



GIS-Based Spatial Distribution and Distance Analysis of Public Facilities at Lampung State Polytechnic

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Abstract

The spatial distribution of campus facilities is a critical determinant of the efficiency of spatial planning in higher education institutions. This study examines the spatial distribution pattern of campus public facilities using the Average Nearest Neighbor (ANN) method within a Geographic Information System (GIS) framework. The study was conducted at Lampung State Polytechnic using centroid point data of buildings with a total study area of 202,943.98 m². The analysis yielded a Nearest Neighbor Ratio (NNR) of 0.884, indicating a tendency toward spatial clustering. However, this tendency was not statistically significant at the 95% confidence level (Z-score = -1.567; $p = 0.117 > 0.05$), and the building distribution is therefore classified as random. Inter-building distance analysis revealed that the observed mean distance (28.16 m) is approximately 11.6% shorter than the expected distance under a random distribution (31.85 m), suggesting that contextual factors—including land constraints, functional connectivity requirements, incremental development patterns, and utility network efficiency—have collectively influenced building placement. The predominantly random distribution pattern reflects a process of adaptive spatial development conducted without reference to a comprehensive spatial master plan, which may give rise to circulation inefficiencies, utility integration challenges, and suboptimal open space utilization. This study demonstrates that GIS-based spatial statistical analysis affords an objective, quantitative evaluation of campus spatial planning and can serve as a scientific basis for the formulation of more structured, data-driven facility development policies.

Keywords: Average Nearest Neighbor, Spatial Analysis, GIS, Campus Facilities, Spatial Distribution

Abstrak

Analisis distribusi spasial fasilitas kampus merupakan hal yang esensial dalam mengevaluasi efisiensi perencanaan tata ruang perguruan tinggi. Penelitian ini bertujuan untuk menganalisis pola distribusi spasial fasilitas kampus menggunakan metode Average Nearest Neighbor (ANN) berbasis Sistem Informasi Geografis (SIG). Penelitian dilaksanakan di Politeknik Negeri Lampung dengan menggunakan data titik centroid bangunan pada total luas area kajian sebesar 202.943,98 m². Hasil analisis menunjukkan nilai Nearest Neighbor Ratio (NNR) sebesar 0,884 yang mengindikasikan kecenderungan pola mengelompok (clustered). Namun demikian, berdasarkan nilai Z-score sebesar -1,567 dan p-value sebesar 0,117 ($p > 0,05$), kecenderungan pengelompokan tersebut tidak signifikan secara statistik pada tingkat kepercayaan 95%, sehingga distribusi bangunan dikategorikan sebagai pola acak (random pattern). Analisis jarak antarbangunan menunjukkan bahwa jarak rata-rata teramati (28,16 m) lebih kecil sekitar 11,6% dibandingkan jarak harapan distribusi acak (31,85 m), yang mengindikasikan bahwa faktor-faktor kontekstual seperti keterbatasan lahan, kebutuhan konektivitas fungsional, pembangunan bertahap, dan efisiensi jaringan utilitas turut memengaruhi penempatan bangunan. Pola distribusi yang cenderung acak mencerminkan bahwa perkembangan spasial kampus berlangsung secara adaptif tanpa mengacu pada rencana induk (master plan) tata ruang yang komprehensif, yang berpotensi menimbulkan inefisiensi sirkulasi, tantangan integrasi utilitas, dan pemanfaatan ruang terbuka yang tidak optimal. Penelitian ini menunjukkan bahwa analisis statistik spasial berbasis SIG mampu memberikan evaluasi kuantitatif yang objektif terhadap perencanaan tata ruang

kampus dan dapat dijadikan landasan ilmiah dalam perumusan kebijakan pengembangan fasilitas yang lebih terstruktur dan berbasis data di masa mendatang.

Kata kunci: *Average Nearest Neighbor, Analisis Spasial, GIS, Fasilitas Kampus, Distribusi Spasial*

INTRODUCTION

The availability and spatial arrangement of campus public facilities are fundamental to the effective delivery of academic, research, and administrative services in higher education. Inequitable facility distribution diminishes mobility efficiency among campus users, as evidenced at ITS Campus, where inadequate infrastructure was identified as a leading contributor to inefficient movement patterns [1]. Politeknik Negeri Lampung (Polinela), spanning 35 hectares across Bandar Lampung City (6.28 ha) and South Lampung Regency (28.50 ha) [2], has undergone sustained infrastructure expansion. Nevertheless, public facilities comprise only 20% of total campus land [3] and development undertaken in the absence of a coherent spatial planning framework risks generating an uneven distribution pattern that compromises user accessibility [4].

Geographic Information Systems (GIS) represent a computer-based system designed to collect, store, manage, analyze, and display data with geographic references [5]. GIS is capable of integrating spatial and attribute data to produce accurate information on facility distribution patterns, inter-facility distances, and the level of facility accessibility for users [6]. A substantial body of prior research has employed GIS-based approaches to examine the spatial distribution of public facilities. The *Nearest Neighbor Analysis* method is a spatial statistical approach used to determine the distribution pattern of objects based on the distance between nearest points, indicating whether the distribution is *clustered*, *random*, or *dispersed*. The nearest neighbor index generally falls within the range of 0 to 2.15, wherein a value below 1 denotes a clustered pattern, a value of 1 denotes a random pattern, and a value above 1 denotes a dispersed pattern [7]. Research on the spatial distribution of senior high schools in Koja District, North Jakarta, demonstrated that the *Average Nearest Neighbor* method can quantitatively determine the distribution pattern of educational facilities and provide an overview of facility equity levels [8]. Another study in Banyuwangi Regency employing *buffering* and *Nearest Neighbor* methods showed that GIS can assist in evaluating the equitable distribution of educational facilities and in determining the need for new facility construction based on existing spatial distribution [9].

More recent studies have further demonstrated that the expansion of educational facilities in the absence of coordinated spatial planning tends to generate disparities in service accessibility, underscoring the importance of spatial distribution analysis as a tool for promoting more equitable and efficient facility development [10]. Furthermore, infrastructure development priorities can be established with greater precision through the systematic identification of zones that exhibit deficiencies or disparities in educational facility coverage [11].

A review of existing literature reveals that the majority of spatial facility distribution studies have concentrated on general urban settings and educational facilities at the primary and secondary school levels. Research specifically examining the spatial distribution of public facilities within vocational higher education environments—particularly Politeknik Negeri Lampung—remains notably scarce. Accordingly, this study introduces several dimensions of scientific novelty: the analysis of public facility distribution within a vocational campus context, which presents distinct land use characteristics relative to conventional university campuses; the application of the *Nearest Neighbor Analysis* method to quantitatively determine the distribution pattern of campus public facilities, and spatial distance analysis between facilities to evaluate accessibility levels based on actual geospatial data, and utilization of campus geospatial data derived from drone imagery and actual GIS data of Polinela campus.

METHOD

A. Research Location

This study was conducted within the campus grounds of Lampung State Polytechnic (Polinela), situated at Jalan Soekarno-Hatta No. 10, Rajabasa, Bandar Lampung City, Lampung Province, Indonesia. Polinela is a vocational higher education institution occupying a substantial campus area that accommodates a diverse range of academic and supporting facilities. The study area encompasses all buildings and primary facilities within the Polinela campus, including lecture halls, laboratories, a library, canteens, a mosque, sports facilities, administrative offices, and other public amenities serving the entire academic community. This location was selected on the basis that a campus constitutes a complex functional

environment in which the spatial distribution of facilities requires systematic analysis to enhance user mobility efficiency.

Geographically, the Polinela campus is situated at approximately 5°21' S – 5°22' S and 105°14' E – 105°15' E. In the Universal Transverse Mercator (UTM) Zone 48S coordinate system, the campus occupies the range of Easting 439,000 – 440,500 m and Northing 9,405,000 – 9,406,500 m. All spatial data were projected into the UTM Zone 48S coordinate system to ensure the precision of distance measurements and spatial computations. Aerial imagery of the study site, acquired via drone, is presented in Figure 1.



Figure 1. Aerial Image of the Research Location

Research Data

Data collection was conducted systematically in accordance with the requirements of the spatial analysis procedures employed. The data utilized comprised primary data gathered directly through field surveys and secondary data obtained from relevant institutional sources.

1. Primary Data

Primary data refers to data obtained directly through field survey activities and observations within the Polinela campus area. The primary data collected includes:

- GPS (Global Positioning System) Survey:** Geographic coordinates were recorded using a geodetic GPS device with a horizontal accuracy of ≤ 1 meter. The coordinate of each building was measured at the centroid point of the rooftop based on direct field observation. Surveys were carried out under clear weather conditions to maximize satellite signal reception. The resulting coordinate data were recorded in Decimal Degree format and subsequently converted to the UTM coordinate system.
- Drone Imagery Acquisition:** Aerial imagery was acquired using a DJI Mavic 2 Pro multirotor unmanned aerial vehicle (UAV). All flight operations were conducted between 09:00–11:00 Western Indonesia Time (WIB) to ensure

optimal illumination and minimize the occurrence of object shadows.

2. Data Processing

Upon completion of field data collection, a series of digital processing procedures was performed using GIS software, as outlined below:

- Building Polygon Digitization:** Building delineation was performed through on-screen digitization of high-resolution drone imagery in ArcMap 10.8. Each building was traced as a closed polygon representing its physical footprint, with boundary precision maintained to a maximum deviation tolerance of 0.5 meters from the actual building perimeter.
- Building Centroid Extraction:** The geometric centroid of each building polygon was extracted using the Feature to Point function in ArcMap 10.8, with the Inside option enabled to ensure that all centroid points fell within the bounds of their respective polygons. The resulting point layer, representing the central position of each building, served as the primary input for both the ANN and Distance Matrix analyses.
- Public Facility Selection:** From the complete set of digitized buildings, a selection process was undertaken to identify structures classified as campus public facilities, including the library, canteens, mosque and prayer rooms, polyclinic, student activity center, and sports facilities. Selection criteria were based on campus facility inventory records validated through field observation.
- Coordinate Projection:** All spatial data—including building polygons, centroids, and ancillary layers—were reprojected into the UTM Zone 48S coordinate system (WGS 1984 Datum) using the Project function in ArcMap 10.8. The UTM projection was adopted because it employs metric units (meters), which are conducive to precise distance and area calculations.

B. Distribution Pattern Analysis (Average Nearest Neighbor)

The Average Nearest Neighbor (ANN) analysis is a spatial statistical method used to analyze the distribution pattern of a set of points (point pattern) within a defined area [12]. This method is used to identify the distribution pattern of a phenomenon or entity within a geographic area. The Average Nearest Neighbor tool measures the distance between each feature centroid and its nearest neighbor's centroid location. It then averages all these nearest neighbor distances [13].

The Average Nearest Neighbor ratio is given as:

$$ANN = \frac{D_O}{D_E} \quad (1)$$

Where D_O is the observed mean distance between each feature and its nearest neighbor:

$$D_O = \frac{\sum_{i=1}^n d_i}{n} \quad (2)$$

And D_E is the expected mean distance for the features given in a random pattern:

$$D_E = \frac{0,5}{\sqrt{n/A}} \quad (3)$$

In the above equations, d_i , equals the distance between feature i and its nearest neighboring feature, n corresponds to the total number of features, and A is the area of a minimum enclosing rectangle around all features, or it's a user-specified area value.

The ANN analysis was carried out using Geographic Information System software, namely ArcMap 10.8. This stage involved the process of converting building polygons into centroid point layers and identifying buildings that constitute public facilities within the Polinela campus. The interpretation results of the Average Nearest Neighbor value calculations are presented in Table 1.

Table 1. Interpretation of ANN Value

ANN Value	Distribution Pattern	Interpretation
ANN < 1	Clustered	the points tend to gather in certain areas, creating concentrations at specific locations.
ANN = 1	Random	the points are scattered randomly without any identifiable pattern.
ANN > 1	Dispersed	the points are spread evenly with relatively uniform distances between them.

Furthermore, from Table 1, it is possible to analyze whether the infrastructure and facilities are evenly distributed (dispersed) with an ANN value of > 1, clustered with an ANN value of < 1, or randomly distributed (random) with an ANN value of 1. This is crucial in order to ensure that students, lecturers, and all members of the academic community can access campus public facilities with ease and without incurring unnecessary travel time.

C. Significance Test (Z-Score and P-Value)

To ensure that the identified distribution pattern is not merely the result of chance, a statistical significance test was conducted using Z-score and p-value. The Z-score and p-value were obtained directly from the ANN analysis output in ArcMap 10.8. The following provides the interpretation of Z-score values:

- a) Z-score < -1.96 or Z-score > +1.96: the distribution pattern is statistically significant at a 95% confidence level ($p < 0.05$)
- b) Z-score < -2.58 or Z-score > +2.58: the distribution pattern is statistically highly significant at a 99% confidence level ($p < 0.01$)
- c) $-1.96 < Z\text{-score} < +1.96$: the distribution pattern is not statistically significant, meaning that conclusions regarding the distribution pattern cannot be drawn with adequate confidence

D. Euclidean Distance Analysis

Euclidean Distance is the straight-line distance between two points in two-dimensional or three-dimensional space, calculated using the Pythagorean theorem. In this study, the coordinates (x, y) represent the Easting (x) and Northing (y) values of building centroids in the UTM zone 48S projection system, so that the resulting distance values are expressed in meters. Euclidean Distance was selected because it represents the shortest distance between two points in flat space, making it suitable for spatial efficiency analysis at the campus area scale. The distance matrix was calculated using the Generate Near Table or Point Distance function in ArcMap 10.8 software. The output consisted of an attribute table storing the distance values between each pair of building centroids, which were subsequently exported in .dbf or .xlsx format for further processing. The results of the Euclidean Distance analysis were evaluated based on pedestrian comfort standards formulated by urban planning experts. With reference to the walkability guidelines of Gehl (2011) [14] and Handy et al. (2002), the pedestrian comfort thresholds can be seen in Table 2.

Table 2. Comfortable Walking Distance

Distance (meters)	Travel Time (minutes)	Comfort Category
≤ 200 m	≤ 2.5 minutes	Very comfortable – easily accessible by all campus us
201–400 m	2.5–5 minutes	Comfortable – still within normal walking distance
401–800 m	5–10 minutes	Moderately comfortable – may require alternative transportation
> 800 m	> 10 minutes	Less comfortable – internal transportation facilities are needed

Distance analysis was performed by calculating the distance matrix between the centroids of academic buildings using the Distance Matrix function in GIS software. The mean distance value was calculated

to determine the mobility efficiency between campus public facility buildings.

RESULT AND DISCUSSION

A. Spatial Analysis of Public Facilities

This study commenced with a systematic inventory of all buildings classified as public facilities within the Lampung State Polytechnic (Polinela) campus. The inventory identified a total of 50 building units meeting the classification criteria, encompassing lecture halls, laboratories, administrative offices, academic support facilities, and other ancillary structures. Spatial data were collected using a geodetic GPS device capable of delivering high-accuracy coordinate measurements. The geographic position of each building was recorded in the field via GPS survey, thereby generating reliable positional data for each structure. The use of GPS ensured that all collected data carried verifiable and scientifically defensible geographic references.

The GPS coordinates were subsequently overlaid onto high-resolution drone imagery acquired prior to the survey. The use of high-resolution aerial imagery offered considerable advantages in terms of surface detail, enabling more precise delineation of building boundaries than would be possible with conventional satellite imagery. This overlay process confirmed the spatial correspondence between each GPS coordinate and the physical position of the corresponding building as depicted in the imagery. Building polygon digitization was then performed in QGIS (Quantum Geographic Information System) by manually tracing the outer boundary (footprint) of each structure based on its appearance in the drone imagery. The resulting polygons spatially represented the shape and extent of each building. Upon completion of digitization, a centroid point was extracted from each polygon to serve as a single positional representation of the building for use in distance-based spatial analyses.

The extracted centroid points were subsequently used as input for the Average Nearest Neighbor (ANN) analysis in ArcMap 10.8. ArcMap was selected for its ability to execute spatial statistical analyses automatically and generate comprehensive output reports, including the Nearest Neighbor Ratio (NNR), Z-score, and p-value required for the interpretation of spatial distribution patterns. In summary, the inventory at Lampung State Polytechnic confirmed 50 public facility buildings, whose GPS-derived coordinates were overlaid onto drone imagery, digitized as polygons in QGIS, and converted to centroid points for ANN analysis in ArcMap 10.8. The resulting

public facility distribution map of Polinela is presented in Figure 2.



Figure 2. Public Facility Distribution Map

B. Building Distribution Pattern Using Average Nearest Neighbor (ANN)

The Average Nearest Neighbor (ANN) method is among the most widely applied spatial statistical techniques for characterizing the distribution pattern of point features within a defined geographic area. The core principle of this method involves comparing the mean observed distance between each point and its nearest neighbor against the expected mean distance that would arise under a condition of complete spatial randomness across the same area. The ANN ratio is computed as the observed mean distance divided by the expected mean distance, where the latter is derived from a hypothetical random distribution comprising the same number of features over an equivalent total area [15].

The ANN analysis in this study was based on Euclidean distance, which represents the shortest straight-line distance between two points in two-dimensional space. Euclidean distance was deemed appropriate given the relatively confined spatial scale of the campus study area, where the effect of Earth's curvature is negligible. The entire calculation was performed automatically by ArcMap 10.8 using the building centroid point data prepared in the preceding stage. The resulting statistical parameters from the ANN analysis are presented in Figure 3.

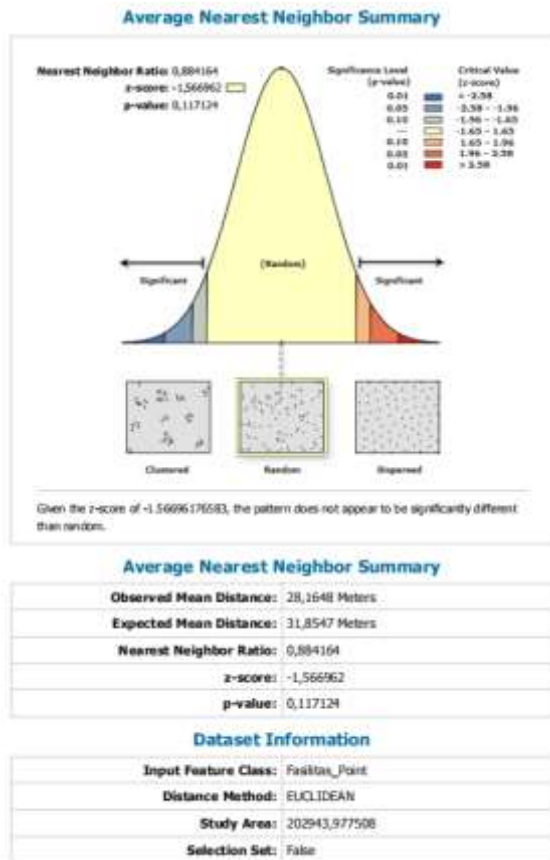


Figure 3. Nearest Neighbor Ratio (ANN) Result

The ANN analysis yielded a set of spatial statistical parameters for characterizing the building distribution pattern, as summarized below:

Table 3. Interpretation of ANN Result

Parameter	Value	Interpretation
Nearest Neighbor Ratio (NNR)	0.884	Indicates tendency toward clustered pattern
Z-score	-1.567	Negative value indicates clustering tendency
P-value	0.117	Not statistically significant at $\alpha = 0.05$

An NNR value of 0.884 does suggest a tendency toward clustering, as it falls below the threshold of 1. However, relying solely on the NNR value to characterize the distribution pattern is methodologically insufficient. Assessment of statistical significance through the Z-score and p-value is necessary to determine whether the observed clustering tendency constitutes a genuine spatial pattern or is attributable to random chance.

A p-value of 0.117, exceeding the threshold of 0.05, indicates that the observed clustering tendency is not statistically significant at the 95% confidence level, implying that the probability of such a pattern arising by chance is approximately 11.7%. From an inferential

perspective, therefore, the spatial distribution of public facility buildings at Lampung State Polytechnic is appropriately classified as random, notwithstanding the NNR value marginally below 1. This conclusion aligns with established principles of inferential statistics, which mandate significance testing before a distributional pattern can be formally affirmed. In the absence of statistical significance, assertions of a clustering pattern lack scientific grounding. Accordingly, at the 95% confidence level, the campus building distribution pattern is determined to be statistically indistinguishable from a random arrangement.

C. Inter-Building Distance Analysis

A key output of the ANN analysis is the comparison between the observed mean inter-building distance and the expected mean distance under a random spatial distribution. The results of this comparison are presented in Table 4.

Table 4. Comparison of Observed and Expected Distance

Distance Type	Value (meters)
Observed Mean Distance	28.16
Expected Mean Distance	31.85
Difference	3.69

The observed mean distance being approximately 11.6% smaller than the expected value indicates that campus buildings tend to be positioned slightly closer to one another than would be expected under a condition of complete spatial randomness across the same area. This tendency points to the influence of contextual factors that promote closer building placement, though their combined effect is insufficient to generate a statistically significant clustering pattern.

Several contextual factors may account for this tendency toward closer-than-random inter-building distances:

- Limited available land:** The campus area has physical boundaries in the form of fences or administrative limits that restrict the construction area. This constraint indirectly encourages new buildings to be placed in closer proximity to existing ones.
- Functional connectivity requirements:** Buildings with interrelated functions, such as lecture halls with laboratories or administrative offices with faculty rooms, tend to be placed in close proximity to facilitate user accessibility.
- Incremental development:** Campus construction that occurs gradually over time tends to occupy available land in the vicinity of existing buildings, naturally resulting in smaller inter-building distances compared to a scenario in which all

buildings had been planned simultaneously from the outset.

- d) **Utility network infrastructure:** New buildings are generally positioned in close proximity to existing utility networks (electricity, water, communications) for cost efficiency in construction and maintenance.

Notwithstanding the observed tendency toward closer inter-building proximity, a p-value of > 0.05 confirms that the pattern remains statistically indistinguishable from a random distribution. This indicates that the degree of variation in inter-building distances is sufficiently large that a mean value slightly below the expected threshold cannot be taken as evidence of systematic spatial clustering. Such conditions are frequently encountered in educational settings that have developed incrementally, without a rigorously enforced spatial planning framework in place from the outset. In contrast to purpose-built residential or industrial areas, which are typically designed in a comprehensive and coordinated manner, campuses that evolve organically in response to academic demand tend to exhibit distributions that approximate randomness, with a marginal clustering tendency attributable to the contextual factors discussed above.

D. Campus Spatial Planning Implications

The findings of the ANN analysis hold several significant implications for the future planning and spatial development of Lampung State Polytechnic. A clear understanding of the existing spatial distribution pattern is a prerequisite for formulating more efficient and integrated campus development strategies. The prevalence of a random distribution pattern indicates the absence of any dominant spatial cluster within the campus. Academic and supporting buildings have been positioned in response to operational demands as they arose over time, rather than in accordance with a coherent spatial master plan. While this pattern is understandable given the incremental nature of campus development, it carries the potential to generate a number of spatial planning challenges, including:

- a) **Circulation inefficiency:** A random distribution may cause the movement routes of campus users, including students, lecturers, and administrative staff, to be inefficient, particularly between buildings that are frequently used in sequence within a single day of activities.
- b) **Utility network integration difficulties:** Buildings dispersed without a defined pattern complicate the integrated and economical planning and development of

utility networks, including drainage, electricity, and internet infrastructure.

- c) **Suboptimal utilization of open space:** Without systematic planning, open spaces between buildings tend to form as residual spaces rather than being purposefully designed as functional green areas or public spaces.
- d) **Aesthetic challenges for the campus area:** Spatially unplanned building distribution may adversely affect the overall visual image of the campus, resulting in a less cohesive appearance.

With respect to spatial efficiency, the present analysis is not in itself sufficient to determine whether the current campus layout is optimal or otherwise. A comprehensive efficiency assessment would require additional analyses, including actual travel distance measurements between facilities, accessibility modeling, and evaluation of green open space availability and distribution—aspects that lie beyond the scope of the ANN method, which is constrained to the measurement of point distribution patterns. Nonetheless, the results of this ANN analysis constitute a meaningful contribution as an initial stage of quantitative campus spatial evaluation, providing an important empirical foundation for:

- a) The formulation of campus development policies based on objective and measurable spatial data.
- b) The determination of priority development zones based on the existing density and concentration of buildings.
- c) The identification of areas requiring more intensive planning intervention to improve spatial integration.
- d) The development of a campus spatial database that can be periodically updated as part of a campus geographic information system.

In summary, the observed tendency toward a random distribution pattern reflects the absence of a dominant spatial cluster, with buildings positioned in response to operational needs rather than a unified planning framework. Definitive conclusions regarding spatial efficiency require further investigation into actual inter-facility travel distances. Nonetheless, these findings constitute a valuable empirical basis for subsequent spatial planning evaluations grounded in quantitative data.

CONCLUSION

The Average Nearest Neighbor (ANN) analysis yielded an NNR value of 0.884, suggesting

a tendency toward spatial clustering in the distribution of campus buildings. However, this tendency was not statistically significant at the 95% confidence level (Z -score = -1.567 ; $p = 0.117$), and the overall building distribution is accordingly classified as random. Analysis of inter-building distances indicated an observed mean distance of 28.16 m, approximately 11.6% smaller than the theoretically expected random distance of 31.85 m. This finding reflects the influence of limited land availability, functional connectivity requirements, incremental construction patterns, and utility efficiency considerations on building placement, rather than adherence to a comprehensive spatial master plan.

The GIS-based spatial statistical analysis proved effective in delivering an objective, quantitative evaluation of campus spatial layout patterns, providing a robust scientific foundation for development policy formulation. Future research is recommended to extend this work through more comprehensive spatial methodologies, including Kernel Density Estimation (KDE), Network Analysis, and Space Syntax Analysis. Overall, this study affirms that the integrated application of GPS surveying, drone-based remote sensing, GIS, and spatial statistical analysis constitutes an effective and efficient approach for the quantitative evaluation of campus spatial conditions. The findings are intended to serve as a reference for Lampung State Polytechnic in developing more structured, spatially data-driven campus facility planning oriented toward the operational efficiency and comfort of the entire academic community.

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