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DETERMINATION OF SUITABLE LANDFILL SITE AT BATU PAHAT USING GIS AND ANALYTICAL HIERARCHY PROCESS

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ABSTRACT

Landfill is the area for the disposal of solid waste. The increase in solid waste production has resulted in existing landfills are no longer able to accommodate the number of waste more and more. Difficulty arises in determining suitable area as landfills causing a lot of problems. This study aimed to determine the appropriate area as landfills in Batu Pahat district by using Geographic Information System (GIS). In addition to the Batu Pahat district has yet to have its own landfill. GIS is an information system that can help make a decision on the form of a map display. The ability of GIS is integrating spatial data and data attributes in the collect, store and analyze the data. Spatial Data used in this study includes street maps, land use maps, map series, gradient map, map of flood area, and map of settlements, location map and a map of the river. This data has been divided into two parts in the form of attribute data includes the criteria constraints and criteria factors. The value of the weights given to factor the relative criteria depending on the importance and value of the rating is determined using the model Hierarchy Analytic approach (AHP). Next method of filtering and grant value weighting is analyzed to produce a map showing the extent of the suitability of the landfill. The results show the suitability of the spaces as landfill area.

Keywords: landfill, geographical information system, analytical hierachy process.

INTRODUCTION

Each country and local authority gives significant attention to their selection of the landfill. The searching for new landfill sites is time-consuming process when the current existing landfill sites are fulfilled. Landfill is the most common method for disposal of solid waste generated by the local community. (Komilis *et al.*, 1999). Landfill is one of the most important aspects in ensuring the solid waste management process runs smoothly. Areas with high density population must have at least one landfill and if no, it will cause problems for users and management. Increasing of amount on waste production from time to time is the main reason why the importance of a waste disposal site. Suitable area for landfill should be designed with well structured plan in terms of the environment and the economy in order to be accepted by the public and at the same time must meet the conditions set. Geographic Information System (GIS) is a system used to collect, store and analyze data and at the same time able to provide the output in visual form (Wan *et al,* 2010). This system also helps in facilitating the process of analyzing the landfill area criteria.

The study area is selected in Batu Pahat district in Johor state which is located in the West Johor (1 ° 5'N 102 ° 56'E). The results of population census in 2000, Batu Pahat has approximately 336.509 in population where the majority of the population is Malay (66.02%), Chinese (32.15%), Indian (1.68%) and other ethnic composition of approximately 0.14% (Seow, 2010). Batu Pahat itself covering 187.702 hectares, including areas where located as Chaah Bharu, Seri Medan, Tanjung Sembrong, Simpang Kiri, Lubok, Linau, Bagan, Peserai, Simpang Kanan, Minyak Beku, Sri Gading, Kampung Baharu, Sungai Punggor, and Sungai Kluang. Figure-1 shows a map of Batu Pahat.

Increment rate of population in Batu Pahat caused the rate of solid waste rise in this area. At this moment, solid waste from Batu Pahat were removed and disposed in Muar and Simpang Renggam due to insufficient landfill area in Batu Pahat. This lead to management cost due to considerable distances and much time consume required for the waste transfer process. A new disposal sites have been proposed and are still in the planning stage located in Bukit Payung, Parit Sulong. However, the people surrounding area were opposition the proposal because just located 2 km away from their settlement. So that, the objective of this study is to identify the criteria to determine the suitable landfill area using GIS technology assist with Analytical Hierarchy Process (AHP) model.

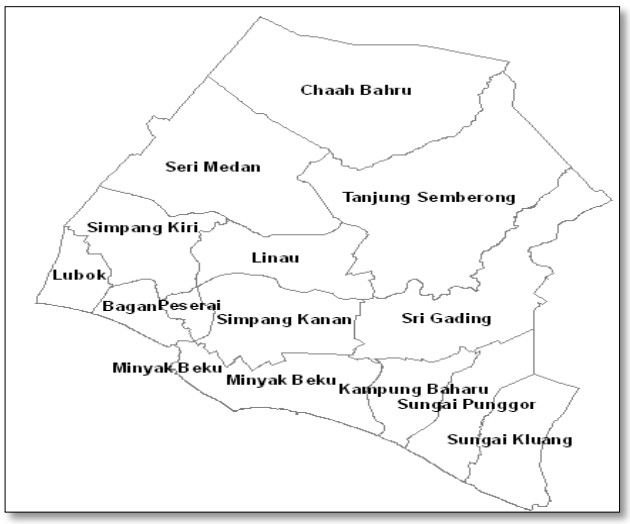

Figure-1. Batu Pahat district map.

Data and method

Geographic Information Systems (GIS) are widely used in many task including the selection of the landfill with a combination of specific criteria to generate maps (Leão *et al.* 2004). GIS is capable to providing spatial analysis tools to isolate, manipulate and produce maps with georeferences. GIS is an ideal method for preliminary site survey and it also has been widely used in fields of study including the siting of solid waste disposal. Figure-2 shows the methodology and process for determining the criteria for waste disposal sites

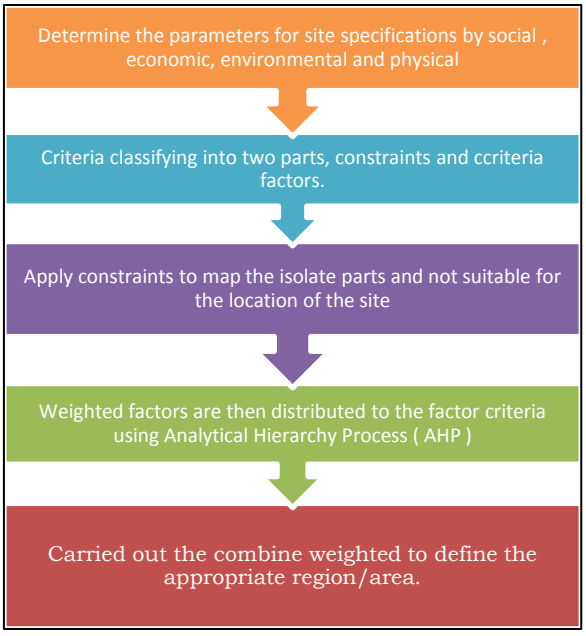

Figure-2. Site selection determination process based on criteria.

Designing and GeoDatabase development

Design and development data in this study include the process as described below:

i. Convert files from *.TAB format to *.SHP format

ii. Placement of image digitizing maps

iii. Buffering process on the road map, rivers and settlements.

iv. Providing the gradient of a contour map

Criteria involved in determining appropriate landfill

There are eight criteria involved in determining a suitable disposal sites, namely flood area, city center, land use, river, road, slope and soil series. Before spatial analysis conducted, factors of constraints and criteria must be clearly identified. The process of identifying both of these criteria have been refer to the Department of Town and Country Planning ie based on the physical, economic , social and environmental as well as previous related studies .

Constraint

Criteria of constraints indicate unsuitable areas based on the rules under which the landfill is prohibited built in areas that may represent a danger to the environment and humans. Its criteria factors may also used to determine which areas are suitable for waste disposal sites.

There are seven criteria constraints;

i. Settlement: Landfills need to be away from populated areas to protect the public from harm and affect health. For this criterion, 500 m buffer is placed.

ii. City: Location landfill should be located away from public areas.

iii. Flood area: Landfill cannot located in a flood area to prevent water pollution caused by solid waste.

iv. River: The landfill adjacent to the river will cause pollution.

v. Developed area: The area to be developed should be protected from landfills to maintain the area and development purposes.

vi. Water Body: Not suitable for placement in a landfill because it can affect water quality and at the same time will affect those around them.

vii. Wetlands: Not suitable for landfill site.

In other hands, criterions are consists of a buffer zone road, slope, land use (grassland, agricultural, open space and forest) and soil series. For criteria factors, grade given to each criterion with reference to previous studies. Description for each criterion factors under the terms of suitability criteria.

a) **Land use:** For this criterion, five categories were used; the lake, grassland, agricultural, and forest terrain.

b) **Soil series:** There are about 20 types of soil series in Batu Pahat. Series of land suitable for landfill only accounted for. Soil series is select when containing low permeability and low infiltration rate.

c) **Access road:** Landfills should not locate adjacent to the road to reduce the health and aesthetic problems. At the same time, the landfill should also not be located away from the road. Therefore, the distance of 500-1000m been considered as a suitable distance to the landfill.

d) **Slope:** Standard suitable gradient for the construction of the landfill is less than 15^0 (Bilhegan *et al.* 2008) because when the slope is too steep, they will complicate the process of construction and maintenance.

The data used in this study was obtained from government agencies where most of the data obtained is in the form of GIS format except for settlements which have been obtained in hard copy. On screem digitizing process has been carried out to convert this data into GIS format.

Factor criteria classification

Before giving the weighting process, the classification criteria are needed to ensure the functionality in the classified or cell values with alternative values using various methods. Classification process can be done with one value at a time or by using a set of values based on such criteria stipulated division (for example, collect points to 10 parts); or in an area (for instant, separate the values into 10 groups containing the same number). The function is designed to enable users to convert many values on the input raster to the desired value, set or alternatives.

Determination of weighted value

Analytical hierarchy process (AHP) and the combined weighting method is used to determine suitable areas for a landfill. AHP is one of the appropriate tools in making decisions that include multi-criteria, flexible and effective in solving complex problems in addition to dividing the problem into smaller parts so it is easier to be solved (Sener *et al.* 2006).

In AHP, a matric created in which each criterion compared with other criteria depending on the importance of the criteria of a scale of 1 to 9. The estimated weights are then calculated to produce the consistency ratio for scale banding pairs. If the consistency ratio > 0.10, the scale of pairs should be calculated to be recomputed to get the consistency ratio < 0.10 (Saaty, 1980). Table-1 show the scale banding pairing in AHP and Table-2 shows the comparative scale factor pairs for the criteria used in this study.

Table-1. Scale of AHP pairs comparison (Saaty, 1993).

1	Equal
2	Between equal and moderate
3	Moderate
4	Between moderate and strong
5	Strong
6	Between strong and very strong
7	Very strong
8	Between very strong and extreme
9	Extreme

Table-2. Matrics of criteria factor in Pairs comparison (Wan *et al*, 2010).

Criteria	Land use	Soil series	Road buffer	Slope
Land use	1	3	5	6
Soil series	1/3	1	3	5
Road buffer	1/5	1/3	1	4
Slope	1/6	1/5	¼	1

After the comparison process is completed, the priorities weighted that have been produced are shown in Table-3.

Table-3. Priority vector (Wan *et al*, 2010).

Criteria	Priority vector
Land Use	0.542
Soil Series	0.264
Road	0.138
Slope	0.058

CR = 0.0833 < 0.10 (Suitable)

Obtained weighted value is then used to calculate the index of suitability landfill by GIS. Size of site suitability is calculated to obtain the required landfill.

RESULTS AND ANALYSIS

Unsuitable Area for landfill results were obtained from the combination of constraint criteria using filtering function in GIS. Figure 3 to 7 shows a map of the constraints and criteria and Figure 8 shows the result of a combination of all these constraints criteria.

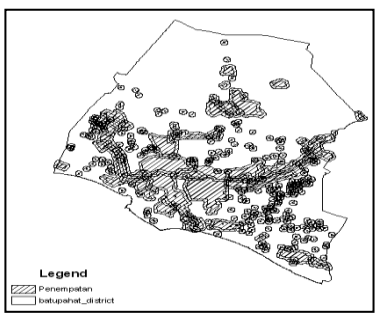

Figure-3. Settlement map.

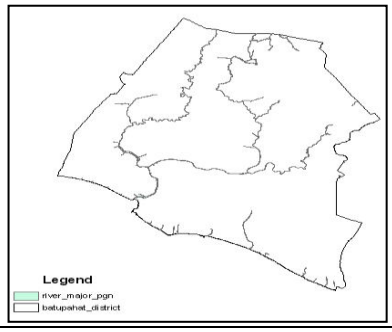

Figure-4. River map.

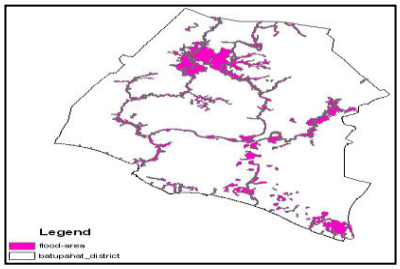

Figure-5. Floods area map.

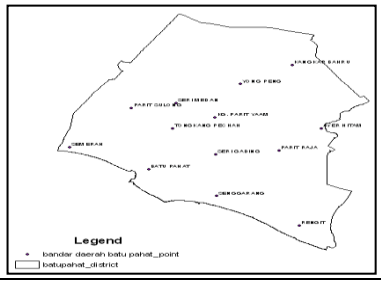

Figure-6. Location map.

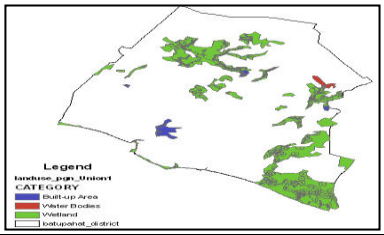

Figure-7. Land use constraint map.

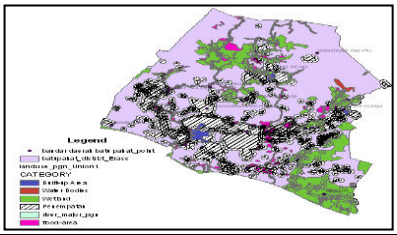

Figure-8. Result of combination in constrain criteria

Results of the combined criteria of constraints, a map showing areas suitable and unsuitable produced as shown in Figure-9.

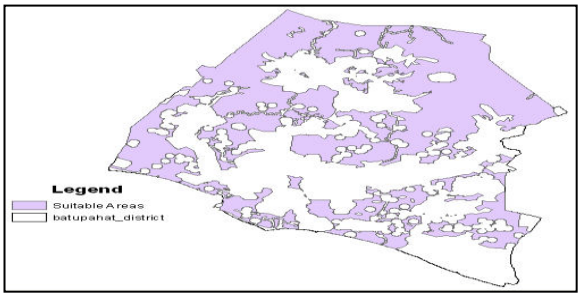

Figure-9. Map for the best and not suitable areas for landfill.

The next process involves suitable areas for landfill. At this process, the criteria of the factors that have given the grades from 1 to 4 were used. This represents the value of grade level appropriateness landfill in less suitable to the most suitable. Grading criteria shown in Tables 4, 5, 6 and 7. Once the process done, the criteria for the classification process are obtained. The results combined all the factors corresponding to the diagram shown in number 10, 11, 12 and 13.

Table-4. Land use grading number (Wan *et al*, 2010).

Land use type	Grade
Lake	1
Forest	2
Grassland	3
Agriculture / Terrain	4

Table-5. Soil series grading number (Wan *et al*, 2010).

Soil series type	Grade
Selangor	1
Peat/Serdang	2
Steepland	3
Urban Land/Kranji	4

Table-6. Road buffer grading number (Wan *et al*, 2010).

Road buffer distance (m)	Grade
0-500	1
500-1000	4
1000-1500	3
>1500	2

Table-7. Slope gradient grading number (Bilhegan, 2008).

Degree of slope (°)	Grade
>25	1
20-25	2
6-20	3
0-6	4

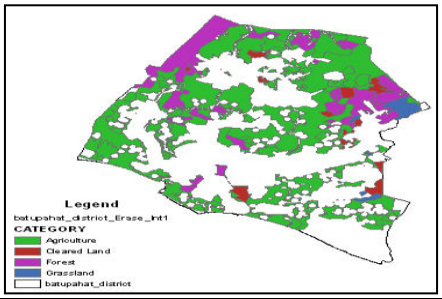

Figure-10. Map of regions in accordance with the land use type.

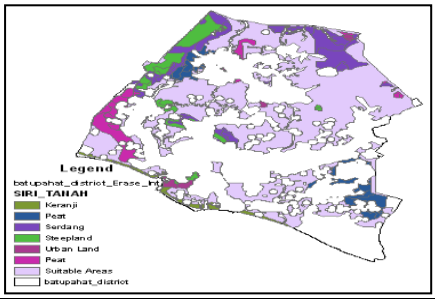

Figure-11. Map of regions in accordance with the soil series type.

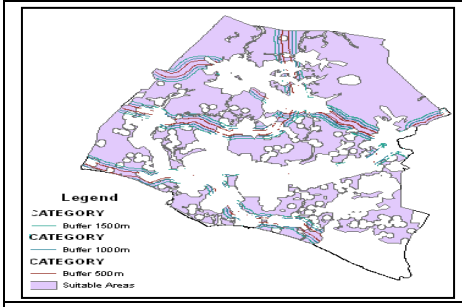

Figure-12. Map of regions in accordance with the road.

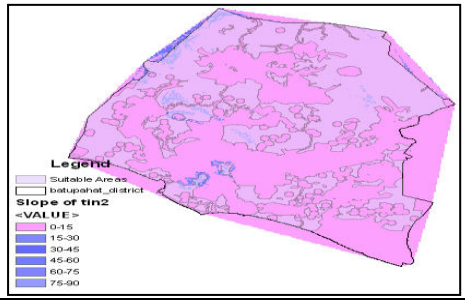

Figure-13. Map of regions in accordance with the slope.

The next step is to classify the map according to the given grade. Figures number 14, 15, 16 and 17 shows the results of the classification map.

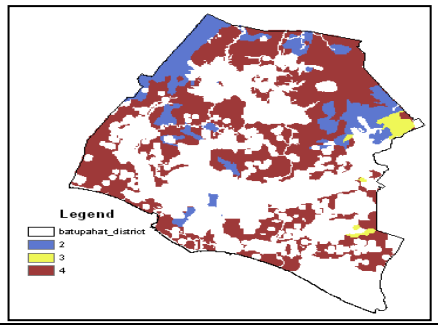

Figure-14. Results from the suitable area referred to land use criteria.

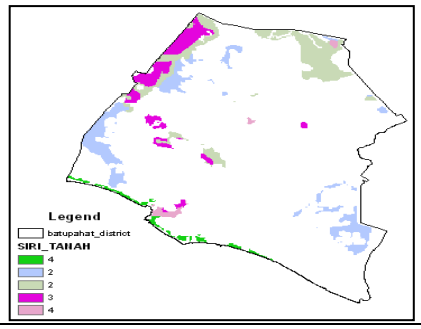

Figure-15. Results from the suitable area referred to oil series.

Figure-16. Results from the suitable area referred to road buffer distance.

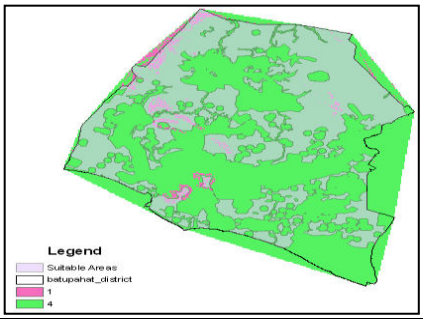

Figure-17. Results from the suitable area referred to degree of slope.

After the classification process is done, the final process is screening where the vector sum of the weighted of priorities were added to getting the suitability of the area map. The result is shown in Figure-18.

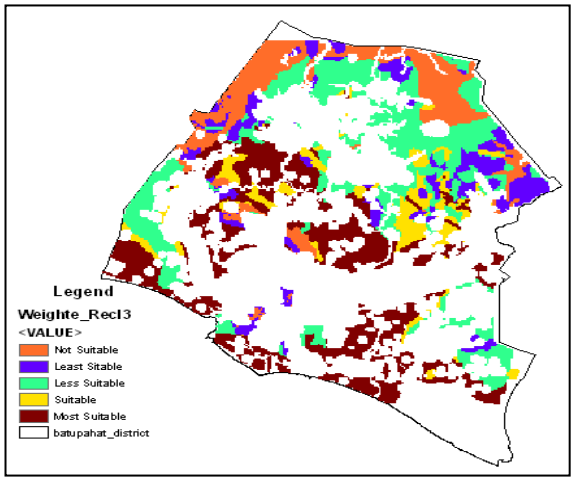

Figure-18. Map of suitability level of landfill area.

Many areas can be proposed as a landfill except at the Simpang Kanan. To ensure that the GIS output can be adopted, the manual process of screening was performed using the land suitability map along with a map Batu Pahat obtained from the Department of Town and Country Planning The screening manual results found that the area suitable as landfill issued by the GIS is acceptable because it is located in an area with no constraints. As Bukit Payung location that has been proposed as a new area for landfill in Batu Pahat, it was found located in the right area but slightly close to populated areas as shown in Figure-19.

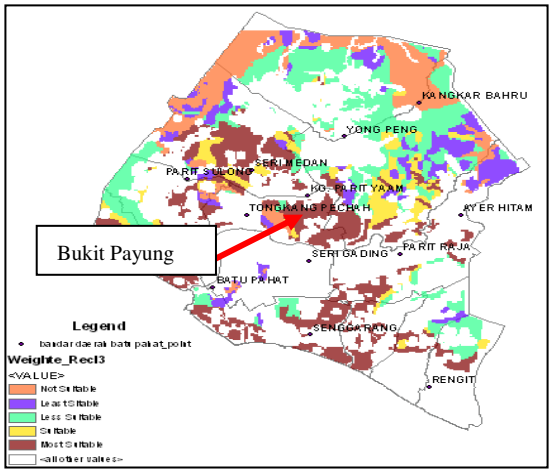

Figure-19. The appropriate level for the landfill by City.

The criterion setting in the classification process made by local authority. At the same time, there are also obstacles in conducting this study in terms of data acquisition data e.g. settlements which are not available in GIS format and need to digitize process in which the results obtained may be affected. For improvement in future studies, the criteria used to determine the

appropriate area as a landfill can be coupled with appropriate and relevant parameter.

CONCLUSIONS

As whole, the objectives of the study were to determine the appropriate area as a landfill in Batu Pahat is reached where the use of Geographic Information Systems and applications have provided results that might be applicable. In addition, the criteria for determining the area of suitable sites have been able to determine where all the rules and regulations governing the determination of areas and sites have been issued by the Town and Country Planning Department. Conclusions can be made based on the results obtained are GIS is a tool that can help in combining various information from various sources and it is also able to assist in the decision making process.

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