micro-level resource base
Geo-Creative Cluster (Z)	Cross-ethnic collective capability to create creative-economy value grounded in geoheritage	[15, 34]	Meso-level coordinating capability
Sustainable Tourism (Y)	Destination performance across economic-socio-cultural-environmental dimensions	[1, 5]	Destination-level performance outcome

Against this backdrop, the study proposes a conceptual model linking community role (X), geo-creative cluster (Z), and sustainable tourism (Y) in the Toba Caldera. The model addresses a specific gap concerning whether cluster-based collective capability helps translate community participation into measurable economic, socio-cultural, and environmental tourism outcomes in a geopark setting. Two research questions guide the analysis:

- a) To what extent does community role influence geo-creative cluster formation and sustainable tourism in the Toba Caldera?
- b) Does geo-creative cluster mediate the relationship between community role and sustainable tourism?

Based on this framework, the study examines whether community role strengthens sustainable tourism directly and whether geo-creative cluster contributes an additional pathway through which that relationship may operate in the Toba Caldera. The analysis is conducted in a socio-culturally diverse geopark setting, and that diversity is represented through stratified sampling across the principal ethnic communities. Formal cross-ethnic path comparisons, however, are reserved for future research.

2. METHODOLOGY

2.1 Design, context, and analytical objectives

This study employs a quantitative explanatory design using PLS-SEM to examine the structural relationships among community role, geo-creative cluster, and sustainable tourism

in the Toba Caldera. The analytical objective is to estimate both direct and indirect relationships among these constructs within a culturally differentiated geopark context. Although ethnic stratification was used to ensure socio-cultural representation in the sample, formal multi-group comparison of structural paths is not reported in this article and is instead proposed for future research.

2.2 Population, unit of analysis, and sampling

The study population comprised creative-economy and tourism MSME actors, attraction managers, community and *Pokdarwis* leaders, and other local stakeholders operating within the Toba Caldera Geopark. The unit of analysis was the actor or entity participating in the geotourism-creative economy value chain, particularly in relation to geo-product production, destination management, marketing, and inter-actor networking.

A stratified-purposive sampling approach was employed. Ethnicity was used as the stratification basis, while purposive criteria were applied to ensure that respondents occupied roles relevant to the functioning of the geotourism and creative-economy ecosystem. Specifically, respondents were selected based on their involvement in one or more of the following domains: geo-product production, destination management, promotion and marketing, and collaborative or institutional networking.

The four ethnic groups—Toba, Karo, Simalungun, and Pakpak—were selected because they represent the principal socio-cultural communities embedded in the Toba Caldera landscape and are prominently associated with its geotourism and creative-economy ecosystem. Their material culture, culinary traditions, ritual practices, vernacular design, and geo-cultural storytelling contribute substantially to the region’s geo-products, visitor experiences, and destination narratives. Accordingly, these groups were treated as analytically relevant strata rather than as merely demographic categories. Their inclusion also strengthens the contextual relevance of the study by ensuring that the sample reflects the socio-cultural diversity of the geopark environment. Using $\alpha = 0.05$, power = 0.80, and $f^2 = 0.15$, the minimum sample requirement was estimated at approximately 87 observations per path comparison.

To preserve representation across strata, the sampling design initially aimed to secure a minimum of approximately 40 respondents from each ethnic group. This threshold was used as a pragmatic minimum to ensure that each stratum was adequately represented in the dataset. However, the final survey dataset used for analysis comprised 386 respondents in total, thereby exceeding the minimum requirement and improving the robustness of the model estimation.

The final dataset was distributed in a near-balanced manner across the four ethnic strata, with each group representing approximately one-quarter of the total sample.

2.3 Instrument, scale, and operationalization

The questionnaire employed a five-point Likert scale ranging from 1 (very low/strongly disagree) to 5 (very high/strongly agree). In the final model reported in this article, all retained constructs were estimated reflectively after indicator purification. community role was modeled directly from retained original questionnaire items rather than from parcels, aggregated indicators, lower-order construct scores, or a higher-order specification.

- X (community role) - reflective: 12 retained indicators representing participatory planning, attraction co-management, geo-product curation, narrative development, and local support for destination strengthening.
- Z (geo-creative cluster) - reflective: 8 retained indicators representing perceived cluster readiness, coordination, branding, and collective support mechanisms in the local creative-economy ecosystem.
- Y (sustainable tourism) - reflective: 6 retained indicators representing economic, socio-cultural, and environmental sustainability outcomes.

Indicator purification was undertaken to remove empirically weak items while preserving conceptual coverage at the construct level. Accordingly, the final community role construct reflects retained original items, and the reported reliability and validity values correspond to this final reflective measurement model rather than to any form of score aggregation.

Content validity was assessed by a panel of geopark/creative-economy experts; face validity via readability testing. A pilot test ($n \approx 30-50$) was used to screen weak indicators prior to full estimation.

Table 2 summarizes the principal criteria used in the final model, namely loading adequacy, composite reliability, Average Variance Extracted (AVE), and Heterotrait-Monotrait Ratio (HTMT) for the retained reflective constructs, together with model-fit and structural indicators used to support interpretation.

Table 2. Measurement and structural quality criteria

Component	Indicator	Formula	Target
Reflective	Loading (λ)	indicator-construct correlation	≥ 0.70 (0.40-0.70 may be retained if CR/AVE adequate)
Reflective	Composite Reliability (ρ_c)		0.70-0.95
Reflective	AVE		≥ 0.50
Discriminant	HTMT	cross-/intra-construct correlation ratio	≤ 0.85 (strict) / ≤ 0.90
Supplementary	Indicator VIF	item-level redundancy diagnostic	interpret cautiously; high values suggest overlap
Structural	R^2		0.25; 0.50; 0.75 significance assessed by bootstrap t-value and p-value
Structural	Indirect effect ($\alpha\beta$)		

Note: AVE = Average Variance Extracted; CR = Composite Reliability; HTMT = Heterotrait-Monotrait Ratio; VIF = Variance Inflation Factor.

2.4 Data collection procedure and ethics

A structured survey (face-to-face/online) was administered with informed consent, anonymity, and the right to withdraw. Enumerators were trained in construct definitions, ethics, and quality control (skip logic, attention checks). Secondary data (policy, actor mapping) supported triangulation. The study

adhered to ethics board approval/IRB and secure data-handling standards.

2.5 Data quality and bias mitigation

Procedural remedies included anonymity, instructions emphasizing that there were no right or wrong answers, randomized item order, and separation of construct blocks. Harman’s single-factor test and full-collinearity VIF were considered as supplementary diagnostics of common method bias, while data cleaning addressed missing values, outliers (Mahalanobis distance/boxplots), straight-lining, and response time patterns.

2.6 Partial Least Squares-Structural Equation Modeling analytical steps

2.6.1 Measurement model evaluation

- Loadings (λ): ≥ 0.70 , while indicators in the 0.40-0.70 range may be retained when composite reliability and AVE remain adequate.
- Composite Reliability (ρ_c): values above 0.95 were interpreted cautiously because they may indicate indicator redundancy.
- Average Variance Extracted (AVE):
- $AVE \geq 0.50$ indicates that a construct explains more than 50% of the variance of its indicators.
- HTMT for discriminant validity: $\leq 0.85/0.90$.

2.6.2 Geo-creative cluster in the final measurement model

After empirical purification, the geo-creative cluster construct was retained as a reflective construct in the final model. Its evaluation therefore followed the same logic as the other retained constructs, namely loading adequacy, composite reliability, AVE, and discriminant validity. Indicator-level VIF values were reported only as supplementary diagnostics of possible overlap rather than as criteria for formative adequacy.

2.6.3 Structural model

- R^2 for endogenous constructs (0.25 weak, 0.50 moderate, 0.75 substantial).
- Effect size (f^2) by predictor.
- Inner VIF for multicollinearity (ideal < 5).
- Predictive relevance via Q^2 (blindfolding, > 0) or PLSpredict ($Q^2_{predict} > 0$; PLS RMSE/MAE \leq linear benchmark).

2.6.4 Mediation test ($X \rightarrow Z \rightarrow Y$)

- Indirect effect: $\alpha\beta$, with $\alpha = \beta_{(X \rightarrow Z)}$, $\beta = \beta_{(Z \rightarrow Y)}$.
- Total effect: $\tau = c' + \alpha\beta$, with $c' = \beta_{(X \rightarrow Y)}$.
- VAF: $VAF = \alpha\beta / (\alpha\beta + c')$

The mediation effect was assessed through the magnitude and significance of the indirect effect, together with its relation to the total effect. VAF was reported for descriptive completeness, while substantive interpretation prioritized statistical significance and effect size.

2.7 Ethical considerations

This study followed institutional ethical protocols. All participants provided informed consent. Sensitive budget and policy data were anonymized, securely stored, and used solely for research purposes, in accordance with national guidelines

for public sector research.

3. RESULT AND DISCUSSION

3.1 Context and data

The study was conducted within the geotourism-creative economy ecosystem of the Toba Caldera UNESCO Global Geopark. The units of analysis were MSME and creative-economy actors, attraction managers, and community mobilizers drawn from the four principal ethnic groups. A total of 386 valid responses were analyzed using PLS-SEM in SmartPLS 4.1 to evaluate the structural relations among community role (X), geo-creative cluster (Z), and sustainable tourism (Y).

3.2 Respondent characteristics

Table 3 presents the socio-demographic and ethnic profile of the respondents. The sample comprised 386 respondents, with a slight female majority (53.1%) over male respondents (46.9%). In terms of age, the largest group was 21-30 years (35.5%), followed by 31-40 years (26.4%), indicating that the sample was dominated by respondents in the productive working-age population. Educationally, most respondents had completed senior secondary education (39.4%), while 32.9% had attained diploma or bachelor-level qualifications. In occupational terms, entrepreneurs and MSME actors constituted the largest group (37.0%), followed by farmers (24.9%), suggesting that the sample was closely connected to the local productive and tourism-related economy. In addition, most respondents reported monthly incomes between Rp1,000,000 and Rp2,500,000 (46.4%), reflecting the economic profile of local stakeholders operating within lower-to middle-income conditions.

Table 3. Respondent characteristics

Characteristic	Category	n	%
Sex	Male	181	46.9
	Female	205	53.1
Age	21-30 years	137	35.5
	31-40 years	102	26.4
	41-50 years	83	21.5
	> 50 years	64	16.6
Education	Primary (SD)	59	15.3
	Junior Secondary (SMP)	48	12.4
	Senior Secondary (SMA/SMK)	152	39.4
	Diploma/Bachelor	127	32.9
Occupation	Entrepreneurs/MSMEs	143	37.0
	Farmers	96	24.9
	Public/private employees	87	22.5
	Other informal workers	60	15.6
Income/month	< Rp1,000,000	54	14.0
	Rp1,000,000-Rp2,500,000	179	46.4
	Rp2,500,001-Rp5,000,000	121	31.3
	> Rp5,000,000	32	8.3
Ethnic Group	Toba	97	25.1
	Karo	97	25.1
	Simalungun	96	24.9
	Pakpak	96	24.9
Total		386	100.0

From the perspective of stratification, the ethnic composition of the sample was distributed in a near-balanced manner across the four principal groups in the Toba Caldera,

namely Toba (25.1%), Karo (25.1%), Simalungun (24.9%), and Pakpak (24.9%). This balanced allocation supports the study's stratified sampling design and ensures that the dataset adequately reflects the socio-cultural diversity embedded in the geopark's geotourism and creative-economy ecosystem.

3.3 Descriptive analysis

Descriptive analysis summarizes responses from 386 participants using the indicators retained in the final measurement model. The constructs assessed are community role (X), geo-creative cluster (Z), and sustainable tourism (Y), each measured on a five-point Likert scale.

Construct means were interpreted using equal-interval categories, and the results are presented at construct level to maintain readability and consistency with the journal's reporting style (Table 4).

Table 4. Descriptive statistics by construct (retained indicators, n = 386)

Construct	# of Items	Grand Mean	Category	Substantive Note
Community Role (X)	12	3.72	Good	Community support, local initiative, and destination stewardship are generally perceived as positive.
Geo-Creative Cluster (Z)	8	3.65	Good	Perceived cluster readiness and coordination are positive, but not yet strong enough to act as an effective transmission mechanism.
Sustainable Tourism (Y)	6	3.67	Good	Economic, socio-cultural, and environmental outcomes are perceived positively at a moderate-good level.

All three constructs fall within the "Good" category (X = 3.72; Z = 3.65; Y = 3.67). This indicates that respondents generally viewed community participation, cluster readiness, and sustainable tourism performance positively, although these descriptive averages do not by themselves establish a strong mediating relationship among the constructs.

The descriptive pattern nevertheless suggests a supportive baseline ecosystem. The structural model presented in the following section clarifies whether these generally positive perceptions translate into statistically meaningful relationships among community role, geo-creative cluster, and sustainable tourism.

3.4 Model evaluation

The final measurement model retained 12 indicators for community role (X), 6 indicators for sustainable tourism (Y), and 8 indicators for geo-creative cluster (Z). For community

role specifically, the construct was estimated from retained original items rather than from parcels or aggregated scores. All retained indicators exceeded the common loading threshold of 0.70, with X ranging from 0.705 to 0.900, Y from 0.785 to 0.937, and Z from 0.852 to 0.933. Reliability and convergent validity were satisfactory across constructs, and HTMT values for X-Y, X-Z, and Y-Z remained well below conventional thresholds, supporting discriminant validity (Table 5).

Table 5. Measurement model—reliability and validity of retained constructs

Construct	Type	Measurement Evaluation	Conclusion
Community Role (X)	Reflective	12 retained indicators; $\lambda = 0.705-0.900$; Cronbach's $\alpha = 0.957$; Composite Reliability = 0.962; AVE = 0.682	Reliable and valid
Sustainable Tourism (Y)	Reflective	6 retained indicators; $\lambda = 0.785-0.937$; Cronbach's $\alpha = 0.947$; Composite Reliability = 0.958; AVE = 0.792	Reliable and valid
Geo-Creative Cluster (Z)	Reflective	8 retained indicators; $\lambda = 0.852-0.933$; Cronbach's $\alpha = 0.968$; Composite Reliability = 0.973; AVE = 0.818	Reliable and valid

Because all retained constructs in the final model were estimated reflectively, the evaluation emphasizes loading adequacy, reliability, AVE, and HTMT rather than formative outer weights. Several item-level VIF values exceeded 5; these were interpreted cautiously as supplementary indications of possible indicator overlap rather than as evidence of problematic inner-model multicollinearity.

3.5 Structural results

Table 6 summarizes the model fit and explained variance indicators for the structural model.

Table 6. Model fit and explained variance indicators

Metric	Value	Criterion
SRMR	0.043	≤ 0.08 (good fit)
NFI	0.912	≥ 0.90 (good fit)
R ² (Z)	0.016	very weak explanatory power
R ² (Y)	0.290	weak-moderate explanatory power
R ² adjusted (Z)	0.013	close to R ² ; stable estimate
R ² adjusted (Y)	0.286	close to R ² ; stable estimate

For completeness, the indirect effect X→Z→Y was 0.011 (t = 1.348; p = 0.178), indicating that the mediating role of geo-creative cluster is not statistically supported in the final model.

The structural results indicate that community role (X) remains the most important explanatory factor in the model. First, the direct path from community role to sustainable tourism is strong and highly significant ($\beta = 0.520$; t = 11.549; p < 0.001), showing that community participation, local initiative, and destination stewardship directly strengthen sustainable tourism outcomes in the Toba Caldera (Table 7).

Table 7. Structural path results

Hypothesized Path	β	T-Value	P-Value	Sig.	Interpretation
X → Z	0.125	2.242	0.025	Supported	Community role has a small but significant positive effect on cluster development.
Z → Y	0.090	1.904	0.057	Not supported	Cluster effect on sustainable tourism is positive but not significant at the 5% level.
X → Y	0.520	11.549	0.000	Supported	Community role is the dominant direct driver of sustainable tourism.

Second, community role also has a positive and significant effect on geo-creative cluster ($\beta = 0.125$; $t = 2.242$; $p = 0.025$), although the magnitude of this relationship is relatively small. This suggests that stronger community role contributes to cluster formation, but that its explanatory power for cluster development remains limited in practical terms.

Third, the effect of geo-creative cluster on sustainable tourism is positive but not statistically significant at the 5% level ($\beta = 0.090$; $t = 1.904$; $p = 0.057$). Substantively, this indicates that the retained cluster construct has not yet emerged as a sufficiently strong organizational mechanism for converting community-based resources into broader sustainability performance.

The mediation result reinforces this interpretation. Because the indirect effect is not significant, the final model supports a direct-effect explanation more strongly than a mediated-effect explanation. In other words, sustainable tourism in the Toba Caldera is driven primarily by community capability itself, while geo-creative clusters remain an emerging but not yet decisive pathway.

3.6 Indirect effect and diagnostic interpretation

Indirect Effect and Estimation Implications. The indirect effect of $X \rightarrow Z \rightarrow Y = 0.011$ is positive but statistically non-significant ($t = 1.348$; $p = 0.178$). Accordingly, the principal explanatory pathway in the model remains the direct effect of community role on sustainable tourism rather than the indirect route through geo-creative cluster (Table 8).

Table 8. Indirect effect and diagnostic summary

Metric	Value	Interpretation / Notes
Indirect effect (X→Z→Y)	0.011	$t = 1.348$; $p = 0.178$; not significant.
HTMT (X-Y)	0.552	Below common threshold; discriminant validity supported.
HTMT (X-Z)	0.127	Below common threshold; discriminant validity supported.
HTMT (Y-Z)	0.157	Below common threshold; discriminant validity supported.
Item VIF range (X)	1.975-4.858	Moderate redundancy in some retained indicators; interpreted as supplementary only.
Item VIF range (Y)	2.057-6.677	Some retained indicators overlap; monitor for future construct refinement.
Item VIF range (Z)	3.484-6.752	Overlap among retained cluster items is evident; interpret as reflective item redundancy, not formative collinearity.

Discriminant Validity and Item Redundancy. The HTMT values between X and Y (0.552), X and Z (0.127), and Y and Z (0.157) support discriminant validity among the retained constructs. At the same time, several item-level VIF values are

comparatively high, especially within Y and Z, suggesting that some retained indicators may still overlap conceptually. This does not invalidate the model, but it does indicate that future refinement should aim for more parsimonious measurement blocks.

Measurement Interpretation in the Final Model. In the final specification, geo-creative cluster is represented reflectively by eight retained indicators capturing perceived cluster readiness and coordination capacity. Interpretation of Z therefore rests on loading adequacy, reliability, AVE, HTMT, and the structural-path estimates rather than on formative outer-weight diagnostics.

4. CONCLUSION AND POLICY IMPLICATIONS

4.1 Conclusion

This study shows that community role (X) is the primary driver of sustainable tourism (Y) in the Toba Caldera, whereas geo-creative cluster (Z) does not function as a statistically significant mediator in the final model. community role exerts a strong direct effect on sustainable tourism ($\beta = 0.520$; $p < 0.001$) and a smaller but significant effect on geo-creative cluster ($\beta = 0.125$; $p = 0.025$). By contrast, the path from geo-creative cluster to sustainable tourism is not significant at the 5% level ($\beta = 0.090$; $p = 0.057$), and the indirect effect is likewise not significant ($\beta = 0.011$; $p = 0.178$). The model explains 29.0% of the variance in sustainable tourism and only 1.6% of the variance in geo-creative cluster, indicating that sustainable tourism is shaped more directly by community capability than by cluster-based coordination in its present form.

Theoretically, these findings suggest that cluster capability should be interpreted as an emerging organizational condition rather than as a confirmed mediating mechanism in this dataset. In policy terms, the evidence supports a staged strategy: first, strengthen community capability and local governance as the most immediate lever of sustainability; second, continue developing branding, coordination, and market linkages so that geo-creative clusters may become more consequential under more mature institutional conditions.

4.2 Policy implications

Table 9 condenses the policy implications into three mutually reinforcing intervention groups. First, community activation is required because the strongest empirical leverage comes from the direct contribution of local participation to sustainable tourism. Second, cluster and market strengthening should continue, but as a medium-term institutional agenda rather than as an immediately effective mediating mechanism. Third, governance, traceability, and monitoring provide the institutional backbone needed to improve coordination quality, authenticity, and policy learning over time.

Table 9. Policy implications

Policy Group	Main Components	Expected Outcomes
1. Community Activation	Led by district tourism offices, village governments, <i>Pokdarwis</i> , and the Toba Caldera Geopark management unit. Priority actions include participatory attraction co-management, geo-product curation, storytelling workshops, digital marketing clinics, and basic training support.	Faster gains in local participation, stronger visitor experience, improved product readiness, and more immediate improvements in sustainability performance.
2. Cluster and Market Strengthening	Led by the geopark authority, tourism offices, cooperatives/UMKM offices, branding partners, universities, BUMDes, local banks, and CSR partners. Main actions include incremental branding consolidation, marketplace integration, shared packaging and promotion, and staged training in design, sales, storytelling, and bookkeeping.	Gradual strengthening of cluster identity, coordination, and market access, although immediate sustainability gains should not be assumed from clusterization alone.
3. Governance, Traceability, and Monitoring	Led by Bappeda, district governments, the geopark board, trade offices, producer associations, village representatives, and universities. Key actions include geo-product labels, QR-based origin verification, packaging standards, inter-ethnic coordination forums, and dashboard-based monitoring.	Stronger authenticity signaling, better policy learning, improved coordination quality, and more evidence-based destination management over time.

4.3 Limitations and future research

Although the sample was stratified across the principal ethnic groups of the Toba Caldera, this article does not report formal cross-ethnic path comparisons. Such analysis remains an important direction for future research.

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