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Spatial Equity Analysis of Public Facilities in South Tangerang City

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Abstract: The rapid urban expansion of the Greater Jakarta metropolitan area has placed significant pressure on public service provision in its satellite cities, including South Tangerang City. Despite recording the highest Human Development Index (HDI = 84.16) among the Bodetabek region, access to public facilities remains unequal across sub-districts. This study aims to analyse the spatial equity of public facility distribution in South Tangerang City across three sectors: education (primary, junior, and senior high schools), health (public health centres and hospitals), and public transportation (bus stops and train/commuter rail stations). Spatial analysis was performed using two complementary methods: Nearest Neighbour Analysis (NNA), which computes the Nearest Neighbour Index (NNI) — a dimensionless ratio comparing observed mean inter-facility distances to those expected under a random spatial distribution — to identify whether facility point patterns are clustered (NNI < 0.7), random (0.8–1.4), or dispersed (NNI > 1.5); and network-based Service Area Analysis, which delineates reachable zones from each facility via the actual road network. Data were sourced from OpenStreetMap (OSM) and the Indonesian National Topographic Map (RBI BIG 2022), processed in QGIS using the QuickOSM plugin and QNEAT3 network analysis toolbox. Results indicate that most facilities exhibit a clustered distribution pattern, particularly bus stops (NNI = 0.298), schools (NNI = 0.603), and hospitals (NNI = 0.603). Service area analysis revealed significant blank spots primarily in health and transportation sectors: four sub-districts — Pakulonan, Pondok Cabe Udik, Keranggan, and Pakujaya — fall outside the ideal community health centers/clinics service radius, while seven sub-districts are located more than 5 km from the nearest train/commuter rail station. Education and hospital coverage generally meets service standards at the sub-district scale. These findings confirm that public facility distribution in South Tangerang City has not fully satisfied the principle of spatial equity, and that access to public services continues to be determined largely by place of residence.

Keywords: accessibility; nearest neighbour analysis; network analysis; public facility; spatial equity

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1. Introduction

The expansion of Jakarta's metropolitan area has driven an urban sprawl phenomenon into the Bodetabek region (Bogor, Depok, Tangerang, South Tangerang, and Bekasi). South Tangerang City, as one of the key satellite cities, has experienced substantial population growth and high commuter mobility directed towards Jakarta. According to Statistics Indonesia (BPS), the majority of daily commuting movement in Greater Jakarta originates from the Bodetabek zone, representing 64.5% of the total 4,414,974 commuters in 2023, while Jakarta contributes 35.5%, placing considerable strain on transportation and public service networks [1].

Among the Bodetabek cities, South Tangerang recorded the highest Human Development Index (HDI) of 84.16 in 2024, reflecting a high quality of human capital. Its demographic structure is dominated by the productive-age population (72%) and school-age population (0–14 years, 22.3%), creating a high demand for public facilities — particularly in education, health, and transportation [2]. However, several news sources and prior studies have reported deficiencies in the availability and distribution of these facilities. Specifically, public junior high school capacity was insufficient to accommodate all elementary school graduates in 2025 [3]; only 36.2% of the population had access to mass public transportation [4]; and public health facilities have been reported as inadequate to meet community needs [5].

In addition, South Tangerang City is one of the areas with the highest proportion of commuters in the Greater Jakarta area, with 18.5 percent of its residents making daily trips outside the city for work [6]. This proportion indicates the community's high dependence on activity centers outside the city, which must be balanced by the availability of public facilities. A similar situation exists in the core area of Central Jakarta, where only 41% of public transportation stops are within a five-minute walk [7]. All these sources indicate a disparity in service accessibility between the metropolitan core and its periphery.

Spatial equity, defined as the fair distribution of public service benefits and burdens across geographic space, provides a key framework for evaluating the adequacy of facility provision [8,9]. In the context of public services, spatial equity focuses on whether facilities and services are distributed proportionally to population needs. The concept of horizontal equity further emphasises that populations with similar characteristics across different locations should receive comparable levels of access to services [9].

Accessibility, as defined by Geurs and van Wee [10] and further expanded in recent studies, encompasses four interacting components: transportation (the road network system), land use (the distribution of facilities), temporal (time availability), and individual (user characteristics) [9-12]. Previous studies on the spatial equity of public facilities in Indonesia have generally focused on a single facility type, leaving a gap in comprehensive, multi-sectoral analysis. For instance, Rizky et al. [13] applied network analysis to health facilities in Lampung; Lady et al. [11] used nearest neighbour analysis for school distribution in the Talaud Islands; Muazir et al. [12] analysed the spatial concentration of educational facilities in Pontianak; and Hidayat [14] assessed BRT accessibility in Purwokerto. Hardi and Murad [15] noted that a BRT station does not serve 51% of Jakarta's total area.

Ramadhanis et al. [16] also noted spatial disparities across several sectors in Jakarta, such as North Jakarta, where 50.20% of the area lacks access to healthcare services and 51.92% has inadequate educational infrastructure, compared to Central Jakarta, which has the highest accessibility with 57.43% of the area well-served for education and 65.06% for healthcare services. Taufiqurrahman et al. [17] demonstrate that disparities exist in the city of Tangerang, where the distribution of hospitals tends to be random, approaching a clustered pattern. South Jakarta also faces the same issue: out of 10 sub-districts, public hospitals are distributed across only 8 sub-districts in a scattered pattern. None of these studies simultaneously examined multiple facility categories within a single urban area, limiting their utility for integrated planning interventions.

This study addresses this gap by simultaneously analysing the spatial equity of three categories of public facilities in South Tangerang City, using Nearest Neighbour Analysis (NNA) and network-based Service Area Analysis in QGIS. NNA was selected because it provides a statistically rigorous measure of spatial concentration through the Nearest Neighbour Index (NNI), enabling objective comparison of point distribution patterns across facility types. Network-based service area analysis was preferred over simpler Euclidean buffer methods because it accounts for actual road topology and connectivity, producing more realistic representations of accessibility that reflect the routes residents must actually travel. The combination of both methods allows identification not only of whether facilities are unevenly distributed (via NNA) but also of which specific areas remain unserved (via service area analysis), providing a comprehensive diagnostic tool for spatial planning [18, 19]. The specific objectives are: (1) to characterise

the spatial distribution patterns of public facilities; (2) to assess whether the distribution meets the principles of spatial equity and the applicable planning standards (SNI 03-1733-2004); (3) to identify sub-districts experiencing service gaps (blank spots); and (4) to formulate spatially targeted policy recommendations for improving access equity.

2. Methods

2.1. Study Area

The study area as shown in **Figure 1** is South Tangerang City (Kota Tangerang Selatan), located in Banten Province, Indonesia, covering a total area of 164.85 km². The city borders the Special Capital Region of Jakarta to the north, Tangerang City and Tangerang Regency to the west, Depok City to the east, and Bogor Regency to the south. As of 2025, South Tangerang has a total population of approximately 1.5 million inhabitants, with a population structure dominated by productive-age adults (72.0%) and school-age children (22.3%) [2]. The city is administratively divided into 7 districts and 54 sub-districts.

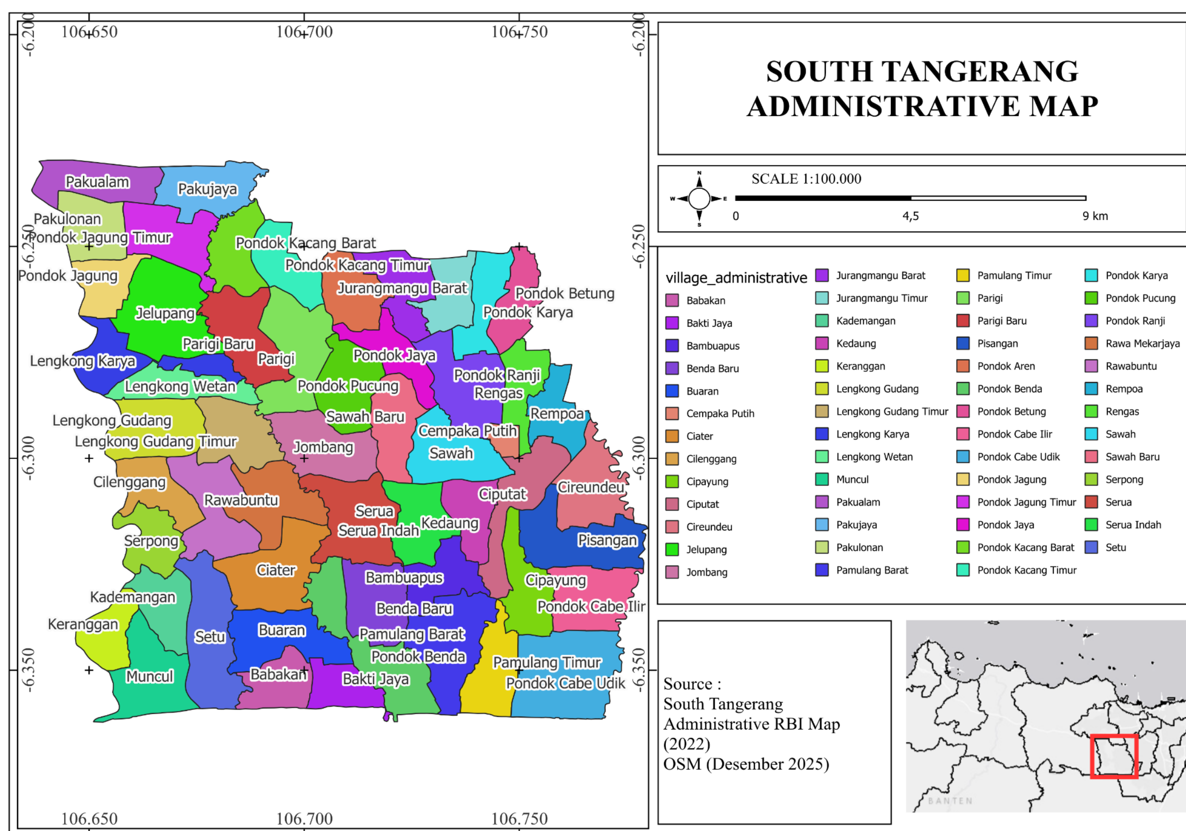

Figure 1. Administrative boundary of South Tangerang City

2.2. Research Procedures

This study relied exclusively on secondary data from publicly available and officially published sources. Administrative boundary data were obtained from the Indonesian National Topographic Map published by the Geospatial Information Agency (BIG) in 2022. Spatial data on public facilities and the road network were extracted from OpenStreetMap (OSM), accessed in 2025, using the QuickOSM plugin within QGIS. OSM is a widely used Volunteered Geographic Information (VGI) platform in urban and accessibility studies [20], though completeness may vary across areas.

Prior to analysis, a two-stage data quality assessment was conducted to evaluate the completeness and positional accuracy of the extracted OSM data. First, thematic completeness was assessed by cross-referencing the extracted facility points against Google Maps listings for the same facility categories within the study area. Facilities present in Google Maps but absent from the OSM dataset were flagged as potential omissions, while duplicate or misclassified entries were removed. Second, positional accuracy was evaluated through a visual inspection method, in which each facility point was overlaid on Google Satellite imagery loaded directly within QGIS via the XYZ Tiles service. The spatial correspondence between each point and its visible footprint on the imagery was examined manually to detect gross positional errors. Points exhibiting clear misalignment with the corresponding building or site were corrected or excluded from the dataset. This approach follows established practice in VGI validation studies, which commonly employ reference datasets and visual comparison as ground-truth proxies when field verification is not feasible. The road network extraction used OSM tags highway = primary, secondary, and tertiary to represent the main road hierarchy relevant for the analysis. Facility point data were spatially filtered using a 5 km buffer from the administrative boundary of South Tangerang City to account for potential spillover effects and to minimise edge-effect bias [21].

The three facility categories were selected based on their direct relevance to the daily service needs of South Tangerang's population and their explicit coverage in SNI 03-1733-2004 planning standards. Education facilities were prioritised because 22.3% of the population is school-age (0–14 years) [2], making equitable school access a fundamental planning requirement. Health facilities were included because primary healthcare like community health centers/clinics and hospitals represent constitutionally mandated public services whose spatial coverage directly affects population welfare [5]. Transportation facilities (bus stops and train/commuter rail stations) were chosen because South Tangerang's identity as a Jakarta commuter city makes transit accessibility critical to residents' economic participation [2]. These three sectors collectively cover the essential dimensions of urban public service delivery for a satellite city context. The categories examined are: (1) education — primary schools, junior high schools, and senior high schools, both public and private; (2) health — public health centres and hospitals; and (3) public transportation — bus stops and train/commuter rail stations. The road network was used as the primary spatial input for network analysis.

2.2. Nearest Neighbour Analysis (NNA)

Nearest Neighbour Analysis (NNA) is a spatial statistical method for identifying the distribution pattern of point features, originally developed by Clark and Evans [22]. The method computes the Nearest Neighbour Index (NNI) as the ratio between the observed mean nearest-neighbour distance and the theoretically expected mean distance under a random spatial distribution:

$$NNI = \frac{\bar{d}(obs)}{\bar{d}(exp)} \quad where \quad \bar{d}(exp) = \frac{0{,}5}{\sqrt{(\frac{n}{A})}} \tag{1}$$

where,

NNI : Nearest Neighbour Index (dimensionless)

$\bar{d}(obs)$: observed mean nearest-neighbour distance (m)

$\bar{d}(exp)$: expected mean distance under complete spatial randomness (m)

n : number of points

A : study area (m²)

The NNI ranges from 0 (maximum clustering) to approximately 2.15 (maximum dispersion). Interpretation follows the classification by Guo et al. [23], as presented in **Table 1**. Statistical significance is assessed using the Z-score; a value below −1.96 or above +1.96 indicates that the observed pattern is statistically significant at the 95% confidence level. NNA was computed in QGIS using the 'Average Nearest Neighbor's tool.

Table 1. NNI classification for spatial pattern interpretation [23]

NNI Range	Spatial Pattern Classification	NNI Range
0 – 0.7	Clustered (concentrated pattern)	0 – 0.7
0.8 – 1.4	Random (dispersed pattern)	0.8 – 1.4
1.5 – 2.15	Uniform/Dispersed (evenly distributed)	1.5 – 2.15

2.2. Network-Based Service Area Analysis

Service area analysis was performed using the QNEAT3 plugin (QGIS Network Analysis Toolbox 3) in QGIS, which delineates reachable zones from each facility based on travel distance along the actual road network. This network-based approach provides a more realistic representation of accessibility compared to Euclidean (straight-line) buffer analysis, as it accounts for road topology and connectivity [12].

The road network was pre-processed to ensure topological validity using the v.clean tool in GRASS GIS (integrated within QGIS), correcting for disconnected segments, dead ends, and duplicate edges. The service radius threshold for each facility type was determined based on applicable national standards and relevant references, as summarised in **Table 2**.

Table 2. Distance standard thresholds used for service area analysis

Facility Type	Distance (m)	Reference/Standard
School	3,000	SNI 03-1733-2004
Hospital	5,000	Permenkes No. 75/2014, Article 22
Community Health Center/Clinic	1,500	SNI 03-1733-2004
Bus Stop	400	Valentine et, al. 2020 [24]
Train/Commuter Rail Station	4,500	Givani et, al. 2007 [25]

The distance thresholds in **Table 2** represent maximum acceptable travel distances along the actual road network. The 400 m threshold for bus stops reflects standard pedestrian walking distance to transit, consistent with international walkability guidelines [24]. The 3,000 m school threshold follows SNI 03-1733-2004 and represents a reasonable cycling or short-vehicle distance. The 1,500 m community health center/clinic threshold is specified in SNI 03-1733-2004 as a walking-distance standard for primary health access. Hospital (5,000 m) and train/commuter rail station (4,500 m) thresholds reflect motorised access norms [25]. All distances were measured along the road network, not Euclidean straight-line distances. The output service area polygons were spatially overlaid with the sub-district administrative boundaries to assess coverage at the sub-district level. Blank spots were operationally defined as sub-district areas, or portions thereof, lying outside the service area polygon of the nearest facility of the same type. These were interpreted as indicators of spatial service gaps.

3. Result and Discussion

3.1. Spatial Distribution Patterns

The NNA results for all five facility categories are summarised in **Table 3**. The Z-score and NNI values collectively characterise the nature and strength of the spatial distribution pattern. Bus stops exhibit the most extreme clustering (NNI = 0.298, Z = −32.27), meaning the observed mean inter-facility distance (108 m) is only 30% of the expected random distance (362 m). This pattern is consistent with transport planning theory, which posits that bus stops are typically deployed linearly along main road corridors and activity centres [26, 27]. However, this concentration implies that large residential areas beyond these corridors remain unserved, which is confirmed by the service area analysis (Section 3.2).

The extreme clustering is primarily caused by the concentration of TransJakarta and private bus routes along high-demand arterial roads such as Jalan Raya Serpong, BSD City corridors, and the Ciputat–Pondok Indah axis — while residential areas set back from these corridors receive no service coverage. This structural pattern, driven by commercial route profitability rather than equity-based planning, directly creates the blank spots identified in Section 3.2.

Table 3. Nearest Neighbour Analysis results for public facilities in South Tangerang City

Facility	n	NNI	Z-Score	Pattern
Bus Stop	579	0.298	−32.27	Clustered (very strong)
School	757	0.603	−20.88	Clustered
Hospital	139	0.603	−8.94	Clustered

Schools and hospitals share an identical NNI value of 0.603 (Z = −20.88 and −8.94, respectively), both statistically significant. The mean inter-school distance of approximately 204 m reflects high spatial co-location, consistent with the principle that strategically important public facilities tend to cluster near high-density residential and commercial areas to maximise accessibility [28]. This co-location can be explained by the tendency of both public and private schools to locate near residential developments, particularly in planned township areas such as BSD City, Bintaro, and Alam Sutera, where developer-built facilities are concentrated. The identical clustering value for hospitals suggests a similar agglomeration logic: private hospitals tend to locate near affluent residential and commercial zones, reinforcing spatial concentration. Muazir et al. [12] reported a similar concentration pattern for educational facilities in Pontianak City, suggesting this is a common phenomenon in Indonesian urban contexts.

Community health centers and clinics show a weaker clustering tendency (NNI = 0.825, Z = −3.74). While still statistically significant, the distribution approaches randomness, reflecting a deliberate decentralisation policy for primary healthcare provision under which community health centers are designed as spatially distributed service points rather than concentrated centres [29]. This near-random distribution likely results from government mandates requiring community health center to be established at the sub-district level, creating a more spatially uniform provisioning pattern than market-driven facilities. Railway stations (NNI = 0.851, Z = −1.10) show a pattern that is statistically indistinguishable from random; however, with only n = 15 points, the NNA has limited statistical power. Station locations are primarily determined by existing rail corridor alignments rather than population density gradients [30].

Overall, the predominantly clustered patterns confirm that public facility distribution in South Tangerang City is inconsistent with the principle of horizontal equity [9]: populations with similar service needs in different areas do not receive equivalent access, as facility provision concentrates in areas with higher economic activity and population density, leaving peripheral areas underserved.

3.2. Service Area Coverage and Blank Spot Identification

Network-based service area analysis revealed differential coverage patterns across the three facility sectors. Results are illustrated in **Figure 2**. The map illustrates the spatial distribution of service coverage for three essential public facilities (education, transportation, and health) using a color gradient overlay. Red-shaded areas indicate locations in closest proximity to the nearest facility, transitioning through orange and yellow toward green as distance increases. Green-shaded areas represent the outermost boundary of the service catchment zones, where accessibility remains limited. Uncolored areas, distinguished by a hatched pattern, fall entirely outside the defined service boundaries, indicating populations that are not adequately covered by the current public facility networks and highlighting critical spatial gaps that require attention from policymakers and urban planners.

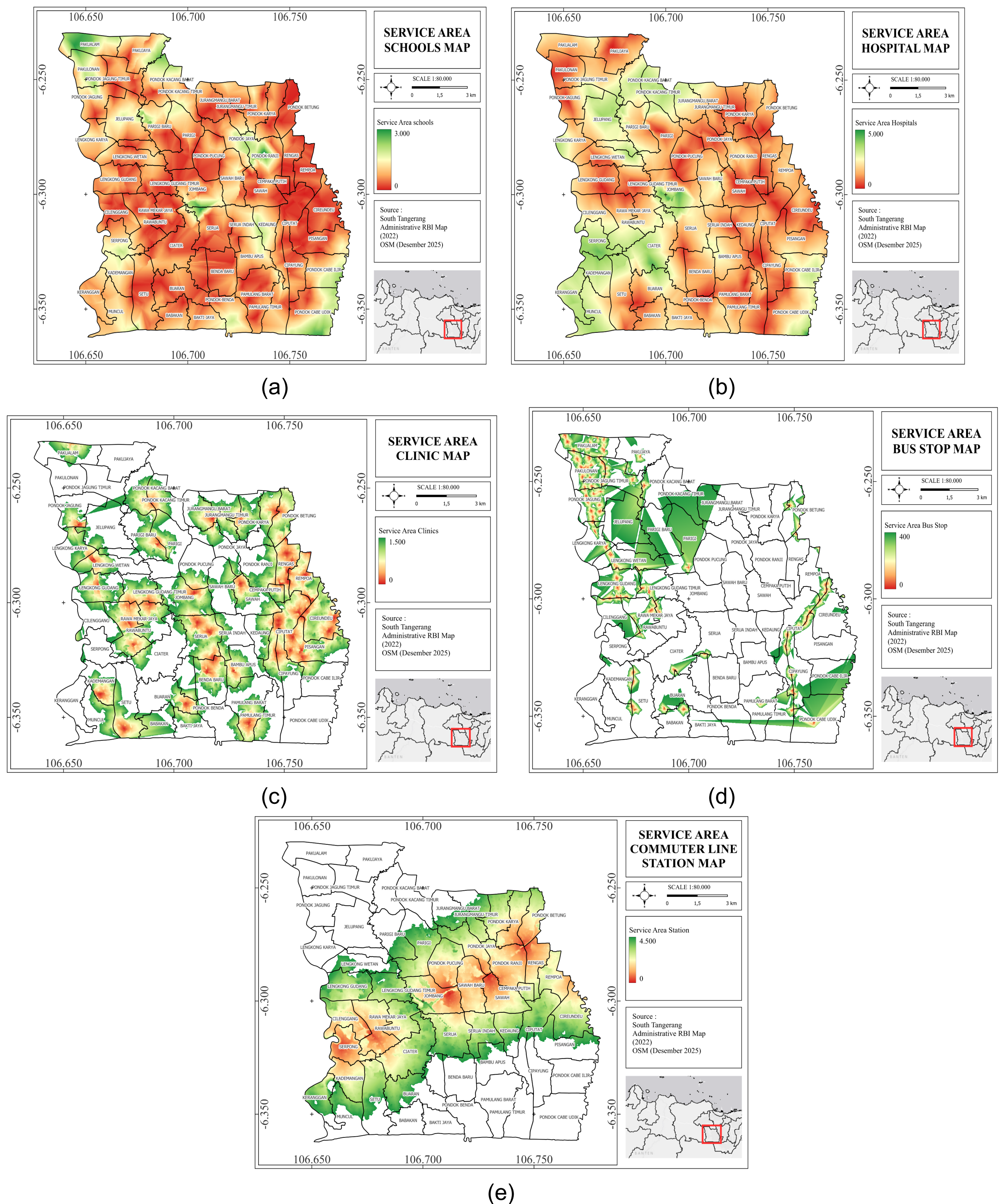

Figure 2. Network-based service area maps for education, health, and transportation facilities in South Tangerang City

Education facilities (3,000 m threshold). All 54 sub-districts fall within the service area of at least one school, with mean distances ranging from 267 m (Cempaka Putih) to 1,956 m (Pakualam). No sub-district constitutes a blank spot at this scale, indicating that the spatial distribution of schools is broad enough to provide coverage within the standardized service radius despite being clustered in absolute terms.

Regarding the 5,000 m threshold for hospitals, all sub-districts are covered by at least one hospital within the 5,000 m network distance. Mean distances to the nearest hospital range from approximately 0.5 km (Cempaka Putih) to 3.4 km (Serpong). No blank spots were identified for hospital coverage, consistent with findings by Ramadan et al. [31] that hospital accessibility in Indonesian cities is generally higher than for primary health facilities.

Health facilities like community health centers/clinics based on a 1,500 m threshold. Four sub-districts consisting of Pakulonan, Pondok Cabe Udik, Keranggan, and Pakujaya are located outside the ideal 1,500 m community health center/clinic service radius (Table 4). These sub-districts are characterised by peripheral geographic locations, often bordering adjacent regencies (Kabupaten Tangerang or Depok), where the nearest primary health facilities are administratively located outside South Tangerang City's jurisdiction.

Table 4. Sub-district identified as blank spots by facility type

Facility Type	Blank Spot Sub-district	Characteristic
Community Health Center/Clinic (>1,500 m)	Pakulonan, Pondok Cabe Udik, Keranggan, Pakujaya	Peripheral location; nearest community health center in adjacent regency
Train/Commuter Rail Station (>5,000 m)	Pondok Benda, Pondok Cabe Udik, Pondok Jagung, Pakulonan, Pakualam, Bakti Jaya, Pakujaya	Far from existing rail corridor; no feeder service
Bus Stop (no stop within range)	Bambu Apus, Bakti Jaya, Serua Indah, and others	No bus route coverage; residential areas off main corridors

Transportation — train/commuter rail stations (4,500 m threshold). Seven sub-districts have no railway station within the 4,500 m service radius, and several have the nearest station more than 5 km away (Table 4). The distribution pattern of train/commuter rail stations is primarily determined by the alignment of existing rail corridors, creating systematic access gaps in areas not traversed by the rail network. A'rachman et al. [32] reported a similar finding for integrated public transport accessibility in Central Jakarta, where only 35% of the area was served by the combined transit network.

Transportation — bus stops (400 m threshold). Bus stop coverage exhibits the most critical spatial disparity. Several sub-districts — including Bambu Apus, Bakti Jaya, and Serua Indah — have no bus stop within the 400 m walking distance threshold, making their entire area a blank spot. This is particularly concerning given that bus transit is typically the most accessible public transport mode for residents without access to the rail network. Muttaqin et al. [33] similarly found that only 7.78% of Jakarta's area was covered by bus stops within a 300 m walking radius.

These findings collectively demonstrate that while South Tangerang's aggregate facility count may appear adequate, the spatial distribution and network connectivity of these facilities are insufficient to guarantee equitable access across all sub-districts, particularly in peripheral areas. This is consistent with the theoretical framework of spatial equity articulated by Truelove [8] and Bennett [9], who argue that spatial inequity can persist even when the total number of facilities seems sufficient, if their geographic distribution does not align with the spatial distribution of needs.

4. Conclusion

This study analysed the spatial equity of public facility distribution in South Tangerang City across education, health, and transportation sectors using Nearest Neighbour Analysis and network-based service area analysis in QGIS.

The main findings are: (1) most public facilities, particularly bus stops (NNI = 0.298), schools and hospitals (NNI = 0.603), exhibit statistically significant clustered distribution patterns, indicating spatial concentration rather than equitable dispersal. This deviates from the principle in SNI 03-1733-2004 that facilities should follow service radius thresholds tied to population units. For example, primary healthcare centers are expected to serve residents within 1,500 m, schools within 1,000 to 3,000 m depending on level, and transportation facilities should be integrated into the local road network; (2) service area analysis identified coverage gaps in the primary healthcare sector, with four sub-districts outside the service radius according to the standard for community health centers/clinics, and in the transportation sector, with seven sub-districts located more than 5 km from the nearest train/commuter rail station and several lacking bus stop coverage; (3) educational facilities and hospital coverage generally meet the service distance thresholds in the standard, since schools are reachable within the prescribed limits and hospitals serve at the district scale; and (4) the overall distribution of public facilities does not fully satisfy the principle of horizontal spatial equity, as access remains influenced by place of residence, reflecting a gap between the hierarchical service structure envisioned by the SNI 03-1733-2004 standard and the actual spatial reality observed in the study area.

The policy implication of these findings is that improving equity in South Tangerang City requires a paradigm shift from facility-based planning, focused on total quantity, to access-based planning, prioritising spatial distribution relative to population needs. Specific interventions recommended include: establishing new auxiliary health posts or government clinics in Pakulonan, Pondok Cabe Udik, Keranggan, and Pakujaya; developing feeder transit routes integrated with existing train/commuter rail stations for the seven underserved sub-districts; and expanding bus stop networks and route coverage in Bambu Apus, Bakti Jaya, Serua Indah, and adjacent areas.

Future research should incorporate field verification of OSM facility data, facility capacity data to enable supply–demand analysis, and socioeconomic overlay analysis to better capture the multidimensional nature of accessibility disparities in rapidly urbanising Indonesian cities.

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