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A GIS-BASED STUDY ON THE SPATIAL DISTRIBUTION PATTERNS OF PUBLIC SENIOR HIGH SCHOOLS IN PEKANBARU CITY

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ABSTRACT: This study analyzes the spatial distribution of public senior high schools in Pekanbaru City using a Geographic Information System (GIS) approach. Location data from 19 schools were collected through field surveys and analyzed using the Average Nearest Neighbour (ANN) method in ArcGIS. The analysis produced a Nearest Neighbour Ratio (NNR) of 1.44, with a significant z-score and p-value, indicating a dispersed distribution pattern. This means that schools are relatively spread across the city rather than concentrated in certain areas. Although this pattern suggests a degree of spatial balance at the city level, several districts still lack public senior high schools, showing that equitable access to upper secondary education has not been fully achieved. The findings emphasize the importance of integrating GIS and spatial analysis into education planning to support more equitable, efficient, and data-driven policies for school facility provision in growing urban areas.

Keywords: Geographic Information System (GIS), spatial distribution, public senior high schools, Average Nearest Neighbour (ANN), educational facility planning

1. INTRODUCTION

Education plays a crucial role in human life, as it represents a conscious effort by individuals to accumulate adequate and optimal provisions to face future life challenges [1]. Education functions as a fundamental pillar of national development because, through this process, high-quality human resources who are intelligent, skilled, and possess strong moral character can be developed to achieve societal welfare [2].[3]. Furthermore, education serves as a key driver of national progress, as higher levels of educational attainment contribute to a nation being more respected and valued in the global context [4]. Without quality education, human resources are unable to optimally develop their potential, causing a nation to lag behind in various aspects of life [5].

Upper secondary education and the presence of public senior high schools play a strategic role in promoting equitable access to quality education, particularly in urban areas experiencing dynamic population growth and spatial change [6].[7]. Uncontrolled population growth directly increases the demand for upper secondary education facilities to accommodate prospective new students [8]. Spatial imbalances between population growth and school capacity often result in service deficits in rapidly developing areas, while other areas experience surplus capacity [9]. This situation presents a significant challenge, as the capacity of public senior high schools is frequently disproportionate to the number of prospective students within their respective service areas [10].

This distributional imbalance indicates that spatial planning is often not yet fully responsive to dynamic demographic pressures and the proportional needs for socio-economic services [9].[11]. Studies have shown that spatial planning which is not integrated with demographic data and land-use change tends to widen disparities in access to public facilities such as education, transportation, and open spaces, thereby exacerbating service inequality in urban areas [12]. The gap between ideal planning visions and on-the-ground development practices is frequently evident when population growth and land-use conversion exceed the carrying capacity of a region [9]. This condition underscores the need for a more proactive, data-driven planning approach to address spatial

challenges that hinder the realization of sustainable settlements [9].

These imbalances lead to spatial access disparities, whereby some students are required to travel longer distances, experience limited school choices, or are not accommodated within the public education system, making the objective of equitable educational service provision difficult to achieve optimally. Moreover, the concentration of schools in specific locations without population-based planning further reinforces uneven service patterns across different areas within a city. Educational equity is strongly influenced by spatial factors, as imbalances in school distribution patterns can generate disparities in access and differences in educational quality between regions.

Uneven school distribution patterns contribute to increased student travel distances and reflect weak integration between educational planning and urban spatial planning. This imbalance in the distribution of educational facilities results in unequal service coverage areas, where facilities located farther apart are required to support a wider service burden compared to facilities that are closely clustered [13]. The proximity of educational facilities to densely populated residential areas alone cannot be considered a sufficient indicator of equitable provision, as uniform and evenly distributed locations also play a critical role in determining community accessibility to educational services [7]. Ultimately, irregular spatial patterns affect not only students' travel distances but also school capacity loads, class size density, and the overall quality of educational services provided by each school.

Areas with a low concentration of schools tend to experience higher service pressure, whereas areas with an excessive concentration of facilities may lead to inefficiencies in the utilization of educational infrastructure. This situation indicates that the location and distribution of facilities are critical factors in achieving comprehensive equity in access to education. Weak integration between educational and spatial planning has the potential to hinder government efforts to provide educational facilities that meet the needs of the entire population and are easily accessible [14]. Such misalignment results in the placement of educational facilities that is often inconsistent with patterns of residential development and the distribution of the school-age population.

As a result, some areas experience shortages in educational services, while other areas exhibit suboptimal utilization of educational facilities. Geographic Information Systems (GIS) are effectively used to analyze and map school distribution patterns both visually and quantitatively in support of data-driven educational planning. In this context, the application of GIS functions not only as a mapping tool but also as a decision-support instrument capable of integrating and presenting the relationships among school locations, regional characteristics, and population distribution.

Such spatial information assists in identifying areas that are adequately served as well as areas that continue to experience deficiencies in educational services, thereby enabling the formulation of equity-oriented policies that are more targeted, objective, and evidence-based. The application of spatial analysis through GIS allows for a comprehensive evaluation of the adequacy of school capacity relative to the size of the school-age population, as well as the distribution of the quality of public senior high schools [10]. [13]. Spatial statistical analyses, such as Nearest Neighbor Analysis (NNA), are employed to determine tendencies in school distribution patterns and to understand their spatial characteristics across different areas. Furthermore, GIS-based studies demonstrate that spatial mapping can help reveal underserved areas by visualizing service distribution and gaps in service coverage relative to residential areas, thereby enabling more precise and effective policy planning support [15].

Through this approach, distribution patterns can be identified as clustered, random, or uniformly dispersed, thereby providing an overview of the level of spatial regularity in the placement of educational facilities within a given area. Such information is essential for assessing the extent to which school locations reflect the principle of equitable access, as disproportionate patterns may lead to disparities in service coverage between regions. Consequently, spatial statistical analysis plays a crucial role in clarifying the relationship between urban spatial structure and the provision of upper secondary education services in a more objective manner.

Other spatial studies indicate that a GIS-based approach not only assists in identifying school distribution patterns but also evaluates the accessibility of educational services and objectively reveals underserved areas, thereby providing a solid basis for more targeted policies on the equitable provision of educational facilities [16]. Accordingly, a spatial approach using GIS strengthens the synergy between educational planning and regional planning in efforts to achieve more equitable access to upper secondary education. Furthermore, GIS-based studies have found that analyses of school

distribution can uncover service limitations in areas that appear administratively served, demonstrating that spatially supported planning contributes to equity not only in terms of quantity but also quality and geographic accessibility of educational services [17]. Other research shows that, beyond examining distribution patterns, spatial analysis is also essential for assessing the accessibility of educational services by considering road networks and population distribution, as this provides a comprehensive understanding of areas that remain underserved and the need for additional facilities [18].

Pekanbaru City, as a center of urban growth, experiences dynamic residential development and a continually changing number of school-age residents, resulting in spatial shifts in the demand for upper secondary education services. Changes in population dynamics and urban spatial expansion can directly affect the distribution of educational facilities, as rapid residential growth often creates imbalances between school locations and educational service needs across different areas of the city, thereby requiring spatial evaluation to formulate responsive facility placement strategies [19]. An analysis of the distribution patterns of public senior high schools in Pekanbaru City is therefore necessary to identify the level of equity in educational facility provision and to serve as a foundation for fair and spatially informed educational planning. Without an understanding of the characteristics of existing facility distribution, policies for school expansion or development risk being misdirected and may instead exacerbate disparities in access between regions. Consequently, spatial analysis of the distribution of public senior high schools is essential to ensure that the provision of educational facilities aligns with population distribution patterns and supports the realization of equitable educational services at the city level.

2. METHODS

This study employs a quantitative approach combined with spatial analysis to examine the distribution patterns of public senior high schools in Pekanbaru City. This approach aims to produce objective, systematic, and generalizable conclusions based on the collected numerical data [20] The quantitative approach is selected because it allows for objective measurement of the spatial distribution of schools based on geographic location data, while spatial analysis is used to identify the characteristics and tendencies of school distribution patterns within the urban geographic space. This research is descriptive-analytical in nature, as it aims to describe and analyze the distribution patterns of public senior high schools without testing causal relationships among variables.

The data used in this study consist of spatial data and attribute data. The spatial data comprise the coordinate points of public senior high school locations in Pekanbaru City, obtained from relevant institutions and verified using base maps and supporting imagery. The attribute data include school identification information, such as school names and the districts in which the schools are located. In addition, an administrative map of Pekanbaru City is used as the basis for spatial analysis to display the distribution of schools within the city's administrative boundaries.

Data collection was conducted through field surveys by plotting the locations of all public senior high schools in Pekanbaru City to obtain spatial data on the geographic positions of the schools. Location points were determined using the Global Positioning System (GPS) to record the coordinates of each school, which subsequently served as the basis for compiling the school distribution map. The coordinate data obtained from the survey were then processed and visualized using Geographic Information Systems (GIS) to display the spatial distribution of schools within the city's administrative boundaries.

Data analysis in this study was conducted using a spatial approach based on Geographic Information Systems (GIS) to identify the distribution patterns of public senior high schools in Pekanbaru City. The primary data analyzed consist of point locations of public senior high schools obtained through digitization and spatial data processing.

The initial stage of analysis involved digitizing public senior high school buildings using satellite imagery in ArcGIS version 10.3. The digitized school buildings were stored as polygon data representing the physical boundaries of each public senior high school. Because distribution pattern analysis requires point-based data, the polygon data were subsequently converted into point data.

The process of converting polygon data into point data was carried out by determining the centroid of each public senior high school building. The technical conversion steps were performed through the *ArcToolbox > Data Management Tools > Features > Add Geometry Attributes* menu by selecting the centroid geometry property to ensure that the generated points were located at the center of each digitized building. The coordinate system used was adjusted to match the coordinate reference system of Pekanbaru City.

After the centroid points were obtained, the next step involved calculating the X and Y coordinates in the attribute table of the digitized data. This process was conducted by opening the Attribute Table and selecting the *Calculate Geometry* option for the X and Y coordinate fields, using the source data coordinate system. This stage aimed to ensure that each point contained geographic coordinate information that could be further processed in subsequent analyses.

The generated X and Y coordinates were then displayed as a point layer through the *ArcToolbox > Data Management Tools > Layer and Table Views > Make XY Event Layer* menu. At this stage, the table containing the X and Y coordinates was used as the input, and the appropriate coordinate system was specified, resulting in a point layer representing the spatial distribution of public senior high schools that was ready for spatial analysis.

After the point distribution data of public senior high schools were established, the analysis was continued using the Average Nearest Neighbour (ANN) method to determine the tendency of school distribution patterns. The ANN analysis was conducted through the *ArcToolbox > Spatial Statistics Tools > Analyzing Patterns > Average Nearest Neighbour* menu by entering the converted point layer as the feature class. The Generate Report option was selected to automatically produce the statistical report.

The ANN calculation process was performed automatically by the ArcGIS software, producing outputs in the form of the nearest neighbor index (R), Z-score, and p-value, which indicate the characteristics of the distribution patterns of public senior high schools. The R value was used to determine whether the distribution pattern was clustered, random, or dispersed.

The results of the ANN analysis were then accessed through the *Geoprocessing > Results* menu by opening the report file (NearestNeighbour_Result), which automatically displays the analysis outcomes in the form of statistical tables and supporting visualizations. These results were subsequently interpreted to explain the spatial distribution patterns of public senior high schools in Pekanbaru City.

3. RESULTS AND DISCUSSION

The distribution pattern of public senior high schools (SMAN) in Pekanbaru City was analyzed using a spatial approach based on Geographic Information Systems (GIS) with the Average Nearest Neighbour (ANN) method. This analysis aimed to determine whether the distribution pattern of SMAN was clustered, random, or dispersed. The ANN method operates by calculating the ratio of the observed nearest neighbor distance for each point to the expected distance under a random distribution; a ratio value below 1 indicates a clustered pattern, a value close to 1 indicates a random pattern, and a value greater than 1 indicates a dispersed pattern. This approach enables objective conclusions to be drawn regarding the spatial distribution characteristics of geographic features [21].

Table 1 Spatial Distribution of Public Senior High Schools in Pekanbaru City

No	Sekolah	Alamat	Point_X	Point_Y
1	SMAN 1	Kec. Lima Puluh	101,453749	0,52586
2	SMAN 2	Kec. Payung Sekaki	101,431258	0,520921
3	SMAN 3	Kec. Rumbai	101,429074	0,570727
4	SMAN 4	Kec. Marpoyan Damai	101,433951	0,462914
5	SMAN 5	Kec. Marpoyan Damai	101,442153	0,502582
6	SMAN 6	Kec. Tenayan Raya	101,475328	0,534974
7	SMAN 7	Kec. Senapelan	101,431102	0,542742
8	SMAN 8	Kec. Sail	101,458602	0,509278
9	SMAN 9	Kec. Lima Puluh	101,457948	0,526373
10	SMAN 10	Kec. Tenayan Raya	101,485922	0,491969
11	SMAN 11	Kec. Tenayan Raya	101,484427	0,511917
12	SMAN 12	Kec. Binawijaya	101,36257	0,48983
13	SMAN 13	Kec. Rumbai Barat	101,417428	0,668322
14	SMAN 14	Kec. Bukit Raya	101,468427	0,450262
15	SMAN 15	Kec. Tuahmadani	101,392168	0,442452
16	SMAN 16	Kec. Rumbai Timur	101,475202	0,574467
17	SMAN 17	Kec. Payung Sekaki	101,383899	0,512673
18	SMAN 18	Kec. Bukit Raya	101,465258	0,478055
19	SMAN 19	Kec. Binawidya	101,406796	0,467973

Based on the data presented in Table 1, a total of 19 public senior high school locations were identified and distributed across the entire administrative area of Pekanbaru City. The coordinate points were obtained through field surveys and subsequently processed using ArcGIS version 10.8. The spatial data were analyzed using the Average Nearest Neighbour feature within the Spatial Statistics Tools.

Furthermore, the ANN analysis produced a Nearest Neighbour Ratio (NNR) value of 1.44, with a

z-score of 3.74 and a p-value of 0.00. An NNR value greater than 1 indicates that the distances between public senior high school locations in Pekanbaru City tend to be farther apart than would be expected under a random distribution. In addition, the positive and statistically significant z-score (p-value < 0.05) suggests that the observed distribution pattern did not occur by chance. These results are illustrated in Figure 1, with the corresponding spatial pattern map shown in Figure 2 below.

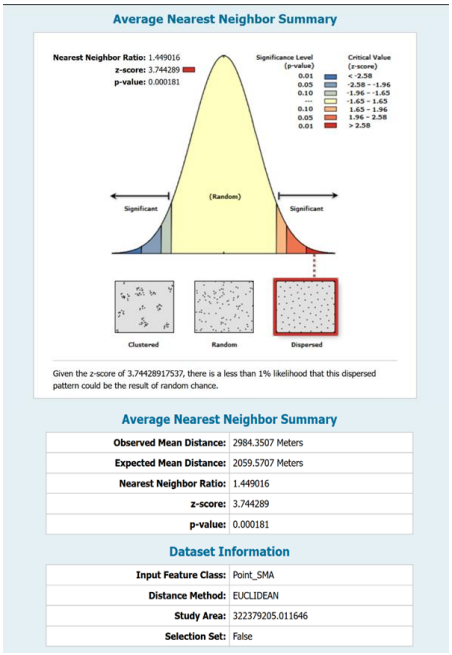

Fig. 1 Nearest Neighbor Values of Public Senior High Schools in Pekanbaru City

The results of the nearest neighbor analysis and the spatial pattern map indicate that the distribution of public senior high schools in Pekanbaru City can be classified as a dispersed pattern. This means that, spatially, public senior high schools in Pekanbaru City are relatively evenly distributed across various districts and are not concentrated in a single area. However, the presence of two districts without any public senior high schools indicates that spatial equity has not yet been fully achieved across the entire administrative area of the city.

A dispersed distribution pattern generally suggests that educational facility planning has taken accessibility to residential areas and transportation networks into account, so that no area is entirely without basic or secondary education services, although challenges to equitable provision remain in the context of population growth and urban dynamics. By comparison, a study conducted in Koja District found that a dispersed pattern of senior high school distribution reflects a relatively even allocation of facilities, although additional schools are still required to meet the full demand of the school-age population [22].

Other studies have also found that even when school distribution appears spatially even based on analysis, variations in accessibility between central and peripheral areas remain evident, highlighting the need for adaptive planning to ensure facility accessibility for all segments of society [23]. Similarly, research using GIS and ANN approaches indicates that although school distribution patterns may appear dispersed in spatial analysis, the distribution of educational facilities often does not yet reflect optimal accessibility for all population groups, particularly in peripheral areas with limited access [24].

Other analyses that integrate spatial distribution and school accessibility have found that uneven distribution and limited access in certain areas can increase students' travel distances while simultaneously reducing their opportunities to receive equitable educational services. Consequently, the reorganization of school locations and GIS-based planning need to be considered in educational policy formulation [25].

4. CONCLUSION

Based on the results of the Geographic Information System (GIS)–based spatial analysis using the Average Nearest Neighbour (ANN) method, the distribution pattern of public senior high schools in Pekanbaru City can be classified as dispersed. This is indicated by a Nearest Neighbour Ratio (NNR) value of 1.44 accompanied by statistically significant z-score and p-value results. These findings suggest that, in general, the placement of public senior high schools is not concentrated in specific areas and has considered spatial regularity at the city scale. Nevertheless, the existence of several districts without public senior high schools indicates that spatial equity in access to upper secondary education has not yet been fully achieved across the entire administrative area of Pekanbaru City.

The findings of this study highlight the importance of utilizing GIS and spatial statistical analysis as an objective, data-driven foundation for educational planning. Stronger integration between educational planning and urban spatial planning is required to ensure that policies related to the expansion or development of public senior high schools are more responsive to population growth dynamics and residential development. Thus, spatial analysis serves not only to identify patterns in the distribution of educational facilities but also to support the formulation of more equitable, efficient, and sustainable policies for the provision of upper secondary education services at the city level.

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