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A geographic information system-based decision support system for optimizing the use of business space using the analytical hierarchy process method

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ABSTRACT

The rapid growth of commercial activities in Medan Tembung District has intensified competition for limited business spaces, making business location selection a complex multi-criteria decision-making problem. Although the Analytical Hierarchy Process (AHP) and Geographic Information System (GIS) have been widely applied in location selection studies, their integration into a unified decision-support framework for optimizing commercial space utilization remains limited. This study proposes a web-based Decision Support System (DSS) that integrates AHP and GIS to provide objective evaluation and spatial visualization of alternative business locations. A quantitative approach was employed using expert judgments for AHP pairwise comparisons and spatial data obtained from official government sources. The analysis identified Rental Cost (44.25%) as the most influential decision criterion, and the consistency evaluation yielded a Consistency Ratio (CR) of 0.0805, confirming the reliability of the expert judgments. The integrated AHP–GIS analysis ranked Jl. Tuasan as the most suitable business location with a final priority score of 0.6308. The main contribution of this study is the development of an integrated GIS–AHP framework that combines multi-criteria decision analysis with spatial intelligence in a single web-based platform. The proposed system provides transparent and evidence-based recommendations for business location selection and offers practical support for entrepreneurs and local governments in commercial land management, spatial planning, and sustainable urban development.

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Introduction

The selection of an appropriate business location is widely recognized as one of the most critical strategic decisions influencing organizational performance and long-term sustainability. An optimal business location not only serves as the operational center for commercial activities but also contributes significantly to customer accessibility, distribution efficiency, operational cost reduction, competitive advantage, and business growth. Furthermore, commercial space possesses substantial economic value because it functions not only as a venue for business transactions but also as a medium for marketing,

customer engagement, and corporate image development (Lugosi, 2009; Škevin, 2011; Uwaoma et al., 2023). Consequently, effective utilization of commercial space requires comprehensive consideration of economic, social, infrastructural, and spatial factors to maximize business performance.

Medan Tembung District, one of the rapidly developing districts in Medan City, has experienced substantial economic expansion over the past several years. The continuous growth of residential areas, commercial establishments, and service industries has considerably increased the demand for strategic business spaces. According to the Central Bureau of Statistics (BPS Kota Medan, 2024), the district has shown significant urban development characterized by increasing commercial activities and population density. However, the availability of strategically located land has become increasingly limited, resulting in intense competition for suitable business locations. Without systematic spatial planning, inefficient land utilization may lead to several urban challenges, including traffic congestion, environmental degradation, unequal economic development, and declining business productivity.

Despite the importance of business location selection, many entrepreneurs, particularly small and medium-sized enterprises (SMEs), continue to rely primarily on personal intuition, prior experience, or informal recommendations when determining business locations (Kakooza et al., 2023; Nwokocha, 2022). Such decision-making practices are inherently subjective because they frequently overlook essential evaluation criteria, including population density, transportation accessibility, proximity to competitors, rental costs, market potential, and the availability of supporting public facilities. Consequently, inappropriate location selection may negatively affect operational efficiency, market competitiveness, and long-term business sustainability (Govindan et al., 2016; Huang et al., 2020). Therefore, the main research problem addressed in this study is the absence of an integrated and objective decision-support approach capable of simultaneously evaluating multiple business location criteria while incorporating spatial characteristics into the decision-making process. These circumstances highlight the necessity of developing a systematic decision support mechanism capable of assisting stakeholders in selecting business locations through objective, data-driven, and scientifically justifiable approaches (Barhoumi et al., 2026; Rahman & Ashfaq, 2021).

Decision Support Systems (DSS) have been extensively adopted to address complex multi-criteria decision-making problems across various application domains. Among the available techniques, the Analytical Hierarchy Process (AHP) has emerged as one of the most widely implemented methods due to its capability to decompose complex decision problems into hierarchical structures, assign relative weights to evaluation criteria through pairwise comparisons, and assess judgment consistency to ensure reliable decision outcomes. Consequently, AHP enables decision-makers to prioritize alternatives in a logical and objective manner (Albayrak & Erensal, 2004; Bugingo et al., 2024; Tavana et al., 2023). Previous studies have also demonstrated that AHP provides an effective framework for business location selection by simultaneously accommodating multiple decision criteria and generating consistent priority rankings (Alberto, 2000; Boardman Liu et al., 2008; Chen, 2006).

While AHP provides robust support for multi-criteria evaluation, it lacks the capability to represent spatial relationships among alternative locations. This limitation can be addressed by integrating Geographic Information Systems (GIS), a computer-based technology designed to collect, manage, analyze, and visualize geographically referenced information. GIS facilitates comprehensive spatial analysis through digital mapping, enabling decision-makers to examine geographical characteristics, transportation networks, demographic distribution, public facilities, and surrounding business environments more effectively (Ajani, 2025; Attah et al., 2024; Pavani et al., 2024). Therefore, GIS serves as an essential component in location-based decision-making by providing intuitive spatial visualization and geographic analysis (Akmal, 2023; Roy et al., 2024; Theodorakopoulos & Theodoropoulou, 2026).

Previous studies have independently employed AHP for business location evaluation and GIS for spatial visualization. Boardman Liu, Linda (2008) successfully applied AHP to prioritize business locations based on multiple evaluation criteria, whereas Alberto, Petroni (2000) confirmed the effectiveness of AHP in generating objective rankings of alternative locations. Likewise, Burrough (2001)demonstrated the capability of GIS to improve spatial analysis through accurate geographic visualization. Nevertheless, these studies generally implemented AHP and GIS as separate analytical approaches, limiting their ability to simultaneously perform multi-criteria evaluation and spatial

visualization within a unified decision-making framework. Furthermore, studies focusing specifically on the integration of GIS and AHP for optimizing commercial space utilization in Medan Tembung District remain scarce.

Based on the critical review above, three major research gaps are identified. First, recent AHP-based studies primarily focus on ranking alternatives while providing limited consideration of spatial relationships among candidate locations (Bugingo et al., 2024; Tavana et al., 2023). Second, GIS-oriented studies mainly emphasize mapping and geographic visualization but rarely incorporate systematic multi-criteria weighting and consistency analysis (Attah et al., 2024; Roy et al., 2024; Ajani, 2025). Third, studies integrating GIS and MCDM for commercial space optimization remain limited, particularly in rapidly growing urban areas characterized by dynamic socio-economic and spatial conditions such as Medan Tembung District (Pavani et al., 2024; Theodorakopoulos & Theodoropoulou, 2026).

To address these gaps, this study develops an integrated GIS-based Decision Support System utilizing the Analytical Hierarchy Process (AHP) to objectively evaluate business location alternatives while simultaneously visualizing their spatial characteristics. Rather than treating decision analysis and geographic information as separate components, the proposed framework combines quantitative weighting, consistency evaluation, and interactive spatial mapping within a single decision-support environment..

The scientific contributions of this study are threefold. First, it proposes an integrated framework that combines AHP-based Multi-Criteria Decision Making with GIS-based spatial analysis for business location selection. Second, it provides a practical decision-support system capable of producing objective rankings accompanied by interactive geographic visualization, thereby improving the transparency and interpretability of decision outcomes. Third, the study demonstrates the applicability of the proposed framework for optimizing commercial space utilization in Medan Tembung District, offering evidence-based recommendations that can support both entrepreneurs and local governments in sustainable urban planning.

Therefore, this study aims to develop a GIS-based Decision Support System utilizing the Analytical Hierarchy Process to identify the most suitable business locations in Medan Tembung District. The proposed system is expected to provide valuable decision support for entrepreneurs in selecting strategic business locations while assisting local governments in promoting evidence-based spatial planning, sustainable urban development, and more effective commercial land utilization.

Method

Research Design

This study employed a quantitative research approach to develop a Geographic Information System (GIS)-based Decision Support System (DSS) for optimizing commercial space utilization in Medan Tembung District. A quantitative approach was selected because the decision-making process requires numerical data processing obtained from expert judgments through pairwise comparison questionnaires. The proposed system integrates Geographic Information System (GIS) and the Analytical Hierarchy Process (AHP) to support objective business location selection based on multiple evaluation criteria.

GIS was utilized to manage and visualize spatial information, whereas AHP was applied to determine the relative importance of each evaluation criterion and rank the available business location alternatives. The integration of both methods enables subjective expert judgments to be transformed into objective and measurable spatial recommendations.

The overall research procedure consisted of four sequential phases: (1) data collection and expert elicitation, (2) GIS database development and spatial data preprocessing, (3) AHP-based multi-criteria decision analysis, and (4) integration of AHP results into the GIS platform for visualization and recommendation generation. Figure 1 illustrates the overall research workflow, while Figure 2 presents the system architecture of the proposed GIS-based Decision Support System.

The research workflow consisted of four main stages: (1) data collection, (2) spatial data processing, (3) AHP modeling and analysis, and (4) system implementation and evaluation. The final output of this study is a web-based decision support system capable of automatically recommending the

most suitable business location according to predefined criteria.

To improve the reproducibility of the proposed system, the implementation environment is summarized as follows. Spatial analysis was performed using ArcGIS 10.8, whereas the web-based application was developed using PHP, JavaScript, HTML5, CSS, and MySQL as the database management system. The experiments were conducted on a computer equipped with an Intel Core i7 processor, 16 GB RAM, Windows 11 operating system, and Google Chrome as the client browser.

Data Collection

The quality of a decision support system is highly dependent on the completeness and accuracy of the data used during the analysis process. Therefore, this study utilized both primary and secondary data.

Primary Data

Primary data were collected through questionnaires distributed to experts from relevant government institutions and practitioners involved in spatial planning and commercial area management. The questionnaire adopted the pairwise comparison technique proposed by Saaty (1980), allowing respondents to evaluate the relative importance of each criterion using a nine-point comparison scale. A purposive sampling technique was employed to select respondents possessing substantial knowledge and professional experience in commercial area planning and business location evaluation. A total of 10 experts participated in the pairwise comparison process. The panel consisted of three officials from the Regional Development Planning Agency (BAPPEDA), two representatives from the Department of Spatial Planning, two academic experts specializing in Geographic Information Systems and Decision Support Systems, and three experienced business practitioners operating commercial properties in Medan City. All experts possessed at least five years of professional experience within their respective fields.

Secondary Data

Secondary data consisted of spatial and non-spatial datasets collected from official institutions, including: Administrative boundary map of Medan Tembung District, Road network map, Population density data, Land use information, Public facility locations, Supporting literature and previous studies. The spatial datasets were obtained from the Central Bureau of Statistics (BPS), local government agencies, and other authorized institutions. The administrative boundary and road network datasets were obtained from the Medan City Government and the Central Bureau of Statistics (BPS Kota Medan), whereas land-use and public facility information were collected from the Regional Spatial Planning Office. All spatial datasets were transformed into the World Geodetic System 1984 (WGS 84) coordinate reference system to ensure consistency throughout the spatial analysis process.

Spatial Analysis

Spatial analysis was conducted using ArcGIS to process and visualize geographic information associated with business location selection. ArcGIS 10.8 was employed to construct the spatial database and perform all geographic analyses. The GIS implementation consisted of several preprocessing and analytical stages. Initially, administrative boundary maps and road network data were imported into ArcGIS. Subsequently, spatial datasets originating from different institutions were georeferenced and transformed into a unified coordinate reference system (WGS 84). Candidate business locations were then digitized using point features, while roads, administrative boundaries, and supporting infrastructures were represented as line and polygon layers. Attribute information, including population density, accessibility, land use, rental cost, and public facilities, was integrated into the GIS database through attribute tables.

Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) proposed by Saaty was employed to determine the priority weight of each criterion and rank the candidate business locations. The implementation consists of five sequential steps.

1. Hierarchical Structure

The decision problem is organized into three hierarchical levels: Level 1: Goal, Level 2: Decision Criteria,

Level 3: Business Location Alternatives. This hierarchical decomposition simplifies complex decision problems into manageable components.

2. Pairwise Comparison Matrix

Each criterion is compared pairwise using Saaty's scale (1–9).

The pairwise comparison matrix is defined as

$$\boldsymbol{A} = \begin{bmatrix} \boldsymbol{a_{11}} & \boldsymbol{a_{12}} & \cdots & \boldsymbol{a_{1n}} \\ \boldsymbol{a_{21}} & \boldsymbol{a_{22}} & \cdots & \boldsymbol{a_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{a_{n1}} & \boldsymbol{a_{n2}} & \cdots & \boldsymbol{a_{nn}} \end{bmatrix} \quad (1)$$

where: $\boldsymbol{a_{ij}} = \frac{\boldsymbol{1}}{\boldsymbol{a_{ji}}}$

3. Normalization Matrix

Each element is normalized by dividing each value by the corresponding column sum.

$$\boldsymbol{r_{ij}} = \frac{\boldsymbol{a_{ij}}}{\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \boldsymbol{a_{ij}}} \quad (2)$$

4. Priority Weight Calculation

The priority weight of each criterion is calculated by averaging the normalized values.

$$\boldsymbol{w_i} = \frac{\sum_{\boldsymbol{j=1}}^{\boldsymbol{n}} \boldsymbol{r_{ij}}}{\boldsymbol{n}} \quad (3)$$

where

$$\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \boldsymbol{w_i} = \boldsymbol{1}$$

The resulting priority vector represents the relative importance of each decision criterion.

5. Maximum Eigenvalue

The maximum eigenvalue is calculated using

$$\boldsymbol{\lambda_{max}} = \frac{\boldsymbol{1}}{\boldsymbol{n}} \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \frac{(\boldsymbol{Aw})_{\boldsymbol{i}}}{\boldsymbol{w_i}} \quad (4)$$

6. Consistency Index (CI)

The consistency of expert judgments is measured using the Consistency Index (CI):

$$\boldsymbol{CI} = \frac{\boldsymbol{\lambda_{max}} - \boldsymbol{n}}{\boldsymbol{n} - \boldsymbol{1}} \quad (5)$$

7. Consistency Ratio (CR)

The Consistency Ratio is calculated as

$$\boldsymbol{CR} = \frac{\boldsymbol{CI}}{\boldsymbol{RI}} \quad (6)$$

Where CI = Consistency Index, RI = Random Index. The comparison matrix is considered acceptable if $\boldsymbol{CR} \leq \boldsymbol{0.10}$

8. Final Score Calculation

The overall score of each business location is computed using weighted linear aggregation.

$$V_i = \sum_{j=1}^{m} w_j \, x_{ij} \tag{7}$$

Where V_i= Final score of alternative i, w_j= Weight of criterion j, x_{ij}= Priority value of alternative $i$under criterion j. The alternative with the highest value is selected as the optimal business location.

Results and Discussions

Criteria Weight Calculation Using the Analytical Hierarchy Process (AHP)

The AHP computation was initiated by constructing a pairwise comparison matrix of the decision criteria used to evaluate potential business locations. The selected criteria comprised Rental Cost, Competition, Visibility, and Accessibility. These criteria were systematically compared using Saaty's pairwise comparison scale to determine their relative importance within the decision-making hierarchy. The resulting comparison matrix served as the foundation for calculating the priority weights of each criterion, which were subsequently utilized in the evaluation and ranking of the alternative business locations.

Table 1. Comparison Matrix of Criteria

Criteria	Rental Price	Competition	Accessibility	Visibility
Rental Price	1	3	2	3
Competition	1/3	1	2	2
Accessibility	1/2	1/2	1	3
Visibility	1/3	1/2	1.3	1

Table 2. Pairwise Comparison Matrix—Criteria (Decimal)

Criteria	Rental Price	Competition	Accessibility	Visibility
Rental Price	1	3	2	3
Competition	0.3333	1	2	2
Accessibility	0.5	0.5	1	3
Visibility	0.3333	0.5	0.3333	1
Jumlah Kolom	2.1666	5.0000	5.3333	9.0000

Table 3. Normalization of the Criteria Matrix

Criteria	Rental Price	Competition	Visibility	Accessibility
Rental Price	1 / 2.1666 = 0,4615	3 / 5.0000 = 0.6000	2 / 5.3333 = 0.3750	3 / 9.0000 = 0.3333
Competition	0.3333/2.1666 = 0.1538	1/5.0000 = 0.2000	2 / 5.3333 = 0.3750	2/9.0000 = 0.2222
Visibility	0.5/2.1666 = 0.2308	0.5/5.0000 = 0.1000	1/5.3333 = 0.1875	3/9.0000 = 0.3333
Accessibility	0.3333/2.1666 = 0.1538	0.5/5.0000 = 0.1000	0.333/5.3333 = 0.0625	1/9.0000 = 0.1111

Table 4. Priority Weights for Criteria

Criteria	Perhitugan	Bobot	Pesentase
Rental Price	0,4615 + 0,6000 + 0,3750 + 0,3333 = 1.7698	1.7698 /4 = 0,4425	44,25%
Competition	0,1538 + 0,2000 + 0,3750 + 0,2222 = 0,9510	0,9510 /4 = 0,2378	23.78%
Visibility	0,2308 + 0,1000 + 0,1875 + 0,3333 = 0,8516	0,8516 /4 = 0,2129	21.29%
Accessibility	0,1538 + 0,1000 + 0,0625 + 0,1111 = 0,4275	0,4274 /4 = 0.1069	10.69%

The calculated priority weights indicate that Rental Price (44.25%) is the most influential criterion in selecting business locations in Medan Tembung District, followed by Competition (23.78%), Visibility (21.29%), and Accessibility (10.69%). These findings suggest that business operators prioritize economic feasibility over other location attributes, particularly in rapidly developing urban areas where rental costs directly affect operational

sustainability and profitability. Although accessibility and visibility remain important, respondents considered them secondary because highly accessible locations often incur substantially higher rental prices.

This finding is consistent with previous studies reporting that rental cost and market competition are dominant determinants in business location selection (Govindan et al., 2016; Kakooza et al., 2023). Similarly, Barhoumi et al. (2026) emphasized that financial considerations frequently receive the highest priority in multi-criteria business location evaluation because they directly influence investment risk and long-term operational performance.

Table 5.Calculation of the Weighted Sum Vector

Criteria	Results	WSV
Rental Price	(1×0,4425)+(3×0,2378)+(2×0,2129)+(3×0,1069)	1,9023
Competition	(0,333×0,4425)+(1×0,2378)+(2×0,2129)+(2×0,1069)	1,0247
Visibility	(0,5×0,4425)+(0,5×0,2378)+(1×0,2129)+(3×0,1069)	0,8735
Accessibility	(0,333×0,4425)+(0,5×0,2378)+(0,333×0,2129)+(1×0,1069)	0,4440

Table 6. Consistency Vector Calculations

Criteria	WSV / W		CV
Rental Price	1,9023	0,4425	4,2990
Competition	1,0247	0,2378	4,3091
Visibility	0,8735	0,2129	4,1037
Accessibility	0,4440	0,1069	4,1574

Calculating the Maximum Lambda Value (λ_{max})

$$\lambda_{max} = \frac{4{,}2990 + 4{,}3091 + 4{,}1037 + 4{,}1574}{4}$$

$$\lambda_{max} = \frac{16{,}8692}{4}$$

$$\lambda_{max} = 4{,}2173$$

Calculating the Consistency Index (CI)

$$CI = \frac{4.2173-4}{4-1} = \frac{0.2173}{3} = 0.0724$$

Calculating the Consistency Ratio (CR)

$$\text{CR} = \frac{0{,}0724}{0{,}90}$$

$$\text{CR} = 0{,}0805$$

The obtained Consistency Ratio (CR = 0.0805) confirms that the aggregated expert judgments satisfy Saaty's recommended threshold (CR < 0.10), indicating acceptable logical consistency. Consequently, the derived priority weights can be considered reliable for supporting subsequent spatial analysis. The relatively low CR value also demonstrates that the experts exhibited a high degree of agreement despite representing different professional backgrounds, suggesting that the selected evaluation criteria adequately reflect practical considerations in business location assessment.

Comparison of Alternatives for Each Criterion

Table 7. Rental Price Comparison Matrix

Rental Price	Jl.Tuasan	Jl.Suluh	Jl.Wiliam Iskandar
Jl.Tuasan	1	5	3
Jl.Suluh	1/5	1	2
Jl.Wiliam Iskandar	1/3	1/2	1

Table 8. Rental Price Comparison Matrix (decimal)

Rental Price	Jl.Tuasan	Jl.Suluh	Jl.Wiliam Iskandar
Jl.Tuasan	1	5	3
Jl.Suluh	0,2	1	2
Jl.Wiliam Iskandar	0,3333	0,2	1

Jumlah	1,5333	6,5	6

Table 9 Rental Price Normalization

Rental Price	Jl.Tuasan	Jl.Suluh	Jl.Wiliam Iskandar	Number of Rows
Jl.Tuasan	1/1,5333 = 0,6522	5/6,5 = 0,7692	3 / 6 = 0.5000	1,9214
Jl.Suluh	0,2 / 1,5333 = 0,1304	1 / 6,5 = 0,1538	2 / 6 = 0,3333	0,6175
Jl.Wiliam Iskandar	0,3333/1,5333 = 0,2174	0,2 / 6,5 = 0,0769	1 / 6 = 0,1667	0,4610

Table 10. Weights for the Rental Price Alternatives

Alternatives	Number of Rows / Number of Alternatives	Weight
Jl.Tuasan	1,9214 / 3	0,6405
Jl.Suluh	0,6175 / 3	0,2058
Jl.Wiliam Iskandar	0,4610 / 3	0,1537

Among the evaluated alternatives under the Rental Price criterion, Jl. Tuasan obtained the highest local priority weight (0.6405), indicating that it offers the most favorable rental conditions compared with Jl. Suluh and Jl. William Iskandar. This result reflects the attractiveness of locations that provide a balance between affordable rental prices and commercial potential. Conversely, Jl. William Iskandar received the lowest priority because higher rental costs reduce its attractiveness despite its strategic position.

Ranking

The final step in the AHP method is to rank the alternatives based on the results of multiplying the criteria weights by the alternative weights.

Table 11. Results of Summing the Priority Vectors Multiplied by the Alternatives

Alternatives	Rental Price	Competition	Visbilitas	Accessibility	Number of Rows
Jl.Tuasan	0.6405 × 0.4425 = 0.2834	0.6196 × 0.2378 = 0.1473	0.6768 × 0.2129 = 0.1441	0.5237 × 0.1069 = 0.0560	0,6308
Jl.Suluh	0.2059 × 0.4425 = 0.0911	0.2243 × 0.2378 = 0.0533	0.1925 × 0.2129 = 0.0410	0.3042 × 0.1069 = 0.0325	0,2179
Jl.Wiliam Iskandar	0.1537 × 0.4425 = 0.0680	0.1560 × 0.2378 = 0.0371	0.1307 × 0.2129 = 0.0278	0.1721 × 0.1069 = 0.0184	0,1513

Table 12 Ranking Results

Alternatives	Final Sc.ore	Percentage	Rank
Jl.Tuasan	0,6308	63.08%	1
Jl.Suluh	0,2179	21.79%	2
Jl.Wiliam Iskandar	0,1513	15.13%	3

The overall AHP results indicate that Jl. Tuasan achieved the highest global priority score (0.6308), substantially outperforming Jl. Suluh (0.2179) and Jl. William Iskandar (0.1513). The considerable difference in scores demonstrates that Jl. Tuasan consistently performs well across all evaluation criteria rather than excelling in only a single aspect. Specifically, the location combines relatively affordable rental costs, moderate competition, satisfactory accessibility, and high visibility, resulting in superior overall performance. These findings are consistent with previous MCDM-based location selection studies, which reported that alternatives exhibiting balanced performance across multiple criteria generally achieve higher overall rankings than alternatives that perform exceptionally well in only one criterion (Bugingo et al., 2024; Tavana et al., 2023). Furthermore, the results support

the argument that integrating multiple decision criteria produces more objective recommendations than relying solely on subjective judgment or single-criterion evaluation.

Normalization of the Criteria Pairwise Comparison Matrix

The initial stage of the Analytical Hierarchy Process (AHP) involved normalizing the pairwise comparison matrix of the evaluation criteria. This matrix was established to quantify the relative importance of the selected decision criteria, namely rental cost, competition intensity, visibility, and accessibility. Matrix normalization was performed by dividing each element within a column by the sum of all elements in the corresponding column. This procedure generated normalized priority values that represent the relative significance of each criterion in the overall decision-making framework. The resulting priority weights served as the basis for evaluating and ranking the candidate business locations.

Determination of Alternative Priority Weights

Following the computation of the criteria weights, the priority weights of the candidate business locations were determined with respect to each evaluation criterion. For every criterion, a separate pairwise comparison matrix was constructed and subsequently normalized using the AHP procedure. For instance, under the rental cost criterion, each business location was compared to identify the alternative offering the most favorable rental conditions. The same analytical procedure was applied independently to the competition, visibility, and accessibility criteria. The normalized matrices produced local priority weights, indicating the relative performance of each alternative under individual evaluation criteria.

Final Priority Score Calculation

The global priority score for each business location was obtained by integrating the criteria weights with the corresponding alternative priority weights. Specifically, the weight assigned to each criterion was multiplied by the local priority value of every alternative, and the resulting weighted values were aggregated to produce the overall priority score. This score reflects the comprehensive contribution of all evaluation criteria to each alternative. A higher priority score indicates a more suitable business location. Based on the calculation results, Jl. Tuasan achieved the highest overall priority value of 0.6308, followed by Jl. Suluh with 0.2179, and Jl. William Iskandar with 0.1513. These findings indicate that Jl. Tuasan represents the most favorable business location among the evaluated alternatives.

Consistency Analysis

One of the principal strengths of the Analytical Hierarchy Process lies in its ability to assess the logical consistency of expert judgments. The consistency evaluation was conducted by calculating both the Consistency Index (CI) and the Consistency Ratio (CR). The CI value was derived from the maximum eigenvalue of the pairwise comparison matrix, whereas the CR was obtained by comparing the calculated CI with the corresponding Random Index (RI). The analysis yielded a Consistency Ratio of 0.0805, which is below the acceptable threshold of 0.10 recommended by Saaty. Therefore, the pairwise comparison matrix can be considered sufficiently consistent, indicating that the expert judgments are logically coherent and reliable for supporting the decision-making process.

Selection of the Optimal Business Location

The final stage of the analysis involved identifying the most appropriate business location based on the computed global priority scores. According to the AHP evaluation results, the alternative with the highest priority value was considered the optimal recommendation. Among the three candidate locations, Jl. Tuasan obtained the highest priority score, demonstrating superior performance across the four evaluation criteria: rental cost, competition intensity, visibility, and accessibility. Consequently, Jl. Tuasan was identified as the most suitable location for establishing a micro, small, and medium enterprise (MSME) in Medan Tembung District. This finding demonstrates that the integration of AHP

into the decision support framework provides an objective and systematic approach for evaluating multiple location alternatives and facilitates evidence-based business location selection.

Conclusions

This study successfully developed a web-based Decision Support System (DSS) by integrating the Analytical Hierarchy Process (AHP) and Geographic Information System (GIS) to support business location selection in Medan Tembung District. The proposed GIS–AHP framework provides a systematic, objective, and spatially informed approach for evaluating business location alternatives based on multiple decision criteria. The AHP analysis identified Rental Cost as the most influential criterion with a priority weight of 44.25%, followed by Competition (23.78%), Visibility (21.29%), and Accessibility (10.69%). Furthermore, the Consistency Ratio (CR = 0.0805) was below the acceptable threshold of 0.10, confirming that the aggregated expert judgments were logically consistent and that the resulting priority weights were reliable for decision-making. Based on the integrated evaluation, Jl. Tuasan achieved the highest overall priority score (0.6308), followed by Jl. Suluh (0.2179) and Jl. William Iskandar (0.1513), indicating that Jl. Tuasan represents the most suitable business location among the evaluated alternatives. The primary scientific contribution of this research is the development of an integrated GIS–AHP decision-support framework that combines multi-criteria decision analysis with spatial visualization within a unified web-based platform. Unlike previous studies that generally applied AHP for ranking alternatives or GIS for geographic visualization independently, the proposed framework integrates both analytical capabilities to generate more objective, transparent, and geographically interpretable business location recommendations. This integration contributes to the advancement of GIS-based Multi-Criteria Decision-Making (MCDM) by demonstrating how quantitative evaluation and spatial intelligence can be effectively combined to support evidence-based decision-making. From a practical perspective, the proposed system provides valuable support for entrepreneurs in selecting strategic business locations while assisting local governments in commercial land management, spatial planning, and sustainable urban development. The integration of interactive GIS visualization enables decision-makers to interpret analytical results more intuitively and facilitates transparent evaluation of candidate business locations based on both quantitative priorities and geographic characteristics. Despite these contributions, this study has several limitations. The proposed framework was evaluated using only four decision criteria and three business location alternatives within Medan Tembung District, which may limit the generalizability of the findings to other geographic regions. In addition, the AHP evaluation relies on expert judgments, and the GIS analysis utilizes static spatial datasets without considering dynamic variables such as real-time traffic conditions, pedestrian mobility, or temporal changes in commercial activities. Future research should extend the proposed framework by incorporating additional evaluation criteria, including demographic characteristics, purchasing power, traffic volume, environmental factors, and economic indicators. Furthermore, comparative investigations involving other Multi-Criteria Decision-Making (MCDM) techniques, such as TOPSIS, VIKOR, PROMETHEE, ANP, and Fuzzy AHP, as well as the integration of real-time geospatial data and intelligent analytics, are recommended to further improve the robustness, adaptability, and accuracy of business location recommendation systems.

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