

Integrating Geographic Information Systems and Multi-Criteria Decision Analysis for Sustainable Waste Management: The Case Study of Polewali and Binuang

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ABSTRACT

The increasing volume of urban waste, driven by population growth and urbanization, has become a significant environmental issue in the Polewali and Binuang Regencies. Inadequate waste management can cause severe harm to the environment and public health. Selecting the optimal location for Temporary

Storage Sites (TSS) is a crucial part of waste management systems; however, this process is often complex and subjective. This study aimed to identify suitable locations for establishing new TSS in the Polewali and Binuang Regencies using an objective, systematic geographic analysis. The quantitative approach utilized Geographic Information Systems (GIS) and Multi-criteria Decision Analysis (MCDA) to assess five key criteria: slope gradient, land use, accessibility, distance to waste sources, and buffer zones of existing TSS. Spatial data for each criterion were analyzed in ArcGIS using a weighted overlay method to generate a suitability map. The study identified 42 highly recommended locations for TSS construction, primarily in areas with flat to gently sloping terrain, non-residential land use, easy access to main roads, and proximity to waste sources, thereby enhancing logistical efficiency. These findings provide science-based empirical data that local governments can utilize directly to improve the efficiency and coverage of more sustainable waste management.

Keywords-Geographic Information System (GIS); Multi-Criteria Decision Analysis (MCDA); waste management; temporary storage site; spatial analysis

I. INTRODUCTION

The rapid global urbanization and population growth have led to an unprecedented increase in Municipal Solid Waste (MSW) generation, making it one of the most urgent environmental issues worldwide [1, 2]. Poor waste management can lead to significant negative effects, including environmental degradation, soil and water pollution, and various health risks to communities [3, 4]. In modern waste management systems, Temporary Storage Sites (TSS) act as collection points before waste is moved to Final Processing Sites (FPS) [5, 6]. Choosing the best location for a TSS is crucial because it directly affects operational efficiency, logistics expenses, and the reduction of social and ecological impacts [7, 8]. The site selection process is often complex due to the many factors that need to be evaluated, including technical feasibility, social considerations, and economic factors [9]. The traditional method of site selection, which often depends on subjective judgment, has proven insufficient in tackling multidimensional challenges [10]. Integrating GIS technology with MCDA is widely regarded as the best approach in spatial planning and site selection [11, 12]. The GIS-MCDA method enables systematic, objective, and transparent spatial evaluations by simultaneously combining multiple criteria to produce land suitability maps [13, 14]. Its strength lies in its capacity to clarify complex interactions between variables and provide a solid scientific basis for decision-making [15].

The subdistricts of Polewali and Binuang, chosen as study locations, are facing challenges in upgrading their waste management infrastructure to keep pace with ongoing developments. Strategic planning for deploying new waste transfer stations is essential to enhance the efficiency and reach of waste management systems. Despite this urgency, there is limited research that explicitly uses GIS-MCDA to propose waste transfer station locations in this region, resulting in a significant knowledge gap.

II. METHODOLOGY

This research employs a quantitative approach that integrates GIS and MCDA to identify and recommend appropriate sites for TSS in the Polewali and Binuang districts [13-16]. The five criteria, slope gradient, land use, accessibility, distance from waste sources, and TPS buffer zones, follow standard approaches in the international GIS-MCDA literature for waste facility siting. Studies in various developing

countries, such as Debre Berhan, Ethiopia [17], and Jhapa District, Nepal [14], also use a similar combination of biophysical (e.g., slope and land use) and socioeconomic (e.g., distance to roads and settlements) criteria. This consistency verifies the validity of the methodological framework used in this study. However, the primary contribution of this study is its local adaptation via the Analytic Hierarchy Process (AHP) weighting process, which involves regional experts. While other studies may emphasize distance from settlements due to high population pressure, this study places the greatest weight on slope gradient (35.5%). This decision strategically addresses the specific geographical and financial challenges in Polewali and Binuang, where optimizing construction cost efficiency and mitigating geotechnical risks are top priorities for local governments with limited budgets. This demonstrates how a global method can be carefully adjusted to create solutions relevant to the local context. The complete workflow includes four main stages: (1) data collection and preparation, (2) suitability analysis and reclassification of criteria, (3) criteria weighting using the AHP, and (4) weighted overlay analysis to generate the final suitability map. The spatial analysis was performed using ArcGIS software and its Spatial Analyst extension.

A. Data Acquisition and Preparation

The data for this study were collected from both primary and secondary sources to ensure a thorough analysis. Secondary spatial data included a 30-meter SRTM Digital Elevation Model (DEM) for slope analysis and high-resolution satellite imagery with 0.5-meter resolution from the SAS.Planet program, used for visual interpretation and digitization of the land-use map. Vector data (shapefiles) for the road network, administrative boundaries, and existing TSS locations were obtained from the national geospatial agency. A crucial step in ensuring data quality was the use of primary data for key criteria. Specifically, the locations of trash-generating sites were determined through direct field surveys (ground-truthing), which greatly improved the accuracy of the proximity analysis. To ensure analytical validity and compatibility, all spatial data layers were aligned to a consistent coordinate projection system before analysis.

B. Suitability Analysis and Reclassification

Thematic maps were created for each of the five determining criteria: slope, land use, accessibility, proximity to waste sources, and buffer zones of existing TPS. To prepare

each criterion for the weighted overlay analysis, a reclassification and standardization process was performed. Each criterion's spatial data layer was reclassified onto a standardized suitability scale from 1 (Unsuitable) to 5 (Highly Suitable). This process guarantees that all layers are comparable and can be integrated logically. The specific thresholds, classifications, and suitability scores for each criterion are detailed in Table I.

TABLE I. RECLASSIFICATION AND STANDARDIZATION OF CRITERIA FOR TSS SUITABILITY ANALYSIS

| Criteria | Class | Score | Justification |
|-----------------------------|---|--------------------------------|--|
| Slope Gradient | 0–8% (Flat) | 5 (Highly Suitable) | Minimizes socioeconomic impacts and land use conflicts |
| | 8–15% (Gentle) | 4 (Suitable) | |
| | 15–25% (Somewhat steep) | 3 (Fairly Suitable) | |
| | 25–45% (Steep) | 2 (Less Suitable) | |
| | >45% (Very Steep) | 1 (Not Suitable) | |
| | 8–15% (Gentle) | 4 (Suitable) | |
| Land Use | Open/Vacant Land | 5 (Highly Suitable) | Exclusion area to avoid negative impacts |
| | Fields / Farmland | 4 (Suitable) | |
| | Rice fields & shrubbery | 3 (Fairly Suitable) | |
| | Settlements, Plantations, Protected Areas | 1 (Not Suitable) | |
| | Open/Vacant Land | 5 (Very Suitable) | |
| Accessibility | 0–500 m from Main Road | 3 (Suitable) | Optimizing operational efficiency and the range of the waste collection fleet. This distance is commonly used in similar studies |
| | 500–1000 m from Main Road | 2 (Sufficiently Suitable) | |
| | >1000 m from Main Road | 1 (Less Suitable) | |
| Distance from Waste Sources | 0–500 m from Waste Sources | 3 (Very Suitable) | Minimizes travel distance, fuel costs, and vehicle emissions |
| | 500–1000 m from Waste Sources | 2 (Fairly Suitable) | |
| | >1000 m from Waste Source | 1 (Not Suitable) | |
| Existing TPS Buffer | Within buffer >500 m from existing TPS | 1 (Suitable) | To ensure equitable distribution of new facilities and avoid overlapping service areas |
| | Within a buffer of 0-500m from the existing TPS | 0 (Not compliant) | |
| | Within a 0-500m buffer zone from existing TPS | 0 (Not Suitable / Excluded) | |

1. Slope: The slope map was created from the DEM data. Areas were classified by their gradient, with flatter regions

(e.g., 0-8%) receiving higher suitability scores as they are more cost-effective for construction [18].

2. Land Use: The land use map was produced by digitizing satellite imagery. Areas such as dense settlements and protected zones were marked as unsuitable and excluded from consideration, whereas open or vacant land received high suitability scores [19-21].

3. Accessibility & Proximity: Buffer analysis was used to evaluate accessibility and distance from waste sources. For accessibility, areas within a 0–500-meter radius of the main road network were considered highly suitable. Similarly, for proximity to waste sources, a distance of 0-500 meters was considered optimal for improving logistical efficiency. Exclusion zones were also created by buffering existing TPS locations to ensure an even distribution of new sites.

C. Criteria Weighting Using Analytic Hierarchy Process (AHP)

The AHP was used to conduct an objective and systematic assessment of the importance of criteria [22]. The AHP is a structured MCDA approach that helps organize and analyze complex judgments by breaking down the problem into a hierarchical structure. The process involves pairwise comparisons of all criteria to evaluate their relative importance in achieving the study's goal.

1) Expert Panel Composition and Bias Mitigation

The pairwise comparison process was based on assessments from five specialists chosen for their direct expertise in urban planning and environmental science relevant to the study area. The panel included two senior academics in urban and regional planning, an environmental scientist specializing in waste management, a practitioner from the local environmental agency, and a spatial planning consultant. While a larger and more diverse group of stakeholders might provide broader perspectives, the focused nature of this expert panel was considered suitable for developing a scientifically based technical assessment.

To reduce potential subjectivity and ensure the accuracy of the judgments, the consistency of the pairwise comparison matrix was thoroughly assessed. The analysis produced a Consistency Ratio (CR) of 0.07, which is comfortably below the acceptable threshold of 0.10. According to [23], a CR of 0.10 or less shows that the experts' judgments are consistent and reliable, reducing the chance of random or biased weighting. This numerical check confirms the validity of the weights used in the overlay analysis. This comparison used Saaty's 1-9 scale, where a score of 1 indicates equal importance, and 9 represents an excessive importance of one criterion over another [23]. The relative weights for each criterion were calculated from the pairwise comparison matrix. A consistency check was performed to verify the assessments by calculating the Consistency Ratio (CR) [23]. A CR value of 0.10 or lower is considered acceptable, indicating that the judgments are consistent and the resulting weights are reliable for analysis.

The paired comparisons in this study were conducted by five specialists in urban planning and environmental science. The analysis yielded a Consistency Ratio (CR) of 0.07, which is below the 0.10 threshold, confirming the validity of the obtained weights. The final normalized weights for each criterion are shown in Table II.

TABLE II. FINAL WEIGHTS OF CRITERIA BASED ON AHP ANALYSIS

| Criteria | Weight |
|-----------------------------|--------|
| Slope Gradient | 35.5 |
| Distance from Waste Sources | 25.2 |
| Land Use | 18.8 |
| Access | 12.5 |
| Existing TPS Buffer Zone | 8 |
| Total | 100.0 |

D. Weighted Overlay for Site Identification

The final step involves combining all thematic layers using the weighted overlay analysis tool in ArcGIS. The importance of each criterion, determined by AHP, is assigned to each reclassification suitability map. The overall suitability index (A_i) for each location (pixel) is calculated by summing the products of the criterion weights (W_j) and the suitability scores from the criteria maps (C_{ij}), as shown in the following equation:

$$A_i = \sum_{j=1}^n W_j * C_{ij}$$

This approach generates a conclusive suitability map that categorizes the entire study region into several levels of suitability (e.g., extremely appropriate, moderately suitable, unsuitable). Areas labeled as “highly suitable” are then identified as potential sites for further TPS development.

III. RESULT ANALYSIS AND DISCUSSION

A. Analysis of Criteria for Determining TPS Locations

1) Slope Gradient

The slope criteria map, created from DEM data analysis, classifies the research area into five categories: flat (0–8%), gentle (8–15%), moderately steep (15–25%), steep (25–45%), and very steep (>45%). Figure 1 shows that areas with flat to gentle slopes, indicated in green and yellow, are common in the southern and western parts, especially along the coastline of Polewali District and in some parts of Binuang District. In the analytical model, the slope criteria were given the highest weight (35.5% according to AHP analysis) due to its critical significance in assessing technical feasibility and cost-effectiveness. Level or gently inclined terrain, usually found in coastal areas, significantly reduces building costs, improves access for heavy machinery, and lessens environmental risks such as debris landslides. This criterion aligns with best practices in civil engineering for waste management facilities, ensuring that the chosen location is both geographically suitable and physically and financially feasible.

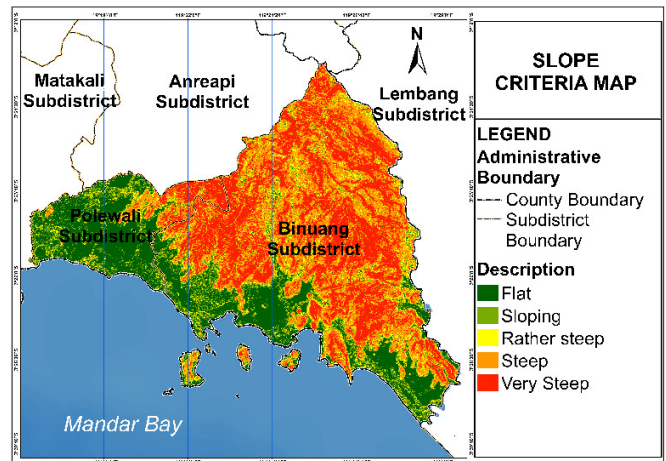


Fig. 1. Map of Polewali and Binuang Districts.

2) Land Use

Analysis of land use shows that the research area is mainly made up of fields and farmland (brown), especially in the central to northern parts (Figure 2). This location is ideal for installing TPS because it is in a sparsely populated area with plenty of open space. Other areas, such as rice paddies, scrubland, and unused land, have moderate suitability. On the other hand, residential zones, plantations, aquaculture sites, and coastal areas are unsuitable for TPS development.

The land-use criteria (18.8% weight) serve as an essential tool for socio-ecological assessment. This method proactively addresses potential land-use conflicts and community resistance by avoiding residential areas, productive plantations, and protected zones. Choosing farmland or vacant land as alternatives demonstrates efforts to reduce the impact on productive agricultural regions and sensitive ecosystems in the area. This strategy is essential in the context of growth in Polewali and Binuang, where balancing infrastructure development with environmental sustainability is vital for long-term success.

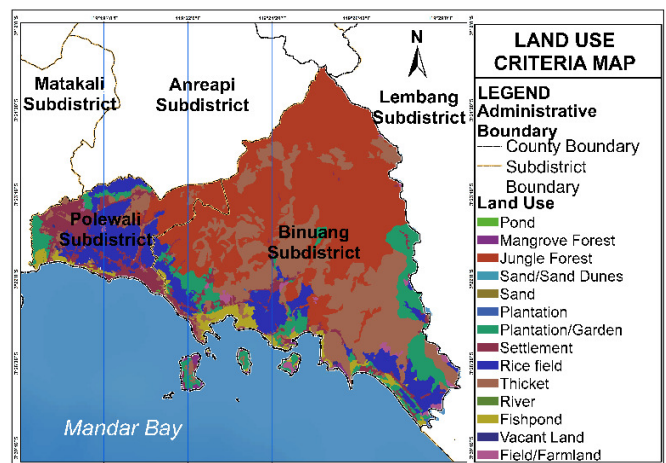


Fig. 2. Map of Land Use Criteria in Polewali and Binuang Districts.

3) Accessibility

The accessibility map categorizes regions according to their proximity to the main road network into three categories: appropriate (0–500 m, red), adequate (500–1000 m, yellow), and unsuitable (over 1000 m, green). The mapping results (Figure 3) indicate that most areas in the Polewali and Binuang subdistricts are classified as appropriate, as shown by the dominance of red. This means most locations are easily accessible by road, enabling efficient deployment of the trash transport fleet. Despite its reduced weight (12.5%), accessibility remains a key factor for smooth everyday operations. This moderate weight indicates a strategic principle: sites with better physical (slopes) and geographical (proximity to waste sources) features might be favored, even if they are not directly on the main road, as long as they are within a suitable access range. This provides flexibility in planning while maintaining essential qualities.

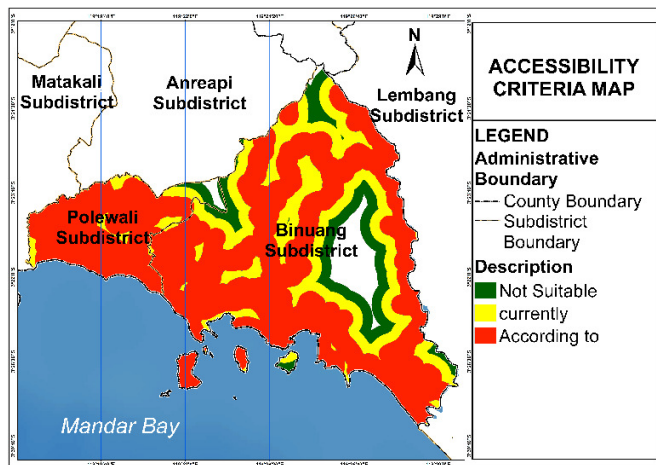


Fig. 3. Map of Accessibility Criteria for Polewali and Binuang Districts.

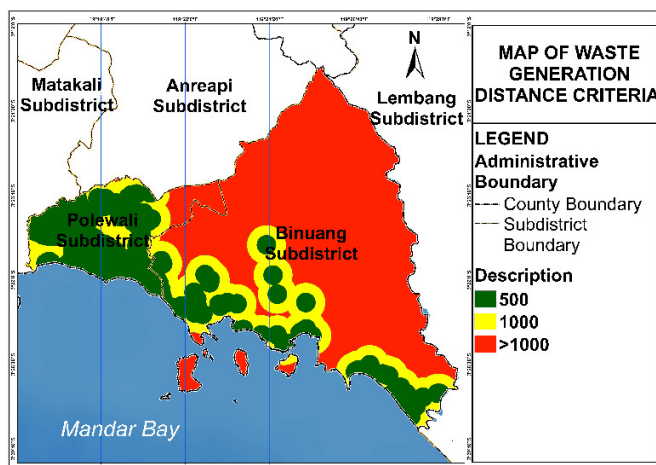


Fig. 4. Map of Waste Disposal Distance Criteria for Polewali and Binuang Districts.

4) Distance of Waste Generation

Proximity to waste sources is a critical factor for logistical efficiency. The waste distance map (Figure 4) is classified into three categories: very acceptable (0–500 m, green), moderately suitable (500–1000 m, yellow), and unsuitable (>1000 m, red). Regions designated as extremely appropriate (green) are dispersed around population centers, particularly in the coastal regions of Polewali District and certain areas of Binuang.

The emphasis on proximity to waste sources (weight 25.2%) is crucial for logistical efficiency. Choosing sites near residential areas allows the waste management system to reduce fuel costs, lower emissions from transport vehicles, and improve collection efficiency. Integrating these criteria with slope considerations guarantees that the proposed sites are both physically viable and operationally optimal for the research region.

B. Analysis of Temporary Disposal Site Recommendations

This study identified 42 recommended sites for the construction of new TPS following a weighted overlay analysis that accounted for all parameters. The distribution map of these areas (Figure 5) illustrates a strategic pattern concentrated on urban centers and maritime routes. Each suggested site satisfies the primary criteria, including being situated on level or sloping terrain to reduce building costs and environmental risks (weight 35.5%) and being in proximity to waste sources to enhance logistical efficiency (weight 25.2%). Furthermore, each site is assured of sufficient accessibility (weight 12.5%) owing to its closeness to the primary road network and actively mitigates potential social problems by omitting residential areas and productive land.

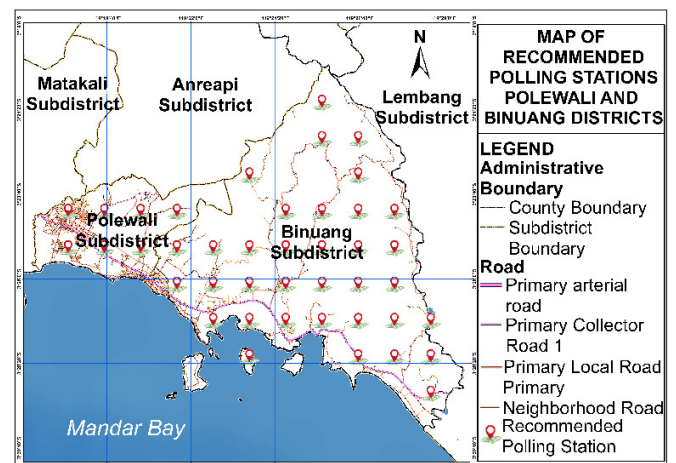


Fig. 5. Map of Recommended Temporary Disposal Sites in Polewali and Spatial Pattern Analysis and Implications for Sustainable Development.

This recommendation map provides geographical locations and supplies local governments with a scientifically robust spatial database. This database serves as a foundation for objective decision-making during the comprehensive planning, field verification, and land purchase phases. The GIS-MCDA methodology employed ensures transparency and objectivity in complex decision-making, enabling stakeholders to understand

the rationale behind each proposed placement. It is important to acknowledge the model's sensitivity to the criteria weights derived from the AHP analysis. The final suitability map is most influenced by the slope gradient criterion, which holds the highest weight of 35.5%. Consequently, any significant reduction in this weight would likely increase the suitability of moderately sloped areas, potentially shifting recommendations towards the northern, more elevated regions of Binuang. Conversely, the model is least sensitive to the Existing TPS Buffer Zone criterion (8.0% weight). While a formal sensitivity analysis was beyond the scope of this study, this understanding of the model's dynamics is crucial for decision-makers who may wish to adjust the weights in response to evolving local priorities. Future research should incorporate a quantitative sensitivity analysis to systematically test the model's robustness under different weighting scenarios [24].

The analysis results demonstrate a clear clustering of the 42 recommended locations, predominantly in low-lying coastal regions near population centers (Figure 5). This pattern is intentional, reflecting the spatial interaction of the criteria with the highest weights. These locations satisfy the criteria of flat slopes (weighted at 35.5%) and proximity to waste sources (weighted at 25.2%), rendering them optimal for cost-efficient construction and operational logistics. Nevertheless, this concentration also highlights the necessity of carefully managing strategic trade-offs within the framework of sustainable development.

- **Efficiency vs. Environmental Justice:** Although these sites are located outside densely populated residential areas to reduce direct impacts, their clustering may lead to environmental justice concerns, where communities around the clusters disproportionately bear negative externalities (e.g., increased waste truck traffic, potential odors, and property value declines) [25]. Future planning should aim for a more equitable distribution of facilities to prevent an uneven environmental burden.
- **Land Use Conflicts:** Many optimal locations are on fallow or farmland. Although this land is not currently highly productive, converting it may conflict with long-term food security goals or harm small farmers. The trade-off between urban sanitation infrastructure needs and agricultural land preservation must be a serious policy consideration.
- **Social Risks and the "Not In My Backyard" (NIMBY) Phenomenon:** Proximity to waste sources for logistical efficiency inherently increases the risk of social resistance from surrounding communities, a phenomenon known as NIMBY [26]. The implementation process must proactively manage this risk through dialogue and fair compensation.

Thus, this recommendation map serves not only as a technical guide but also as a tool to facilitate deeper policy discussions on balancing economic efficiency, environmental sustainability, and social justice, in line with the principles of Sustainable Development Goal (SDG) 11: Sustainable Cities and Communities.

C. From Spatial Recommendation to Practical Implementation: The Need for Field Validation

It is important to present the 42 recommended locations not as final decisions but as a scientifically validated shortlist to streamline and focus future planning stages (Table III).

TABLE III. TABLE OF RECOMMENDED COORDINATE POINTS FOR TEMPORARY DISPOSAL SITES IN POLEWALI AND BINUANG DISTRICTS

| Polling Station Recommendations | Coordinates |
|---------------------------------|-----------------------|
| Recommendation 1 | -3.402569, 119.310119 |
| Recommendation 2 | -3.419319, 119.310119 |
| Recommendation 3 | -3.402569, 119.326869 |
| Recommendation 4 | -3.419319, 119.326869 |
| Recommendation 5 | -3.419319, 119.343619 |
| Recommendation 6 | -3.419319, 119.360369 |
| Recommendation 7 | -3.436069, 119.360369 |
| Recommendation 8 | -3.436069, 119.377119 |
| Recommendation 9 | -3.452819, 119.377119 |
| Recommendation 10 | -3.452819, 119.393869 |
| Recommendation 11 | -3.436069, 119.410619 |
| Recommendation 12 | -3.452819, 119.410619 |
| Recommendation 13 | -3.469569, 119.444119 |
| Recommendation 14 | -3.452819, 119.477619 |
| Recommendation 15 | -3.486319, 119.477619 |
| Recommendation 16 | -3.402569, 119.343619 |
| Recommendation 17 | -3.402569, 119.360369 |
| Recommendation 18 | -3.419319, 119.377119 |
| Recommendation 19 | -3.419319, 119.393869 |
| Recommendation 20 | -3.436069, 119.393869 |
| Recommendation 21 | -3.469569, 119.393869 |
| Recommendation 22 | -3.402569, 119.410619 |
| Recommendation 23 | -3.419319, 119.410619 |
| Recommendation 34 | -3.369069, 119.427369 |
| Recommendation 24 | -3.402569, 119.427369 |
| Recommendation 25 | -3.452819, 119.427369 |
| Recommendation 27 | -3.385819, 119.444119 |
| Recommendation 28 | -3.452819, 119.444119 |
| Recommendation 29 | -3.469569, 119.460869 |
| Recommendation 30 | -3.469569, 119.477619 |
| Recommendation 31 | -3.385819, 119.393869 |
| Recommendation 32 | -3.419319, 119.427369 |
| Recommendation 33 | -3.436069, 119.427369 |
| Recommendation 34 | -3.369069, 119.444119 |
| Recommendation 35 | -3.402569, 119.460869 |
| Recommendation 36 | -3.352319, 119.427369 |
| Recommendation 37 | -3.402569, 119.444119 |
| Recommendation 38 | -3.419319, 119.460869 |
| Recommendation 39 | -3.436069, 119.460869 |
| Recommendation 40 | -3.452819, 119.460869 |
| Recommendation 41 | -3.419319, 119.444119 |
| Recommendation 42 | -3.436069, 119.444119 |

This study serves as a strategic spatial screening tool, linking broad regional concerns to specific site-level interventions [27]. Moving from this GIS-based model to actual implementation requires a crucial phase of thorough field validation. As we recommend in our conclusion, local governments should use this list as a starting point for detailed feasibility studies. This subsequent phase must include: (1) Technical field surveys to evaluate geotechnical conditions, soil properties, and current site accessibility; (2) Socio-economic analysis to examine land ownership, acquisition costs, and potential effects on local communities; and (3)

Public consultation and engagement to assess community acceptance and proactively address possible social conflicts. Only after completing these comprehensive validation stages can a recommended site be considered truly suitable for development.

This study's findings can be viewed through Campbell's Planner's Triangle, which states that sustainable urban planning must manage the conflicts among economic growth, environmental protection, and social equity. The GIS-MCDA model applies this framework by explicitly balancing these three pillars. The high emphasis on slope gradient (35.5%) is directly related to the economic aspect, with a focus on cost-effective construction methods. The environmental pillar is upheld by excluding protected areas and designating vacant land as highly suitable, thereby helping prevent ecological damage. The social equity aspect is addressed by reducing dense settlements to lower potential land-use conflicts and the NIMBY phenomenon.

This study demonstrates the usefulness of GIS-MCDA as an effective tool for tackling the theoretical challenges of sustainable development in a practical planning context. This research's main contribution is not the creation of a new method but the careful adaptation and contextualization of the globally standardized GIS-MCDA framework to the specific social and environmental situation in West Sulawesi. This approach produces a reproducible, locally relevant model for sustainable waste management planning that can be applied in other developing regions. To bridge the gap between academic research and field implementation, this study recommends a practical roadmap for the Polewali Mandar Regency Government. The resulting maps and spatial databases are not intended as final decisions but serve as spatial decision-support tools [28] during the early planning stages.

A phased implementation plan is suggested to help the local government turn these findings into actionable policies.

1) Short-Term (0–1 Year):

- Dissemination and Initial Verification: Formally present the 42 recommended sites to the Polewali Mandar Regency Government.
- Preliminary Field Surveys: Execute swift field verification of the top 5-10 highest-scoring locations to validate current land use and accessibility. Stakeholder Engagement: Commence initial public consultations to assess community perceptions and identify possible social constraints.

2) Medium-Term (1–3 Years):

- Comprehensive feasibility studies include conducting detailed technical evaluations for the most suitable locations. These evaluations encompass geotechnical analysis, Environmental Impact Assessments (AMDAL), and land tenure investigations.
- Site prioritization and land acquisition involve concluding site selection based on feasibility study outcomes and initiating the requisite legal and financial procedures for land acquisition.

3) Extended Duration (3–5+ Years):

- Budget allocation and detailed engineering design (DED) involve securing funding through regional budgets (APBD) and developing comprehensive construction plans.
- Establish new TSS and integrate them into the current waste management logistics system.

However, it is important to recognize the limitations of this study. The model emphasizes spatial variables and does not yet include critical non-spatial factors, which are often key determinants of successful implementation in the field. Factors such as land ownership status (which affects the ease and cost of acquisition), detailed geotechnical soil conditions, and most importantly, the perceptions and social acceptance of the local community, are not considered. Additionally, a formal sensitivity analysis was not performed to test the robustness of the results against variations in criteria weights, which is a limitation. These variables should be analyzed in future research. Given these findings and limitations, several recommendations are proposed. Local governments should treat the 42 suggested sites as an initial list requiring field verification and comprehensive feasibility assessments. This process should include detailed technical evaluations and public participation to ensure socioeconomic viability and minimize potential conflicts. Additionally, it is advisable to improve this model by incorporating additional variables, such as hydrological data, to prevent water-source contamination, and by using more objective weighting methods, such as AHP, to enhance the model's accuracy and validity.

IV. CONCLUSION

This project aims to provide data-driven solutions to key issues in locating waste collection stations in the Polewali and Binuang subdistricts. The study successfully achieved its objectives through careful geographic analysis. It concluded that combining Geographic Information Systems (GIS) with Multi-criteria Decision Analysis (MCDM) is a highly effective and superior approach for planning waste management infrastructure. This analysis identified 42 optimal sites for new waste collection facilities, most of which are situated in easily accessible coastal lowlands near residential areas but outside residential zones and environmentally sensitive regions. This study offers two main contributions: practical and methodological. It provides an accessible spatial database and advisory maps for the Polewali Mandar Regency Government. These data offer a solid scientific foundation for spatial policy development, financial allocation, and further technical planning, thereby enhancing transparency, objectivity, and accountability in infrastructure projects. Additionally, this study delivers an analytical framework that can be replicated and adapted to address similar issues in other parts of Indonesia facing urbanization and waste management challenges, thereby expanding the existing literature on regional planning. Ultimately, the long-term goal of this research is to develop a sophisticated hybrid spatial–non-spatial MCDA model that directly incorporates key variables such as land price, social acceptance, and land ownership into the analysis. This would create a truly comprehensive and adaptable decision-support system for urban infrastructure planning.

REFERENCES

- [1] P. T. Williams, *Waste Treatment and Disposal*, 2nd ed. Chichester, U.K.: John Wiley & Sons, Ltd, 2005.
- [2] S. Kaza, L. C. Yao, P. Bhada-Tata, and F. Van Woerden, *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*. Washington, DC: World Bank, 2018.
- [3] A. A. Mahessar, K. Ansari, A. L. Qureshi, K. C. Mukwana, A. A. Pathan, and S. M. Kori, "Impact of Encroachment and Hyderabad City Effluents on Pinyari Canal," *Engineering, Technology & Applied Science Research*, vol. 10, no. 3, pp. 5784–5789, June 2020, <https://doi.org/10.48084/etasr.3507>.
- [4] A. Eshete, A. Haddis, and E. Mengistie, "Investigation of environmental and health impacts solid waste management problems and associated factors in Asella town, Ethiopia," *Heliyon*, vol. 10, no. 6, Mar. 2024, Art. no. e28203, <https://doi.org/10.1016/j.heliyon.2024.e28203>.
- [5] N. Nickdoost, H. Jalloul, and J. Choi, "An integrated framework for temporary disaster debris management sites selection and debris collection logistics planning using geographic information systems and agent-based modeling," *International Journal of Disaster Risk Reduction*, vol. 80, Oct. 2022, Art. no. 103215, <https://doi.org/10.1016/j.ijdr.2022.103215>.
- [6] D. Adlan, F. S. Islami, C. T. Handoko, and S. Susanti, "Identifikasi Kelayakan Infrastruktur Tempat Penampungan Sampah (TPS) Di Kota Palembang," *Jurnal Teknik Sipil LATERAL*, vol. 1, no. 2, pp. 1–10, Nov. 2023, <https://doi.org/10.52333/lateral.v1i2.243>.
- [7] D. D. Julianto, A. Purwani, and S. Bouguern, "Analysis of Location Determination for Temporary Waste Collection Points Using p-dispersion Method: An Application to Yogyakarta City, Indonesia," *Journal of Novel Engineering Science and Technology*, vol. 2, no. 02, pp. 59–67, Aug. 2023, <https://doi.org/10.56741/jnest.v2i02.369>.
- [8] G. D. Lontoc, Ma. B. L. D. Diola, and M. H. T. Peralta, "Multi-criteria evaluation of suitable locations for temporary disaster waste storage sites: the case of Cavite, Philippines," *Journal of Material Cycles and Waste Management*, vol. 25, no. 5, pp. 2794–2808, Sept. 2023, <https://doi.org/10.1007/s10163-023-01705-9>.
- [9] K. B. S. Shekari, N. N. Samany, M. Omidipoor, and S. H. Darehbadami, "Uncertainty Modelling of Waste Disposal Site Selection (Case Study: Marivan City)," *Asian Journal of Water, Environment and Pollution*, vol. 15, no. 4, pp. 89–98, Oct. 2018, <https://doi.org/10.3233/AJW-180061>.
- [10] G. Garcia-Garcia, "Using Multi-Criteria Decision-Making to optimise solid waste management," *Current Opinion in Green and Sustainable Chemistry*, vol. 37, Oct. 2022, Art. no. 100650, <https://doi.org/10.1016/j.cogsc.2022.100650>.
- [11] J. Chauhan and S. Ghimire, "A Comprehensive Geospatial Analysis for Optimal Waste Disposal Site Selection: Integrating Environmental, Social and Economic Factors," *Kathmandu University Journal of Science, Engineering and Technology*, vol. 17, no. 2, Dec. 2023, <https://doi.org/10.3126/kuset.v17i2.62122>.
- [12] H. Karimi, S. Amiri, J. Huang, and A. Karimi, "Integrating GIS and multi-criteria decision analysis for landfill site selection, case study: Javanrood County in Iran," *International Journal of Environmental Science and Technology*, vol. 16, no. 11, pp. 7305–7318, Nov. 2019, <https://doi.org/10.1007/s13762-018-2151-7>.
- [13] H. I. Mohammed, Z. Majid, Y. B. Yamusa, M. F. M. Ariff, K. M. Idris, and N. Darwin, "Sanitary Landfill Siting Using GIS and AHP: A Case Study in Johor Bahru, Malaysia," *Engineering, Technology & Applied Science Research*, vol. 9, no. 3, pp. 4100–4104, June 2019, <https://doi.org/10.48084/etasr.2633>.
- [14] H. Poudel, S. Ghimire, and S. Upadhyaya, "Suitability Analysis for Waste Disposal Site Using GIS Based Multi-Criteria Decision Analysis: A Case Study of Jhapa District, Nepal," *Nepal Journal of Multidisciplinary Research*, vol. 6, no. 3, pp. 115–128, Nov. 2023, <https://doi.org/10.3126/njmr.v6i3.59543>.
- [15] A. A. Mwais and I. Mahamid, "Using a Fuzzy Model to Evaluate Risks caused by Variation Orders in Construction Projects," *Engineering, Technology & Applied Science Research*, vol. 15, no. 1, pp. 19030–19036, Feb. 2025, <https://doi.org/10.48084/etasr.8558>.
- [16] T. Dobocho Wanore, Z. Abera Angello, and Z. Menberu Fetanu, "Optimized landfill site selection for municipal solid waste by integrating GIS and multicriteria decision analysis (MCDA) technique, Hossana town, southern Ethiopia," *Heliyon*, vol. 9, no. 11, Nov. 2023, Art. no. e21257, <https://doi.org/10.1016/j.heliyon.2023.e21257>.
- [17] B. Asefa and W. Mindahun, "Suitable Solid Waste Disposal Site Selection Using Geographical Information System (GIS): A Case of Debre Berhan Town, Ethiopia," *American Journal of Environmental Protection*, vol. 7, no. 1, pp. 17–23, June 2019, <https://doi.org/10.12691/env-7-1-4>.
- [18] W. Gao, X.-C. Bian, W.-J. Xu, and Y.-M. Chen, "Storage Capacity and Slope Stability Analysis of Municipal Solid Waste Landfills," *Journal of Performance of Constructed Facilities*, vol. 32, no. 4, Aug. 2018, Art. no. 04018036, [https://doi.org/10.1061/\(ASCE\)CF.1943-5509.0001180](https://doi.org/10.1061/(ASCE)CF.1943-5509.0001180).
- [19] S. S. Bilgilioglu, C. Gezgin, O. Orhan, and P. Karakus, "A GIS-based multi-criteria decision-making method for the selection of potential municipal solid waste disposal sites in Mersin, Turkey," *Environmental Science and Pollution Research International*, vol. 29, no. 4, pp. 5313–5329, Jan. 2022, <https://doi.org/10.1007/s11356-021-15859-2>.
- [20] A. S. Chandel, A. E. Weto, and D. Bekele, "Geospatial technology for selecting suitable sites for solid waste disposal: a case study of Shone town, central Ethiopia," *Urban, Planning and Transport Research*, vol. 12, no. 1, Dec. 2024, Art. no. 2302531, <https://doi.org/10.1080/21650020.2024.2302531>.
- [21] A. C. Pramono, Y. Pratiwi, and Muchlis, "Mapping a Potential Location of Temporary Waste Storage Sites (TPS) in Sorong and East Sorong Districts using Geographic Information Systems (GIS)," *Engineering And Technology Journal*, vol. 9, no. 6, pp. 4321–4328, June 2024, <https://doi.org/10.47191/etj/v9i06.21>.
- [22] A. A. H. M. Shukor, N. M. Ishak, S. A. Salleh, and F. Othman, "Waste Management: Landfill Selection Using Gis and Analytical Hierarchy Process," *IOP Conference Series: Earth and Environmental Science*, vol. 1316, no. 1, Nov. 2024, Art. no. 012003, <https://doi.org/10.1088/1755-1315/1316/1/012003>.
- [23] T. L. Saaty, "Decision making with the analytic hierarchy process," *International Journal of Services Sciences*, vol. 1, no. 1, 2008, Art. no. 83, <https://doi.org/10.1504/IJSSCI.2008.017590>.
- [24] Y. Chen, J. Yu, and S. Khan, "The spatial framework for weight sensitivity analysis in AHP-based multi-criteria decision making," *Environmental Modelling & Software*, vol. 48, pp. 129–140, Oct. 2013, <https://doi.org/10.1016/j.envsoft.2013.06.010>.
- [25] D. Schlosberg, *Defining Environmental Justice: Theories, Movements, and Nature*. Oxford University Press, 2007.
- [26] K. Burningham, "Using the Language of NIMBY: A topic for research, not an activity for researchers," *Local Environment*, vol. 5, no. 1, pp. 55–67, Feb. 2000, <https://doi.org/10.1080/135498300113264>.
- [27] J. Malczewski, "GIS-based multicriteria decision analysis: a survey of the literature," *International Journal of Geographical Information Science*, vol. 20, no. 7, pp. 703–726, Aug. 2006, <https://doi.org/10.1080/13658810600661508>.
- [28] J. Court and J. Young, "Bridging research and policy in international development: an analytical and practical framework," *Development in Practice*, vol. 16, no. 1, pp. 85–90, Feb. 2006, <https://doi.org/10.1080/09614520500450925>.