Available online at
http://journal.uitm.edu.my/ojs/index.php/BEJ

e-ISSN: 2637-0395

Built Environment Journal 23(1) 2026, 114 – 128.

Built Environment Journal

Site Suitability Assessment for Domestic Waste Disposal Area in Kota Bharu, Kelantan Using the Analytical Hierarchy Process and Geographical Information System

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ARTICLE INFO

Article history:
Received 07 March 2024
Revised 24 April 2025
Accepted 28 June 2025
Online first
Published 01 January 2026

Keywords:
Domestic Waste Disposal
Site Suitability
Multi-Criteria Decision Analysis
Analytical Hierarchy Process
Geographical Information System
Waste Management

DOI:
10.24191/bej.v23i1.978

ABSTRACT

This study was conducted to evaluate the potential site location for waste disposal in Kota Bharu, Kelantan, using Analytical Hierarchy Process (AHP) and Geographical Information System (GIS). Seven (7) criteria were considered and ranked based on the literature review and experts' opinions to identify potential waste disposal sites. The data used in this study consist of vector and raster data, including land-use categories, information on residential areas, road networks, slope, and soil types. Additionally, GIS analysis, including Weighted Overlay analysis, was explored and utilised in this study. The output of this study is a suitability map for domestic waste disposal sites using GIS techniques. At the end of the evaluation, the suitability map was divided into four (4) categories: restricted, unsuitable, less suitable, and highly suitable. The area and proportion of each category relative to the total study area were depicted, and the two (2) most suitable potential site areas were identified.

INTRODUCTION

Domestic Waste (DW) encompasses various materials such as trash, waste, sludge, and other forms of garbage generated by human activities and living organisms. These materials are typically disposed of rather than recycled, including waste from industrial, agricultural, commercial, and social activities.

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https://doi.org/10.24191/bej.v23i1.978

However, this definition excludes sewage from residential areas, silt in water bodies, pollutants in industrial wastewater, suspended particles in irrigation systems, and other common water contaminants.

The primary challenge lies in finding suitable locations for domestic waste disposal (Asefa et al., 2021). Yet, the disposal sites and methods can pose serious environmental and health risks (Ismail, 2016). Key concerns revolve around their impact on groundwater and surface water quality, air pollution, soil contamination, odor emissions, and issues related to domestic waste transportation (Chabuk et al., 2017).

Waste collection, transportation, and disposal represent significant challenges in major cities in Malaysia. Many state and local government authorities acknowledge their inability to effectively manage the problem (Sk et al., 2020). Open dumping remains the primary method of domestic waste disposal in most cities. In residential areas like Kota Bharu, facilities for house-to-house collection of domestic waste are rare. Instead, individuals are expected to deposit their refuse at designated points, where available, for collection by vehicles for final disposal. However, due to the lack of regular routine collection, communal points, often referred to as dumps, are typically located in open spaces along street ends, becoming nuisances for the area (Shah et al., 2019).

Many studies have examined various methods, and one (1) suitable approach for identifying potential domestic waste disposal areas is the use of Multi-criteria Decision Analysis (MCDA), which includes the Analytical Hierarchy Process (AHP) (Berisa & Birhanu, 2016; Ghoutum et al., 2020; Ibrahim et al., 2019; Olanibi & Emmanuel, 2022). Analysis of site selection requires this method because it allows decision-makers to arrange decision-making criteria against alternative solutions through hierarchical decision modeling. The site selection process for waste areas using GIS MCDA consists of four (4) fundamental stages that include criterion establishment, factor standardisation, weight establishment and weighted linear combination (Jerie, 2017). The process of weighted linear combination enables factors to merge through weighted application of criterion values for creating suitability maps.

Generally, the identification of suitable criteria was initiated through a comprehensive literature review and expert ratings utilising the Analytical Hierarchy Process (AHP) method. Table 1 lists several criteria used by previous studies related to this topic. Based on the literature review, seven (7) criteria were chosen and rank through experts. The criterion including: distance from residential area, land use, slope, soil type, distance from water bodies, road network and distance from airport. Subsequently, potential locations were determined via multiple GIS analyses, including weighted overlay analysis to achieve the aim of this study which to assess suitability site for the establishment of a new waste disposal area in Kota Bharu, Kelantan.

Table 1. List of criteria from previous study

Authors (Year)	Study Area	List Of Criteria Used	Buffer Zone
Zeinab Ghaed Rahmat (2016)	Behbahan, Iran	Distance to Groundwater	>1500m
		Distance to surfaces water	> 2500m
		Distance to urban and rural areas	> 15000m
		Land uses	Unused lands
		Distance to roads	> 3000m
		Slope	< 10%
		Soil Type	Land unit 1.2
		Distance to waste generation places	<2000m

https://doi.org/10.24191/bej.v23i1.978

		Land cover	Barren land
Ali Chabuk (2016)	Al-Qasim Qadhaa, Babylon, Iraq	Groundwater depth	between 0 ~1.5 m
		Land use	Exclude industrial area, university and argriculture land
		Rivers	>1000m
		Roads	>500m
		Railways	>500m
		Urban centers	>5000m from streams
		Village	>1000m from borders
		Archaeological sites	>1000m
		Gas pipelines	>300m
		Oil pipelines	>75m
		Power lines	>30m
Ismail Usman Kaoje (2016)	Birnin Kebbi, Nigeria	build-up areas	1,500m away
		water body	30m away
		transport routes	200m away
		forest reserve and agric lands	200m away
		Soil type	low permeability
		Landform	located not on slope surfaces within study area
Habiba I Mohammed (2019)	Johor Bahru	Water bodies	<3000m
		Soil type	Highly permeable
		Slope	0 - 50°
		Elevation	>1500m
		Residential	>2000m
		Airports	>12000m
		Geology	Intrusive
		Road	1000 – 2000m
		Population	Low density
		Land Use / Land Cover	Vacant land
Md Mainul Sk (2020)	Durgapur city	Land elevation	102 – 104m
		Slope	72 - 89°
		Soil	Sandy clay loam to clay
		Geological structure	Alluvium
		Land use / land cover	Built-up
		Distance to surface water	<200m
		Distance to tube wells and wells	<100m

https://doi.org/10.24191/bej.v23i1.978

		Distance to roads	>400m
		Distance to industrial belts	<500m
		Distance to sensitive places	<500m
		Land cost value	13.75 - 23.00lakh
Ahmed Mussa (2021)	Logia town, afar region, Ethiopia	Road	>4900m
		Built-up	>4900m
		River	>2000m
		Fault	>3000m
		Well points	>5000m
		Geology	Mud flats
		Soil type	Lithosols
		Land use / Land cover	Bare land
		Slope	11 – 20°
Oluwagbemiga A (2022)	Ilesa, Nigeria	Distance to Water Body	>960m
		Distance to Residential Areas	>8000m
		Distance to Road	100 – 1000m
		Slope	0 - 5°
		Geology	Complex Charnock /Granite
		Soil type	Nitisols

Source: Authors (2025)

MATERIALS AND METHODS

The methodology comprised four (4) phases. Phases 1 and 2 focused on identifying the study's objectives and criteria through a comprehensive literature review and expert input from various agencies. Phase 2 specifically involved conducting site suitability analysis, necessitating extensive data collection to complete each step of the study. Therefore, various data sets needed to be acquired from both public and private agencies including road network, soil type, DEM of Kota Bharu district to derive the slope, location of nearest airport, land use and resident area of the study area. The research obtained secondary information from reliable internet resources combined with reports and journals alongside governmental institutions manuals. The Department of Town and Country Planning inside the Administrative Offices of Kota Bharu district serves as the source for collecting all related data. The collected data including all the mentioned information is organised in GIS environment and processed for analysis. Additionally, a questionnaire was distributed to experts involved in waste disposal area site selection to gather more information about the potential site selection.

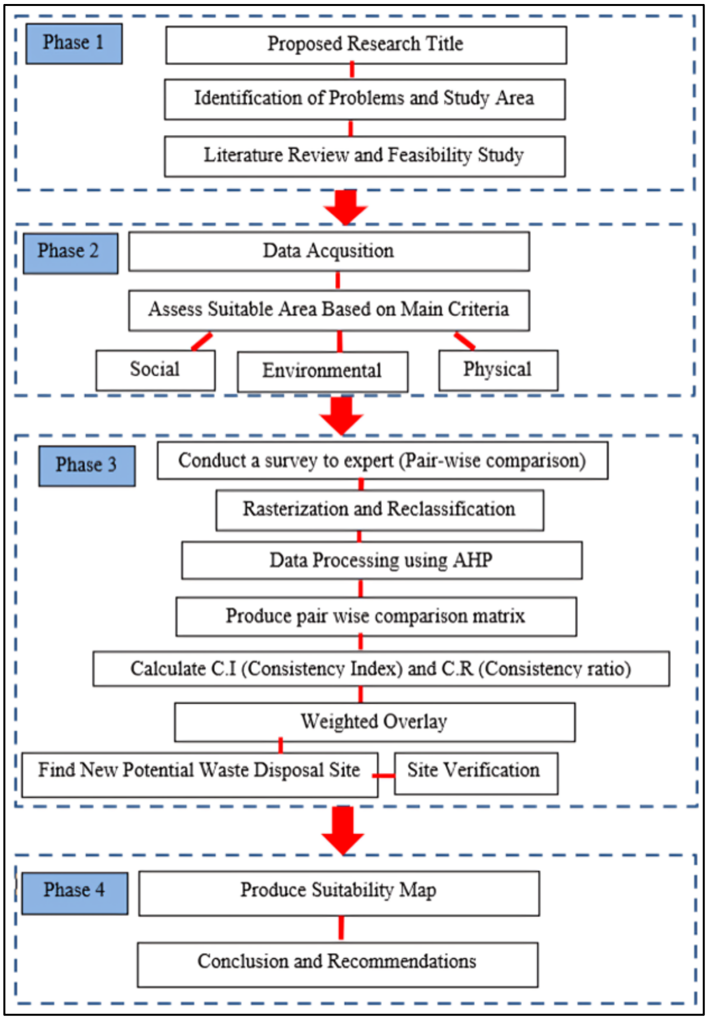

Fig. 1. Methodology Flowchart

Source: Authors (2025)

Study Area

This study was conducted in Kota Bharu district, Kelantan, Malaysia, situated on the east coast of Peninsular Malaysia. Kota Bharu stands out as the most densely populated area among the main cities on the east coast of West Malaysia with a population density of 1,379/km², attributed to an urbanisation rate of 2.0% over a decade (Department of Statistics Malaysia, 2020). In 2020, Kota Bharu's population stood at 555,757 people, experiencing an annual population growth rate of 1.7% from 2010 to 2020, the highest recorded among the years surveyed.

Due to population growth, many residential areas will either be elevated or upgraded. Consequently, the government will need to utilise a significant amount of open space to construct new residential areas, resulting in a low percentage of available land for locating new domestic waste sites. Furthermore, in Kota Bharu, the domestic waste disposal site in Pengkalan Chepa is currently non-operational due to several

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factors. These factors include frequent fires and smoke, which have been disturbing the surrounding residents. Additionally, the site's proximity to the Sultan Ismail Petra Pengkalan Chepa Airport, the encroachment of the buffer zone into the residential area, and other issues such as unpleasant odors, flies, and challenges related to the route taken by compressor trucks, all contribute to the problem (MPKB, 2021). Consequently, the waste disposal area has been relocated to a temporary center in Bachok. The distance between this temporary site in Bachok and Kota Bharu's city center is approximately 37 km, which typically takes about half an hour to travel by car, while a garbage truck requires about an hour for a one-way journey. Figure 2 illustrates the study area of domestic waste disposal in Kota Bharu.

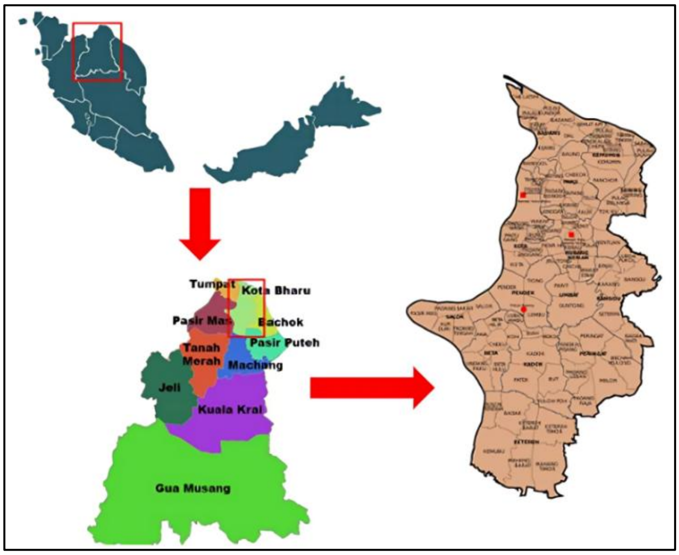

Fig. 2. Study Area

Source: Authors (2026)

Criteria

Table 2 shows seven (7) evaluating criteria: two (2) for the social factor, three (3) for the environmental factor, and two (2) for the physical factor, all derived from various references. The criteria were utilised in GIS to identify suitable areas based on these factors. Each criterion was categorised into three (3) classes: unsuitable, less suitable, and highly suitable. Table 1 illustrates how these seven (7) criteria are distributed across the three (3) main factors: social, environmental, and physical. To facilitate reclassification, all data in vector format must be converted to raster format. Following rasterisation, each data set requires reclassification based on its specific types.

In this study, experts' opinions and literature reviews in relevant fields, along with available data about the study area, were considered to classify each criterion into sub-criteria and assign suitability rating values to each class. This was carried out by decision-makers who gave their opinions about the sub-criteria. To prepare the data for each criterion and its sub-criteria, various GIS analyses were conducted, including buffer, clip, extract, overlay, proximity, conversion, and reclassification.

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Table 2. List of criteria used in the study

Social Factor	Environmental Factor	Physical Factor
Distance from resident area	Slope	Road network
Land use	Soil type	Distance from airport
	Distance from water bodies	

Source: Authors (2025)

Analytical Hierarchical Process (AHP)

The Analytic Hierarchy Process (AHP) relied on ratings derived from expert opinions, followed by pairwise comparisons between criteria. Subsequently, these ratings were incorporated into AHP to assess the consistency ratio (CR). To calculate CR, the consistency index (CI) was initially computed using Equation 1 (Mussa & Suryabhagavan, 2021).

Pairwise Comparison Matrix

Assessments of the importance of each criterion are crucial for initiating the AHP methodology. Therefore, experts with relevance to waste disposal site selection and a vested interest in the topic completed a pairwise comparison survey for the seven (7) main criteria. This survey aimed to determine the weight value for each criterion, thereby enhancing the study's validity. The participating experts are local individuals from Kota Bharu with background knowledge in waste area site selection.

All participants in the survey were tasked with determining the importance of the criteria by engaging in sets of pairwise comparisons. The survey comprised main criteria and sub-criteria levels of decision hierarchy. The first level delineated the three (3) main categories of criteria: social, environmental, and physical. The second level detailed the seven (7) evaluating sub-criteria pertaining to different aspects of site suitability. Each criterion was compared with every other criterion, and its relative importance was graded on a scale of one (1) to nine (9). This survey aimed to discern which criteria respondents deemed more important and to what extent, using a scale from one (1) to nine (9) as shown in Table 3.

Table 3. Saaty's fundamental scale

The Intensity of Pairwise Comparison	Definition
1	Equal Importance/preference
2	Weak
3	Moderate Importance/preference
4	Moderate plus
5	Strong Importance/preference
6	Strong plus
7	Very Strong Importance/preference
8	Very Strong to Extremely Strong Importance
9	Extremely Importance/preference

Source: Aragonés-beltrán et al. (2014)

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Consistency Index (CI)

The calculation of the Principal Eigenvalue, also known as λmax, involved taking the sum of products between each weightage element that was previously determined and the total of the reciprocal matrix's diagonal values. The formula to obtain a consistency index is shown in the equation 1, where n is the number of comparisons and λ max is the Principal Eigen value. (Sivasankar & Rathinam, 2017).

$$CI = \frac{\lambda\, max - n}{n - 1} \tag{1}$$

Consistency Ratio (CR)

To ensure that the scores collected from the questionnaire were consistent, CR was conducted. A CR of less than 0.10 is seen to be appropriate while a greater value necessitates reevaluating the ratings. Equation 2 represents the formula, where CI stands for Consistency Index and RI can be ascertained using the Random Consistency Index Table as presented in Table 4. (Usman et al., 2016).

$$CR = \frac{CI}{RI} \tag{2}$$

Table 4. Random Consistency Index Table

Number of criteria (n)	1	2	3	4	5	6	7	8	9	10	11
Random consistency Indices (RI)	0	0.0	0.58	0.90	1.12	1.12	1.24	1.32	1.41	1.49	1.51

Source: Mohammed et al. (2019)

Weighted Overlay

Before conducting the weighted overlay analysis, it is imperative to ensure that all data intended for input into the analysis have been projected into the same projection and coordinate system and are in raster format. There are a total of seven (7) layers based on the criteria used. Each layer has been assigned different scores based on priority calculations, as shown in Table 4, to facilitate the weighted overlay analysis and generate the suitability output map.

Weighted overlay represents a method which assigns standardised value measurements to various inputs to support integrated assessment. The implementation of weights depends on objective approaches and personal decisions made by the decision-making authority. All the input layers underwent weighted overlay analysis including surface water/river, land use, road network, slope, residential area, and soil maps. The assignment of different thematic layers with weights took place as part of the process to determine which factors influence site suitability. Weighted overlay analysis served as the tool for determining the best areas for domestic waste disposal in Kota Bharu.

Data Visualisation

A map containing comprehensive map elements, based on seven (7) criteria, was generated to visualise the suitability of sites within the study area. The map illustrates four (4) class categories of suitability: restricted, unsuitable, less suitable, and highly suitable. Results obtained from the site suitability analysis demonstrate that highly suitable areas are sufficient to accommodate the waste generated. Several steps

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were implemented within the GIS environment to produce the site suitability map of potential area for locating domestic waste disposal in Kota Bharu, Kelantan, utilising spatial analysis tools.

Site Verification

The output results suggest that two (2) potential candidates for locating domestic waste disposal in Kota Bharu have been identified. To validate these findings, a site visit was conducted to ascertain which location or area is suitable for the disposal of domestic waste, based on the results depicted in the generated map.

RESULTS AND DISCUSSION

After determining the weights for each criterion and sub criteria based on the experts' choice, the weighted overlay method was used to determine the final output suitability map for a waste disposal site in Kota Bharu, Kelantan.

Weightage of Criteria

After the expert had given the weightage of each criterion, then the weights were calculated by using AHP method. Two (2) methods can be used which are Aggregation and Consensus. The aggregation method has been used in this study which is synthesising the individual's judgment and combines them to derive the priorities.

To ensure the correctness of the calculated weighted value for all the main criteria and also sub-criteria, the sum of all the criteria of weightage must be equal to 1. The total sum of all the priorities must be 1. The value of the priorities was used as an input value in order to run the weighted overlay analysis. Table 5 shows the priorities calculation for each criterion.

Table 5. Priorities Calculation

Criteria	Sub-Criteria	Standardise Weightage	Total Weight	%
Residential area	Less than 0.5km	0.005	0.055	5
	0.5 – 1.0km	0.007		
	More than 2.0km	0.043		
Land use	Agriculture	0.016	0.135	14
	Forest	0.015		
	Bareland	0.104		
Slope	Less than 5°	0.008	0.113	11
	5° - 10°	0.085		
	More than 10°	0.020		
Soil type	Alluvial soils	0.003	0.051	5
	Lithosols soils	0.037		
	Latheric soils	0.011		
Distance from water bodies	Less than 2km	0.005	0.030	3

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	2 -3km	0.003		
	More than 3km	0.022		
Road network	Less than 1km	0.009	0.110	11
	1 – 2km	0.084		
	More than 2.5km	0.017		
Distance from airport	Less than 4km	0.069	0.506	51
	4 – 9km	0.047		
	More than 10km	0.389		

Source: Authors (2025)

Suitability Map of Domestic Waste Disposal

A suitability map was created using weighted overlay analysis. In this process, the influence value is determined by the AHP calculation. The scale value is derived from the evaluation scale of the sub-criteria, where the most important criteria have the highest value and the less important criteria have the lowest value. To conduct weighted overlay, all data layers must be in a standardised raster format. The Site Suitability Map for Domestic Waste Disposal in Kota Bharu is illustrated in Figure 3. The area has been classified into four (4) classes: orange denotes restricted areas, red indicates unsuitable areas, blue represents less suitable areas, and green signifies highly suitable areas. The "restricted" category encompasses open land and recreational, community, transportation, infrastructure, utility, industrial, commercial, and mixed development areas.

To choose an appropriate domestic waste disposal site in the study area, a comparison of various locations was conducted based on their environmental, social, and economic impacts. Through weighted calculations, the relative importance of each parameter was determined for all criteria, including distance from residential areas, land use, slope, soil type, distance from water bodies, road network, and proximity to the airport. Following the reclassification of all criteria, the suitable location for the domestic waste disposal area was determined using weighted overlay analysis.

Out of the total study area in Kota Bharu, 40% (37229 acres) fall under restricted land use which included open land and recreation, community institutions and facilities, transportation, infrastructure and utilities, industry, commercial, and mixed development, 2% fall under unsuitable, 47% fall under less suitable and 11% fall under highly suitable for domestic waste disposal area. Determination of suitability classes were based on EIA Guidelines Waste Treatment and Disposal from the Department of Environment Malaysia as well as reviewing literature review (Eliawa, 2022; Ghoutum et al., 2020) and as presented in Table 1. The red circle on the map in Figure 3 shows the two (2) different areas (Wakaf Bharu and Melor) which is the most suitable area for locating the domestic waste disposal site. Table 4.11 shows the total area of each value with weighted overlay results. Figure 3 (a) shows the Site Suitability Map for Domestic Waste Disposal in Kota Bharu, while Figure 3 (b) shows the Site Suitability Map for Domestic Waste Disposal in Kota Bharu with existing waste disposal.

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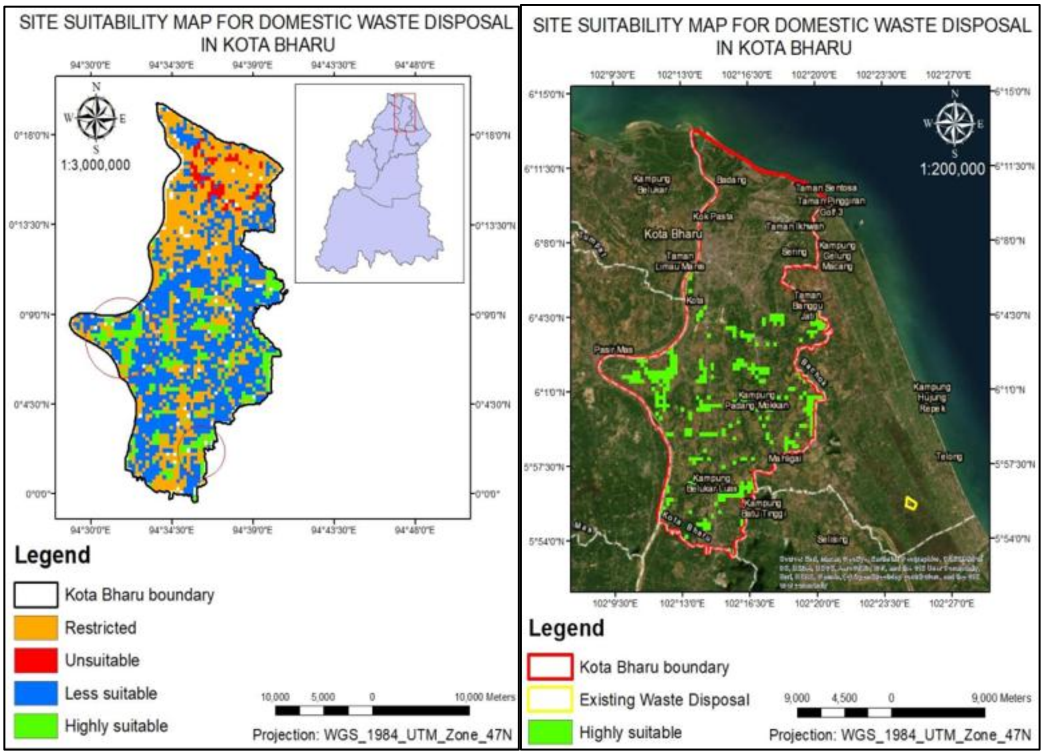

Fig. 3. Site Suitability Map

Source: Authors (2025)

Site Verification

Based on the output result, two (2) candidates are potential in locating domestic waste disposal in Kota Bharu. To check whether the area is suitable which has been derived from the analysis, a site visit has been performed to determine which location or area that are suitable for locating the domestic waste disposal. Two (2) candidates are determined which is in Lorong Tukang Perak, Wakaf Bharu, and Mahligai, Melor. According to EIA Guidelines for Waste Treatment and Disposal (Domestic Waste) from the Department of Environment (DOE), every state in Malaysia has a different total land area to construct a domestic waste disposal site. In Kelantan, the total area has been set which is less than 80 acres. Another existing domestic waste disposal is at Kg. Telong Mukim Beris Lalang, Bachok the area for the whole land is 76.6 acre according to the Urusetia Penerangan Kerajaan Negeri Kelantan (UPKN). Candidate one (1) (Wakaf Bharu) in terms of criteria used in the analysis, the area is highly suitable because the area is far away from the resident area, airport, road, water bodies, and land use which is bareland area. The slope is medium which is not very high and not very low. Figure 4 shows the area of Candidate one (1).

Candidate two (2) (Melor) in terms of criteria used in the analysis the area is less suitable because the area is far away from the resident area, water bodies, airport, and road and for land use, this area is under forest which is less suitable to locate the domestic waste disposal. The slope is also very high which is not suitable for domestic waste disposal. Figure 5 shows the area of candidate two (2).

Fig. 4. Candidate one

Source: Authors (2025)

Fig. 5. Candidate two

Source: Authors (2025)

CONCLUSION

This study aims to assess the potential site area for domestic waste disposal in Kota Bharu through AHP and GIS analysis which produces comprehensive suitability maps. There are seven (7) main criteria considered in this study, which are distance from resident area, slope, soil type, distance from water bodies,

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road network, distance from airport, and land use. The results show that the most important criterion is distance from airport (51%) due to safety requirements and regulatory necessities, while the least important criteria is distance from water bodies (2%). AHP and GIS integration established an efficient methodology to handle the multiple-element decision problems encountered during waste disposal site selection processes. It is important to exercise caution when evaluating results because both the weight assignment process and data accuracy issues subject results to potential interpretation issues. The study results provide practical advantages to urban planners and municipal authorities through site selection validation which fulfills the standards of the EIA Guidelines Waste Treatment and Disposal.

The study presents different beneficial aspects but does contain various restrictions. Findings may encounter generalisability problems because data availability stands alongside the scale of analysis as well as the lack of social or economic data. It is suggested for future research to include demographic density information in addition to historical environmental records and residential opinions to fill current gaps in knowledge. The value of this research could be strengthened through investigation of new decision methods alongside prolonged site performance assessments. The research makes an important contribution to sustainable waste management knowledge development focused on developing urban areas.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of Universiti Teknologi Mara (UiTM) Shah Alam and Fakulti Alam Bina (FAB) for providing the facilities to support and conduct this research.

CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

AUTHORS' CONTRIBUTIONS

Wan Nur Nisa carried out the data collection, data processing for the research and wrote the article. Shakila Tahir contributes to the data collection procedure process. Nurhanisah Hashim designed the research methodology, supervised the research and writing progress. Ainon Nisa Othman and Abdul Rauf Abdul Rasam reviewed and revised the article and approved for the article submission.

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