HOW GIS CAN BE A USEFUL TOOL TO DEAL WITH LANDFILL SITE SELECTION

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ABSTRACT

Scarcity of land for waste disposal in most large urban areas is one of the serious and growing potential problems nowadays. Even though there are some efforts to reduce and recover the waste, land filling is still the most common method for waste destination. Landfill site selection in urban areas is a critical issue due to its huge impact on the economy, ecology, and the environmental health. Therefore, numerous criteria must be considered and the selection process is a complicated since it has to integrate social, environmental and technical parameters. In this study, the most suitable candidate sites for locating landfill in Klang District, as a case study area are determined by using an integration of the Geographical Information System (GIS) and Multi Criteria Decision Making (MCDM) method. For this purpose, eleven input map layers are prepared and two different MCDM methods which are Weighted Linear Combination (WLC) and Analytical Hierarchy Process (AHP) are implemented to GIS. The first stage of procedure is initial screening process to eliminate unsuitable land where only 6% of the total study area is suitable for landfill sitting. These suitable areas are further examined by deploying the AHP method in order to obtain relative importance weights followed by the application of WLC method for a calculation of suitability index. The resulting land suitability is reported on a grading scale of 1–4, which is the least to the most suitable areas respectively. Research findings show that only five areas are identified as the most suitable location for landfill with the grading values greater than 2.67

1. INTRODUCTION

Today, waste management encompasses the new concepts like waste reduction, recycling, high tech collection, compaction, thermal treatment, sanitary landfills as well as waste and leachate treatment. All these are some parts of the strategies to focus on environmental protection in solid waste management. For the longest time, waste management in Malaysia hinged on disposal and as a result, almost all waste produced ended up in landfills. Alam Flora provides Integrated Solid Waste Management (ISWM) with the aim to encourage waste minimization and recycling and not just disposal. Hierarchy of waste management that has been adopted was based on the principle of 3R (Reduce, Reuse and Recycle) (Alam Flora, 2004).

Availability of land for disposal of municipal waste via landfilling is getting scarce nowadays. Landfills have created various problems such as ground water contamination and uncontrolled emission of landfill gases causing an explosion. All these problems resulted into the unwelcome of landfill by the communities all over the world. Landfill sitting becomes one of the problems being confronted by the waste management planners due to the current permitting and sitting requirements and also its operations. Beside that, an escalating environmental degradation and awareness, increasing cost, community and political opposition, increasing of population densities, shortage of land availability and public health concerns also contribute to the difficulty of choosing suitable land for landfill (Daneshvar, R. et al., 2005, Mahini, A. S. et al., 2006, Sener, B. et al., 2006 and Siddiqui, M.Z. et al., 1996).

Therefore, in a landfill siting process there are many factors that must be taken into consideration and carefully evaluated. As a result, the most suitable site to be selected should cause minimum impacts to the environment, society and economy as well as conforming with the regulations and generally accepted by the public. However, it would be time consuming and tedious to implement such a complex procedure by using manual processing approaches (Kao et al., 1996). In addition, there are numerous data to process and sometimes it might be repeated for several times till the best site is found.

Site selection analysis can be improved by using GIS. GIS is a suitable tool for site selection since it has the capability to manage large amount of spatial data that comes from various sources. Kao et al., (1996) pointed out that large amount of spatial data can be processed using GIS and thus, it potentially saves time that would normally be spent in selecting an appropriate site. While Daneshvar et al., (2005) claimed that GIS is an ultimate method for preliminary site selection as it efficiently stores, retrieves, analyzes and displays information according to user-defined specification. However, GIS can be limited by the existing sources of data needed in siting analysis.

Nowadays GIS has been used as a tool in a landfill site selection analysis. GIS provides the decision maker with a powerful set of tools for the manipulation and analysis of spatial information. Using a Geographic Information System (GIS), it is possible to process a huge amount of spatial data in short time and so the screening process is much easier. GIS can help to reduce remarkably the areas that have to be examined on the site, although the final decision has to be taken after field studies.

In this study, analysis of landfill site selection has been carried out by employing GIS. The District of Klang, Selangor state, which is highly populated and fast growing development area, is chosen as a case study area. The multi criteria decision making (MCDM) method has been integrated with two methods have been employed namely the analytical hierarchy process (AHP) and weighted linear combination (WLC).

3. STUDY AREA

Klang town is the Royal Capital of the State of Selangor and is also one of the main gateways to Malaysia via sea. It is located about thirty-two kilometers to the west of Kuala Lumpur and six kilometers east of Port Klang. The district area includes several islands, namely Pulau Ketam, Pulau Kelang, Pulau Tengah, Pulau Selat Kering, Pulau Selat Gedung, Pulau Che Mat Zin and Pulau Indah. It is bounded on the north by the Kuala Selangor District, on the east by Petaling District and on the south by Kuala Langat District. Port Klang, which is Malaysia's premier port, is located eight kilometers to the southwest of Klang Town. This territory area of 61847 ha contains residential, commercial, industrial and port area.

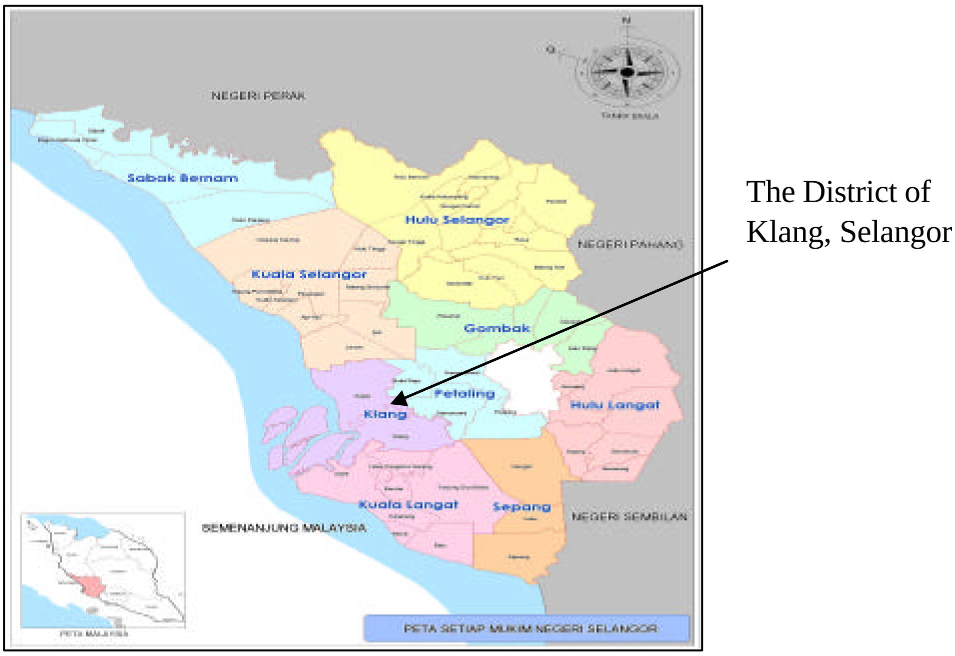

Figure 1. Location of the study area

4. METHOD AND RESULT

The presented method starts with the identification of evaluation criteria or parameters needed for landfill siting. All these parameters have been identified based on the local guidelines such as Town and Country Planning Department (TCPD) guideline for waste disposal siting and also guideline from the Department of Environment (DOE). Besides, the related information about landfill siting has also been reviewed from the international practices like Environmental Protection Agency (EPA) from the United States plus review from related literatures. All the data pertaining to these parameters were taken from the relevant agencies, however not all parameters are included in this study due to the lack of data availability. In this study eleven (11) parameters have been identified for landfill site selection namely surface water, residential area, railway, flood prone, swamp, archeology or historical site, slope, soil type, land use, road accessibility and urban area.

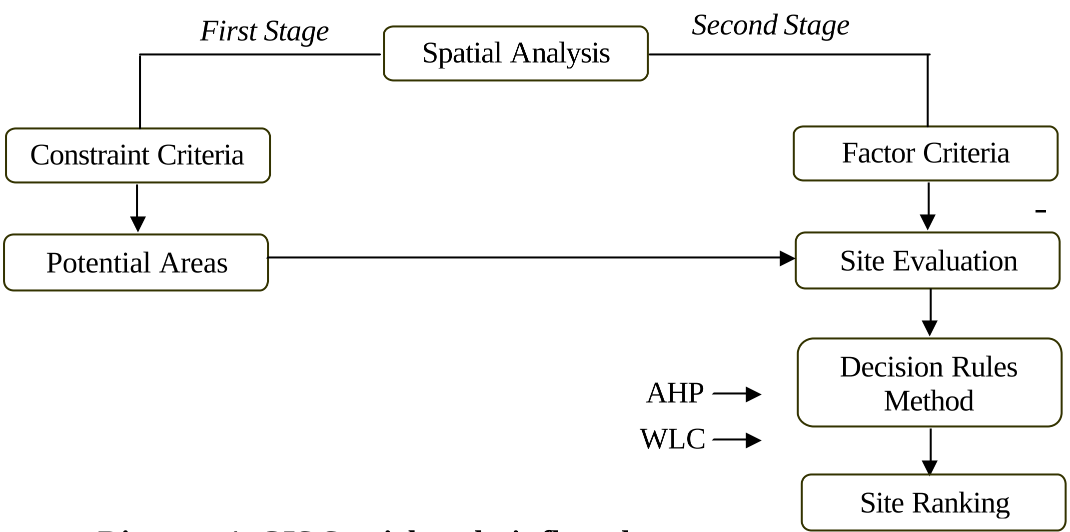

Diagram 1. GIS Spatial analysis flow chart

No.	Criteria	Buffer Zone
1	Surface water	100m
2	Residential area	500m
3	Urban area	500m
4	Railway	500m
5	Flood area	Restricted area
6	Swamp	Restricted area
7	Historical site	Restricted area

Table 1. List of constraint criteria

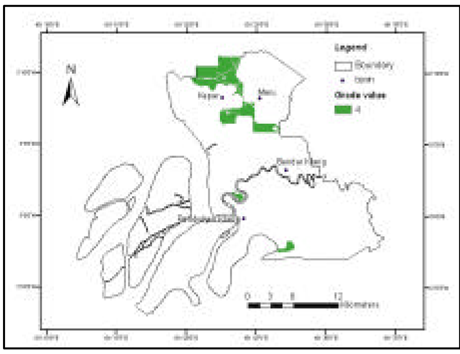

Figure 2. Land use map

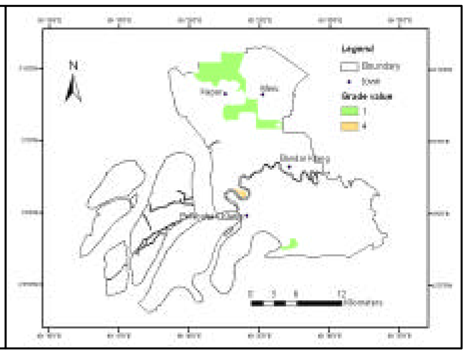

Figure 3. Soil type map

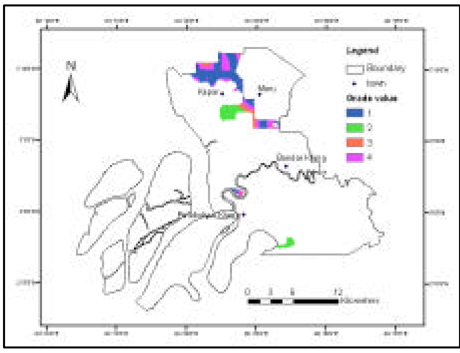

Figure 4. Road map

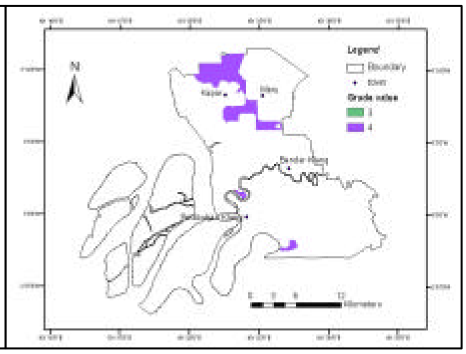

Figure 5. Slope map

There are two stages of analysis as shown in above diagram 1 where, firstly it starts with an elimination process of unsuitable parcels of land for siting a landfill. Suitable parcels of land resulted from the first stage undergo a second stage of analysis where there are two types of Multi Criteria Decision Making (MCDM) methods have been employed a namely analytical hierarchy process (AHP) and weighted linear combination (WLC). Table 1 above explains list of the constraint criteria. At the first stage, these criteria are used to identify unsuitable parcel of land for landfill according to the local regulation. By considering these criteria, it was found that only 6% which is 3588ha of the total area than can be considered as suitable land. These few areas can be suggested as a suitable list of land to the Local Authority but, this is not a final result as further step needs to be applied in order to narrow down these suitable areas

Therefore, four parameters are chosen to further investigate these potential areas namely land use, soil type, road accessibility and slope under the second stage of spatial analysis. This stage is applied to rank the potential areas based on attributes recorded on GIS data maps. These criteria are not easily quantifiable or measurable using related units and thus, a suitable approach is needed to make these criteria commensurable. Therefore, a grading scale value of 1 to 4 is applied to these criteria to indicate its suitability for landfill siting which is ranging from least to the most suitable, respectively.

Figures 2 to 5 above show the potential areas which are 6% of the total District of Klang area, that have been further evaluated by the four factor criteria and each map consist of a grading scale value of 1 to 4 in each cell in order to display its level of suitability for locating landfill. The next step is the integration of the analytical hierarchy process (AHP) and weighted linear combination (WLC) on this part. The AHP method which is developed by Saaty, T. L. (1980) is an effective approach to extract the relative importance weights (RIW) of the criteria. It is based on the pairwise comparisons which are used to determine the relative importance of each criterion.

A matrix is constructed where each criterion is compared with the other criteria relative to its importance, based on a scale of 1 to 9 which means its level of importance varies from equal importance to the extreme importance, respectively. Then, a weight estimate is calculated and used to derive a consistency ratio (CR) of the pairwise comparisons, If CR > 0.10, then some pairwise values need to be reconsidered and the process is repeated until the desired value of CR < 0.10 is reached. A detailed explanation about the AHP method can be found in Saaty, T. L. (1980). Finally, WLC method is applied to compute the suitability index value of the potential areas based on the equation as follows (equation 1):

$$S_i = \sum_{j=1}^{n} w_j * x_{ij} \qquad (1)$$

Where Si is the suitability index for area i, wj is the relative importance weight of criterion j, xij is the grading value of area i under criterion j and n is the total number of criteria. The suitability index is calculated using the grading value of factor criteria as shown in Figures 2 to 5 with their corresponding relative importance weight taken directly from the last column in the Table 2.

Factor criteria	Land use	Soil type	Road	Slope	***RIW***
Land use	1	3	5	6	0.542
Soil type	1/3	1	3	5	0.264
Road	1/5	1/3	1	4	0.138
Slope	1/6	1/5	1/4	1	0.058

Table 2. Pairwise comparison matrix and relative importance weight

$\lambda_{max} = 4.225$ CI = 0.075 $RI_4 = 0.9$ and CR = 0.0833 < 0.1

The level of suitability for each cell on these potential areas is finally calculated by applying the above formula. Suitability index value is the final value obtained where it varies from lowest to the most suitable site according to the grading scale of 1 to 4. Figure 6 below displays the final grading value obtain which is called suitability index. An increasing of the suitability index indicates the more suitable that site to be a landfill. Sites with suitability index from 2.00 to 2.67 are less suitable to become a landfill site. Sites with index from 2.24 to 4.00 are considered the most suitable ones however it covers only on the small part. Therefore, the second ranking of suitability index which is from 2.67 to 3.34 can be considered as the most suitable sites available at the District of Klang.

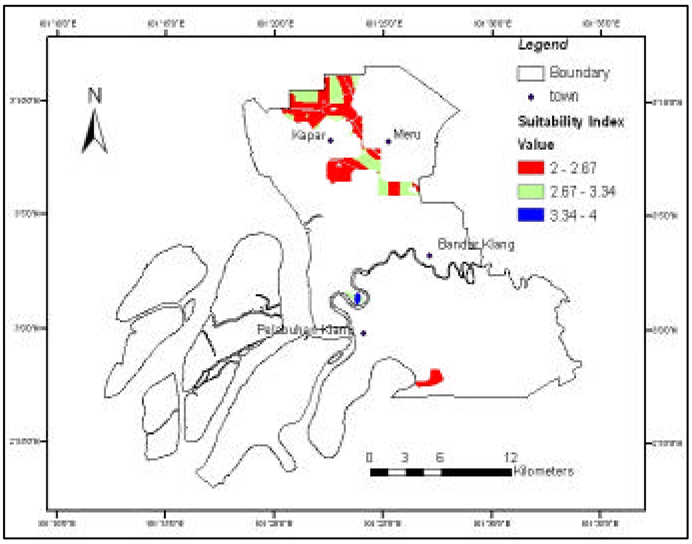

Figure 6. Road map

5. CONCLUSIONS

The presented approach is easy to understand and it can illustrate which areas are better or less suitable for landfill site selection. The criteria used in this study are not fixed factors since it can vary from area to area and these criteria can be changed accordingly in the analysis process. Apart from that, the presented methodology can explain clearly and directly the analysis and results in an easily understandable format. As a result, when the approach and results of the suitability map could be clearly understood, it can assist in getting full support especially from the public.

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