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Research Article

Polycentricity in Bandung 2025: A Spatial Analysis Integrating Bootstrap Methods and Sustainable Urban Policy

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Abstract

Urban development in many metropolitan regions is shifting from monocentric to polycentric structures, offering pathways toward more sustainable, equitable, and resilient cities. This study analyses the polycentric transformation of Bandung's Central Business District (CBD) using an integrated spatial and econometric approach. Data from 118 observation points across seven commercial corridors were examined through Local Indicators of Spatial Association (LISA) and bootstrapped regression with 10,000 resamples to improve reliability. The results reveal a significant spatial clustering pattern (Moran's I = 0.482, $p < 0.05$) and identify four functional clusters: Primary Commercial Nucleus, Strategic Corridor, Sub-Centre Embryo, and Low-Intensity Zone. Regression analysis demonstrates strong explanatory power ($R^2 = 0.821$), with cultural and locational factors exerting the most decisive influence, followed by economic activity and accessibility. In contrast, government policy shows a negative association, suggesting that regulatory complexity can constrain growth and spatial agglomeration. These findings indicate that Bandung's polycentric evolution is shaped more by cultural vitality and market dynamics than by top-down policy intervention. The study contributes empirical evidence to debates on urban polycentricity and provides practical insights for property valuation, spatial planning, and taxation frameworks. By linking the results to the United Nations Sustainable Development Goal 11, the research highlights polycentric development as a viable strategy for promoting inclusive and sustainable metropolitan futures..

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1. Introduction

Urban development in recent decades has been marked by a structural shift from monocentric to polycentric forms, where multiple centres function as interconnected hubs of economic, social, and cultural activities (Derudder et al., 2022). Classical examples can be found in European regions such as the Randstad and Rhine-Ruhr, while in North America, suburban expansion and transit-oriented policies have further reinforced polycentric metropolitan patterns (OECD, 2021). In Asia, similar transformations are evident, driven by large-scale infrastructure investments and governance reforms (Chen & Liu, 2021). The case of Shanghai demonstrates how cultural economies and heritage-based creative districts generate multi-nodal CBDs (Zhang & Chen, 2022), while studies in Southeast Asia confirm that cultural heritage and place identity are critical to sustaining polycentric urban forms (Tan & Nguyen, 2023).

Alongside cultural forces, state intervention has emerged as another determinant shaping polycentric structures. In China, spatial planning policies and administrative reforms have played a decisive role in fostering new sub-centres (Liu & Wang, 2023). However, the relationship between policy frameworks and organic market-driven dynamics is often contested. For example, in Southeast Asia, governance fragmentation and uneven implementation complicate

outcomes, as illustrated in Greater Jakarta, where sub-centres developed partly as functional extensions of the central nucleus under infrastructural and market pressures (Surya et al., 2023). These comparative insights suggest that polycentricity is not a uniform trajectory but the product of locally specific interactions between culture, governance, and economy.

The growing attention to polycentricity also reflects its perceived contribution to sustainable development. Scholars highlight its potential to limit urban sprawl, promote accessibility, and distribute economic opportunities more evenly across metropolitan areas (Jansen & De Lange, 2020). Despite these promises, empirical assessments remain challenging due to conceptual ambiguities in defining centres and methodological limitations in capturing spatial heterogeneity (Liu et al., 2022). Recent studies have called for integrative approaches that combine spatial statistics with policy-oriented analysis to provide more robust and comparable evaluations of polycentric development (Chen et al., 2023; Aziz et al., 2023).

Within this debate, Bandung represents a particularly relevant case. As part of the Jakarta–Bandung Mega-Urban Region, the city has evolved as both an educational and creative hub, characterized by substantial cultural capital and historical legacies (Firman & Setiawan, 2023). Earlier studies observed its transition from monocentric to polycentric structures (Mukhoriyah et al., 2021). However, these analyses remain primarily descriptive and neglect the role of spatial dependencies, regulatory complexity, and intangible cultural dynamics. Comparable research in Indonesian cities such as Yogyakarta (Raharjo & Pratiwi, 2022) and Surakarta (Aziz et al., 2023) similarly highlights the gap in integrating cultural economy and governance into empirical models of CBD transformation.

Anchoring the study within the United Nations Sustainable Development Goal 11 reinforces its broader relevance. Polycentric structures are directly aligned with the pursuit of inclusive, resilient, and sustainable cities by reducing over-reliance on single centres, encouraging spatial equity, and supporting cultural identity. Bandung's transformation, therefore, provides not only a context-specific case but also a valuable contribution to global debates on sustainable metropolitan planning. To address existing research gaps, this study employs a hybrid methodology that integrates spatial autocorrelation with bootstrapped regression, enabling a nuanced examination of how cultural, regulatory, locational, and economic variables collectively shape the emergence of polycentric CBDs.

2. Methods

2.1 Study Area and Data Collection

This study identified seven major commercial corridors in Bandung City as the subject of research. These corridors consist of Jalan Asia-Afrika, Jalan Dago, Jalan Merdeka, Jalan Naripan, Jalan Kepatihan, Jalan Cihampelas, and Jalan Cibadak. The selection of locations was based on preliminary findings indicating that these corridors have intense trade and service activities. Data was collected across all designated corridors. Overall, this study used 118 observation points distributed proportionally across each corridor, with an average of 15 points per corridor, to ensure representative coverage. QGIS software was used to extract initial spatial data from the OpenStreetMap (OSM) layer, providing a digital base map for projecting the geographical distribution of all observed locations. In April–June 2025, structured field observations and rapid surveys were conducted on 5–10 businesses in each corridor for qualitative data, including cultural and government policy variables. These surveys and observations were designed to measure sub-variable indicators that are not available in OpenStreetMap.

2.2 Variable Operationalisation

The analysis process began with the creation of seven independent variables derived from several initial sub-variable indicators. Each variable was operationalised through measurable indicators, with clear data sources and measurement techniques. Table 1 defines the main variables and examples of their indicators.

Table 1. Operational Definition of Variables

No	Variables and Definitions	Sub-Variable Indicators (Data Sources)	Measurement (Scale)
1	Number of Businesses: The density of business units in an area.	Number of business units in an area. (Field observation)	Direct count of business units within an area of 400m2 from the observation point. (Ratio)
2	Location: Proximity to established city centres.	1. Distance to the centre of the CBD (City Hall). 2. Building density. (OpenStreetMap, Field Observations)	1. Euclidean distance in metres. 2. Score of 1-5 based on observation (1: very high, 5: very low). (Ratio, Interval)
3	Accessibility: Improved accessibility that supports sustainability.	1. Types of public transport. 2. Road width. 3. Presence or absence of traffic congestion. (OpenStreetMap, Field Observations)	1. Number of types of transport available (numerical). 2. Road width in metres. 3. Score of 1-5 based on observation (1: congested, 5: free-flowing). (Ratio, Interval)
4	Land Price: The economic value of land.	1. Sales Value of the Taxable Object Valuation. 2. Indications of land price increases. (Government Publications, Surveys)	1. Sales Value Of The Taxable Object value per m² (in IDR). 2. Score of 1-5 based on interviews with business actors (1: significant increase, 5: decrease). (Ratio, Interval)
5	Economic Activity: The level of concentration of business and commercial activities.	1. Level of pedestrian traffic. 2. Presence of businesses open 24 hours. (Field observation)	1. Score of 1-5 based on observation (1: very crowded, 5: quiet). 2. Number of businesses open 24 hours. (Interval, Ratio)
6	Infrastructure: Availability of facilities supporting economic activities.	Road conditions and public facilities. (Field observations)	Score 1-5 based on observation (1: very good, 5: poor). (Interval)
7	Government Policy: The Impact of Regulations and Spatial Planning	1. Land use zoning. 2. Government incentives. 3. Impact on business operations. (Policy Documents, Surveys)	1. Compliance with the Spatial Planning Regulation (score 1-5, 1: highly compliant, 5: non-compliant). 2. Presence or absence of incentives (binary: 0/1). 3. Score 1-5 based on survey (1: highly facilitating, 5: highly hindering). (Interval, Nominal)

8	Culture: Unique characteristics that attract public interest.	1. The existence of cultural sites. 2. Cultural activities. 3. Efforts to integrate local culture. 4. Cultural appeal. (OpenStreetMap, Observation, Survey)	1. Number of cultural sites within an area of 400m2. 2. Frequency of cultural activities (score 1-5). 3. Number of businesses with cultural elements. 4. Score 1-5 based on survey (1: very interesting, 5: not interesting). (Ratio, Interval)

Source: Analysis, 2025

To construct robust variables, a data synthesis process was applied through three stages:

1. Indicator Selection: Relevance and data availability were used to select sub-variable indicators. Indicators with a strong correlation to the main variable are retained, while unnecessary indicators are eliminated. Due to the limited number of indicators, this selection process does not employ statistical methods such as PCA, but rather relies on a review of the literature and researcher consensus.
2. Data Transformation: For ratio indicators (such as the number of businesses, location, and land prices), the natural logarithm (ln) transformation is used to normalize all indicators of different scales. For interval indicators, the ln transformation can be interpreted as elasticity.
3. Aggregation: For each variable, the transformed indicators are aggregated using a simple average to form a single composite score. For example, the score for the 'Culture' variable is the average of all normalised cultural indicators. Weighting is not applied due to the lack of a strong theoretical basis for assigning different weights to indicators.

Limitations in Indicator Aggregation: The author acknowledges that the use of simple averages without weighting is a limitation, despite reliability tests indicating adequate internal consistency. The relative contribution of each indicator to its theoretical construct can be determined through techniques such as the Analytical Hierarchy Process (AHP) or loadings from Principal Component Analysis (PCA). This method can be used to determine the ideal weighting. The use of these more sophisticated weighting techniques is an important topic for further research.

2.3 Analytical Framework

To test the influence of the seven independent variables on CBD formation, the quantitative analysis framework began with multiple regression modelling using SPSS. To improve the reliability and robustness of the estimates, particularly in addressing violations of the standard distribution assumption, model uncertainty, heteroscedasticity, spatial dependence, and parameter inaccuracy, this study employs a bootstrap regression procedure with 10,000 samples. Recent developments in spatial econometrics indicate that the bootstrap approach can provide more accurate uncertainty estimates for spatial model parameters. This supports the use of this method (Liu et al., 2022; Suh & Lee, 2023). This method has been tested to improve model strength and handle the complexity of urban spatial data. It has also been used in a recent study (Zhang & Li, 2021). Furthermore, the non-standardised residuals generated from the regression model are sent for spatial dependency analysis.

The Local Indicators of Spatial Association (LISA) method is employed in the R software for spatial dependency analysis to identify statistically significant spatial clusters ($p < 0.05$), which are then visualized in LISA cluster maps (Chen, 2024). The LISA method was chosen for its proven ability to identify spatial cluster patterns and outliers, as well as being supported by recent theoretical advances in spatial dependency analysis. This methodology typically employs cross-platform workflows, such as SPSS, QGIS, and R, to integrate statistical analysis, spatial modeling, and residual diagnostics capabilities. This hybrid method enables the quantification of factors that determine CBD formation, providing a comprehensive understanding of its spatial manifestations.

2.4 Data Analysis and Model Assumption Testing

To demonstrate the strength and practical relevance of the relationships tested, this study utilised regression analysis reporting standardised effect sizes (β) and the partial contribution of each predictor (f2). To find statistically significant spatial clusters, additional spatial dependency analysis was performed in R software (version 4.5.1) using the spdep package (version 1.3-13) and the Local Indicators of Spatial Association (LISA) method. Model assumption checks included tests for linearity, homoscedasticity, multicollinearity (with VIF < 5), and residual independence through Moran's I and Lagrange Multiplier tests. To test model robustness, alternative specifications, spatial weight variations, and leave-one-corridor-out sensitivity tests were used. To avoid p-hacking and ensure transparency in reporting results, all variables specified in the research design are reported, including those with insignificant results.

3. Results, Analysis, and Discussions

3.1 Spatial Patterns and Cluster Identification

When these findings are incorporated into discussions about polycentricity worldwide, they reveal Bandung's unique position and open up new perspectives. The dynamics in Bandung are more in line with the narrative of organic (bottom-up) growth found in several Latin American and European metropolitan areas. The dominant narrative in China emphasises the strong role of state intervention (top-down) in the formation of polycentricity (Chen et al., 2023; Cheng & Shaw, 2017). The most dominant variables, 'Culture' (elasticity 12.3%) and 'Economic Activity', with a negative correlation with the 'Government Policy' variable, underline the idea that the polycentric transformation in Bandung is more a result of market forces, society, and unique local characteristics. The results not only reinforce the idea that the phenomenon of polycentricity is universal but, more importantly, confirm that the manifestation of this phenomenon is greatly influenced and shaped by the local context, including government structure, economic power, and cultural capital. Bandung's unique multi-centre development model is a result of its context as both a 'creative city' and a city of education, with limited land available in the centre.

A quantitative analysis of the spatial structure of the CBD in Bandung shows a pattern of non-random spatial dependence. The initial analysis began by tracking the geographical distribution of all locations, which showed that Bandung's seven main corridors had the most economic activity.

Figure 1. Map of Observation Locations in Bandung City

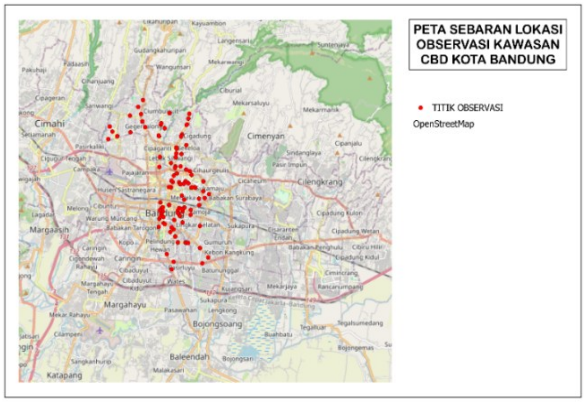
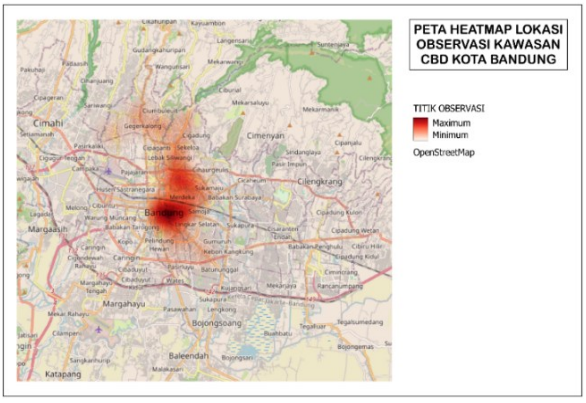


Figure 2. Heatmap of Economic Activity Intensity in Bandung City's Central Business District



Source: Analysis, 2025

Observation points are scattered across seven main corridors in Bandung City, as shown in Figure 1. Global spatial autocorrelation testing yielded a Moran's I index of 0.482 ($p < 0.05$), indicating that economic activity exhibits a significant tendency to be clustered geographically.

Figure 2 shows a heat map depicting the intensity of economic activity based on kernel density estimates. Areas with the highest concentration (hotspots), mainly in the city centre, are shown in red, and areas with the lowest

concentration are shown in white. This heat map visually illustrates this clustering pattern. This heat map confirms the clustering pattern found through Moran's I analysis.

LISA analysis was used to dissect spatial heterogeneity at the local level. Based on the spatial autocorrelation function framework (Chen, 2021), this study identified and described four statistically significant spatial cluster categories. These categories are:

1. Primary Commercial Nucleus (High-High): The established commercial heart of the city, identified along the Asia-Africa Road, Braga Road, and around City Hall.
2. Strategic Corridor (High-Low): Areas of high economic value bordering less intensive areas, such as along Merdeka Road.
3. Sub-Centre Embryo (Low-High): Indicates the emergence of secondary growth centres in locations such as the Simpang Dago and Cihampelas Road corridors, characterised by a concentration of creative businesses, cafes, and campuses.
4. Low-Intensity Zone (Low-Low): Transition areas with low economic activity, typically located on the outskirts of corridors, such as Cibadak Road.

In addition, kernel density heatmap analysis provides geographical precision for identifying the epicentre of economic activity, as identified through LISA. According to this study, the polycentric structure of Bandung City consists of:

1. The central CBD core, coinciding with the Primary Commercial Nucleus (HH). This centre is located between Jalan Asia-Afrika, Jalan Braga, and Alun-Alun (coordinates: -6.921093, 107.606433). This area is the city's established economic centre and has the highest business density.
2. The Secondary CBD Centre is aligned with the Embryonic Sub-Centre cluster (LH). This centre is located on Jalan Riau towards Dago. Its location is -6.906934, 107.610581. This area exhibits significant economic activity and serves as a supporting center. Organic dynamics such as creative activities and proximity to education drive this activity.

The identification of the coordinates of these two centres reinforces the findings of the LISA analysis while providing crucial geographical clarity for urban planners and policymakers in designing and managing the polycentric metropolitan spatial structure of Bandung.

Figure 3. Local Moran's I Cluster

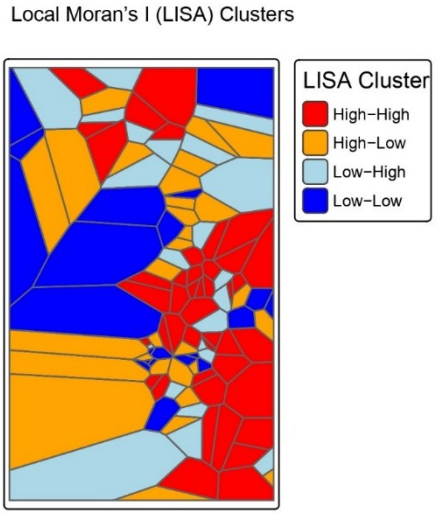
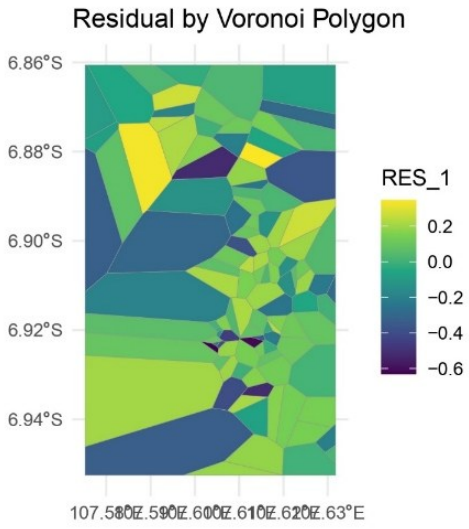


Figure 4. Residual by Voronoi Polygon



Source: Analysis, 2025

The LISA cluster map for economic activity in Bandung City is shown in Figure 3. Four statistically significant ($p < 0.05$) spatial clusters were found on this map based on Voronoi polygon analysis. High clusters (HH) in red indicate primary commercial nuclei where high-activity areas surround high-activity areas; low clusters (HL) in pink indicate strategic corridors where low areas border high areas; and low clusters (LH) in light blue indicate sub-centre embryos where areas This map not only confirms the polycentric pattern, but also provides geographical precision for locating centres of economic activity.

The Voronoi polygon map of regression residuals is shown in Figure 4. Each polygon shows the area of influence of each observation point. Specific colours indicate residual values: red indicates positive residuals in an under-predicting model, and blue indicates harmful residuals in an over-predicting model. This visualization helps identify spatial patterns of variation that the regression model does not explain. It may reveal unmodelled spatial dependencies or additional components not covered in the model.

3.2 Determinants of CBD Formation

With 10,000 samples, multiple regression modelling using the bootstrap technique produced a model with very high explanatory power (R2 = 0.821). The results of this modelling are presented in Table 2 below.

Table 2. Multiple Regression Results with Bootstrap for CBD Development Determinants

No	Variable	B	Sig.	BCa 95% CI	Interpretation
1.	(Constanta)	-2.013	<.001	[-2.590, -1.577]	-
2.	Ln_Lokasi	0.174	<.001	[0.083, 0.262]	Proximity to the traditional city centre is still very significant
3.	Aksesibilitas	0.111	<.001	[0.077, 0.138]	Proximity to major transport links enhances the appeal of a location
4.	Ln_Harga Tanah	0.060	0.082	[-0.007, 0.132]	Land prices follow business concentration
5.	Aktivitas Ekonomi	0.122	0.001	[0.055, 0.181]	High business density encourages agglomeration
6.	Infrastruktur	0.077	0.005	[0.025, 0.133]	Adequate infrastructure strengthens economic vitality
7.	Kebijakan	-0.106	<.001	[-0.148, -0.043]	Strict regulations and complex licensing procedures can stifle growth.
8.	Budaya	0.123	0.002	[0.059, 0.205]	Areas with unique cultural value and atmosphere attract investment and visitors
	R^2	0.821			The model explains 82.1% of the variance in CBD development.

Source: Analysis, 2025

To understand the magnitude of each variable's influence in greater depth, the resulting multiple regression equation is as follows:

Regression Equation (Log Model):

Ln(JumlahUsaha) = -2.013 + 0.174*Ln_Lokasi + 0.111*Aksesibilitas + 0.060*Ln_HargaTanah + 0.122*AktivitasEkonomi + 0.077*Infrastruktur - 0.106*Kebijakan + 0.123*Budaya

The dependent variable, the number of businesses, and the independent variables, location and land price, are used in this model through a natural logarithm (ln) transformation. This transformation allows regression coefficients to be interpreted directly as elasticity or semi-elasticity. This provides an easy understanding of the percentage reaction of the number of businesses to changes in explanatory variables. The interpretation of the results is as follows:

1. Elasticity (Variables in log form): For the variables Ln_Location and Ln_LandPrice, the coefficients represent elasticity. Example: The coefficient of Ln_Location of 0.174 indicates that for every 1% increase in the location factor score (e.g., proximity to a traditional centre), the number of businesses is expected to increase by an average of 0.174%, ceteris paribus (assuming other variables remain constant).
2. Semi-Elasticity (Variables in Linear Form): For linear variables, such as Accessibility, economic activity, Infrastructure, Policy, and Culture, the coefficients represent semi-elasticity. Example: A Culture coefficient of 0.123 indicates that for every one-unit increase in the culture score, the number of businesses is expected to increase by 12.3% (0.123 * 100%), assuming other variables remain constant. Similarly, the Policy coefficient of -0.106 indicates a 10.6% decrease for every one-unit increase in the policy barrier score.

This interpretation reinforces the finding that, in addition to economic and location factors, culture is a powerful driver of space productivity (each unit increase in the culture score increases the number of businesses by 12.3%). In comparison, restrictive policies have the potential to be a significant obstacle to economic activity growth in Bandung's CBD (each unit increase in the policy barrier score decreases the number of businesses by 10.6%).

The use of bootstrap regression with 10,000 resamples and a 95% BCa confidence interval not only increases the reliability of parameter estimates against potential violations of distribution assumptions but is also explicitly designed to capture the uncertainty inherent in interdependent spatial data (Liu et al., 2022). This procedure provides a more robust foundation than conventional regression methods. Empirically, narrow confidence intervals that do not include zero (such as for Accessibility [0.077, 0.138]) not only indicate high estimation precision but also confirm the statistical significance of these variables. Conversely, wider confidence intervals that include zero (such as for Ln_Land Price [-0.007, 0.132]) indicate greater estimation uncertainty and are consistent with a marginal level of significance ($p = 0.082$). Thus, this approach ensures that the resulting statistical inferences are more reliable for policy decision-making, thereby strengthening the validity of the findings and confidence in the interpretation of the research results.

3.3 Organic Polycentric Dynamics and the Role of Policy in the Context of Sustainability

The identified association between spatial analysis and regression is consistent with the proposition that observed spatial clustering can be understood as a manifestation of economic agglomeration forces. The dominance of the Economic Activity variable is empirically consistent with classical urban economic theory, in which the concentration of business units acts as a magnet, attracting more activity and creating a pattern consistent with a self-reinforcing growth cycle.

When placed in dialogue with the existing literature, these findings provide important insights. In contrast to the findings of Chen et al. (2023), which emphasise the role of state intervention, and the studies of Cheng & Shaw (2017) and Wen & Tao (2015), which underline the effectiveness of a top-down approach in polycentric planning in China, the patterns of association in this study are more consistent with the narrative that organic market dynamics (bottom-up) market dynamics are the main driving factor of polycentricity in Bandung. This pattern is reflected in the dominance of the Culture and Economic Activity variables, which represent the societal power and market influence.

Furthermore, the significant negative association of the Government Policy variable suggests that regulatory complexity has the potential to discourage economic activity growth—an aspect often overlooked in the discourse on polycentricity, which is dominated by narratives of positive top-down intervention. These findings may reflect more than just a planning-implementation gap at the local level (Hakim et al., 2021), but are also a manifestation of broader governance and policy coordination challenges inherent in the development of polycentric metropolitan areas. As identified by Setiawan & Firman (2023) in their recent study in the context of the Jakarta-Bandung Mega-Urban Region, fragmentation of authority and a lack of policy integration between jurisdictions can create regulatory uncertainty that actually hinders organic dynamics and investment, which in this study proved to be the primary driver of Bandung's polycentricity.

3.4 Sustainability through Sub-Centre Development: Evidence and Opportunities

Theoretically, the identification of the 'Sub-Centre Embryo' (Low-High) cluster can be seen as preliminary evidence consistent with the concept of sustainable urban evolution. This finding not only reinforces the theoretical framework but also aligns with the results of a study by Fernández-Maldonado et al. (2014) in Latin American metropolitan areas, which confirmed that identifying secondary sub-centres is a critical step in analyzing and planning polycentric metropolitan spatial structures. These findings are also in line with the results of a study by Mukhoriyah & Arifin (2022) conducted in the Greater Bandung Metropolitan Area, which shows that land prices are not only determined by traditional accessibility factors, but also by the formation of economic activity clusters that shape polycentric patterns. The location and characteristics of these clusters can be hypothesised as the result of spatial spillover effects, where pressure and density in the primary nucleus correlate with the emergence of secondary centres in locations that have their own advantages (close to campuses, creative atmosphere). Methodologically, the integration of LISA and bootstrap regression has proven capable of capturing this complexity, offering a more robust analytical framework than approaches that ignore spatial dependencies. However, to confirm the causal relationship and temporal dynamics of this spillover mechanism, further longitudinal research is needed. The development of these centres can contribute significantly to the sustainable development goals of Bandung by:

1. Reducing Environmental Burden: Shortening travel distances and reducing dependence on private vehicles to reach the city centre, which in turn can reduce carbon emissions.
2. Promoting Economic Equity: Spreading growth centres and employment opportunities, reducing spatial disparities between the centre and the periphery.
3. Preserving Local Character: Strengthening the cultural and creative identity of neighbourhoods (as seen in Dago and Cihampelas) can prevent the homogenisation of urban spaces.

3.5 Implications of Sustainable and Differentiated Policies

Based on the identified association patterns, the policy implication is the need for a differentiated approach based on cluster typology to achieve sustainability goals:

1. Primary Commercial Nucleus (HH): Policies should focus on demand management and conservation, such as congestion management, parking, and preservation of historical and cultural assets to maintain long-term attractiveness and sustainability.
2. Sub-Centre Embryo (LH): Proactive policies and integrated incentives are needed to facilitate sustainable and inclusive growth. These strategic steps should include: (1) accelerating the development of sustainable supporting infrastructure, in the form of integrated public transport corridors connecting sub-centres, safe and comfortable bicycle and pedestrian networks, and the development of multifunctional green open spaces (RTH) that serve as the lungs of the city and social spaces for the community; (2) simplification of selective business licensing with preference given to businesses that apply environmentally friendly principles; (3) provision of fiscal and non-fiscal incentives for green buildings and sustainable investment; and (4) protection of the unique character and identity of the area, which is its main attraction. This policy must be supported by detailed zoning regulations and the establishment of green building technical standards to ensure consistency in implementation.

3. Strategic Corridors (HL) and Low-Intensity Zones (LL): Revitalisation and connectivity policies are needed to connect and spread the economic benefits from HH to LL, for example, through infrastructural improvements, incentives for renovation, and the development of green corridors. The negative impact of government policies requires immediate action through a comprehensive regulatory audit to remove barriers and restore the economic vitality of strategic areas.

3.6 Implications for Assessment Practices and Sales Value of the Taxable Object Policies

The findings of this study have direct and profound implications for commercial property valuation practices and the Sales Value of the Taxable Object policy in the polycentric city of Bandung. Until now, the mass appraisal approach to Sales Value of the Taxable Object has often been monocentric, facing challenges in applying market values (Susetyo et al., 2020; Juanda et al., 2021), and has not adopted more advanced spatial and machine learning methods to capture complex value dynamics (Rahayu & Saputra, 2023). Conventional approaches often fail to capture value dynamics driven by intangible factors and economic agglomeration. The finding that location and cultural factors are highly dominant in determining spatial productivity in Bandung aligns with the results of a study by Rahayu & Aziz (2022) in Surakarta, which also revealed that land value patterns are significantly influenced by the identification of organically formed sub-centres of activity. Similar findings regarding the gap between the Sales Value of the Taxable Object and market value in polycentric areas were also reported by Nugroho et al. (2024) in Yogyakarta, further confirming that the monocentric approach is outdated. The consistency of these findings across several Indonesian cities not only validates the study's results but also strengthens the urgent argument for implementing a polycentric and nationally differentiated property valuation approach, shifting away from the traditional monocentric paradigm.

First, this study provides an empirical and quantified value map. The findings regarding the strong influence of location and cultural variables on property values are consistent with the literature, which shows that property prices not only reflect physical characteristics but also capitalise on development policies and the intangible attributes of an area. This methodological approach, which integrates spatial variables, aligns with the latest developments in the mass appraisal literature in Indonesia, where spatial hedonic models, such as Geographically Weighted Regression (GWR), are being adopted for greater accuracy (Wibisono & Hidayat, 2022). The relationship between polycentric cluster formation and property values found in Bandung is consistent with the pattern revealed by Han (2005) in Singapore, where the identification of sub-city centres significantly influences the spatial clustering of property values. The most dominant Cultural and Location variables in this study indicate that commercial property values in Bandung are not only determined by physical access, but also by the unique character and identity of the area (place identity).

This calls for a more granular and differentiated assessment approach. For example, a shop house in the Braga (HH) area, which has historical value and a distinctive cultural atmosphere, should have a different base value than a shop house with similar physical specifications in a newly developed area, even though they are administratively located in the same trade zone. This granular approach aligns with calls to go beyond traditional location factors and incorporate cultural and environmental attributes into the valuation model (Permana et al., 2018), thereby strengthening the argument for applying a polycentric and differentiated valuation approach.

Second, the identification of Embryonic Sub-Centre (LH) clusters opens up opportunities for prospective appraisal. Areas such as Cihampelas and Dago, which show high growth potential but whose current property values are still ‘discounted’, need special attention. Directorate General of State Assets can utilise these findings and consider applying more sophisticated predictive modelling techniques, as proposed in recent studies (Rahayu & Saputra, 2023), to develop models that reflect the future value potential of an area, not just its historical value. This can prevent the underpricing of state assets and create a more equitable tax base as the area matures.

Third, the findings regarding the negative association of policy variables are an important caveat. The complexity of licensing and regulations associated with hampering economic activity is correlated with a decline in value. Therefore, the recommended regulatory simplification efforts will not only enhance the ease of doing business but also have the potential to increase the aggregate value of land and property in strategic areas, thereby expanding the tax base.

For the Directorate General of State Assets and the Directorate General of Taxes in the West Java region, the results of this study can serve as an academic basis for:

1. Updating the Land Value Zone (ZNT) with a polycentric approach, in which each sub-centre (HH and LH) has its own value weighting that reflects its unique determining factors.
2. Proposing the integration of qualitative indicators and spatial analysis methods (such as GWR) into the mass appraisal model, possibly through a scoring system or machine learning modelling (Rahayu & Saputra, 2023), to improve the accuracy of the Sales Value of the Taxable Object.
3. Providing input for the revision of the Bandung City Spatial Plan (RTRW) to officially recognise and strengthen the function of the Embryonic Sub-Centre (LH) area as a new growth centre, so that spatial planning and taxation policies can be aligned and mutually supportive.

3.7 Policy Implications and Recommendations for Further Research

Based on these findings, strategic recommendations are directed at two stakeholder groups:

1. For local government (Bandung City Government, West Java Provincial Government) and central government (Ministry of Finance's Directorate General of State Assets):
   a. Adopt differentiated spatial policies: Policies must move away from a one-size-fits-all approach. Policy formulas must be specific to each cluster: demand management and conservation policies for Primary Nuclei (HH), and proactive policy packages in the form of infrastructure acceleration, licensing simplification, and fiscal incentives for Sub-Centre Embryos (LH) to spur sustainable growth.
   b. Conduct a Comprehensive Regulatory Audit: Findings on the negative impact of policies demand immediate corrective action. A comprehensive regulatory audit is needed to identify and remove excessive and restrictive regulations, particularly in strategic corridors and sub-centre areas.
   c. Modernise the Property Assessment Approach and Sales Value of the Taxable Object Determination: For the Directorate General of State Assets and the Directorate General of Taxes of the Ministry of Finance, these findings provide a strong empirical basis for revolutionising the mass appraisal approach, as has been argued in various studies (e.g., Susetyo et al., 2020; Juanda et al., 2021). The concrete recommendations are:
      - Developing polycentric Land Value Zones, where each sub-centre (HH and LH) has its own value weighting that reflects its unique determinants (culture, location)
      - Integrating qualitative indicators (intensity of cultural activities, pedestrian traffic) into the assessment model through a scoring system, so that the Tax Object Sales Value can capture the intangible values quantified in this study.
      - Considering prospective assessments for high-potential LH areas, to avoid underpricing state assets and create a more equitable tax base.
2. For further research, future studies should be designed to capture causal and temporal dynamics. Two main approaches are suggested:
   a. Longitudinal Analysis: Use time-series data to track the evolution of spatial clusters and confirm the direction of causality of the identified relationships.
   b. More Complex Spatial Modelling: Applying methods such as Geographically Weighted Regression (GWR) to explore local variations in the relationships between variables, or Spatial Durbin Models (SDM) to more accurately quantify spillover effects.

Thus, this study not only contributes to academia but also provides an empirical roadmap that policymakers can directly adopt to transform spatial planning and land value policies in Bandung and other polycentric cities in Indonesia.

4. Conclussion and Recommendation

This study utilises a robust methodological integration between spatial analysis (LISA) and bootstrapped regression to map the polycentric structure and quantify the determinants shaping Bandung City's CBD. Three core findings are transformative both academically and practically: First, spatial analysis confirmed a non-random and concentrated

development pattern (Moran's I = 0.482), with the identification of four functional clusters: Primary Commercial Nucleus (HH), Strategic Corridor (HL), Sub-Centre Embryo (LH), and Low Intensity Zone (LL). This pattern is consistent with the proposition that organic evolution is driven by economic agglomeration and spatial spillover effects, whereby new growth centers emerge in response to saturation and dynamics in the primary nucleus. First, spatial analysis confirms a non-random and concentrated development pattern (Moran's I = 0.482), with the identification of four functional clusters: Primary Commercial Nucleus (HH), Strategic Corridor (HL), Sub-Centre Embryo (LH), and Low Intensity Zone (LL). This identification, supported by analytical developments in spatial autocorrelation functions (Chen, 2021), is consistent with the proposition that organic evolution is driven by economic agglomeration and spatial spillover effects, whereby new growth centers emerge in response to saturation and dynamics in the primary nucleus.

Second, an explanatory model with very high predictive power was generated from regression modelling reinforced with 10,000 bootstrap samples (R2 = 0.821). This analysis not only proved the validity but also measured the strength of influence of each component. The results show that the two most important predictors are culture (elasticity of 12.3%) and location (elasticity of 0.174%), followed by economic activity and accessibility. The results show that traditional physical and economic factors increasingly determine the value and productivity of Bandung City's space. Intangible factors such as regional identity and cultural characteristics are becoming increasingly decisive.

Third, and most importantly, are the results showing a significant negative correlation of government policy components. These results clearly demonstrate that regulatory complexity and licensing processes are correlated with a decline in economic growth. These results correct the standard narrative that usually emphasises only the benefits of policy intervention.

Overall, these results not only verify Bandung's polycentric structure but also inform us about how organic dynamics can be used to achieve sustainable development goals. As thoroughly researched by Li and Liu (2023), a well-managed polycentric structure is positively correlated with sustainability outcomes, including reduced travel distances, lower carbon emissions, and more equitable economic benefits. Therefore, Bandung's polycentric transformation should be viewed as a strategic opportunity and investment to build a low-carbon, resilient, and inclusive urban structure. The main contribution of this study is the strong empirical value map provided by the methodological integration of spatial analysis (LISA) and regression bootstrap, which is increasingly recognised in the spatial econometric literature (Suh & Lee, 2023; Liu et al., 2022). In future spatial and taxation policies, this map should be used to encourage sustainable practices such as the development of integrated public transport between sub-centres, the preservation of green open spaces, and incentives for green development. The polycentric sustainability literature empirically supports these practices. To capture causal and temporal dynamics, as well as local variations that are not accessible in this cross-sectional study, longitudinal approaches and more complex spatial modelling (such as Geographically Weighted Regression/GWR or Spatial Durbin Model/SDM) are highly recommended for further research. Therefore, it is hoped that polycentric development in Bandung will drive economic growth while creating spatial justice and environmental sustainability. This will make Bandung a model of sustainable metropolitanism in Indonesia.

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