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Mapping Tourism-Driven Regional Inequality Through Village Clustering: Evidence from Gianyar Regency, Bali.

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Abstract
Aggregate tourism growth in developing economies does not automatically translate into spatially equitable outcomes, as economic gains persistently concentrate in dominant nodes while surrounding villages remain structurally excluded. This study introduces longitudinal K-Means clustering combined with cluster transition mapping to track village economic mobility in Gianyar Regency, Bali across 2021–2023. Data covering 70 villages were analyzed using Adjusted Rand Index, transition tabulation, and multiple inequality indices to ensure cluster stability and spatial interpretability. Results reveal accelerating spatial bifurcation, with 72.9 percent of transitional villages reclassified into the peripheral tier by 2023 and tourism facility inequality surging from 20.03 to 54.62 times across tiers. Upward mobility to the hub tier was entirely absent throughout the observation period. These findings qualify convergence assumptions in both Growth Pole Theory and Hirschman's trickling-down framework through mechanistically distinct pathways: hub growth raises commercial viability thresholds that structurally foreclose peripheral entry, while backwash dominance operates as a potential steady state rather than a transitional precursor to spread. Policy responses must be tier-differentiated, with hub villages requiring investment redirection, transitional villages requiring supply chain integration, and peripheral villages requiring state-led infrastructure equalization as a prerequisite for economic participation.

Keywords: intra-regional bifurcation; longitudinal cluster analysis; spatial polarization; tourism-driven inequality

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INTRODUCTION

Tourism-led growth has become one of the most widely adopted development strategies across developing economies, particularly in regions where the sector serves as a primary driver of employment, foreign exchange, and sub-national economic diversification. Yet this strategy carries an embedded paradox: aggregate tourism growth does not automatically translate into spatially equitable outcomes. Rapid tourism expansion repeatedly produces conditions in which economic gains concentrate in dominant destination nodes while surrounding villages remain structurally excluded from the benefits of regional growth (Tripathi & Yenneti, 2024; Zhang, 2023). This tension is directly implicated in the global sustainable development agenda. SDG 8 calls for inclusive and sustainable economic growth

and decent work; SDG 10 explicitly targets the reduction of inequality within and among countries; and SDG 11 demands inclusive, safe, and sustainable human settlements. Collectively, these goals establish spatial equity in tourism-driven regions as a measurable development obligation.

The concentration of tourism's economic benefits follows a recognizable spatial logic. Tourists converge on destinations with established reputations and dense hospitality offerings, anchoring visitor expenditure to a small number of nodes. Investors follow demonstrated demand toward those same locations, and infrastructure investment reinforces existing nodes further. Peripheral villages, lacking critical mass in facilities and financial intermediation, progressively lose factor inputs to growing cores, producing self-reinforcing divergence rather than convergence. This dynamic is consistent with Growth Pole Theory (Perroux, 1970) which predicts that dominant nodes attract disproportionate economic activity through agglomeration. Donovan et al (2024) further show that denser and larger agglomerations produce robust productivity advantages. Duranton and Puga (2004) identify localized externalities that systematically advantage established nodes, Martin and Sunley (2010) demonstrate that early concentration advantages lock in through institutional complementarities, and Hirschman (1958) establishes that polarization effects draw capital, labor, and resources from peripheral areas toward the core in the early stages of growth, deepening peripheral disadvantage before trickling-down forces can offset it.

Capturing this stratification empirically requires indicators that reflect not tourism activity alone, but a village's underlying structural capacity to participate in and retain benefits from regional tourism growth. The variables in this study reflect exactly that: tourism facilities (hotels, lodgings, and restaurants) as proxies for tourism intensity and reception capability (Zhang et al., 2024); trade facilities (shopping complexes, permanent markets, semi-permanent markets, open markets, and minimarkets) as indicators of local economic circulation (Kopczewska et al., 2024); financial institutions (government banks, private banks, BPR, KUD, Kopinkra, Kospin, and other cooperatives) as measures of capital accessibility and intermediation (Liu et al., 2024), BTS towers as proxies for digital-economic connectivity (Sakti et al., 2024); and population density as a measure of market concentration and service demand intensity (Kopczewska et al., 2024). Empirically, Tripathi and Yenneti (2024) find that inclusive spatial development requires socio-spatial transformation beyond tourism centers, and Wang and Tziamalis (2023) show that tourism's distributional impact depends on the maturity of local economic infrastructure, conditions that vary sharply across village economies. Zhang (2023) confirms that tourism's effects are nonlinear and spatially heterogeneous, simultaneously benefiting cores while marginalizing peripheries, and Liu et al., (2024) and Ibanescu et al. (2023) establish that spillover effects are geographically bounded, leaving sub-threshold villages unable to capture visitor expenditure regardless of broader regional growth. Where polycentric nodal configurations exist, however, Chen et al., (2024) finds significant welfare spillovers across neighboring areas, suggesting that distributional capacity may be contingent on nodal structure rather than sectoral expansion alone.

Yet collectively, existing studies remain methodologically limited. Zhao et al., (2023) establish that spatial heterogeneity in tourism concentration exists across villages, but their cross-sectional design captures only a static snapshot, making it impossible to determine whether that heterogeneity is deepening or reversing over time. Li et al., (2024) analyze tourism disparities at the prefecture level but do not extend to village-scale trajectories. Shi et al., (2022) identify tiered hierarchies but cannot determine whether peripheral positions are structural or progressive. Collectively, the literature identifies where polarization is concentrated and what factors sustain it, but cannot establish whether sub-regional units are shifting between developmental tiers.

Across these strands, existing literature has yet to examine longitudinally how tourism concentration is associated with changes in village-level economic hierarchy, leaving open whether tourism growth produces inclusive development or deepening regional polarization at the sub-regional scale. Temporal evidence of shifting growth pole dynamics in Bali is equally absent. Clustering studies consistently produce static typologies without inter-period mobility analysis, generating administratively useful labels but not the trajectory-informed interpretive capacity needed for time-sensitive policy. Gianyar Regency was selected to address these gaps. Ubud's dominance creates a clear mono-nodal configuration in which growth pole dynamics can be observed without confounding competing centers, while 70 villages across seven sub-districts with differential tourism exposure provide sufficient internal variation to examine how concentration shapes village economic stratificationat the sub-regional scale.

This study examines the temporal dynamics of village economic differentiation in Gianyar Regency across 2021–2023, using tourism and infrastructure facility distribution as proxies for local economic capacity to trace longitudinal shifts in village economic hierarchy, including hub consolidation and the contraction of the transitional tier, and to assess how tourism facility concentration relates to inter-village stratification and spatial access inequality, ultimately constructing a longitudinally grounded village economic typology as a basis for differentiated regional development policy. The novelty of this study lies in two contributions: in regional economics, it introduces longitudinal k-means clustering with explicit cluster transition mapping to track the directional dynamics of village hierarchy, revealing not merely that inequality exists, but whether villages are ascending or descending; in tourism geography, it provides village-scale longitudinal evidence that mono-nodal tourism concentration is associated with deepening spatial polarization rather than distributional diffusion.

METHOD

This study employed an exploratory unsupervised learning design using the K-Means algorithm for clustering analysis. Although K-Means is sensitive to outliers and lacks an inherent mechanism for determining the optimal number of clusters (Anggraini et al., 2026) , it was selected for its ability to capture regional homogeneity through interpretable cluster centroids, enabling the delineation of spatial development typologies (Yu & Luo, 2024). The research methodology pipeline can be seen in Figure 1.

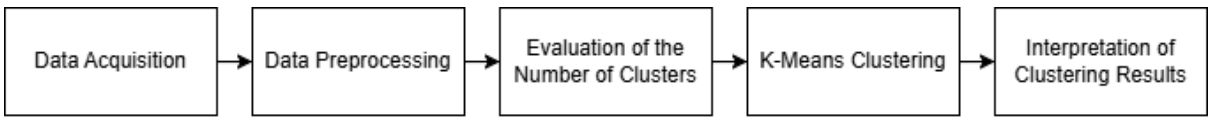

Figure 1. Research methodology pipeline

This study utilized a secondary data obtained from publications by the Badan Pusat Statistik (BPS) of Gianyar Regency from the annual "Kecamatan Dalam Angka" publications for the 2021–2023 period, covering 70 village units per year. Variable selection and theoretical justification for each dimension are established in the Introduction.

Data preprocessing included data cleaning using Z-score outlier detection ($|Z| > 3$), with identified outliers treated through Winsorisation at the 5th and 95th percentiles. Features were then aggregated into composite measures representing total financial facilities, total trade facilities, and total tourism facilities. To address potential concerns regarding multicollinearity and feature redundancy, a Pearson correlation matrix analysis was conducted, with all pairwise correlation coefficients falling below the conventional threshold of $r = 0.90$, confirming that each dimension captures a substantively distinct aspect of local economic structure without significant linear overlap. RobustScaler normalization was applied to all variables to reduce the influence of extreme values and ensure balanced contributions to the clustering solution.

The optimal number of clusters k was determined through a combined evaluation of the Elbow Method, the Silhouette Coefficient, and the Davies-Bouldin Index (DBI), across k = 2-10. Repeated-runs stability analysis was conducted over 500 independent initializations per annual model using K-Means++ seeding, evaluated via pair-stability and the coefficient of variation (CV%) of within-cluster inertia. For 2021, pair-stability was relatively low at 69.77% with an inertia CV of 0.17%. For 2022, pair-stability improved to 88.24% with a CV of 0.70%. For 2023, pair-stability further increased to 93.58% with an inertia CV of 0.08%. Overall, these results suggest a progressive improvement in clustering stability across years.

To capture temporal dynamics across 2021–2023, separate K-Means models were estimated for each annual cross-section, with cluster labels interpreted via centroid profiles. Inter-cluster differences were validated using Kruskal-Wallis H-tests across all five dimensions, followed by post-hoc Dunn tests with Bonferroni correction. Distributional inequality was quantified using the Gini coefficient, Coefficient of Variation, Theil T, and Atkinson index, alongside Max/Min centroid ratios. Year-over-year membership transitions were tabulated and the Adjusted Rand Index computed for each consecutive period to assess structural stability.

RESULTS AND DISCUSSION

Results

The Elbow Method identified k = 5 as the point of diminishing returns in within-cluster variance reduction, while the Silhouette and DBI consistently indicated k = 2 as the statistically optimal solution across all three years. k = 2 was deliberately rejected because a binary partition collapses the structurally distinct transitional tier central to detecting the bifurcation dynamics this study examines. k = 5 produces fragmentation beyond what village-scale administrative data can meaningfully distinguish. k = 3 was selected as a deliberate trade-off between statistical optimality and theoretical-policy interpretability, consistent with three-tier stratification widely employed in regional development literature. Silhouette scores at k = 3 remain the second-highest across all values tested (can be seen in table 1), and their progressive improvement indicates genuine structural sharpening of economic differentiation.

Table 1. Silhouette score and dbi result

K	SS 2021	SS 2022	SS 2023	DBI 2021	DBI 2022	DBI 2023
2	0.707	0.708	0.704	0.478	0.473	0.436
3	0.341	0.361	0.446	1.052	1.034	1.015
4	0.262	0.282	0.422	1.108	1.097	0.881
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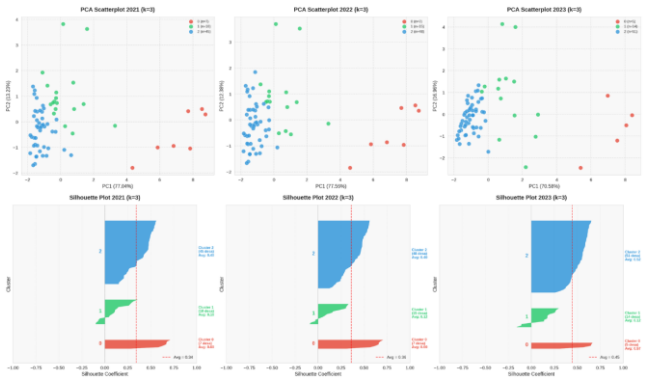

Figure 2. PCA scatterplot and silhouette plot (2021-2023)

The first two principal components explained 87.5%, 88.9%, and 90.3% of total variance in 2021, 2022, and 2023 respectively (Figure 2). The resulting spatial distribution reveals a stark geometric divide rather than a smooth developmental continum. A massive, tightly packed cluster 2 dominates the lower end of the primary axis, standing completely disconnected from the small, highly isolated cluster 0 located at the extreme high end. Squeezed between these two extremes is the cluster 1. Cluster 0 consistently records the highest scores, confirming its status as a highly cohesive and structurally isolated elite tier. Interestingly, cluster 2 shows significant improvement in its cohesion over time. Conversely, cluster 1 maintains weak scores, including some negative values.

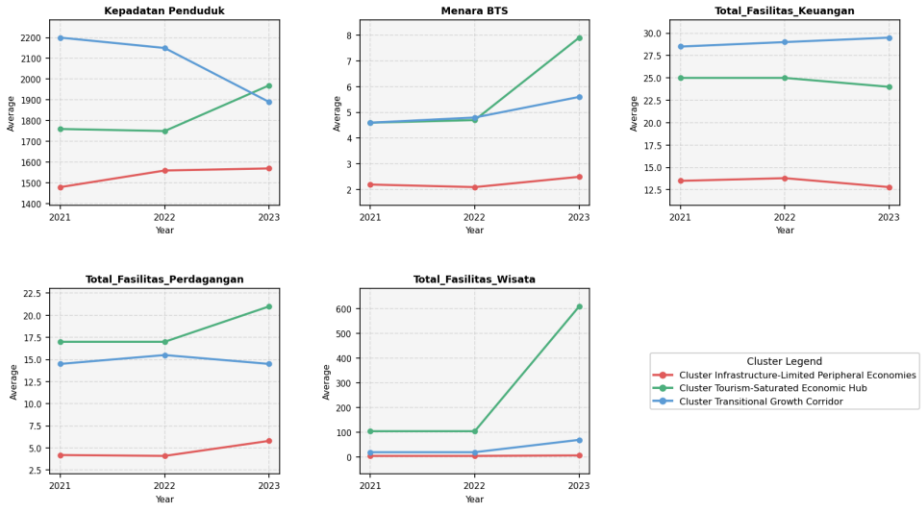

Figure 3. Centroid trajectory across 2021-2023

Figure 3 presents the centroid trajectory of all five dimensions across the 2021–2023 period. Cluster 0 is identified as the Tourism-Saturated Economic Hub because it demonstrates the strongest acceleration in tourism-related facilities by 2023, accompanied by continuous improvements in trade activity and digital infrastructure. This trajectory indicates a highly concentrated pattern of economic development in which tourism functions as the primary catalyst for broader regional growth. Cluster 1 is classified as the Transitional Growth Corridor, reflecting its consistently high concentration of financial institutions despite relatively modest tourism development. The centroid pattern suggests an intermediate stage of regional transformation, where financial capacity has expanded more rapidly than tourism-related economic activities, resulting in a development profile that remains transitional rather than fully diversified. Cluster 2 is designated as the infrastructure-Limited Peripheral Economies, as it consistently records the lowest centroid values across all five dimensions throughout the observation period. This pattern reflects persistent structural limitations in economic activity, tourism capacity, accessibility, and supporting infrastructure, indicating that these regions continue to experience slower development and weaker integration into broader regional economic dynamics.

The distribution of each cluster reveals a clear structural polarization dynamic. The peripheral cluster expanded steadily from 45 villages (64.3%) in 2021 to 51 (72.9%) in 2023, largely absorbing villages from the transitional cluster, which contracted from 18 (25.7%) to 14 (20.0%). The hub cluster remained exclusive, declining marginally from 7 to 5 villages (7.1%) by 2023. No village achieved upward reclassification to hub cluster across either transition period, suggesting that Gianyar's tourism economy is trending toward a bifurcated structure.

The Kruskal-Wallis results reveal a consistent pattern across 2021–2023, with total financial institutions, trade facilities, tourism facilities, and BTS towers remaining statistically significant at $p < 0.001$ across all three years, while population density proved unstable as a differentiator, significant only in 2021 ($H = 10.079$, $p = 0.007$) but non-significant in 2022 and 2023. Post-hoc Dunn Test results confirm that the infrastructure-Limited Peripheral Economies (ILPE) cluster differs significantly from the Transitional Growth Corridor (TGC) ($p < 0.001$ across nearly all variables and years) and from the Tourism-Saturated Economic Hub (TSEH) ($p < 0.01$ in most cases), whereas pairwise comparisons between the TGC and the TSEH consistently yield non-significant results ($p = 0.158–1.000$). Among all variables, tourism facilities produced the highest H-statistics throughout the observation period and were the only variable for which both the ILPE vs. TGC and ILPE vs. TSEH pairs attained significance at $p < 0.001$ consistently, while BTS tower infrastructure exhibited an emerging differentiation between the peripheral and hub clusters in 2023 ($p = 0.021$), suggesting accelerating digital infrastructure investment in tourism-dominant villages during the post-pandemic recovery.

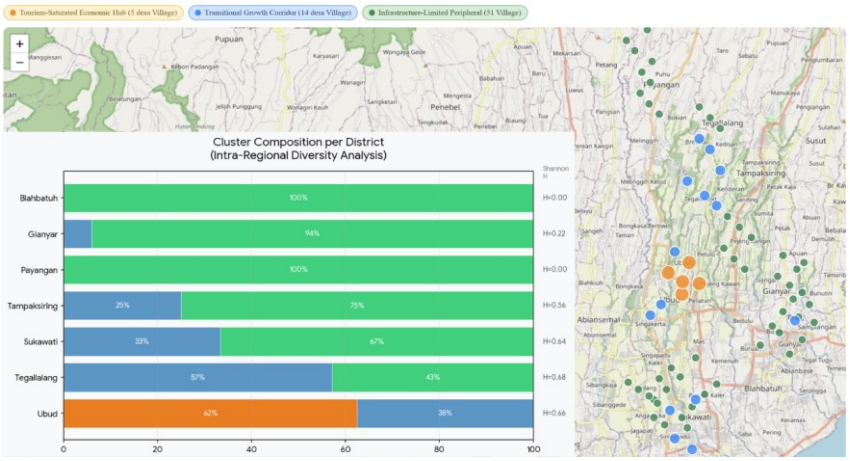

Figure 4. Spatial distribution and cluster composition (2023).

Spatial distribution (Figure 4) reveals highly asymmetric cluster compositions across districts. Ubud concentrates all hub villages alongside 38% transitional villages; Tegallalang leads non-hub districts in transitional villages proportion (57%), followed by Sukawati (33%) and Tampaksiring (25%); while Payangan and Blahbatuh show no compositional diversity, with all villages classified as peripheral. These patterns suggest that developmental diffusion from the regional core may not be uniform, appearing to favor specific administrative corridors while leaving others with limited economic diversification.

Table 4. Tourism inequality indices 2021-2023

Cluster	Year	Gini	CV (%)	Theil T	Atkinson
Tourism-Saturated Economic Hub	2021	0.162	31.74	0.046	0.022
Tourism-Saturated Economic Hub	2022	0.158	31.13	0.044	0.021
Tourism-Saturated Economic Hub	2023	0.341	62.12	0.190	0.096
Transitional Growth Corridor	2021	0.343	67.31	0.196	0.094
Transitional Growth Corridor	2022	0.315	58.77	0.160	0.079
Transitional Growth Corridor	2023	0.350	64.10	0.198	0.100
Infrastructure-Limited Peripheral	2021	0.513	105.80	0.350	0.165
Infrastructure-Limited Peripheral	2022	0.478	91.74	0.286	0.141
Infrastructure-Limited Peripheral	2023	0.486	92.95	0.306	0.154

The maximum-to-minimum cluster ratio reveals a striking sectoral asymmetry. While physical access indicators suggest gradual regional equalization, this appears to contrast with a marked divergence in Gianyar's tourism sector. The Max/Min ratio for tourism facilities jumped from 20.03× in 2021 to 54.62× in 2023, suggesting that tourism infrastructure remains highly concentrated within a small cluster of villages.

Table 4 reports within-cluster inequality indices for tourism facility distribution across 2021–2023. The hub cluster's internal Gini rose from 0.162 to 0.341, accompanied by a CV increase from 31.74% to 62.12% and Theil T from 0.046 to 0.190, suggesting increasing differentiation as certain villages become more dominant within an already dominant group. The Transitional Growth Corridor's Gini moved modestly from 0.343 to 0.350, with Theil T ranging from 0.160 to 0.198, indicating limited structural change within this intermediate tier. The peripheral cluster's Gini remained consistently above 0.47, with CV ranging from 91.74% to 105.80% and Theil T from 0.286 to 0.350, reflecting that access to tourism facilities remains severely and persistently unequal even among villages with low aggregate tourism activity.

The Adjusted Rand Index declined from 0.76 (2021-2022) to 0.56 (2022-2023), reflecting an acceleration in tier membership change. Among the 11 villages that shifted classification in the latter period, eight moved downward from the transitional tier into the peripheral tier, while three moved upward from the peripheral into the transitional tier. Zero village attained Hub tier classification in either period. This directional asymmetry, occurring simultaneously with extraordinary tourism facility concentration in the hub tier, is consistent with a structural divergence pattern in which rapid hub scaling is associated with the declining ability of Transitional villages to sustain their classification.

Discussion

The trajectory across 2021–2023 reveals accelerating spatial bifurcation: tourism facility concentration deepens stratification rather than generating upward convergence among surrounding villages, with digital connectivity and financial access following the same centripetal pattern. As this gap widens, the threshold for competitive tier membership rises, making redistribution progressively more difficult even as regional tourism volumes expand. This pattern is consistent with Duranton and Puga's (2004) argument that localized externalities systematically advantage established nodes, and with Donovan et al. (2024) confirmation that agglomeration economies generate productivity advantages that persist robustly across decades and contexts.

Hirschman's (1958) proposition that polarization effects are transitional and that trickling-down forces will eventually prevail is challenged by the Gianyar pattern, where hub tier concentration intensified monotonically while transitional tier experienced net downward mobility, warranting a recharacterization of polarization dominance in mono-nodal tourism economies as a potential steady state rather than a precursor to trickling-down effects. Trickling-down transition requires peripheral accumulation to eventually close the gap with hub growth; the Gianyar pattern shows hub agglomeration compounding faster than peripheral territories can accumulate, structurally preventing that transition. Growth Pole Theory faces a mechanistically distinct challenge: where Perroux (1970) assumes hub growth improves viability conditions for surrounding territories through diffusion, the evidence suggests the opposite. Hub-tier facility and connectivity concentration raised the relative threshold for competitive cluster membership, producing structural exclusion through relative deprivation rather than absolute decline. As this threshold rose, new capital reinvested in hub-adjacent zones where agglomeration externalities were already established, bypassing transitional and peripheral tiers and compounding the hub's advantage each cycle, consistent with the net downward mobility observed across 2021–2023. Both qualifications converge on a structural

lock-in condition untheorized by either framework, suggesting a boundary condition under which spread-effect predictions become structurally inapplicable.

The longitudinal design of this study produces knowledge that prior cross-sectional approaches cannot. Zhao et al., (2023) establish that spatial heterogeneity in tourism concentration exists across villages, but their cross-sectional design captures only a static snapshot, making it impossible to determine whether that heterogeneity is deepening or reversing over time. Li et al., (2024) analyze tourism disparities at the prefecture level but do not extend to village-scale trajectories. Shi et al., (2022) identify tiered hierarchies but cannot determine whether peripheral positions are structural or progressive. The present study confirms that stratification exists, consistent with these prior findings, but extends that conclusion: Gianyar's economic hierarchy is not merely unequal but increasingly rigid, a trajectory these designs are constitutively unable to detect.

Zero upward mobility to the hub tier operationalizes what cross-sectional designs cannot produce: not static disparity, but dynamic exclusion, in which aggregate regional growth forecloses upward mobility rather than merely failing to distribute it. This conflicts with Chen et al., (2024), whose polycentric context produces welfare improvements across neighboring areas. The divergence is contextually explicable: polycentric systems distribute growth through multiple nodes, whereas Gianyar's mono-nodal structure concentrates entry cost escalation at a single attractor, bypassing surrounding villages entirely. This boundary condition, mono-nodal tourism concentration without redistributive coordination, limits the applicability of spillover-based findings and challenges the broader premise that sectoral expansion distributes benefits spatially, a premise whose empirical limits Zhang (2023) and Tripathi and Yenneti (2024) have documented at the regional level but which has not been operationalized at village scale within a longitudinal framework.

This study extends path dependence theory by specifying the mechanism and timeframe through which structural closure consolidates in mono-nodal tourism economies, dimensions left unspecified in Martin and Sunley's (2010) framework. Commercial viability threshold escalation, constitutes a lock-in pathway that observable within a three-year window, substantially shorter than the multi-decadal processes path dependence frameworks typically assume. This mechanism is contingent on a specifiable boundary condition: structural lock-in of this kind consolidates only under mono-nodal tourism intensification where no redistributive counterweight operates, a condition under which spread-effect predictions become inapplicable. Methodologically, employing longitudinal K-Means estimation with Adjusted Rand Index computation, transition tabulation, and multiple inequality indices shift the unit of inference from disparity magnitude to disparity trajectory, establishing a replicable template for village-scale tourism impact studies where the policy question concerns whether stratification is consolidating rather than how large it is.

The policy architecture must be tier-differentiated. For hub villages, where tourism facility concentration accelerated sharply across the observation period and internal cluster inequality widened considerably by 2023, policy responses should prioritize carrying capacity regulation, infrastructure load management, and investment redirection mechanisms that channel hospitality capital toward adjacent areas. For transitional villages, the predominant trajectory of downward reclassification into the peripheral tier confirms that their intermediate position is structurally precarious rather than a stable waypoint toward hub status; targeted spillover programs are therefore required, including supply chain integration with hub-tier hospitality operations, workforce development anchored in transitional villages, and preferential licensing arrangements that distribute accommodation capacity spatially. For peripheral villages, where tourism facility inequality remained severe and persistent while upward mobility to the hub tier was entirely absent, market mechanisms are structurally insufficient: state-led infrastructure equalization establishing minimum service thresholds for

digital connectivity and financial institution access is the appropriate institutional response, not as a stimulus for organic tourism growth but as a prerequisite for participation in non-tourism economic circuits less sensitive to the proximity dynamics governing visitor expenditure distribution.

This study has two limitations. The clustering solution is inherently influenced by the selection of variables, as the five composite dimensions are constructed from facility-based administrative indicators rather than direct measures of household income or welfare. In addition, although the clustering methodology reveals consistent associations between temporal development patterns and structural outcomes, it does not provide definitive evidence of causality. The proposed sequential mechanism is theoretically supported and aligns with the observed empirical patterns, yet confirmation of causal relationships requires more rigorous experimental or quasi-experimental approaches. Future research should prioritize causal identification of the threshold escalation mechanism using natural experiments or instrumental variable designs, incorporate household welfare and income-based indicators to validate infrastructure-derived stratification measures, examine spatial spillover effects to delineate the boundaries of hub influence, and extend comparative analyses to other mono-nodal tourism-dependent regions to determine whether the bifurcation dynamics observed in Gianyar represent a broader phenomenon or remain specific to the local context.

CONCLUSION

This study shows that tourism-driven development in Gianyar Regency (2021–2023) intensified spatial polarization rather than fostering inclusive growth, as village hierarchies became more rigid and tourism activities remained concentrated in established hubs. By combining longitudinal K-Means clustering with cluster stability and inequality analyses, the study extends regional disparity assessment from static measurement to the identification of dynamic spatial trajectories, demonstrating how mono-nodal tourism development reinforces cumulative divergence and long-term spatial lock-in. These findings highlight the importance of differentiated development strategies, including investment reorientation in core tourism areas, stronger economic linkages for transitional villages, and infrastructure improvement in peripheral areas. Although the analysis is limited to facility-based administrative indicators and does not establish causality, it provides a robust empirical basis for understanding tourism-induced spatial restructuring. Future research should employ causal analytical approaches, incorporate household welfare indicators, and examine the generalizability of these patterns across other tourism-dependent regions.

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