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DETERMINING STRATEGIC LOCATIONS FOR RENTAL HOUSING DEVELOPMENT WITH GIS AND EXPERT SYSTEMS AROUND THE EDUCATIONAL AREA OF UNIVERSITAS SULAWESI BARAT

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Abstract. Agglomeration is no longer confined to the economic sector but has also expanded into education, generating concentration effects around higher-education institutions. A similar phenomenon is evident around the campus of Universitas Sulawesi Barat in Majene Regency, where the rapid growth of rental housing risks triggering uncontrolled urban sprawl. This study aims to (1) identify the key factors influencing the selection of potential locations for rental housing and (2) determine the most suitable locations based on these factors. A quantitative approach was applied, integrating Spatial Multi-Criteria Analysis (SMCA) within a Geographic Information System (GIS) and the Analytic Hierarchy Process (AHP) as an expert-system method. The findings show that the influencing factors are grouped into three categories: environmental physical (development suitability based on land capability), socio-economic (comfort, proximity to campus, and access to public facilities), and policy (spatial planning guidelines). Expert weighting yielded environmental physical factors as the dominant criterion (69.9%), followed by policy (16.9%) and socio-economic factors (13.2%). The classified results identify high-potential rental housing areas covering 858.95 hectares (25.64% of Banggae Timur Subdistrict), distributed across 12 villages. The framework provides a transparent and replicable model for guiding education-led urban development in similar regional contexts.

Keywords: potential location, rental housing, urban development, GIS, expert system, Universitas Sulawesi Barat.

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1. Introduction

Majene Regency is one of the regions in West Sulawesi Province. According to the Regional Spatial Plan (RTRW) of West Sulawesi Province, outlined in Provincial Regulation No. 1 of 2014, Majene is designated as a Regional Activity Center (PKW) and a center for education in West Sulawesi (Pemerintah Provinsi Sulawesi Barat, 2014). This policy has implications for the growth of Majene City, which must be carefully managed to avoid uncontrolled urban sprawl. Urban sprawl refers to unplanned and uncoordinated city growth, often disconnected from road networks and characterized by haphazard development in suburban areas (Pahlevi et al., 2023). Rapid and uncontrolled housing development in suburban areas can lead to scattered settle-

ments that are not integrated into the main road network, rendering urban infrastructure ineffective (Burchell et al., 2005).

In the past three years, the development of campus facilities at Universitas Sulawesi Barat has grown significantly. This has paralleled the increasing number of students, faculty, and staff, contributing to ongoing and future development around the campus. As a result, land clearance and rapid, unregulated land conversion are inevitable. As the university expands, the demand for rental housing (boarding houses) has also risen in line with this growth. This is consistent with Montgomery's view, cited in Kuncoro, which states that agglomeration occurs due to the spatial concentration of economic activities aimed at achieving cost savings (Kuncoro, 2002). Entrepreneurs will

capitalize on this situation for economic gain. However, the logical consequence of this is the limited availability of space. Continuous land conversion into built-up areas will lead to increased building density (densification) (Rindarjono, 2013). Such densification is one form of negative settlement development, potentially leading to environmental degradation and slum conditions. To prevent these issues, early and appropriate planning becomes important.

This study aims to identify potential locations for rental housing development around the campus of Universitas Sulawesi Barat by considering physical, socio-economic, and policy factors through spatial and expert system approaches. The results of this research provide a perspective for addressing the ongoing dynamics of urban development.

According to Sumaatmadja (1981), the position of an object in space provides a deeper understanding of related geographic phenomena. The term “potential” in the Indonesian Dictionary refers to strength, ability, or capacity – implying the possibility for further development. Thus, “potential location”, especially in spatial or regional terms, refers to a place that has the potential for development because it meets certain criteria. In this study, potential rental housing locations refer to areas within the absolute boundaries of Banggae Timur District.

In the context of spatial planning, a campus can be considered part of a city’s infrastructure. According to Grigg (as cited in Suripin, 2004), infrastructure encompasses the physical facilities in a city or country, often referred to as public infrastructure. As infrastructure consists of various components, its planning must take into account the relationships and impacts among these components. Educational institutions fulfill the community’s need for higher education. Land use involves any human intervention, whether permanent or temporary, on land resources to gain benefits that fulfill material or spiritual needs (Ahmad, 1997). Additionally, Jayadinata (1992) identifies several factors that influence land use patterns, including social behavior, which is shaped by social values and processes, such as centralization (the grouping of people due to economic infrastructure) and decentralization. In this research, the presence of the university contributes to the centralization of the population in certain areas (Ramdlani et al., 2013).

Education services on a regional or national scale create a potential market for other related economic sectors. Population growth due to education-driven migration increases the demand for essential goods. According to Pappas and Hirschey (as cited in Ramdlani et al., 2013), demand refers to the amount of goods or services that customers are willing and able to purchase over a given period under specific conditions. The area surrounding a campus becomes a “market” where students come to fulfill their needs for food, accommodation (boarding houses), photocopying services, internet access, and other academic necessities. To meet students’ needs, local businesses open around the campus, offering easier, more efficient, and accessible services (Ramdlani et al., 2013).

According to Law No. 1 of 2011, Article 1, Paragraph 1, housing and settlement areas are an integrated system consisting of housing development, settlement management, maintenance and improvement of slum areas, land provision, financing systems, and community involvement (Pemerintah Republik Indonesia, 2011). According to Nurdini (2009), rental housing is a temporary living arrangement for young people who have left their parents’ homes for educational reasons.

Geographic Information Systems (GIS) comprise hardware, software, geographic data, and human resources working together to capture, store, update, manage, manipulate, integrate, analyze, and display geographically based information (Puntodewo et al., 2003). Geographical information, in its simplest form, relates to the location and layout of specific objects, further expanding its function as a tool for processing spatial data into information (Merry et al., 2023). One of the spatial analysis techniques used is Spatial Multi-Criteria Analysis (SMCA), which is applied to achieve goals through education, negotiation, aggregate weighting, or voting (Caprioli & Bottero, 2021). There are various methods for organizing and representing decision-making stages, including single-objective stages like recommending locations for specific land uses (Aliyu & Ludin, 2015).

Efraim Turban defines expert systems as containing expertise, experts, knowledge transfer, inference, rules, and explanation capabilities. This expertise is acquired formally or informally. One application of expert systems is the Analytic Hierarchy Process (AHP), which is a general theory of measurement. AHP is often used to derive ratio scales from pairwise comparisons. These comparisons are obtained through both actual and relative measurements of preferences, importance, or feelings. This makes AHP particularly useful for deriving ratio scales from qualitative factors such as opinions, feelings, behaviors, and beliefs (Saaty, 2001). AHP is widely used for supporting spatial decision-making. For example, Caprioli and Bottero (2021) applied AHP to analyze suitable locations for healthcare infrastructure in Turin, Italy, demonstrating its relevance for urban infrastructure planning. Other studies, such as Singh et al. (2019) applied fuzzy-based AHP for road route planning in India, showing its utility in complex spatial decision-making contexts. Han et al. (2020) used AHP to optimize road network selection by considering topological, geometric, and contextual characteristics of roads. AHP can also be combined with other methods, as demonstrated by Konstantinos et al. (2019) who combined AHP with TOPSIS to select optimal wind farm installation locations in Greece, showing how AHP resolves conflicting parameters in spatial decision-making.

Several previous studies have used similar approaches and themes. Desafitri (2018) analyzed the factors of boarding house selection using Kaiser-Meyer-Olkin (KMO) and Bartlett’s Test. The study focused on people’s perceptions in choosing boarding houses, with the finding that facilities such as guest rooms, shared TV rooms,

shared pantries, and well-maintained buildings are key factors for residents. The main difference with this study is the focus, which lies on selecting locations for rental housing development. Another study by Mustafa et al. (2021) examined school location selection using GIS and SMCA, focusing on demographic indicators, security, and constraints. The difference with this study lies in the research subject, as the current study focuses on rental housing locations, leading to different indicators and variables. Another study by Al-Shalabi et al. (2006) developed a model for evaluating potential development locations to support housing decisions, using spatial multi-criteria analysis combined with AHP. Differences in this study include the use of socio-economic indicators in determining potential locations. A similar study by Kadriansari et al. (2027) analyzed residential land suitability using GIS and AHP for determining parameter weights, focusing primarily on socio-environmental aspects. So far, the authors have not found studies that use the same topic and analytical process as this one, making this research a fresh contribution to determining potential locations for rental housing with an integrated consideration of physical, socio-economic, and policy factors. The results of this study are expected to provide insights for stakeholders in directing urban development.

2. Data and methodology

2.1. Research period and location

This study was conducted over a four-month period, starting from June to September 2024. The research area is situated around the campus of Universitas Sulawesi Barat, within the administrative boundaries of Banggae Timur Subdistrict, Majene Regency, West Sulawesi. The research area is delineated in Figure 1.

2.2. Variables and data

The research variables are structured according to the study's two objectives: (1) to formulate the factors influencing the selection of potential locations, which comprise three main groups: environmental physical factors (development suitability), socio-economic factors (comfort/cleanliness, distance to campus, distance to public and social facilities), and applicable policies/regulations (Spatial and Regional Planning, RTRW); and (2) to identify potential rental housing areas by combining expert weights derived through AHP with attribute scores analyzed through SMCA, and finally classifying the results using the Geometric Interval method. The full variable matrix linking objectives, variables, data types, sources, analysis techniques, and outputs is provided in the Supplementary File (Table S1).

2.3. Data collection techniques

Primary data were collected through field observation (including drone surveys to identify land use, buildings, and public facilities), photographic documentation, and questionnaires distributed to expert respondents from academia, government, and rental housing practitioners. Secondary data – covering development plans, statistical records, and base maps – were obtained from the Majene Regency Bappeda, the Public Works Office, ATR/BPN Majene, and relevant scientific literature.

2.4. Analysis techniques

The stages and analysis techniques used in this study include:

- ### 1. Formulating factors influencing the determination of potential rental housing locations

The variables in this research are generally categorized into environmental physical, social, economic, and



Figure 1. Map of the study area in Banggae Timur subdistrict, Majene (source: author's data processing, 2024)

regulatory factors. The determination of parameters for each variable was based on literature reviews, regulations, standards, theories, and empirical approaches. At this stage, each parameter was assigned a score based on the literature review.

2. Simplifying scoring values

The summed score values for each parameter were simplified using Boolean logic. The basic principle of Boolean logic uses two values, 0 (false) and 1 (true). This binary principle is often applied in spatial analysis to determine ideal locations. Each score indicating a potential location for development was simplified by assigning a value of 1, and non-potential locations were given a score of 0.

3. Weight determination using expert systems

Weight determination through expert systems aimed to identify the priority parameters among the influencing factors. The Analytical Hierarchy Process (AHP) method was used to analyze the most significant factors in determining potential rental housing locations. This analysis was based on a pairwise comparison matrix from the questionnaire, allowing calculation and comparison of the criteria. The consistency index formula was then applied to validate the data.

4. Consistency assessment

The previously normalized weight values for each parameter were tested for consistency (validity). AHP has a built-in mechanism to check whether pairwise comparisons are consistent. In AHP, the consistency is acceptable if the result is less than 0.1. Consistency tests were conducted using the Expert Choice software. If the result exceeds 0.1, recalculation is necessary, particularly in determining the importance between two parameters being compared. This may indicate inconsistencies during the respondents' input process.

5. Combination weighting

Combination weighting involved aggregating the weight values from all respondents. According to Saaty (2004), there is no specific formula for the number of respondents required for AHP, but a minimum of two respondents is needed. The results of the combination calculation were used as input for the SMCA analysis to obtain the final score for each criterion.

6. Overlay (spatial overlay analysis)

The overlay analysis was conducted to merge information (attributes) in the form of scores for each factor and combine them with weight values based on the expert evaluations through the AHP process. This analysis was carried out using GIS applications and the SMCA method. SMCA was initially used to analyze physical environmental data to provide recommendations on land suitability for residential purposes. The land capability analysis assessed nine land capability units, including: 1) morphological capability, 2) ease of development, 3) slope stability, 4) foundation stability, 5) water availability, 6) drainage, 7) erosion risk, 8) waste disposal, and 9) disaster vulnerability. The method was subsequently used to calculate the social-economic factor scores, with indicators including: 1) comfort, based on slum level in the area, 2) proximity to the campus (Putera, 2016), measured by distance from the campus area. The proximity considered ideal for rental housing development is 0–1 km, and 3) proximity to public facilities, where a distance of 0–500 meters is ideal for rental housing (Putera, 2016). Each parameter of the social-economic factors was scored based on theoretical or research rationalization and analyzed spatially using overlay techniques. The score for each parameter was summed to guide land suitability for rental housing development based on social-economic factors. Policy factors were scored based on the spatial plan guidelines of Majene Regency. Spatial planning for protected areas was given a score of 0, indicating it is unsuitable for housing development, while areas designated for cultivation were given a score of 1, indicating suitability for rental housing development. The scores for all three factors were multiplied by the weight values from expert evaluations and overlaid to obtain the final values representing potential locations.

2.5. Research flow design

The research flowchart is presented in Figure 2. The research process consists of three main stages: input, analysis, and output. The input stage collects spatial and attribute data, policy and regulatory documents, and ques-

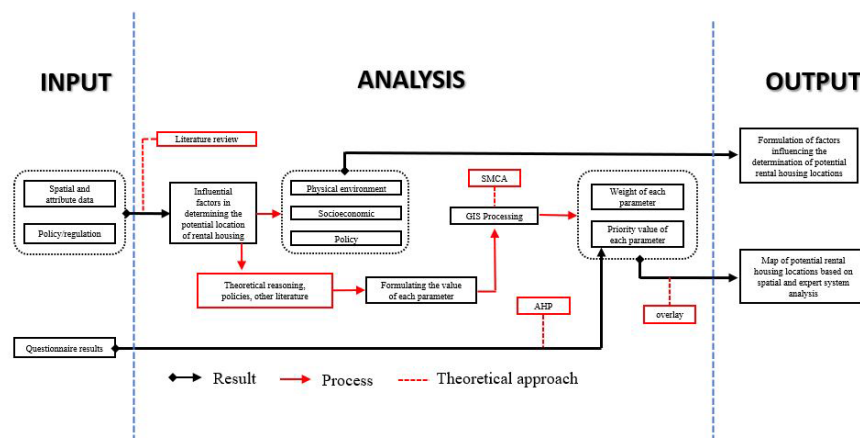


Figure 2. Research flowchart (source: author's data synthesis and processing, 2024)

tionnaire results. The analysis stage identifies the factors influencing potential rental housing locations. This stage uses literature review and theoretical reasoning. The factors are grouped into three categories: environmental physical, socio-economic, and policy. GIS processing and Spatial Multi-Criteria Analysis (SMCA) support this classification. The Analytic Hierarchy Process (AHP) then determines the weight and priority value of each parameter. The output stage produces two results. The first result is the formulation of factors influencing the determination of potential rental housing locations. The second result is a map of potential rental housing locations, based on the spatial and expert system analysis.

3. Results and analysis

3.1. Determining factors influencing potential rental housing locations

The factors are organized into three categories: environmental physical, socio-economic, and policy.

Environmental Physical Factors. Each of the nine LCU parameters was first mapped individually as a thematic layer (provided in the Supplementary File, Figure S1a–i). These layers were then processed and combined to produce a land capability map (Figure 3). The summed scores were grouped into five land capability classes (A–E) using the threshold ranges from the Ministry of Public Works guideline; the resulting class distribution is presented in

Table 1. The full combination of LCU score values across all 20 land-class units, including their spatial coverage, is provided in the Supplementary File (Table S2). Following the Ministry of Public Works guideline, Classes D and E – identified as having slightly high to very high development capability – are recommended for residential development and are therefore assigned a score of 1; Classes A, B, and C receive 0. The resulting binary classification of the environmental physical factor across the study area is shown in Figure 4.

Table 1. Land capability class summary for environmental physical factor (source: author's data processing results, 2024)

Class	Score range	Development capability	Area (Ha)	Score
A	80–88	Very low development capability	86.39	0
B	89–97	Low development capability	1,949.47	0
C	98–105	Medium development capability	488.90	0
D	106–114	Slightly high development capability	391.73	1
E	115–123	Very high development capability	458.19	1

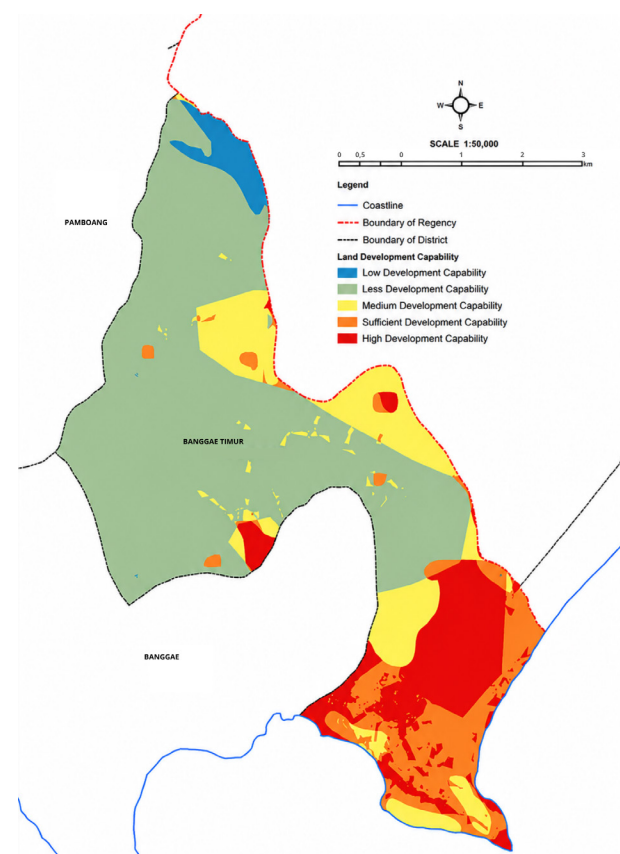


Figure 3. Land development capability (source: author's data processing, 2024)

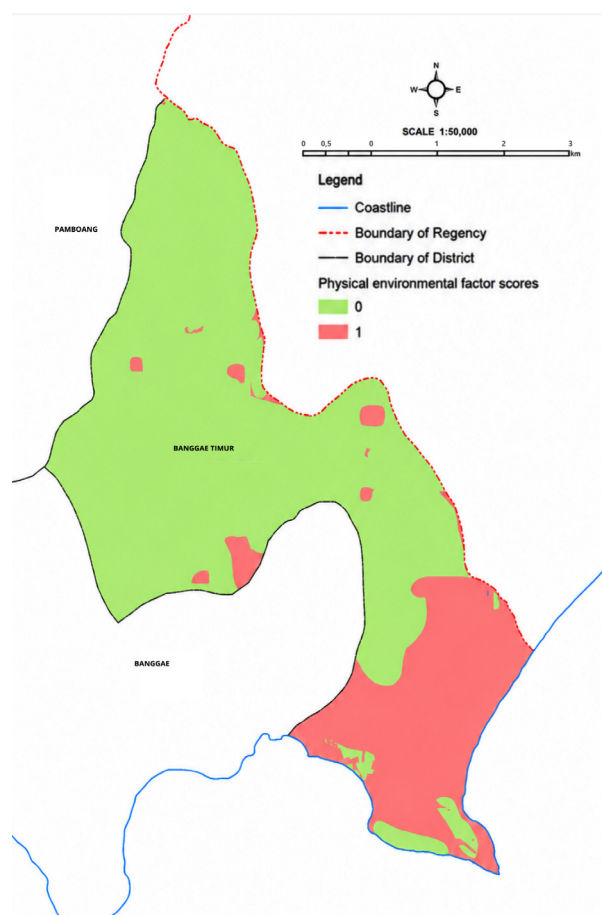


Figure 4. Environmental physical factor classification (source: author's data processing, 2024)

Socio-Economic Factors. The combined scoring of the three socio-economic indicators is presented in Table 2; the spatial classification is shown in Figure 5. Areas combining non-slum status, ≤ 1 km distance to campus, and ≤ 500 m distance to public facilities receive the highest cumulative score and qualify as suitable for rental housing development.

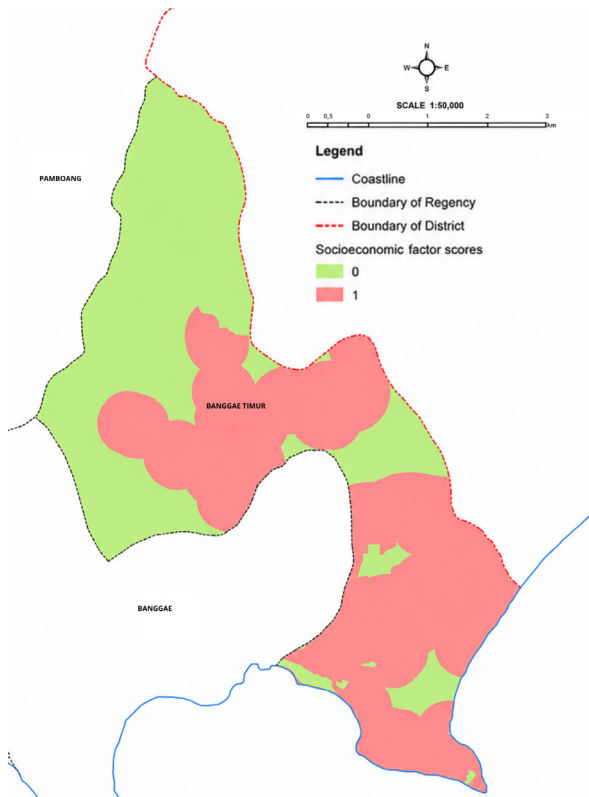


Figure 5. Socioeconomic factor classification (source: author's data processing, 2024)

Table 2. Score determination table for socioeconomic factors (source: author's data processing results, 2024)

Suitability		Proximity to campus		Proximity to public facilities		Total value	Score
Cleanliness	Value	Distance	Value	Distance	Value		
Not slum	1	<1 km	1	>500 m	0	2	1
Not slum	1	<1 km	1	500	1	3	1
Not slum	1	>1 km	0	>500 m	0	1	0
Not slum	1	>1 km	0	500	1	2	1
Not slum	1	>1 km	0	>500 m	0	1	0
Not slum	1	>1 km	0	500	1	2	1
Slum	0	>1 km	0	>500 m	0	0	0
Slum	0	>1 km	0	500	1	1	0

As shown in Table 2, the total value for each parameter combination was normalized into a binary score. A total value of 2 or 3 was normalized to a score of 1, indicating

that the combination meets the socioeconomic suitability criteria. A total value of 0 or 1 was normalized to a score of 0, indicating that the combination does not meet the criteria.

Policy Factors. The scoring outcome based on the RTRW spatial plan is summarized in Table 3 and visualized in Figure 6. Most of the study area falls within cultivation zones, indicating broad suitability from a regulatory perspective.

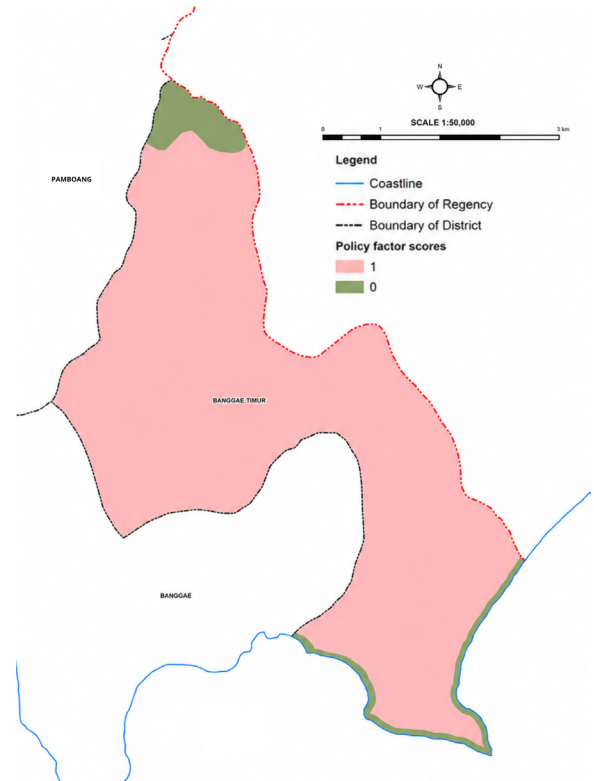


Figure 6. Policy factor classification (source: author's data processing results, 2024)

Table 3. Score determination table for policy factor (source: author's data processing, 2024)

Spatial plan	Function	Total value	Score
Protected area	Protected forest	0	0
Cultivation area	Plantation	1	1
Cultivation area	Residential	1	1
Cultivation area	Wetland agriculture (Paddy field)	1	1
Protected area	Coastal border	0	0
Cultivation area	Fish pond	1	1

The spatial pattern plan classifies each land unit into protected area or cultivation area. Protected area is assigned a value of 0, indicating the area is not recommended for rental housing development. Cultivation area

is assigned a value of 1, indicating the area is suitable for rental housing development.

3.2. Weighting factors influencing the determination of potential locations

Expert weights were obtained from three respondent groups: government, academia, and business practitioners. The government respondent assigned environmental physical factors a weight of 67.4%, policy factors 22.6%, and socio-economic factors 10.1% (CR = 0.08). The academic respondent – a lecturer in Urban and Regional Planning specializing in housing and settlements – weighted environmental physical factors at 73.1%, policy at 18.8%, and socio-economic at 8.1% (CR = 0.06). The business respondent reversed the secondary ranking, weighting environmental physical at 63.7%, socio-economic at 25.8%, and policy at 10.5% (CR = 0.04). This divergence reflects the practitioners' direct interest in user demand. Aggregated across all respondents, environmental physical factors dominated at 69.9%, followed by policy at 16.9% and socio-economic at 13.2%, with an overall consistency ratio below 0.1—satisfying the validity threshold. Detailed AHP outputs for each respondent group are presented in the Supplementary File (Figures S2–S5).

3.3. Determination of potential rental housing locations

The weighted scores from the three factors were summed and aggregated using the dissolve tool in GIS. Each factor is Environmental physical, Socioeconomic, and Policy. Each factor score was first multiplied by its AHP weight. The three weighted scores were then summed into a total value for each spatial unit. The total value ranges from 0 to 10. This value represents the combined suitability level of each location. The dissolve tool merged adjacent areas with the same total value into single polygons. Each polygon shows its corresponding area in hectares. The resulting combinations are summarized in Table 4.

Table 4. Analysis table for determining the value of each supporting factor (source: author's data processing, 2024)

Supporting factors			Total value	Area (ha)
Environmental physical	Socio-economic	Policy		
Score x AHP weight	Score x AHP weight	Score x AHP weight		
0	0	0	0	112.38
0	1	0	1	16.74
0	0	2	2	1,383.82
0	1	2	3	967.36
7	0	0	7	12.56
7	1	0	8	54.97
7	0	2	9	95.38
7	1	2	10	714.81

The aggregated scores were classified into three categories – low, medium, and high – using the geometric interval method, which distributes uneven value ranges proportionally and reduces subjective bias. The spatial output is shown in Figure 7.

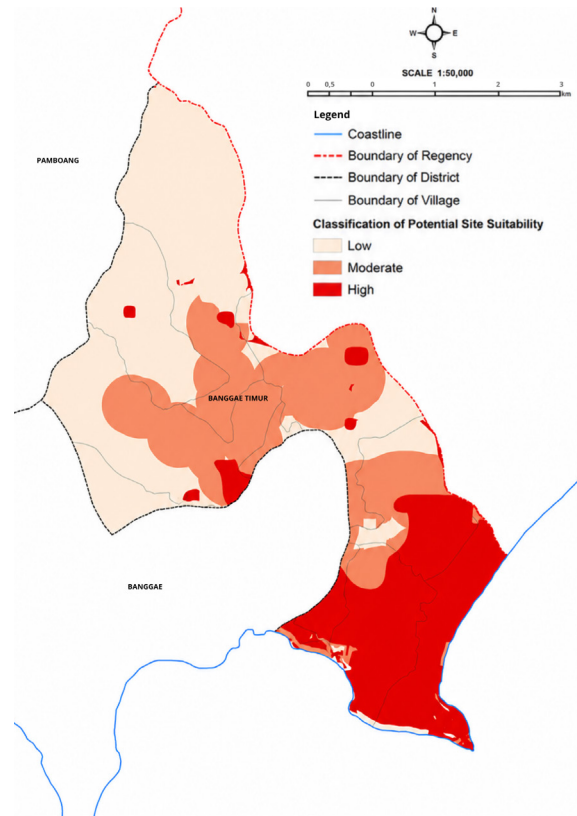


Figure 7. Potential location map for rental housing area in Banggae Timur subdistrict (source: author's data processing, 2024)

Areas classified as high-potential cover 858.95 hectares (25.64% of the subdistrict's total area), distributed across 12 villages. The five largest concentrations are Baurung (307.92 ha), Lembang (266.81 ha), Tande Timur (147.65 ha), Labuang Utara (52.26 ha), and Baruga (30.69 ha). The complete distribution across all villages and classification categories is provided in the Supplementary File (Table S3).

4. Discussion

The integration of SMCA and AHP within a GIS framework provides a transparent and reproducible decision-making procedure for siting rental housing in education-led agglomerations. The dominance of environmental physical factors (69.9%) reflects the practical reality that, in regions with diverse topography and environmental constraints, biophysical suitability sets the binding limit on development. Boolean simplification, expert-driven AHP weighting, and spatial overlay together produce classified zones that local planners and developers can use directly – an advantage over single-criterion or purely qualitative approaches. The 858.95-hectare high-potential area offers

concrete spatial guidance to mitigate uncontrolled sprawl and promote planned densification.

Several limitations qualify these findings. First, the AHP weights derive from three expert groups; expanding the panel and incorporating user-side respondents (students, residents) would strengthen robustness. Second, socio-economic indicators rely on coarse measures – binary slum classification and fixed distance thresholds – that may not capture micro-level mobility and preference variation. Third, the analysis is bounded by the administrative limits of Banggae Timur Subdistrict and does not explicitly model cross-boundary effects or future campus expansion. Fourth, the land capability assessment, while compliant with national regulation, depends on the scale and timeliness of secondary maps. A summary comparison of the study's advantages and limitations is provided in the Supplementary File (Table S4).

The framework's practical implications extend beyond Majene. Local authorities in similar education-driven regions can adopt the model to guide investment in student accommodation, reduce speculative land conversion, and align development with environmental and regulatory carrying capacity. For private developers, the identified high-potential zones represent lower-risk locations balancing campus proximity with environmental and policy compliance. Future work could incorporate dynamic variables (projected enrollment growth, real-time land prices), participatory GIS to capture user preferences directly, and fuzzy AHP or machine learning to reduce expert-judgment subjectivity and improve predictive accuracy.

5. Conclusions

The factors influencing the selection of potential rental housing locations are categorized into three factors: environmental physical factors, socio-economic factors, and policy factors. These three categories were measured based on parameters determined from theoretical reviews and references. The parameters for environmental physical factors include morphological capability (SKL), workability (SKL), slope stability (SKL), foundation stability (SKL), water availability (SKL), drainage (SKL), erosion risk (SKL), waste disposal (SKL), and disaster vulnerability (SKL). The socio-economic parameters consist of comfort (based on slum area designation in Majene Regency), proximity to the campus, and proximity to social facilities. The policy parameters consider the Majene Regency Spatial Planning Regulations (RTRW) (Pemerintah Kabupaten Majene, 2012). Each factor was formulated to obtain scores, which were simplified into values of 0 and 1. The scores for each factor were then multiplied by the weights obtained from expert assessments using the Analytical Hierarchy Process (AHP).

The combined expert assessments showed that environmental physical factors had the highest influence, with a weight percentage of 69.9%, followed by policy factors at 16.9%, and socio-economic factors at 13.2%. The summation results for each factor were classified into three categories: low, medium, and high. This classification

indicates the priority level of potential rental housing locations. The high-potential locations are spread across 12 villages/subdistricts. Baurung Subdistrict has the largest area of potential locations with 307.92 hectares, followed by Lembang Subdistrict with 266.81 hectares.

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Author contributions

AM is responsible for collecting related literature and references, developing research frameworks, spatial data processing and writing articles. FW was responsible for collecting information from experts, AHP data processing and writing the article. RM was responsible for collecting primary and secondary data, formulating research variables. MA was responsible for providing advice and reviewing the research draft.

Disclosure statement

The authors declare no conflict of interest.

References

- Ahmad. (1997). *Evaluasi Penggunaan Lahan Daerah Perbukitan dan Pengaruhnya terhadap Masalah Lingkungan Fisik di Kotamadya Ambon*. [Evaluation of Hilly area land use and its effect on physical environmental problems in Ambon municipality] [Master's thesis, Universitas Gadjah Mada]. UGM Repository. <https://etd.repository.ugm.ac.id/penelitian/detail/267094>
- Al-shalabi, M. A., Mansor, S. B., Ahmed, N. B., & Shiriff, R. (2006, October 8–13). GIS based multicriteria approaches to housing site suitability assessment. In *XXIII FIG Congress. Shaping the Change* (pp. 1–17). Munich, Germany.
- Aliyu, M., & Ludin, A. N. B. M (2015). A review of spatial multi criteria analysis (SMCA) methods for sustainable land use planning (SLUP). *Journal of Multidisciplinary Engineering Science and Technology*, 2(9), 2581–2590.
- Burchell, R., Downs, A., Mccann, B., & Mukherji, S. (2005). *Sprawl costs: Economic impacts of unchecked development*. Island Press.
- Caprioli, C., & Bottero, M. (2021). Addressing complex challenges in transformations and planning: A fuzzy spatial multicriteria analysis for identifying suitable locations for urban infrastructures. *Land Use Policy*, 102, Article 105147. <https://doi.org/10.1016/j.landusepol.2020.105147>

- Desafitri, R. B. L. (2018). Analisis faktor pemilihan kos-kosan menggunakan KMO – Bartlett's test dan kaitannya pada keinginan mendirikan usaha [Analysis of boarding house selection factors using KMO – Bartlett's test and it's relation to the desire to set up a business]. *Jurnal Pengabdian Dan Kewirausahaan*, 2(1), 29–37. <https://doi.org/10.30813/jpk.v2i1.1131>
- Han, Y., Wang, Z., Lu, X., & Hu, B. (2020). Application of AHP to road selection. *ISPRS International Journal of Geo- Information*, 9(2), Article 86. <https://doi.org/10.3390/ijgi9020086>
- Jayadinata, J. T. (1992). *Tata guna tanah dalam perencanaan pedesaan, perkotaan, dan wilayah* [Land use in rural, urban, and regional planning] (3rd ed.). ITB. <https://books.google.co.id/books?id=IwvtAAAAMAAJ>
- Kadriansari, R., Subiyanto, S., & Sudarsono, B. (2017). Analisis Kesesuaian Lahan Permukiman Dengan Data Citra Resolusi Menengah Menggunakan Sistem Informasi Geografis [Analysis of the suitability of residential land with medium resolution image data using geographic information system (Case study: Western Semarang and Eastern Semarang)]. *Jurnal Geodesi Undip*, 6(4), 199–207. <https://ejournal3.undip.ac.id/index.php/geodesi/article/view/18144>
- Konstantinos, I., Georgios, T., & Garyfalos, A. (2019). A decision support system methodology for selecting wind farm installation locations using AHP and TOPSIS: Case study in Eastern Macedonia and Thrace region, Greece. *Energy Policy*, 132, 232–246. <https://doi.org/10.1016/J.ENPOL.2019.05.020>
- Kuncoro, M. (2002). *Analisis spasial dan regional: Studi aglomerasi dan kluster industri Indonesia* [Spatial and regional analysis: A study of agglomeration and industrial clusters in Indonesia]. AMP YKPN Publishing and printing unit.
- Merry, K., Bettinger, P., Crosby, M., & Boston, K. (2023). Geographic information systems. In *Geographic information system skills for foresters and natural resource managers* (pp. 1–23). Elsevier. <https://doi.org/10.1016/B978-0-323-90519-0.00007-8>
- Mustaffa, A. A., Bahiah, B., Rasib, A. W., & Saifullizan, M. B. (2021). GIS and multi-criteria analysis for school site selection (Study case: Malacca historical city). *International Journal of Integrated Engineering*, 13(4), 234–241. <https://doi.org/10.30880/ijie.2021.13.04.022>
- Nurdini, A. (2009). *Kualitas Hunian Sewa Mahasiswa Beberapa Perguruan Tinggi di Kota Bandung: Analisis Faktual dan Perseptual* [Quality of student rental housing at several universities in Bandung City: Factual and perceptual analysis] [Doctoral dissertation, Institut Teknologi Bandung].
- Pemerintah Provinsi Sulawesi Barat. (2014). *Peraturan Daerah Provinsi Sulawesi Barat Nomor 1 Tahun 2014 tentang Rencana Tata Ruang Wilayah Provinsi Sulawesi Barat Tahun 2014–2034* [Regional regulation (Perda) of West Sulawesi Province Number 1 of 2014 concerning the Regional Spatial Planning Plan of West Sulawesi Province for 2014–2034] (2017, February 7, No. LD.2014/No. 1). <https://peraturan.bpk.go.id/Details/20976>
- Pemerintah Kabupaten Majene. (2012). *Peraturan Daerah Kabupaten Majene Nomor 12 Tahun 2012 tentang Rencana Tata Ruang Wilayah Kabupaten Majene Tahun 2011–2031* [Regional regulation (Perda) of Majene Regency Number 12 of 2012 concerning the Regional Spatial Planning Plan of Majene Regency for 2011–2031] (2012, September 28, No. LD.2012/No.12, TLD/No.28). <https://peraturan.bpk.go.id/Details/74059/perda-kab-majene-no-12-tahun-2012>
- Pemerintah Republik Indonesia. (2011). *Undang-Undang Republik Indonesia Nomor 4 Tahun 2011 tentang Informasi Geospasial* [Law of the Republic of Indonesia Number 4 of 2011 concerning Geospatial Information] (2011, No. LN.2011/No. 49, TLN No. 5214). <https://peraturan.bpk.go.id/Details/39136/uu-no-4-tahun-2011>
- Puntodewo, A., Dewi, S., & Tarigan, J. (2003). *Sistem informasi geografis untuk pengelolaan sumberdaya alam* [Geographic information systems for natural resource management]. Center for International Forestry Research (CIFOR). <https://doi.org/10.17528/cifor/001430>
- Ramlani, S., Soekirno, A., & Giriwati, N. S. S. (2013). Karakter Dan Pola Tata Ruang Kawasan Sekitar Kampus Universitas Brawijaya [Character and spatial pattern of the surrounding campus of universitas Brawijaya]. *Review of Urbanism and Architectural Studies*, 11(1), 76–86. <https://doi.org/10.21776/ub.ruas.2013.011.01.8>
- Pahlevi, M. R., Prayitno, G., & Dinanti, D. (2023). Tipologi Fenomena Urban Sprawl Di Kecamatan Driyorejo Kabupaten Gresik [Typology of the urban sprawl phenomenon in Driyorejo District, Gresik Regency]. *Planning for Urban Region and Environment Journal (PURE)*, 12(1), 121–132. <https://purejournal.ub.ac.id/index.php/pure/article/view/481/385>
- Rindarjono, M. G. (2013). *Slum Kajian Permukiman liar Dalam Perspektif Spasial*. [Slum: A study of illegal settlements from a spatial perspective]. Media Perkasa.
- Putera, R. T. (2016). *Penetapan Fasilitas Dan Harga Kamar Kos Dengan Pendekatan Principal Component Analysis Dan Analisa Payback Period (Studi Kasus : Bisnis Rumah Kos Di Kawasan Kampus ITS Sukolilo)*. [Determination of facilities and boarding room prices using a Principal Component Analysis approach and Payback Period analysis (Case study: Boarding house business in the ITS Sukolilo campus area)] [Undergraduate thesis, Institut Teknologi Sepuluh Nopember]. ITS Repository.
- Saaty, T. L. (2001). Analytic network process. In S. I. Gass & C. M. Harris (Eds.), *Encyclopedia of operations research and management science* (pp. 28–35). Springer. https://doi.org/10.1007/1-4020-0611-X_32
- Saaty, T. L. (2004). Fundamentals of the analytic network process – dependence and feedback in decision-making with a single network. *Journal of Systems Science and Systems Engineering*, 13(2), 129–157. <https://doi.org/10.1007/s11518-006-0158-y>
- Singh, M., Singh, P., & Singh, P. (2019). Fuzzy AHP-based multi-criteria decision-making analysis for route alignment planning using geographic information system (GIS). *Journal of Geographical Systems*, 21, 395–432. <https://doi.org/10.1007/S10109-019-00296-0>
- Sumaatmadja, N. (1981). *Studi geografi pendekatan dan analisa keruangan* [Geographical studies: A spatial approach and analysis]. Alumi.
- Suripin. (2004). *Sistem Drainase Perkotaan yang Berkelanjutan* [Sustainable urban drainage systems] (1st ed.). Andi Offset.