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Android Geographic Information System with AHP for Strategic MSME Location Selection

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ABSTRACT
Strategic site selection for micro, small, and medium enterprises (MSMEs) requires transparent assessment of spatial and operational criteria. This study develops an Android geographic information system integrating the Analytic Hierarchy Process (AHP) and OpenStreetMap to screen 30 locations across 25 sub-districts in Asahan Regency, Indonesia. Five criteria were defined from literature, field observation, and consultation with one local-government practitioner. Accessibility received the highest weight (0.3333), followed by safety and comfort (0.2667), proximity to crowds (0.2000), infrastructure (0.1333), and local resources (0.0667). Sekitar Stasiun Kisaran ranked first (0.0391), only 0.0004 above the next two alternatives. The system links numerical priorities with interactive mapping and provides an auditable mobile workflow for preliminary location screening. However, CR = 0.000 results from deterministic ratio construction, not broad expert consensus, and the ranking should not be interpreted as a causal prediction of business performance.
KEYWORDS: Android GIS, Analytic Hierarchy Process, MSME location selection, spatial decision support

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1. INTRODUCTION

Business location decisions combine market access, competition, visibility, logistics, infrastructure, and the characteristics of surrounding demand. Retail and shopping-center studies show that geographic information systems (GIS) can organize spatial demand and competition data, while the Analytic Hierarchy Process (AHP) and related multi-criteria methods make trade-offs among candidate sites explicit [1]–[4]. An Indonesian industrial-site study similarly demonstrates that a web-based GIS–AHP platform can convert spatial criteria into a transparent suitability assessment [5]. In Asahan Regency, the coexistence of urban markets, transport corridors, agricultural centers, and coastal activities creates a location-selection problem in which intuitive judgment alone may overlook important spatial trade-offs.

At the methodological level, GIS-based multi-criteria decision analysis is an established field for combining spatial layers with decision rules [6]. Recent research emphasizes the need to make context, uncertainty, parameter derivation, and sensitivity explicit in spatial decision-support models [7]. AHP remains widely applied because it structures complex problems hierarchically, derives priorities from pairwise comparisons, and provides a consistency diagnostic [8]–[10]. The broader interface between GIS and location science also demonstrates the value of spatial queries and mapping for facility-location decisions [18]. These capabilities are relevant when MSME suitability depends simultaneously on accessibility, activity concentration, infrastructure, local resources, and environmental comfort.

Existing business-location research has integrated GIS with AHP, spatial statistics, and other multi-criteria procedures for supermarkets, pharmacies, shopping centers, and industrial areas [1]–[5]. Facility-siting applications in health care, airports, and urban agriculture further demonstrate the transferability of GIS–AHP workflows across decision contexts [11]–[13]. However, most of these studies use desktop or web environments and sector-specific criteria. A case-specific gap therefore remains for a mobile system that combines transparent weighting, alternative ranking, and interactive OpenStreetMap visualization for preliminary MSME location screening in Asahan Regency, while acknowledging the quality considerations of volunteered geographic information [14], [15] and the implementation constraints of mobile GIS [16].

Accordingly, this study develops an Android-based spatial decision-support system integrating the Analytic Hierarchy Process and OpenStreetMap. The research question examines how a transparent multi-criteria workflow and mobile spatial visualization can support preliminary MSME location screening in Asahan Regency. The study contributes an explicit computational workflow for weighting five location criteria and ranking 30 candidate areas, a mobile interface that connects numerical priorities with geographic distribution, and a critical interpretation of the ranking that considers the effects of a single consulted practitioner, static data, and deterministic construction of the comparison matrix. The objective is decision support rather than prediction of business success.

2. METHODOLOGY

2.1. Research Design and System Development

This study combined a case-study design, multi-criteria decision analysis, and mobile software development. The unit of analysis was a candidate business location. The dataset comprised 30 alternatives distributed across 25 sub-districts in Asahan Regency, together with location identifiers, geographic coordinates, criterion-specific local values, and contextual enterprise-sector recommendations. Coordinates were collected using a GPS-enabled digital mapping application and checked against place names and administrative areas; because OpenStreetMap quality may vary by place and editing history, the mapped coordinates were treated as visualization support rather than an independently validated cadastral dataset [14], [15]. The Android application was developed using the Rapid Application Development approach to support iterative requirements clarification and interface refinement [20].

The development process comprised four phases. Requirements planning defined the decision problem, location criteria, candidate alternatives, and baseline spatial data. Interface and database design specified mobile user workflows, screen structure, and the local data schema. Construction implemented the Android modules in Java, integrated OpenStreetMap, and developed the calculation and administrative functions. Cutover validation verified the availability and basic operation of the implemented modules. A formal multi-user usability study was outside the scope of the current research.

2.2. Analytic Hierarchy Process Formulation

The decision hierarchy contained three levels: the goal (selecting a strategic enterprise location), five criteria (accessibility, proximity to crowds, infrastructure, local resources, and safety and comfort), and 30 location alternatives. The criteria were informed by business and retail location studies [1]–[5], facility-siting applications [11]–[13], field observation, and consultation with one senior staff member of the Department of Cooperatives, SMEs, Trade, and Industry of Asahan Regency. Because only one external practitioner was consulted, the resulting preferences represent a case-specific judgment rather than a multi-expert consensus.

The normalization and consistency calculations follow Saaty's original AHP framework [19], with interpretation informed by subsequent methodological reviews [8]–[10]. The simplified ratio construction used in this study is stated explicitly below.

The reciprocal pairwise comparison matrix A = [aij] contains n × n elements. In this study, each element was generated from the initial preference values using the ratio vi/vj, as expressed in Equation 1.

$$a_{ij} = \frac{v_i}{v_j}, \quad a_{ji} = \frac{1}{a_{ij}}, \quad a_{ii} = 1 \tag{1}$$

where vi and vj are the initial preference values of criteria i and j. This construction enforces reciprocity and transitivity; therefore, a consistency ratio of zero is mathematically expected and should not be interpreted as evidence of agreement among multiple experts.

Column normalization was performed by dividing each matrix element by the sum of its corresponding column, as expressed in Equation 2.

$$r_{ij} = \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}} \tag{2}$$

The criterion priority weight wi was obtained as the arithmetic mean of the corresponding normalized row, as expressed in Equation 3.

$$w_i = \frac{1}{n}\sum_{j=1}^{n} r_{ij} \tag{3}$$

Consistency was assessed from the maximum eigenvalue λmax obtained from the weighted-sum vector, as expressed in Equation 4.

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n} \frac{(A \cdot W)_i}{w_i} \tag{4}$$

The consistency index and consistency ratio were subsequently calculated using Equation 5.

$$CI = \frac{\lambda_{max} - n}{n-1}, \quad CR = \frac{CI}{RI} \tag{5}$$

where RI is the random index for matrix size n. For n = 5, RI = 1.12; a conventional acceptance threshold is CR < 0.10 [8], [19].

2.3. Evaluation Criteria and Spatial Alternatives

Five criteria were selected from business-location studies [1]–[5], GIS–AHP facility-siting research [11]–[13], field observation, and practitioner consultation. Accessibility (K1) was assigned an initial score of 5 and represents ease of access for customers, suppliers, and transport vehicles. Proximity to Crowds (K2) was assigned a score of 3 and reflects the density of surrounding commercial activities, traditional markets, and public hubs. Infrastructure (K3) was assigned a score of 2 and covers road quality, electricity, water availability, and the physical environment. Local Resources (K4) was assigned a score of 1 and represents the availability of raw materials, agricultural products, and local labor. Safety and Comfort (K5) was assigned a score of 4 and reflects public security, cleanliness, traffic safety, and environmental quality.

2.4. Alternative Scoring and Ranking

The 30 alternatives (A1–A30) covered markets, transport corridors, coastal centers, and sub-district administrative or commercial centers across 25 sub-districts. For each criterion, the recorded local value of an alternative was normalized by the total value across all alternatives and multiplied by the corresponding global criterion weight. The five weighted contributions were then summed to obtain a composite relative score. Because the scores are normalized within the evaluated set, they support comparative screening only and are not probabilities of business success. Contextual enterprise-sector associations are discussed only for the leading alternatives and are not treated as independently validated outcome predictions.

3. RESULTS AND DISCUSSION

3.1. Pairwise Matrix and Criterion Weights

Using the initial preference vector (K1 = 5, K2 = 3, K3 = 2, K4 = 1, K5 = 4), the reciprocal comparison matrix was generated by aij = vi/vj. Table 1 reports the resulting values.

The matrix ranks accessibility above the other criteria and local resources as the least influential criterion.

Table 1. Pairwise Comparison Matrix for Evaluation Criteria

Code	K1 (Access)	K2 (Crowds)	K3 (Infrastr)	K4 (Resource)	K5 (Safety)
K1	1.000	1.667	2.500	5.000	1.250
K2	0.600	1.000	1.500	3.000	0.750
K3	0.400	0.667	1.000	2.000	0.500
K4	0.200	0.333	0.500	1.000	0.250
K5	0.800	1.333	2.000	4.000	1.000

Column normalization and row averaging produced the priority vector W = [W1, W2, W3, W4, W5]T. The resulting weights were 0.3333 (33.33%) for Accessibility (K1), 0.2667 (26.67%) for Safety and Comfort (K5), 0.2000 (20.00%) for Proximity to Crowds (K2), 0.1333 (13.33%) for Infrastructure (K3), and 0.0667 (6.67%) for Local Resources (K4).

Table 2 summarizes the normalized weights and criterion ranks. Accessibility accounts for one-third of the total weight, while safety and comfort contributes slightly more than one-quarter.

Table 2. Criteria Priority Weights and Importance Ranking

Code	Criterion Name	Initial Score	Priority Weight (Wi)	Percentage (%)	Rank
K1	Accessibility	5	0.3333	33.33%	1
K5	Safety & Comfort	4	0.2667	26.67%	2
K2	Proximity to Crowds	3	0.2000	20.00%	3
K3	Infrastructure	2	0.1333	13.33%	4
K4	Local Resources	1	0.0667	6.67%	5

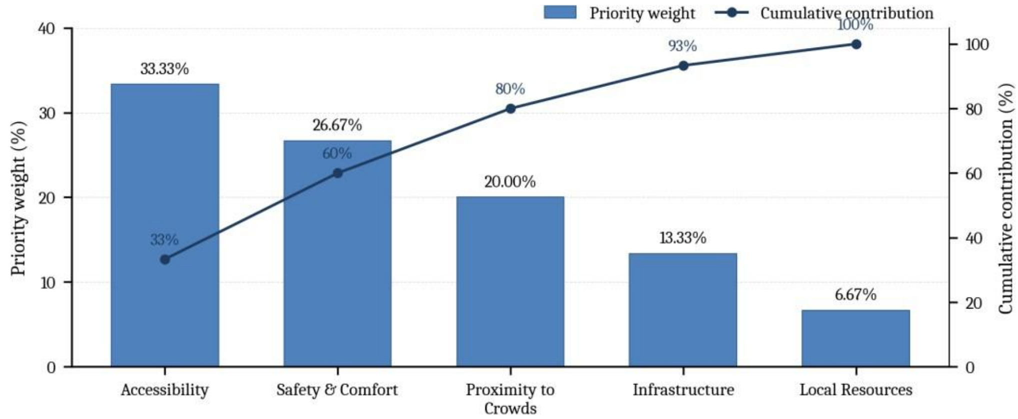

Figure 1. Priority Weights and Cumulative Contribution of MSME Location-Selection Criteria

Figure 1 presents the priority weights together with their cumulative contribution. Accessibility is the dominant criterion (33.33%), followed by safety and comfort (26.67%). Together, these two criteria account for 60.00% of the total decision weight, while the first three criteria account for 80.00%. This concentration indicates that access conditions and the quality of the immediate business environment exert substantially greater influence on the ranking than local-resource availability.

3.2. Consistency Verification

The weighted-sum vector A·W was calculated for all criterion rows. Each weighted-sum element was divided by its corresponding criterion weight to obtain the eigenvalue ratios, and λmax was calculated as the mean of those ratios. The consistency index and consistency ratio were then derived from λmax.

The calculated consistency ratio was 0.000, indicating exact internal consistency of the constructed matrix. This result is expected because every pairwise value was generated from the same ratio scale (aij = vi/vj). It verifies the algebraic consistency of the calculation, but it does not demonstrate inter-expert agreement or external validity of the preference values.

3.3. Alternative Scoring and Spatial Ranking

Each alternative received a normalized local contribution under every criterion. The composite score Sj for alternative j is defined in Equation (6).

$$S_j = \sum_{i=1}^{5} (w_i \cdot s_{ji}) \tag{6}$$

where sji is the weighted normalized contribution of alternative j under criterion i. The sum of all alternative scores is approximately one; therefore, the percentage column expresses relative priority within the 30-location set.

Table 3 summarizes the ten highest-ranked alternatives, while the complete ranking of all 30 candidate locations is provided in Appendix A. Limiting the main table to the leading alternatives improves readability, while the appendix preserves the full audit trail of the ranking.

Table 3. Top 10 Candidate Locations Based on Composite AHP Scores

Rank	Code	Candidate Location	Final Score
1	A5	Sekitar Stasiun Kisaran	0.0391
2	A6	Koridor Jl. HOS Cokroaminoto Kisaran	0.0387
3	A7	Koridor Jl. Imam Bonjol Kisaran	0.0387
4	A8	Simpang Kawat / Hessa Perlompongan	0.0376
5	A3	Sekitar Pasar Kartini Kisaran	0.0371
6	A4	Sekitar Pasar Bhakti Kisaran	0.0371
7	A1	Sekitar Pasar Inpres I Kisaran	0.0362
8	A2	Sekitar Pasar Inpres II Kisaran	0.0362
9	A13	Bagan Asahan Pekan / sekitar TPI	0.0360
10	A11	Pasar/Pusat Air Joman	0.0357

Table 3 shows that A5 (Sekitar Stasiun Kisaran) achieved the highest composite score (0.0391), followed by A6 and A7 (0.0387 each). The difference of only 0.0004 between the first- and second-ranked alternatives indicates that the leading options are closely matched and should be interpreted as a screening shortlist rather than as statistically distinct outcomes. The top-ranked locations are concentrated around transport corridors and commercial centers; A5 is suited to service-oriented MSMEs, whereas A6 and A7 support printing, laundry, food, and small retail activities. These sector associations provide contextual guidance and are not additional variables in the AHP calculation.

The spatial synthesis combines the AHP ranking in Table 3 and Appendix A with the candidate coordinates displayed through OpenStreetMap. Figure 2 presents this geographic layer, allowing the numerical screening results to be examined alongside the distribution of candidate locations. The map is used as an exploratory decision-support layer; its interpretation should consider known variation in volunteered geographic information quality.

Figure 2. GIS Spatial Mapping Result of MSME Locations in Asahan Regency

Figure 2 visualizes the geographic distribution of the alternatives. In contrast to the numerical ranking alone, the map enables users to inspect spatial proximity, regional coverage, and the relationship between high-ranked alternatives and major activity corridors.

3.4. System Design

Following the requirements planning phase, the system design was formulated using Unified Modeling Language (UML) structural models to define software architecture, actor interactions, operational workflows, and data structures.

Use Case Diagram

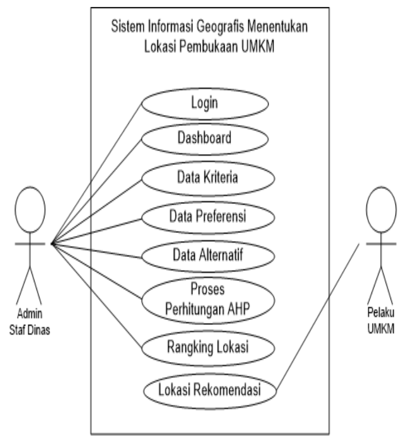

Figure 3. System Use Case Diagram

The Use Case Diagram defines the behavioral interactions between two primary actors—Admin and Community User—and the system modules. The Admin manages criteria preferences, location alternatives, database records, and triggers AHP computations. The Community User accesses spatial map visualizations, location recommendations, and sub-district search functions.

Activity Diagrams

Activity Diagrams model the sequential operational workflows across system modules. Two essential activity workflows are detailed below:

AHP Calculation Process

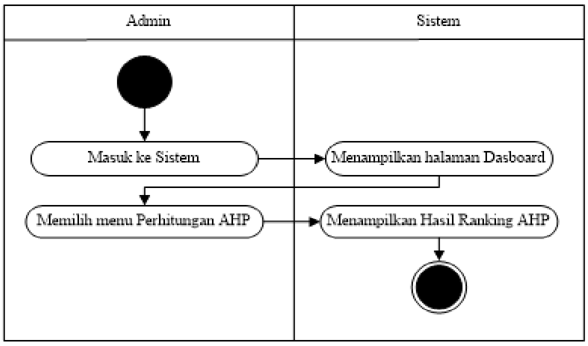

Figure 4. Activity Diagram - AHP Calculation Process

Figure 4 illustrates the AHP Calculation Activity Diagram, which shows the administrative workflow for performing the AHP calculation, including matrix normalization, priority weight calculation, and consistency ratio evaluation.

Location Recommendation

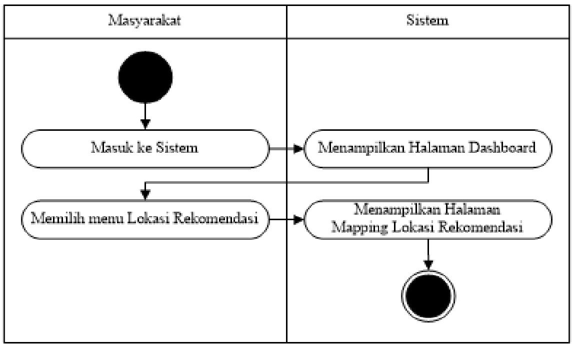

Figure 5. Activity Diagram - Location Recommendation

Figure 5 illustrates the Location Recommendation Activity Diagram, which describes the Community User workflow for accessing GIS map markers, viewing candidate locations, and obtaining location-based MSME business sector recommendations.

3.5. System Implementation

The prototype was implemented as an Android application using Java, OpenStreetMap for spatial visualization, and SQLite for local data storage. The application supports criteria management, alternative-location data, AHP calculation, ranking output, and interactive map visualization. This architecture follows the general mobile-GIS principle of linking field or mobile interfaces with spatial services and map data.

AHP Calculation Process

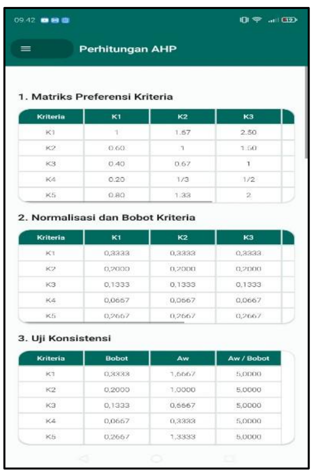

Figure 6. AHP Calculation Process

Figure 6 shows the AHP calculation process interface, which presents the AHP calculation process step by step from the formation of the preference matrix through the calculation stages to the final ranking results.
Location Recommendation Interface

Figure 7. Recommendation Map Interface

Figure 7 hows the GIS-based location recommendation interface. The interface provides an interactive OpenStreetMap view with markers representing candidate locations and allows Community Users to view location-based recommendations for MSME business sectors.

3.6. Comparative Discussion and Methodological Limitations

The final values should be interpreted as relative priorities. The leading alternative, A5 (0.0391), exceeds A6 and A7 (0.0387) by only 0.0004, while the complete score range is 0.0120. Small changes in criterion weights or local values may therefore alter adjacent ranks. Sensitivity analysis is a recognized requirement for evaluating the robustness of deterministic multi-criteria rankings [17]; it was not available in the current dataset and remains necessary for stronger decision validity.

Compared with business-location studies that model demand, competition, regulatory constraints, and detailed geospatial variables [1]–[5], the present work uses a simpler five-criterion structure tailored to the available Asahan data. Its overall logic is consistent with GIS–AHP facility-siting studies [11]–[13] and the broader GIS-MCDA literature [6], [7], while its practical distinction is delivery through an Android interface.

The practical contribution is a transparent prototype linking numerical ranking and mobile spatial visualization. Unlike a map-only application, the prototype exposes the criterion weights and composite priorities used to order alternatives. However, the highest-ranked site cannot be interpreted as causing superior business performance. External validity is limited by the use of one consulted practitioner, static spatial conditions, deterministic matrix construction, the absence of sensitivity analysis, and the lack of a reported multi-user usability evaluation. In addition, OpenStreetMap completeness and positional quality may differ across areas [14], [15], and mobile-GIS performance can depend on device and connectivity conditions [16]. These limitations define the current system as a preliminary screening instrument rather than a validated forecasting model.

4. CONCLUSION

This study developed an Android-based geographic information system integrating the Analytic Hierarchy Process and OpenStreetMap to screen 30 candidate MSME locations in Asahan Regency. Accessibility received the largest criterion weight (33.33%), followed by safety and comfort (26.67%), proximity to crowds (20.00%), infrastructure (13.33%), and local resources (6.67%). Sekitar Stasiun Kisaran achieved the highest relative score (0.0391), although its margin over the next alternatives was small. The main contribution is an auditable mobile workflow that connects multi-criteria calculation with spatial visualization. The zero consistency ratio results from deterministic ratio construction and does not establish broad expert agreement. Future research should use multiple independent experts, report the alternative-level scoring instrument in detail, conduct sensitivity and comparative analyses, incorporate dynamic traffic and commercial data, and evaluate usability with representative MSME and government users.

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DECLARATIONS

Artificial Intelligence Use

Generative AI was used only to assist with language editing during manuscript revision. The authors reviewed the final text and remain responsible for the article content, analysis, and conclusions.

Author Contributions

Ami Amanda: Conceptualization, methodology, software development, data collection, formal analysis, visualization, and writing—original draft. Triase: Supervision, conceptual guidance, methodology review, validation, and writing—review and editing. All authors reviewed and approved the final manuscript.

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Conflict of Interest

The authors declare no conflict of interest.

Ethics Approval / Ethical Clearance

Not applicable. This study did not involve experimental research involving human participants or animals. Practitioner consultation was used only to support the identification and contextualization of location-selection criteria.

Data Availability Statement

The data supporting the findings of this study are presented within the article and its appendix. The research methods and calculation procedures are described in the manuscript. Additional supporting materials may be obtained from the corresponding author upon reasonable request.

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APPENDIX A

The complete ranking is retained for transparency and reproducibility. Scores are relative priorities within the 30-location set and should not be interpreted as probabilities of business success.

Table A1. Complete Ranking of the 30 Candidate Locations

Rank	Code	Candidate Location	Final Score
1	A5	Sekitar Stasiun Kisaran	0.0391
2	A6	Koridor Jl. HOS Cokroaminoto Kisaran	0.0387
3	A7	Koridor Jl. Imam Bonjol Kisaran	0.0387
4	A8	Simpang Kawat / Hessa Perlompongan	0.0376
5	A3	Sekitar Pasar Kartini Kisaran	0.0371
6	A4	Sekitar Pasar Bhakti Kisaran	0.0371
7	A1	Sekitar Pasar Inpres I Kisaran	0.0362
8	A2	Sekitar Pasar Inpres II Kisaran	0.0362
9	A13	Bagan Asahan Pekan / sekitar TPI	0.0360
10	A11	Pasar/Pusat Air Joman	0.0357
11	A9	Hessa Air Genting / Jalur Lintas	0.0356
12	A10	Pusat Air Joman Baru	0.0349
13	A12	Pusat Kecamatan Simpang Empat	0.0349
14	A18	Pusat Kecamatan Pulau Rakyat	0.0349
15	A14	Pusat Kecamatan Sei Kepayang	0.0334
16	A21	Pusat Kecamatan Meranti	0.0333
17	A22	Pusat Kecamatan Pulo Bandring	0.0330
18	A15	Pusat Kecamatan Silau Laut	0.0324
19	A16	Pusat Kecamatan Teluk Dalam	0.0324
20	A19	Aek Loba / Pusat Aek Kuasan	0.0324
21	A20	Pusat Kecamatan Aek Ledong	0.0309
22	A17	Air Teluk Kiri	0.0296
23	A23	Pusat Rawang Panca Arga	0.0296
24	A24	Pusat Kecamatan Buntu Pane	0.0296
25	A25	Pusat Kecamatan Tinggi Raja	0.0296
26	A27	Pusat Kecamatan Rahuning	0.0296
27	A26	Pusat Kecamatan Setia Janji	0.0290
28	A29	Pusat Kecamatan Aek Songsongan	0.0281
29	A30	Pusat Bandar Pasir Mandoge	0.0274
30	A28	Pusat Kecamatan Bandar Pulau	0.0271