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Implementation of Sustainable Development Management in Strategic Decision Making in Determining the Location of Final Processing Places (TPA) Case Study of North Penajam Paser Regency

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Abstract. *This study aims to identify the criteria for sustainable Final Processing Site (TPA) locations based on the Sustainable Development Management framework, determine the relative weights of the criteria using the Analytical Hierarchy Process (AHP) method, and integrate it with Geographic Information System (GIS)-based spatial analysis to produce a landfill location suitability map in North Penajam Paser Regency. In addition, this study also aims to formulate priority zones for landfill locations along with their managerial implications for local governments. To achieve these objectives, the study employed a mixed approach utilizing secondary data in the form of spatial data, statistical data, and spatial planning documents. The study was conducted by deriving criteria from the sustainability dimension and synthesizing previous studies, followed by weighting the criteria using AHP through a secondary/adaptive weighting approach. Furthermore, each criterion was processed in GIS and combined using a weighted overlay technique to produce a site suitability map. The analysis also continued with a suitability test against the RTRW/RDTR and area zoning, which were very suitable for determining priority landfill locations. The results of the study indicate that the weighted overlay analysis produces three suitability classes, namely highly suitable covering an area of 51,341 ha (21.55%), suitable covering an area of 149,066 ha (62.61%), and unsuitable covering an area of 37,701 ha (15.84%). Of the highly suitable area, only 10,893 ha (21.3%) is in line with the RTRW/RDTR. This study also produces three priority zones, namely ZP-01 in Penajam District covering an area of 485 ha, ZP-02 in Waru District covering an area of 1,342 ha, and ZP-03 in Penajam District covering an area of 219 ha. ZP-01 is recommended as the main priority. This study shows that the application of Sustainable Development Management combined with GIS-AHP can provide a more measurable, transparent, and accountable analytical basis in strategic decision-making for determining the location of the landfill.*

Keywords: *AHP; GIS; Landfill Location; North Penajam Paser; Strategic Decision Making; Sustainable Development Management.*

1. Introduction

Waste management is one of the increasingly complex development challenges in Indonesia. Population growth, urbanization, and increased economic activity are driving an increase in waste generation, while the capacity and performance of management facilities (especially Final Processing Sites/TPA) in many regions remain limited. In policy terms, the government has set a national waste management target through Presidential Regulation Number 97 of 2017 (National Policy and Strategy for Household Waste Management and Household-Like Waste/Jakstranas), namely a 30% reduction and 70% handling by 2025. In practice, the determination of landfill locations is still often driven by short-term technical considerations (e.g., land availability, proximity to waste sources, or initial costs), while long-term consequences such as the risk of leachate, emissions, social conflict, and operational costs have not always been positioned as strategic variables.

This phenomenon is reinforced by official data and statements. The National Waste Management Information System (SIPSN) dashboard shows that a large portion of unmanaged waste remains in various regions. The government also emphasized the need to accelerate the elimination of open dumping practices at landfills through monitoring and improvement. This situation emphasizes that landfill site selection can no longer be viewed as merely a technical issue, but rather a strategic one that requires more comprehensive and accountable planning and decision-making.

When linked to the theoretical benchmark of sustainable development, this issue reflects the challenge of balancing the three main pillars of development: environmental, social, and economic. Mensah (2019) asserts that sustainability can only be achieved if the development process simultaneously considers all three dimensions. Meanwhile, Shi et al. (2019) explain that the sustainability paradigm has evolved and demands integrated planning and decision-making processes across dimensions. In a management context, this principle can be realized through the Sustainable Development Management (SDVM) framework, which emphasizes sustainability-based planning, decision-making, and control processes.

Empirically, various studies have shown that landfill site selection is often conducted using analytical approaches such as Geographic Information Systems (GIS) and Analytical Hierarchy Process (AHP). The GIS–AHP approach has proven capable of integrating various criteria and producing objective site suitability maps. However, many studies still focus on the technical aspects of spatial analysis, thus failing to fully address managerial needs for long-term, sustainability-based strategic decision-making. Thus, there is a gap between the technical outputs of GIS–AHP and the need for a strategic decision-making framework in waste management.

The decline in waste volume in 2021 should be interpreted with caution, as it was likely influenced by the COVID-19 pandemic, which suppressed social and economic activities and potentially affected waste generation patterns and recording. Therefore, this fluctuation does not necessarily indicate a structural reduction in waste pressure but needs to be understood within the context of the situation during that period.

The data in the tables above demonstrate the pressure on waste management services due to population growth and the continued significant volume of uncollected waste. From a socio-economic perspective, poverty dynamics and HDI achievements illustrate the capacity and vulnerability of communities that need to be considered in determining the location and management of landfills, including issues of social acceptance and environmental justice. The urgency of this research is further reinforced by the condition of the existing landfill in North Penajam Paser Regency, namely the Buluminung Landfill in Buluminung Village, Penajam District, which currently serves as the primary facility for final waste processing in the region. With a land area of approximately 18.5 hectares, an operational status that has implemented a controlled landfill, and an estimated remaining service life of approximately 1.5–2 years according to the 2025 report, the existence of the existing landfill demonstrates the need for more sustainable landfill location planning. If local governments rely solely on existing facilities without adequate spatial and managerial planning, the risk of operational inefficiency, social conflict, and environmental pressures has the potential to increase in the future. In the context of the IKN buffer zone, these conditions reinforce the urgency of determining landfill locations that are not only technically appropriate, but also measurable, transparent, and future-oriented within the Sustainable Development Management (SDVM) framework. Therefore, this study integrates SDVM as a managerial framework with GIS and AHP as decision-support tools to produce recommendations for landfill locations that are both technically relevant and managerially robust to support sustainable regional development in North Penajam Paser Regency. Various previous studies have shown that landfill location determination based on Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) has been widely used to produce technically suitable location maps. However, most of these studies still place GIS–AHP as the primary analytical objective, so there is little explanation of how these technical results are integrated into the regional government's strategic decision-making framework. In other words, there is still limited research that explicitly links sustainable development principles with managerial processes such as planning, decision-making, and control in the context of public infrastructure location determination.

This gap becomes increasingly important in areas undergoing rapid transformation, such as Penajam Paser Utara Regency, which serves as a buffer zone for the Indonesian capital. In this context, determining the location of a landfill is not only a matter of land suitability, but also a managerial issue involving decision transparency, policy accountability, long-term financial efficiency, and managing trade-offs between environmental, social, and economic dimensions. Therefore, this study offers a novel approach in the form of operationalizing a sustainable development management framework as a basis for establishing criteria and interpreting decisions, by utilizing GIS–AHP as a decision-support tool to generate recommendations for landfill locations that are both technically robust and managerially accountable.

2. Research Methods

This study uses a Sustainable Development Management (SDVM) approach supported by multi-criteria and spatial analysis. This approach was chosen because the problem of determining the location of a Final Processing Site (TPA) cannot be understood solely as a technical issue, but rather is part of a strategic decision-making process that has long-term implications for the environmental, social, and economic dimensions of a region (Mensah, 2019; Purvis et al., 2019).

3. Results and Discussion

3.1. Sustainable Development Management Framework in Landfill Location Decision Making

The results of the criteria determination and weighting indicate that social and environmental dimensions are the dominant considerations, particularly through the criteria of distance from settlements and distance from rivers or water bodies. Within the framework of Sustainable Development Management, this dominance can be understood as the application of the precautionary principle to minimize the risk of long-term impacts on public health and environmental quality. On the other hand, the road accessibility criterion represents the economic-operational dimension, specifically transportation cost efficiency and ease of service.

These findings demonstrate that the SDVM framework does not stop at selecting criteria, but rather requires a traceable process, from goal setting, criteria selection, weighting, to implementation control and evaluation. In the context of long-term planning, SDVM encourages local governments to assess trade-offs. A location that is efficient in terms of transport distance may not be optimal if it poses high social risks or is located in a hydrologically vulnerable zone. Therefore, SDVM integration guides decisions toward a balance between the three pillars of environmental, social, and economic development, rather than simply one-dimensional optimization.

3.1.1. Relevance of Criteria and Weights in the Context of the Study Area

The weighting results indicate that the distance from settlements has the highest weighting, followed by distance from water bodies and road access. This pattern indicates that the decision-making structure in the study prioritizes social and environmental protection aspects over other technical-operational considerations. In the context of North Penajam Paser Regency, as a buffer zone for the Indonesian capital, these results have strong strategic significance. Areas undergoing rapid transformation due to population growth, expanding economic activity, and changes in land use will face increasing social sensitivity to the placement of infrastructure with the potential for negative impacts, including Final Processing Sites (TPA). Therefore, the dominance of settlement criteria indicates that this research model seeks to minimize the potential for social conflict, disruption of comfort, and community resistance from the initial stage of site screening.

The high weighting of the distance from water bodies criterion also indicates that this study places environmental risk as a fundamental consideration. In determining landfill sites, proximity to rivers or water bodies is one of the most sensitive factors because it is directly related to the risk of leachate pollution, water quality degradation, and disruption to the area's ecological function. Therefore, the high priority given to this criterion reflects the application of the precautionary principle within the Sustainable Development Management framework, where location decisions are directed not only at finding available land but also at mitigating potential long-term impacts that could incur greater environmental and social costs in the future.

Meanwhile, the significant emphasis placed on road access indicates that this study continues to consider the dimensions of service efficiency and operational feasibility. In the context of waste management, accessibility is a crucial factor because it relates to smooth transportation, logistics costs, service affordability, and the landfill's ability to integrate into the regional waste management system. However, the results of this study indicate that accessibility is not placed above social and environmental protection. This means that this study establishes a priority structure that does not solely pursue technical efficiency but seeks to balance it with the need for community and environmental protection as part of a sustainability-oriented strategic decision.

These results align with previous studies on GIS-AHP-based landfill site determination, which show that settlements, water bodies, and roads are the most consistent criteria influencing site suitability. In the studies referenced in Chapter II, several studies also place proximity to settlements as a dominant factor due to its association with social sensitivity and NIMBY theory, while water bodies and road access emerge as important factors in balancing environmental protection and service efficiency. This alignment indicates that the weighting pattern in this study is not isolated but consistent with empirical findings from landfill siting studies in various regions. However, what distinguishes this study is that the weighting structure is not merely a technical output but is interpreted within the framework of strategic decision-making in a rapidly developing region influenced by the influence of the new capital city (IKN).

Thus, the relevance of the criteria and weighting in this study can be explained not only in terms of the biophysical characteristics of the region, but also from the development dynamics of the study area. Penajam Paser Utara Regency is not simply a geographic area requiring a new landfill, but also a policy area experiencing pressure from land-use changes, activity growth, and increasing expectations of public services. Therefore, a criteria structure that prioritizes socio-environmental protection can be considered substantively appropriate, as it better aligns with the needs of long-term decision-making that demands a balance between service efficiency, social legitimacy, and environmental sustainability.

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3.1.2. Methodological Implications: Implementation of GIS–AHP in Alternative Location Analysis

Methodologically, these findings demonstrate that the integration of GIS–AHP in research is not merely a mapping tool, but rather a means to translate sustainability preferences into measurable decision models. GIS serves to express the spatial distribution of each criterion, while AHP provides a priority structure for these criteria. Therefore, the resulting suitability map should not be read solely as a technical output, but as a spatial representation of managerial preferences that have been formulated based on a synthesis of the literature and the Sustainable Development Management framework. The separation between constraints and factors is an important step to avoid compensation effects in weighted overlays.

Areas that are regulatory or biophysically unsuitable are eliminated first as constraints, preventing them from being compensated for by high scores on other criteria. Simplifying the final results into three suitability classes also provides methodological advantages by making the analysis output easier to understand and more directly connected to decision-making needs. Thus, GIS and AHP in this study function as complementary decision-support tools, with AHP to prioritize criteria and GIS to translate those priorities into spatial evaluations of alternative locations.

3.2. Implications of the Results of Integrating SDVM with GIS–AHP for Location Recommendations

The results of the integration of Sustainable Development Management with GIS–AHP indicate that more relevant landfill location recommendations are not generated from a single stage of analysis, but rather from a multi-stage screening process that combines technical rationality, policy rationality, and implementation considerations. In this study, the process begins with establishing sustainability-based criteria, AHP weighting, weighted overlay to generate suitability classes, then continues with overlaying the RTRW/RDTR and special zoning in highly suitable areas. This multi-stage structure is important because it shows that landfill location decisions cannot be simplified to selecting points on a map, but must be understood as the result of a managerial process that systematically screens alternatives until truly accountable candidates are obtained.

The finding that only 21.3% of the area is spatially classified as highly suitable and in line with the RTRW/RDTR, while 78.7% is not aligned with spatial planning policies, is one of the most important findings of this study. This figure indicates a significant gap between biophysical-spatial feasibility and policy feasibility. In other words, areas that technically appear ideal for landfill development may not be immediately feasible if they are not within the applicable spatial planning corridor. This finding demonstrates that technically robust GIS results still require a policy validation phase to avoid producing theoretically sound recommendations that are difficult to implement in local government practice.

From a regional development management perspective, this situation has two important implications. First, local governments cannot rely solely on technical analysis results in determining landfill locations, as the final decision must consider regulatory legitimacy to avoid future spatial planning conflicts. Second, the results of this study also indicate that spatial planning documents and waste infrastructure needs need to be interpreted in a more integrated manner. The gap between highly suitable areas and areas that are truly aligned with the RTRW/RDTR does not necessarily mean that spatial planning documents must be immediately revised, but rather indicates the need for stronger synchronization between waste planning, spatial planning policies, and regional development directions. Thus, the results of this study can serve as an initial basis for identifying the intersection between technical rationality and policy rationality in regional waste management.

The integration of SDVM with GIS–AHP in this study also provides added value because it allows the analysis results to be read not simply as a land suitability map, but as a tool to assist in determining policy priorities. Areas that make it to the final stage are not only those with good biophysical conditions, but also those that are relatively more ready to be brought to the field verification, institutional assessment, and public discussion stages. From this perspective, GIS–AHP does not stop at its technical function as a mapping tool, but becomes an instrument to clarify the sequence of decision-making: which locations should be maintained, which should be eliminated, and which require further review. This is in line with the research orientation that from the outset positions GIS–AHP as a decision-support tool, rather than as a final analytical goal.

From a social perspective, this integration also demonstrates that the success of landfill implementation is not determined solely by distance from residential areas or spatial suitability scores. Social sustainability in landfill development also requires quality governance, particularly in the form of public communication, community consultation, information transparency, and equitable impact mitigation. Therefore, the location recommendations generated by this study should be understood as the result of a robust initial screening process, but they still require strengthening through field verification and a consultative process to ensure that the final decision is not only technically sound but also socially and administratively legitimate.

Overall, the main implication of the SDVM integration with GIS–AHP is that landfill site determination needs to be developed through a multi-stage process that combines sustainability, spatial analysis, and policy implementation. For Penajam Paser Utara Regency, this approach is relevant because the region is facing dynamic growth due to its role as a buffer zone for the new capital city (IKN). Under these conditions, landfill site decisions must be more than just technical decisions; they must be strategic decisions that are accountable, transparent, and aligned with the long-term direction of regional development.

3.2.1. Managerial Excellence, Economic Benefits, and Social Benefits of Priority Zones

The priority zones resulting from this study not only demonstrate spatial feasibility but also hold significant managerial, economic, and social value. From a Sustainable Development Management perspective, the success of a location decision is measured not only by whether an area can be used for a landfill, but by the extent to which the location allows the waste management system to operate in a more planned, efficient, and acceptable manner in the long term. Therefore, the priority zones in this study should be read not as final, immediately determined locations, but rather as strategic candidates with relative advantages compared to other alternatives.

Table 5.9 Comparison of Relative Advantages of Priority Zones

Aspect	**ZP-01**	**ZP-02**	**ZP-03**
RTRW/RDTR Compliance	In accordance	In accordance	In accordance
Land area	485 ha	1,342 ha	219 ha
Relative accessibility	Tall	Currently	Currently
Strategic position of service	Tall	Currently	Currently
Capacity development potential	Currently	Tall	Low
Advanced verification focus	Geotechnics and hydrogeology	Road access and land status	Social and spatial details
Priority status	Top priority	Strong alternative	Medium priority

Source: author's analysis results, 2026.

3.2.2. Economic Advantages of Priority Zones from a Management Perspective

From a management perspective, the economic dimension does not simply mean selecting a location with the lowest initial cost, but rather selecting a location that provides systemic efficiency and reduces potential long-term cost burdens. Priority zones that have passed technical and policy screening essentially help local governments reduce the risk of wrong investments, because the alternatives considered have passed an initial selection stage based on sustainability, spatial suitability, and accessibility. Thus, the primary economic benefit of priority zones lies not only in construction costs but also in reducing the costs of decision failures, such as the risk of project cancellation, conflicts over spatial use, or the need for relocation due to regulatory inconsistencies.

Of the three zones generated, ZP-01 was positioned as the top priority despite its smaller area than ZP-02. This indicates that the study did not place land size as the sole economic indicator. ZP-01 was deemed superior due to its more strategic position in the connectivity of the North Penajam Paser Regency and the influence of the IKN area, thus conceptually better supporting service efficiency, transportation route arrangements, and initial implementation stages. Conversely, ZP-02 remains a strong alternative due to its larger area, but this advantage is more appropriately interpreted as potential for medium- or long-term capacity development, rather than automatically being the first priority. Thus, the decision to select ZP-01 reflects a managerial orientation that emphasizes implementation efficiency and service readiness, rather than simply land capacity.

3.3. Social Advantages of Priority Zones

The social advantage of priority zones lies in the fact that they have passed a distance-based screening process with respect to settlements, water bodies, and other sensitive elements. This means that, conceptually, priority zones have a greater opportunity to minimize potential disruption to the community compared to locations that do not pass the selection. In the context of waste infrastructure development, this is crucial because landfill issues often go beyond technical feasibility and develop into issues of community acceptance, risk perception, and policy legitimacy. Therefore, selected priority zones can be seen as having a relative social advantage because they are in a safer position to mitigate potential initial resistance.

However, these social advantages must be interpreted with caution. A safer distance from residential areas does not automatically guarantee high public acceptance. Factors such as risk communication, information transparency, impact mitigation schemes, and community participation will remain crucial during the implementation phase. Therefore, the results of this study should not be interpreted as implying that priority zones are necessarily free from social conflict, but rather that these zones have better social potential for management in consultation and subsequent decision-making processes than other, more spatially problematic locations.

3.3.1. Management Implications

From a managerial perspective, the existence of priority zones offers significant benefits to local governments by simplifying the complexity of decision-making. Without a screening process like the one employed in this study, local governments would be faced with vast areas and numerous potential locations that would be difficult to objectively compare. Priority zoning allows the planning process to be more gradual: governments can begin with the primary candidates and then conduct more focused geotechnical, hydrogeological, social, and land status verification. In this sense, priority zoning serves as a tool to increase the efficiency of the planning process, clarify the sequence of decision-making, and reduce uncertainty in the early stages of site determination.

More specifically, the determination of ZP-01 as the top priority demonstrates that landfill location decisions within the Sustainable Development Management framework are not determined by a single dominant indicator, but by a combination of spatial suitability, accessibility, implementability, and potential social and environmental risks. ZP-02 remains significant as a strong alternative, primarily due to its larger land area, while ZP-03 can be read as an additional candidate that requires greater care in detailed social and spatial verification. This prioritization illustrates that the research findings do not stop at selecting a single location, but rather produce a structured recommendation that allows local governments to develop a phased strategy in accordance with fiscal capacity, institutional readiness, and regional policy dynamics.

Thus, the primary advantage of the priority zones in this study lies in their ability to bridge the results of technical analysis with the needs of implementable public decisions. Priority zones are not simply areas with the highest scores, but rather those most likely to be developed through further verification stages in a more efficient, targeted, and accountable manner. In the context of North Penajam Paser Regency, as a buffer zone for the new capital city (IKN), this is crucial because every public infrastructure decision requires a balance between service needs, fiscal constraints, environmental sustainability, and social legitimacy.

3.3.2. Research Limitations and Implications for Evidence-Based Planning

Although this study produces a systematic analytical framework, several limitations warrant consideration. First, the analysis results are heavily influenced by the quality, resolution, and recency of the spatial data used. Second, the AHP weighting in this study is still based on literature synthesis and has not been validated through direct assessment by local experts. Third, the resulting suitability maps and priority zones still require field verification, particularly regarding geotechnical, hydrogeological, land status, and social acceptance aspects.

These limitations do not diminish the value of the research findings, but rather demonstrate that the analysis should be understood as the initial basis for evidence-based planning, not as a stand-alone final decision. Therefore, this research is more appropriately positioned as an initial screening tool to help local governments narrow down location options objectively and transparently before entering the more detailed technical verification and public consultation stages.

4. Conclusion

Based on the research results and discussion, several conclusions can be drawn which are arranged in accordance with the formulation of the research problem as follows. First, determining the location of a sustainable Final Processing Site (TPA) in North Penajam Paser Regency can be formulated through the Sustainable Development Management framework by deriving criteria that represent environmental, social, and economic/technical dimensions. In this study, the criteria used include distance to settlements, water bodies, roads, slope gradient, land use/land cover, geology, and protected areas. These criteria indicate that determining the location of a TPA is not simply a technical matter of land availability, but rather a strategic decision that must consider environmental protection, social acceptance, and service efficiency in an integrated manner. Second, the criteria weighting using the Analytical Hierarchy Process and its integration with Geographic Information System-based spatial analysis successfully produced a landfill location suitability map in North Penajam Paser Regency. This process demonstrates that the GIS–AHP approach can be used as a decision-support tool to translate the sustainability framework into a measurable and transparent analytical model. The weighted overlay results in three suitability classes: a highly suitable class covering 51,341 ha (21.55%), a suitable class covering 149,066 ha (62.61%), and an unsuitable class covering 37,701 ha (15.84%). These findings indicate that although most areas can generally still be considered, only a limited portion actually has the highest level of suitability to be developed as a candidate landfill location. Third, the priority zones for landfill sites recommended by the research consist of three zones: ZP-01 in Penajam District, covering an area of 485 ha, ZP-02 in Waru District, covering an area of 1,342 ha, and ZP-03 in Penajam District, covering an area of 219 ha. Of these three zones, ZP-01 was designated as the top priority. This determination indicates that location priority is not solely determined by land area, but by a combination of spatial suitability, alignment with the RTRW/RDTR, accessibility, and managerial implement tability. Furthermore, the research results also show that of the total area classified as highly suitable, only 10,893 ha or 21.3% are aligned with the RTRW/RDTR. This finding confirms the difference between biophysical-spatial feasibility and policy feasibility, so that landfill location decisions require a strong integration of technical analysis, spatial planning, and managerial considerations. Thus, this study concludes that the application of Sustainable Development Management combined with GIS–AHP is able to provide a basis for recommendations on landfill locations that are more accountable, transparent, and relevant for strategic decision-making in the North Penajam Paser Regency government.

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