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QUANTITATIVE SPATIAL ANALYSIS OF CLUSTER PATTERNS AND SPATIAL INTEGRATION IN THE CELUK CREATIVE DISTRICT, GIANYAR, BALI

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Abstract

Celuk Village in Gianyar Regency, Bali, has evolved organically into a prominent silver craftsmanship corridor, forming a unique creative economy ecosystem where production workshops, commercial galleries, and tourist interaction spaces coexist within an interconnected spatial hierarchy. This study employs a spatial quantitative approach to analyse distribution patterns, spatial relationships, and functional hierarchies among 70 silver workshops and galleries across a defined 6-month research period. Spatial point data were collected through GPS-based field surveys, validated with positional accuracy tolerance ≤ 3 m, and processed using QGIS software to perform Point Pattern Analysis (PPA) and Kernel Density Estimation (KDE). The analysis identifies clustering tendencies and spatial density hierarchies, revealing a linear aggregation pattern concentrated along the primary west–east corridor connecting Gianyar and Denpasar. Statistical spatial correlation was measured using Nearest Neighbour Index (NNI = 0.69), indicating clustered distribution, supported by strong positive spatial autocorrelation (Moran's $I = +0.89$, $p < 0.05$), confirming significant spatial dependence between neighbouring business units. To clarify the term functional mapping, field observations incorporated structured indicators of Building Function (production, exhibition, mixed use), Architectural Typology (traditional workshop, modern gallery, hybrid façade, adaptive building), and Activity Intensity Level (frequency of visible workers, visitor presence, façade permeability, sidewalk spill-out, and temporal peak markers). The findings demonstrate that spatial configuration in Celuk is shaped not only by economic efficiency and proximity, but also by symbolic cultural markers—such as temples and traditional ornaments—that reinforce spatial identity and distinguish the district from purely commercial corridors. While clustering supports collaborative resource sharing and visibility, the study also detects spatial imbalance between the main spine and peripheral lanes, signalling emerging commercial pressure and declining activity on secondary routes. For sustainable creative district growth, a scale-sensitive integrated spatial planning framework is recommended, applying thematic production–display–tourism zoning supported by community-based governance to maintain economic–cultural balance, walkability, and cultural authenticity. This research contributes empirical spatial metrics and a replicable methodological structure for developing culture-based creative districts in Bali and Indonesia.

Keywords: Celuk, Spatial Analysis, Industrial Clustering, Creative District

1. INTRODUCTION

The village of Celuk in Gianyar Regency, Bali, is widely known as a centre for distinctive silver craftsmanship and is an important part of the local creative economy ecosystem. (Wisudawati et al., 2023). The spatial layout of the area developed organically, with artisan workshops, galleries, and community residences coexisting within a single, interconnected cultural and economic ecosystem. (Widiantara, 2022). The main corridor of the village serves as the backbone for production, trade, and tourism activities, connecting artisans, local buyers, and tourists in an intensive circulation pattern. (Suardana & Sumantra, 2023). This village exemplifies how traditional culture, creative economy, and cultural tourism can interact harmoniously in the context of Bali, strengthening the region's identity as a creative destination. (Srayamurtikanti & Sunarto, 2022). The growth of tourism and the creative economy has gradually transformed Celuk into a creative hub that bridges traditional craftsmanship and the dynamics of the modern market. (Putu Ayu Sita Laksmi & Komang Adi Kurniawan Saputra, 2025).

Most studies on Celuk still focus on mapping the distribution of points and changes in settlement typology, thus failing to explore spatial relations between zones at the district level (Putu Ratih Pradnyaswari Anasta Putri et al., 2022). The district-based approach, which links craft clusters with the spatial structure of creative areas, has not yet been the focus of analysis, despite the latest CCI literature emphasizing the importance of cross-functional spatial patterns and structures. (Dellisanti, 2023). Recent literature highlights the significant role of spatial configuration in shaping cultural identity; however, its application in the context of the Celuk craft area has not been empirically elaborated. (Basri et al., 2025). On the other hand, cultural studies on Celuk silver craftsmanship emphasise the sacred dimension and tradition as determinants of identity, but have not yet systematically linked this to spatial configuration metrics at the regional scale (Suardana & Sumantra, 2023a). Research in Celuk primarily describes changes in typology and distribution patterns due to spatial dynamics, but has not yet modeled these changes as cultural tourism corridors with a network of production, display, and visitation functions (Widiantara & Dwijendra, 2022). In fact, studies on rural tourism in Bali highlight the importance of a cross-actor resource management framework at the village/regional level to understand the shift in land use from production to tourism. (Rosalina et al., 2023).

The latest findings on Bali's tourism policy highlight weaknesses in spatial planning enforcement and accommodation land expansion, which have implications for land use conflicts—but specific studies on Celuk remain scarce (Kerti et al., 2025). Literature on the sensitivity of overtourism in Bali also highlights disturbances in the quality of life and spatial functions, but this has not yet been translated into a diagnosis of micro-spatial conflicts in the Celuk craft corridor (Suyadnya et al., 2025). Existing research on Celuk tends to be descriptive in terms of patterns/typology, and has not yet produced a planning framework that integrates craft production, culture, tourism, and public space (Putu Ratih Pradnyaswari Anasta Putri et al., 2022). Conceptually, the CCI study emphasises the need for an integrated spatial approach to strengthening creative ecosystems. In the context of Bali, these findings align with the need for policy pathways that bridge culture, economy, and space; however, gaps in implementation persist in Celuk (Dellisanti, 2023).

Although various studies have examined the evolution of silver craft production and settlement typology in Celuk Village, most are still limited to point-based mapping and descriptive spatial analysis. These studies generally only identify clusters of artisans

and concentrations of workshops, but rarely extend their analysis to spatial relationships between zones at the regional level. As a result, the relationship between the physical structure of the region and the socio-economic networks that support the creative economy has not been fully explained. This limited understanding at the regional level hinders the formulation of comprehensive planning strategies to balance economic growth with cultural sustainability.

Another important gap relates to the lack of studies on the interaction between spatial configuration and cultural identity in the transformation process of Celuk. Although cultural authenticity and craftsmanship are recognised as key strengths in Celuk's creative character, explanations of how these intangible values are reflected in the spatial organisation of the village remain very limited. The interaction between the built environment, production activities, and social rituals has not been systematically analysed to reveal its contribution to the formation of spatial identity. Without this understanding, the risk of weakening cultural character and aesthetic homogenization increases as commercialization of the area intensifies. The process of transforming traditional artisan settlements into cultural tourism corridors has not been extensively mapped or conceptually explained. Various spatial conflicts have begun to emerge, such as overlapping land uses, reduced pedestrian accessibility, and the dominance of commercial functions along the main corridors. This situation indicates an imbalance between tourism expansion and the preservation of local communities' living spaces. However, few studies have examined this issue as part of a broader spatial system requiring coordinated intervention. Furthermore, there is currently no comprehensive spatial planning framework to guide the sustainable development of the Celuk creative district. Existing policies and community initiatives often operate independently, failing to integrate spatial, cultural, and economic dimensions in a unified manner. The absence of a comprehensive model limits Celuk's potential to develop as a sustainable creative district, where traditional crafts, cultural expression, and tourism development can grow harmoniously within a single planned space.

2. LITERATURE REVIEW

2.1 The Concept of Creative Districts

Creative districts are understood as spatial clusters of cultural and economic activities that reinforce each other, characterized by a distinctive mix of functions, walkability, and symbolic markers of space that shape the district's experience. Within the framework of creative city policy, strengthening spaces and networks between actors is key to converting cultural value into economic value without losing authenticity (G. Evans, 2009). Recent findings in the cultural and creative industries also confirm that the spatial concentration of CCIs (cultural and creative industries) is influenced by the heterogeneity of creativity and *filière* (value chains), resulting in different clustering patterns and spatial requirements across sectors (Dellisanti, 2023).

2.2 Morphological Theory and Spatial Identity

Understanding the relationship between form and behaviour at the neighbourhood scale rests on two theoretical foundations. First, space syntax explains how the configuration and integration of spatial networks influence activity intensity, route choice, and functional concentration (Hillier & Hanson, 1984). Secondly, the city image theory emphasises the role of paths, nodes, and landmarks in building the cognitive identity of an area, which is relevant when production corridors shift to cultural tourism

corridors. (Lynch, 1964). The combination of both provides a lens through which to read Celuk's transformation from a craftsmen's settlement to a visitor-oriented creative district.

2.3 Supporting Empirical Findings

Empirically, POI/GIS-based mapping research indicates that accessibility, infrastructure quality, and cultural continuity are correlated with the concentration of economic activities, including retail and crafts, resulting in hotspots that can be effectively managed through spatial planning strategies. (Fang et al., 2024). On a creative district scale, this concentration pattern requires differentiation between production, display, and tourism zones, along with clear circulation flows to avoid spatial conflicts and ensure a cohesive visitor experience (Dellisanti, 2023). In the context of Bali, studies of tourism villages emphasize the importance of community-based resource management and the integration of local cultural values in maintaining socio-ecological sustainability as tourism pressures intensify. Findings from two Balinese tourism villages emphasise the need for cross-actor strategies that integrate spatial planning, the creative economy, and cultural preservation to ensure that tourism benefits are equitable and identities are preserved (Rosalina et al., 2023).

Specifically, in Celuk, studies of changes in settlement typology and distribution patterns show a significant shift from traditional workshop-houses to more hybrid and commercial forms of space along the main corridor. Research by RUAS and JAZ highlights the impact of Denpasar's urban sprawl and the concentration of functions that necessitate corridor planning and the strengthening of the secondary space network (Widiantara & Dwijendra, 2022). The cultural-craftsmanship aspect highlights the "sacred" dimension and tradition of silver craftsmanship, which forms the basis of the region's identity and needs to be represented in the design of the space and visitor experience (Suardana & Sumantra, 2023b). As a methodological comparison, the study of the spatial distribution of traders (non-crafts) confirms the usefulness of kernel density analysis, nearest neighbour analysis, and spatial correlation for developing zoning and area service strategies (Hadibasyir et al., 2024).

In essence, the theoretical basis (creative city/district, space syntax, city image) and empirical evidence (GIS/POI, tourism village management, changes in Celuk's typology) together point to the need for a development model for the Celuk creative district that integrates production–display–tourism zoning, passable cultural route design, and community-based management to maintain economic–cultural balance (Graeme Evans, 2009).

3. RESEARCH METHODS

The research applies a spatial quantitative approach supported by field observation. The study was carried out within a 6-month research window, covering pre-survey preparation, spatial data acquisition, on-site documentation, GIS processing, and spatial morphology interpretation. This duration was determined to ensure temporal representativeness of spatial behaviour patterns in a creative economic district that is influenced by tourism cycles and production routines.

3.1 Data Collection

a. Spatial Mapping (GIS)

Geographical coordinate data from 70 workshops and silver galleries was collected through field surveys using GPS (Global Positioning System) devices. The

point data was then processed using QGIS software to produce spatial distribution maps, cluster patterns, and activity density levels.

- Sampling points were selected using an equal-interval corridor segmentation strategy along the main village spine (Celuk corridor), ensuring balanced spatial coverage.
- The collected longitude–latitude point dataset was validated through re-plotting accuracy checks (acceptable tolerance ≤ 3 meters' deviation) before GIS processing.
- Spatial data were processed in QGIS using: Point Pattern Analysis (PPA) to detect clustering tendencies (aggregation, dispersal, or randomness), Kernel Density Estimation (KDE) to produce heat-based activity concentration maps, Cluster classification via density quartile hierarchy (Q1 = very low, Q4 = very high activity concentration).

b. Field Observation

To remove the ambiguity of the term functional mapping, the field observations were structured using three primary spatial indicators. The first indicator is Building Function, which classifies each building based on its dominant economic role along the village corridor, namely as a space for production (workshop), exhibition (gallery/showroom), or mixed-use functions that integrate both. The second indicator is Architectural Typology, which identifies the physical character of buildings using key categories such as traditional workshops, modern galleries, hybrid façades that combine local and contemporary architectural expressions, and adaptive buildings that have undergone functional transformation to support commercial and tourism purposes. The third indicator is Activity Intensity Level, which evaluates the degree to which creative economic activities contribute to the formation of street space based on activity frequency, visitor presence, production rhythm, and functional engagement with corridor frontages, including whether business units activate adjacent sidewalks or public interfaces through product displays, access permeability, and visual–social interaction with the spatial circulation of the village.

3.2 Data Analysis

a. Spatial Analysis

Point Pattern Analysis (PPA) and Kernel Density Estimation (KDE) were used to identify spatial clusters and activity density hierarchies. These methods enable the mapping of areas with the highest concentration of creative economic activities, as well as the relationships between business units based on spatial proximity.

b. Kajian Morfologi Ruang

Morphological analysis was conducted through functional mapping to trace the spatial relationship between production areas, exhibition galleries, and tourist spaces. This approach helps explain how economic, cultural, and tourism activities are interconnected within the spatial structure of the Celuk area.

The combination of these two analyses provides a comprehensive understanding of the spatial integration process in the Celuk creative district, as well as a basis for formulating sustainable development strategies oriented towards a balance between economic function and cultural preservation.

4. FINDINGS AND DISCUSSION

4.1 Result

Silver businesses in Celuk Village also face various challenges. Data show that most craftsmen face significant pressure due to rising silver raw material prices, which directly impact their profit margins. In addition, declining consumer purchasing power and a shortage of skilled silver workers are factors that weaken the competitiveness of the local industry. Other issues that have arisen, such as high commissions in the distribution chain and the impact of the COVID-19 pandemic, also affect the business's sustainability.

Table 1. Challenges Facing Silver Businesses in Celuk Village

No	Business Challenges	Frequency (Cases)	Percentage (%)
1	The price of silver raw materials has increased	58	82.8
2	Decline in consumer purchasing power	45	64.3
3	Limited number of silver experts	39	55.7
4	High commission on distribution channels	27	38.6
5	The impact of the Covid-19 pandemic	31	44.3
Total			100

Source: Researchers (2025)

The increase in raw material prices is the main factor that has put pressure on profit margins, followed by the issue of artisan regeneration and a decline in purchasing power after the pandemic. Spatial analysis of the distribution of silver artisans in Celuk Village shows that there are 70 craft businesses scattered across various locations, with the highest concentration along the main west-east road corridor connecting Gianyar and Denpasar. The following is the distribution of silver artisans in Celuk Village.

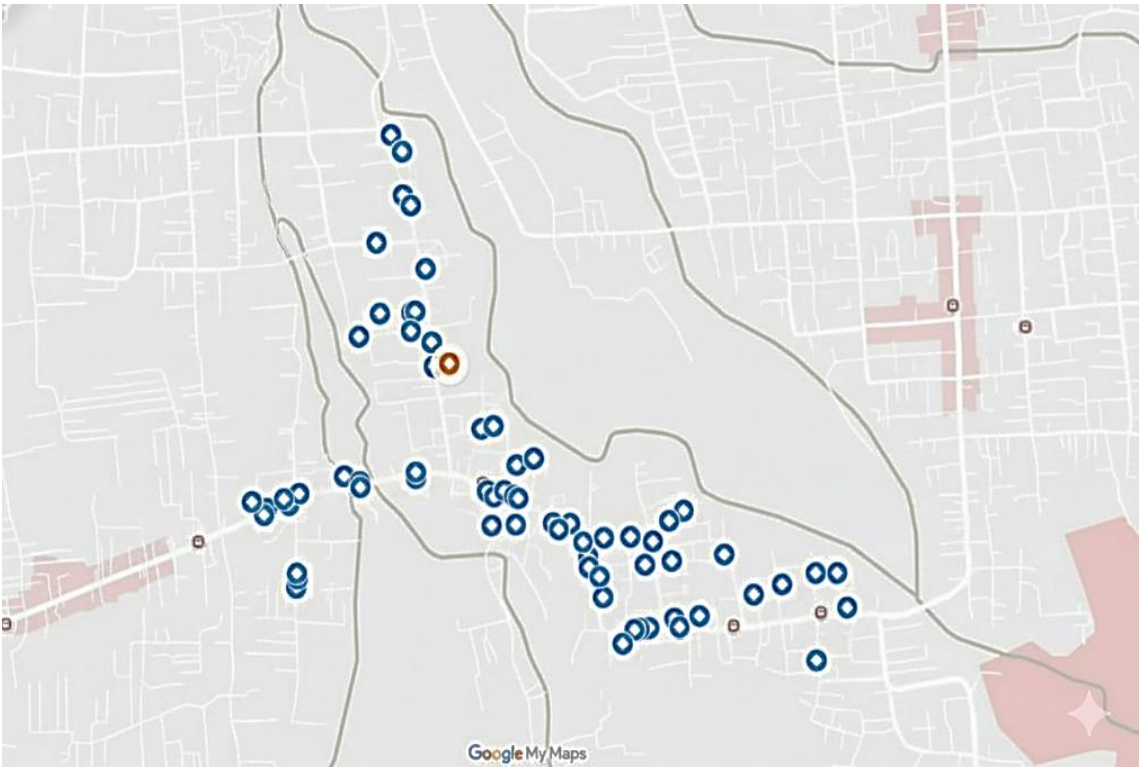


Figure 1. Distribution of Artisans in Celuk Village
Source: Researchers (2025)

This road serves as the primary access route for tourists and trade, giving businesses located along this corridor a strategic advantage in terms of visibility and market accessibility. The application of Kernel Density Estimation (KDE) produces a density map that highlights areas with the highest economic activity intensity, or hotspots, particularly in the central zone of the village, which is also the historical center of the silver trade. This distribution pattern exhibits linear clustering, where business units follow a road pattern and form a mutually supportive spatial chain between production workshops, galleries, and sales outlets.

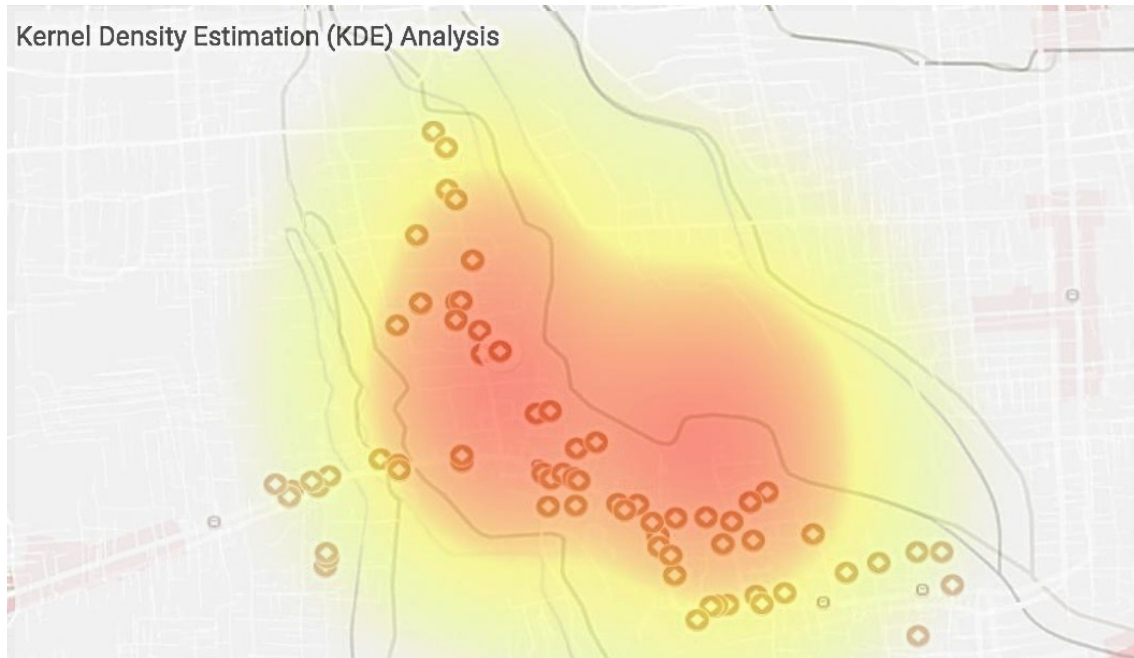


Figure 2. Kernel Density Estimation Analysis Results Map
Source: Researchers (2025)

This pattern indicates a tendency towards clustering (positive spatial autocorrelation), which theoretically will produce a positive and significant Moran's I value.

- Accessibility:** Businesses are concentrated along main traffic routes that are easily accessible to tourists and local shoppers.
- Industrial Cluster Effect:** Referring to the Industrial Clustering theory (Porter, 1998), the presence of similar businesses in proximity can trigger collaboration, supplier sharing, and the formation of regional identity.
- Economic Efficiency:** Artisans in adjacent areas can utilise shared resources and support facilities.

Table 2. Spatial Analysis Statistics

Parameter	Nilai	Interpretasi
Number of Points (n)	70	Total mapped business units
Average Closest Distance (m)	45.2	The distance between units is quite close
Indeks Tetangga Terdekat (NNI)	0.69	Showing a clustering pattern
Moran's I value	+0.89	Strong positive spatial correlation
p-value	< 0.05	Statistically significant cluster patterns

Source: Researchers (2025)

These results confirm that craft activities in Celuk are clustered along main roads, with strong spatial relationships between business units. Further analysis using Moran's I Index shows a positive value close to +1 with a significance level (p-value) < 0.05, which means that there is positive spatial autocorrelation. This suggests that neighbouring businesses tend to share similar characteristics, including business type, operational status, and openness to tourist visits. This phenomenon illustrates the effect of industrial clustering as described in Porter's theory (1998), where proximity between similar industry players can encourage collaboration, economic efficiency, and the formation of regional identity.

In terms of spatial morphology, it was found that areas with high density generally have dual functions of production and sales (store and production)—numbering around 33 units, while pure shops reached 23 units, and production workshops without galleries numbered around nine units. This pattern confirms the trend of integrating economic and cultural functions, where production activities are not only aimed at commercialisation but also serve as experience-based tourist attractions, such as jewellery-making classes.

Table 3. Recommendations for the Celuk Creative Area Development Strategy

Key Issues	Development Strategy	Indicator	Related Actors
Spatial clustering	Establishment of thematic production-display zones	Number of zones formed	Local Government, Department of Industry
Commercial pressure	Diversification of products and tourist routes	New product variations	Artisan community
Accessibility	Revitalisation of the main corridor	Tourist visitation rates	Public Works Agency, Tourism
Regeneration of artisans	Training and incubation programme	Number of active participants	BLK, Educational institution
Area branding	Digital promotions & annual festivals	Increase in annual visits	Bali Provincial Government, Bappeda

Source: Researchers (2025)

This strategy emphasises spatial, economic, and cultural integration to maintain the sustainability of the Celuk creative district. In general, the results of this study indicate that Celuk Village has a resilient spatial structure and high potential for the development of a cultural tourism-based creative district. The clustering of artisans not only increases production efficiency but also creates a unique spatial experience and a strong regional identity. However, overly dense clustering along the main road also has the potential to cause competition for space and economic pressure, so a spatial data-based spatial planning strategy is needed to maintain a balance between economic activity, environmental sustainability, and the preservation of local cultural values.

4.2 Discussion

Spatial analysis results using the Kernel Density Estimation (KDE) and Nearest Neighbour Index (NNI) methods confirm the existence of clustered distribution patterns along the main corridor of Celuk Village. This pattern reinforces previous findings that creative economic activities tend to be concentrated in locations with high accessibility and proximity to major tourist routes (Fang et al., 2024). The linear clustering pattern that emerges in Celuk is similar to the characteristics of creative districts in Southeast Asia, which have developed organically along trade and transport corridors (Dellisanti, 2023).

These findings address the first knowledge gap, namely the limitation of previous studies that only mapped point-based distribution without considering spatial relations

between zones at the regional scale. (Putu Ratih Pradnyaswari Anasta Putri et al., 2022). Quantitative analysis in this study confirms that production, sales, and tourism activities are interconnected in an integrated spatial system. In other words, Celuk not only functions as a craftsmen's settlement, but has also formed a linear creative area structure that demonstrates the functional relationship between the main corridor and secondary routes.

Another aspect identified is the relationship between spatial configuration and cultural identity, which has not been empirically studied much. Field observations reveal that the layout of business premises, the orientation of buildings, and the presence of symbolic elements, such as temples and traditional ornaments, play a crucial role in maintaining the cultural identity of the area. This phenomenon supports the theory of cultural morphology, which states that the form and function of space are determined not only by economic needs but also by symbolic values and local traditions (Suardana & Sumantra, 2023a). In the context of Celuk, this reinforces the role of culture as a "spatial marker" that distinguishes tradition-based creative districts from modern economic areas.

Additionally, spatial imbalances were observed between the main corridor and secondary areas, suggesting the emergence of commercial pressure and competition for space. Several areas with high KDE values underwent a transformation from workshops to shops, while areas with low density showed a decline in economic activity. This phenomenon is consistent with the study's results (Rosalina et al., 2023) and those from other tourist villages in Bali, emphasizing the need for community-based spatial management to avoid economic domination over cultural values. Therefore, an integrated spatial planning framework is necessary to connect production zones, public areas, and tourist routes, thereby maintaining a balance between economic functions and cultural preservation (Sunariya et al., 2024). The findings of this study broaden our understanding of the transformation process of Celuk from a traditional craft settlement into a sustainable cultural tourism corridor, while also closing the gap in previous research that did not explain this spatial integration. The GIS-based quantitative approach provides empirical evidence that the spatial structure of Celuk has the adaptive capacity to develop into a resilient, creative area, with strong potential to serve as a model for the development of culture-based creative districts in Bali and Indonesia.

5. CONCLUSION

This study confirms that Celuk Village in Gianyar Regency is a concrete example of the transformation of traditional craft settlements into cultural and tourism-based creative areas. Through quantitative spatial analysis using the Kernel Density Estimation (KDE) and Nearest Neighbour Index (NNI) methods, empirical evidence was obtained that the distribution of silver businesses in Celuk forms a linear cluster pattern along the main corridor connecting Gianyar and Denpasar. This pattern reveals a direct relationship between the level of accessibility and the concentration of economic activity, while also reflecting the formation of an integrated spatial structure among the production, display, and tourism zones.

The findings also show that the form and function of space in Celuk are not only determined by economic efficiency, but also by symbolic values and local traditions. Cultural elements, such as temples, gates, and traditional ornaments, serve as markers of spatial identity that bind economic function to cultural meaning. Thus, cultural morphology plays a crucial role in maintaining Celuk's unique character amid the pressures of commercialization and rapid spatial change. However, this study also

identifies spatial imbalances between the main corridor and secondary lanes, which have the potential to cause functional conflicts and a decline in activity in peripheral areas. Therefore, an integrated spatial planning framework is needed that links economic functions, public spaces, and cultural preservation through a thematic zoning approach and community-based governance.

Conceptually and empirically, the results of this study enrich our understanding of spatial integration in culture-based creative economy ecosystems. The development model found in Celuk can serve as a reference for other traditional craft areas in Bali and Indonesia, aiming to achieve a balance between economic productivity, cultural sustainability, and humane spatial quality.

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