Songklanakarin J. Sci. Technol.
48 (1), e20260101, Jan. – Feb. 2026

http://www.sjst.psu.ac.th

Review Article

Leveraging GIS for strategic location-based decision-making in Indonesia: A literature review

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Received: 25 March 2025; Revised: 22 July 2025; Accepted: 16 September 2025

Abstract

Indonesia, a country with the fourth-largest population in the world, requires carefully considered decision-making processes. Integrating GIS with various methodologies offers a promising approach to enhancing location-based decision-making processes. The literature review in this article focuses on location-based decision-making in Indonesia from year 2017 to 2024. This study aims to explore the implementation of location-based decision-making in Indonesia by identifying the methods that are often used and providing a comparison between advantages, limitations, and challenges across these diverse sectors. Based on the results, GIS is often used in Disaster Response, Infrastructure, Agro-Fishery, Economy, Power Plants, and Intelligent Systems. GIS and AHP are the most often used methods as they offer a robust framework for location-based decision-making. These methods integrate complex spatial data, identify priority areas, and provide tools for simulating and evaluating the geographic impacts of decisions.

Keywords: decision making, GIS, AHP, location, Indonesia

1. Introduction

Indonesia, a country with the fourth-largest population in the world, requires carefully considered decision-making processes. With highly diverse geographical characteristics it requires comprehensive spatial approaches for planning and policymaking (Andréfouët, Paul, & Farhan, 2022). Geographic Information System (GIS) is an integrated system comprising hardware, software, spatial data, and analytical procedures used to capture, store, manipulate, analyze, and visualize georeferenced information (Maliva & Missimer, 2012). In the context of applied geography, GIS has become a fundamental tool for supporting spatial analysis, particularly in location determination based on multiple physical and socio-economic criteria (Abdulrazzaq, Agbasi, Aziz, & Etuk, 2020; Barillé *et al.*, 2020). The reliability of GIS in supporting location determination can be enhanced through the integration of methods such as Multi Criteria Decision Analysis (MCDA), Analytic Hierarchy Process (AHP), fuzzy logic, and algorithms based on machine learning and optimization models, which facilitate decision-making based on a systematic weighting of multiple criteria (Sahin, Koc, & Sark, 2024; Shekar & Mathew, 2023). The benefits of implementing a combination of GIS and other methods include accelerated analysis processes, enhanced result accuracy, and easier spatial visualization for policy makers (Makkulawu, Soemarno, Santoso, & Mustaniroh, 2023).

Combination of GIS and AHP makes a significant contribution to the planning and development of renewable energy infrastructure (Albraheem & AlAwlaqi, 2023; Şahin, Koc, & Van Sark, 2024; Subagyo, Moh. Yanuar, Bambang, Saleh, & Akhmad, 2023; Yousefi, Moradi, Zahedi, & Ranjbar, 2024). Spatial analysis using GIS can help provide insights for better soil management and fertilization, supporting sustainable agricultural practices (El-Seedy, El-Hamdi, El-Harty, & Saeed, 2024). Zandi *et al.* (2024) applies GIS to

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address the challenges faced by developing countries due to rapid population growth and urban expansion in relation to healthcare services, while other applications include landfill management (Armanuos & Elgaafary, 2023; Elkhrachy, Alhamami, & Alyami, 2023; Oanh *et al.*, 2024) and water resources (Opoku, Shu, & Amoako-Nimako, 2024; Raja Shekar & Mathew, 2023). Based on Ruiz, Sunarso, Bathis, Murti, & Budiarto (2020), GIS integration makes it possible to evaluate suitable locations while taking ecological constraints and infrastructure concerns into consideration. Teniwut, Marimin and Djatna (2019) report on research that helps to improve community wellbeing and shape long-term industrial development strategies. Additionally, GIS based approaches make use of data to develop resilience and efficiency, guaranteeing preparedness and efficient response in the event of emergencies or disasters (Chaulagain *et al.*, 2023; Mshelia & Belle, 2024).

The research method applied in this study is a literature review, which aims to systematically collect, identify, and synthesize findings from previous studies (Snyder, 2019). The article selection process adopts the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method, which provides standardized guidelines for reporting and selecting studies in literature reviews (Page *et al.*, 2021). This study aims to explore the implementation of location-based decision making in Indonesia by identifying the data that are often used and methods across diverse sectors. Sometimes the government has a policy that it wants to implement, but the obstacle is where is the suitable location or region to prioritize for the policy. Through an analysis of how well Geographic Information Systems (GIS) work with other approaches in Indonesian decision-making, this research seeks to offer valuable insights into the application of these technologies for addressing the country's multifaceted challenges.

GIS has proven to offer significant advantages in supporting location-based decision-making in Indonesia (Wigati, Sopha, Asih, & Sutanta, 2023). One of the main strengths of GIS lies in its ability to integrate multidimensional data (Widianingsih, Masri, & Abdullah, 2019), objective multi-criteria analysis (Teniwut *et al.*, 2019), visualization, and simulation (Makkulawu *et al.*, 2023), providing increased efficiency and responsiveness (Karyawan, Hariyadi, Iskandarsyah, & Mahendra, 2024) and strengthening stakeholder collaboration (Prasetyani, Isnanto, & Rosyida, 2023; Wardah & Yani, 2022). Nevertheless, several limitations remain significant challenges in utilizing GIS for decision-making like dependence on data quality and availability (Retnaningtias, Arifin, & Anugia, 2024), subjectivity in weighting (Susiati *et al.*, 2024), technical complexity and resource requirements (Setiawan, Supriyadi, Widodo, & Navalino, 2024) and limitations in uncertainty analysis. But there are some innovations in the use of GIS for strategic decision-making including integration of fuzzy logic and machine learning (Kodong *et al.*, 2019; Wigati *et al.*, 2023), mobile mapping and real-time data, Web-GIS and public participation, high-resolution aerial photo database and network analysis, and spatial economic models. Despite rapid technological advances, the main future challenges include building an integrated national spatial data ecosystem, strengthening spatial literacy at all levels, and ensuring system interoperability across sectors. The active involvement of government, academia, private sector, and society will be essential in determining the effectiveness of GIS in realizing inclusive and sustainable strategic decision-making in Indonesia.

2. Materials and Methods

This study employs a Systematic Literature Review (SLR) method to analyze existing research on location-based decision-making using Geographic Information Systems (GIS) in Indonesia. A systematic review is a research method that aims to identify, evaluate, and interpret research results that are relevant to a particular topic or phenomenon that is the focus of the research (Kitchenham, 2004). The article selection process adopts the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method, which provides standardized guidelines for reporting and selecting studies in literature reviews (Page *et al.*, 2021). This process consists of four main stages: identification of articles from various databases and other sources; screening to eliminate duplicates and irrelevant articles; eligibility assessment by reviewing the full text to ensure compliance with inclusion criteria; and inclusion, in which eligible articles are incorporated into the final analysis.

The identification stage is carried out by searching for articles sourced from the Scopus database using advanced document search. Scopus was chosen because it has a large database of abstracts and citations and has been applied in several previous studies (Arimjaya & Dimyati, 2022; Maghribi *et al.*, 2022). The keywords used to search for articles were "Decision making", "GIS", and "Location"." The search results yielded 2,319 articles. The screening stage in this study involved selecting articles written in English and located in Indonesia. This research has limitations, namely that it only discusses articles with open access. This process resulted in a final selection of 21 articles deemed suitable for inclusion in the review (Figure 1).

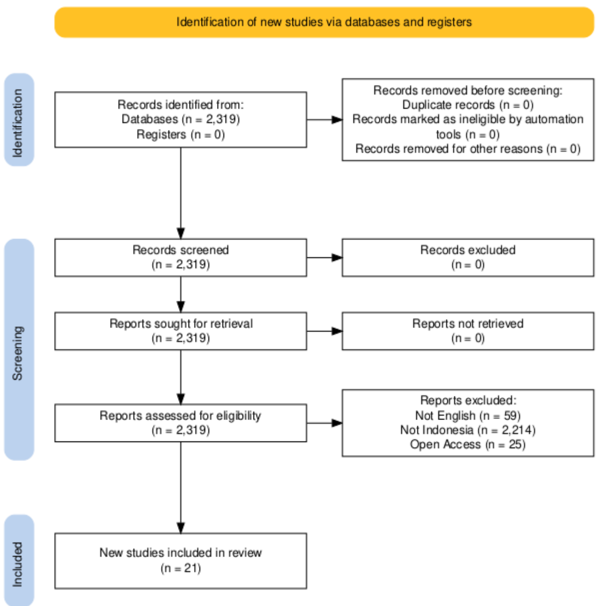

Figure 1. Systematic literature review using the PRISMA method

3. Results and Discussion

Geographic Information System (GIS) has evolved into a central pillar in location-based decision-making in Indonesia. Based on the research that we used, the first paper about Location based decision making was published in 2017, and it implemented a simulation of tsunami evacuation plan using Agent-Based Model Simulation. This is in line with the 2025 Indonesian Disaster Risk Index issued by the National Disaster Management Agency (BNPB), which states that Indonesia is vulnerable to natural hazards, including nine types of threats: earthquakes, tsunamis, volcanic eruptions, landslides, floods, extreme weather, drought, forest and land fires, and extreme waves and abrasion. Research on location-based decision-making has continued to develop in Indonesia. Indonesia has also implemented a one-map policy to integrate all maps produced by ministries and agencies. From its origins as a mere mapping tool, GIS now plays a key role across multiple sectors—including energy (Ruiz *et al.*, 2020), transportation (Jaya *et al.*, 2023), environment (Maghribi *et al.*, 2022), tourism (Wijaya *et al.*, 2021), and national security (Setiawan *et al.*, 202). This transformation is driven by the demand for spatial information that is accurate, timely, and adaptive in facing the dynamics of development, urbanization, and environmental challenges in Indonesia.

3.1 GIS advantages and limitations in decision-making

Most popular method that has been implemented in Indonesia was the integration of GIS-MCDA for optimal site selection. GIS has proven to offer significant advantages in supporting location-based decision-making in Indonesia. Table 1 shows some of the main identified advantages.

Nevertheless, Table 2 shows that several limitations remain significant challenges in utilizing GIS for decision-making.

Table 1. GIS advantages in Indonesia

No	Category	Advantages	Reference
1	Multidimensional data integration	GIS is capable of integrating both spatial and non-spatial data simultaneously. This includes topographic, hydrological, land use, infrastructure, socio-economic data, as well as stakeholder preferences.	(Jaya, Mulyawati, & Yusoff, 2023; Rimadeni, Sofyan, Rahman, Pramana, & Juellyan, 2024; Suprapti, Kusuma, Kardhana, & Cahyono, 2024; Usman *et al.*, 2017; Wigati *et al.*, 2023)
2	Objective multi-criteria analysis	Through the collaboration of MCDA methods (such as AHP and WLC), GIS provides a systematic and objective weighting structure for site selection, resulting in more accountable and transparent outcomes.	(Gemilang *et al.*, 2024; Kodong, Abdollah, & Othman, 2019; Wardah *et al.*, 2022)
3	Visualization and simulation	The spatial visualization capabilities of GIS enable more participatory and evidence-based decision-making, including scenario analysis, impact simulation, and effective communication of results to policymakers and the public.	(Karyawan *et al.*, 2024b; Prasetyo *et al.*, 2018b; W A Teniwut *et al.*, 2019)
4	Increased efficiency and responsiveness	The use of GIS, whether for road damage analysis with MMS or the identification of traffic accident hotspots, accelerates response times and minimizes the need for manual field surveys.	(Ernawati, Baharin, & Kasmin, 2021; Wijaya *et al.*, 2021)
5	Strengthening stakeholder collaboration	GIS facilitates the involvement of various parties through shared visualization, the weighting process, and participatory spatial validation, thereby increasing transparency and acceptance of decision outcomes.	(Retnaningtias *et al.*, 2024b; Ruiz *et al.*, 2020b)

Table 2. GIS limitations in Indonesia

No	Category	Limitation	Reference
1	Dependence on data quality and availability	One of the biggest obstacles is the reliance on accurate, up-to-date, high-resolution spatial data. The lack of consistent or standardized data can reduce the reliability of analyses and recommendations	(Jaya, Mulyawati, & Yusoff, 2023; Rimadeni, Sofyan, Rahman, Pramana, & Juellyan, 2024; Suprapti, Kusuma, Kardhana, & Cahyono, 2024; Usman *et al.*, 2017; Wigati *et al.*, 2023)
2	Subjectivity in weighting	Although MCDA provides an objective framework, the weighting process can still be influenced by subjective bias, especially if broad stakeholder involvement is lacking or if sensitivity validation is not conducted	(Gemilang *et al.*, 2024; Kodong, Abdollah, & Othman, 2019; Wardah *et al.*, 2022)
3	Technical complexity and resource requirements	Optimal GIS implementation requires adequate IT infrastructure, skilled human resources, and inter-agency coordination, which often pose challenges at both regional and national levels	(Karyawan *et al.*, 2024b; Prasetyo *et al.*, 2018b; W A Teniwut *et al.*, 2019)
4	Limitations in uncertainty analysis	Most GIS-MCDA models are not yet fully capable of addressing data uncertainty, dynamic changes, and unforeseen risks, although initial approaches have emerged through the integration of fuzzy methods and sensitivity analysis.	(Ernawati, Baharin, & Kasmin, 2021; Wijaya *et al.*, 2021)

3.2 Innovations of GIS in decision-making

The pace of innovation in the use of GIS for strategic decision-making is rapidly accelerating. One of the most significant trends is the integration of fuzzy logic and machine learning, where a growing body of studies applies methods such as fuzzy AHP, machine learning algorithms, and spatial optimization to address the limitations of subjectivity and improve the prediction of complex variables. Alongside this, the adoption of Mobile Mapping Systems (MMS) and real-time field data collection enables faster updating and higher accuracy of thematic maps, thus supporting more responsive spatial analyses. The rise of web-GIS platforms and open-source participatory GIS further democratizes spatial planning, as these technologies encourage greater public engagement and facilitate community feedback during the validation and planning processes. Another major advance is the development of a national high-resolution aerial photo database, which significantly enhances the monitoring of land use changes, supports anomaly detection, and provides robust infrastructure supervision for both national security and sustainable development objectives. Finally, the application of network analysis and spatial economic models, particularly in the tourism and logistics sectors, allows for comprehensive assessments of accessibility, facility planning, and the identification of optimal development sites based on local potential, ensuring that spatial strategies are data-driven, inclusive, and adaptive to real-world needs.

3.3 Integration of spatial and non-spatial data

GIS is capable of integrating both spatial and non-spatial data simultaneously, enabling comprehensive and multidimensional analyses for strategic location-based decision-making. Spatial data typically encompass georeferenced physical parameters such as topography, land use/land cover, soil type, rainfall, water availability, accessibility, sea depth, and natural hazard risks, which define the biophysical characteristics and constraints of a given area. Non-spatial data, on the other hand, include socio-economic and institutional information such as population density, proximity to settlements, economic indicators, access to public facilities, stakeholder preferences, transportation networks, and administrative boundaries, which capture the human and governance dimensions influencing spatial planning. This classification ensures that decision-making processes account for both the environmental feasibility and socio-economic viability of selected locations, leading to more balanced, sustainable, and context-sensitive outcomes.

4. Conclusions

Integrating Geographic Information Systems (GIS) with Analytical Hierarchy Process (AHP) and Multi Criteria Decision Making (MCDM) is the mostly used approach for location-based decision making in Indonesia. This is consistent with the results of Makkulawu *et al.*, (2023), which underline the potential of integrating GIS and AHP. In Indonesia, GIS for location-based decision making has implementations across various sectors such as Disaster Response, Infrastructure, Agro-Fishery, Economy, Power Plants and Intelligent Systems. Its strengths lie in integrating spatial and non-spatial data, enabling objective multi-criteria analysis, and enhancing visualization for participatory planning. However, challenges remain in data quality, subjective weighting, technical capacity, and uncertainty analysis. Emerging innovations—such as fuzzy logic, machine learning, mobile mapping, and web-based participatory GIS—are improving accuracy, efficiency, and inclusivity, positioning GIS as a critical tool for sustainable and adaptive spatial planning in Indonesia. Furthermore, the ability of GIS to combine environmental, socio-economic, and infrastructural parameters ensures that decision-making processes address both ecological sustainability and socio-economic viability. This integration not only supports more evidence-based and transparent policies but also enhances resilience, adaptability, and stakeholder engagement in responding to Indonesia's dynamic development and environmental challenges.

Table 3. Spatial and non-spatial variables

No	Category	Commonly used variables	Typical application context
1	Spatial	Slope/Topography	Site suitability for energy, infrastructure, tourism, water
2		Soil type	Assessing carrying capacity, erosion risk, aquaculture, tourism
3		Rainfall	Flood risk, water availability, agriculture, tourism
4		Land use/Land cover	Mapping built-up, forests, agriculture, settlements, conservation
5		Accessibility/ Infrastructure	Proximity to roads, power grid, ports, public facilities
6		Sea depth/Water availability	Site selection for coastal power plants, aquaculture, ports
7		Water availability/Drainage	Agriculture, power plant, tourism suitability
8		Natural disaster risk	Flood, landslide, tsunami, volcano risk, vital facilities
9		Satellite imagery/Aerial photography	Land cover validation, infrastructure monitoring, mapping
10	Non-Spatial	Population density & growth	Location of public facilities, tourism, logistics, infrastructure
11		Proximity to settlements	Accessibility, market potential, social risk assessment
12		Economic data (e.g., Regional income, GDP)	Assessing economic impact, tourism, business, industry
13		Access to social facilities	Schools, hospitals, services, places of worship
14		Stakeholder & community preferences	Weighting, AHP/MCDA validation, participatory planning
15		Transportation data (Networks, modes)	Accessibility, transport planning, tourism, logistics
16		Administrative boundaries	Basis for spatial planning and policy

Acknowledgements

Acknowledgments to the Department of Geography, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, for their invaluable support throughout this research and Indonesian Geospatial Information Agency (Badan Informasi Geospasial/BIG) scholarship for funding support.

Author Contributions

Arum Wahyu Hastuti: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – Original draft. Muhammad Dimyati: Writing – Review and editing, Supervision.

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