SOLID WASTE MANAGEMENT: DEVELOPMENT OF AHP MODEL FOR APPLICATION OF LANDFILL SITES SELECTION IN KUANTAN, PAHANG, MALAYSIA

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ABSTRACT

Sanitary landfill is the most common approach of solid waste management used in many countries. However, the present landfill sites in most developing countries are already nearing their capacity due to the increasing population and tremendous urbanization growth that lead to the high generated of municipal solid waste (MSW). Landfill siting is a difficult and complex process requiring evaluation of many different criteria. A multicriteria decision making technique, Analytical Hierarchy Process (AHP), which utilizes a multi-level hierarchy structure consist of objective, criteria, subcriteria, and alternatives is applied in this study. This paper presents the development of the AHP model in selection of an appropriate landfill site in Kuantan, Pahang. The input from the experts has been used to determine the evaluation criteria. Eleven criteria has been selected and classified into four main categories, which are hydrological/hydrogeological factor, morphologic, social criteria and economic impact. Three potential landfill sites had been identified as alternatives, which are Sungai Karang, Tanjung Lumpur and Beserah. As the result, Beserah had been ranked as the first alternatives with highest composite priorities values (0.383), followed by Tanjung Lumpur (0.360) and Sungai Karang (0.266).

Keywords: Municipal Solid Waste, Landfill Siting, Analytical Hierarchy Process (AHP)

1. Introduction

Solid waste management is one of the three major environmental problems faced by municipalities in Malaysia (World Bank, 1993). In Malaysia, solid waste generated consists of a heterogeneous mixture of

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materials including paper, glass, metal, organic material, plastic in varying quantities. It is inevitable by – product of human activities. It is estimated that currently 17,000 tonnes of solid waste is generated daily in Peninsular Malaysia, and this estimation will increase to more than 30,000 tonnes per day by 2020 consequent upon the increasing population and per capita waste generation (MHLG, 2005)

In Malaysia, solid waste management (SWM) is under the control of Ministry of Housing and Local Government which then disseminate the authority to all Local Authority to manage the SWM within their respective areas. Recently, the Solid Waste Management Act, 2007 has been establish to provide proper guidelines and regulations on SWM including disposal as well as clearly stated relevant bodies that are authorized by the Federal Government to impose regulations on SWM throughout Malaysia. It also contains the future plan of SWM in Malaysia parallel to the projected waste generation. The integrated and holistic approach of waste management is supported by the National Strategic Plan, which was endorsed by the Cabinet in 2005. The plan visualized the formation of a department and also the establishment of an Act on Solid Waste Management. This Act is tabled and approved in the form of Solid Waste and Public Cleansing Management Bill in March 2007. As a matter of fact, under the 9th Malaysian Plan, solid waste management is one of the priority areas, as indicated by the intention of the authorities to set up a Solid Waste Department (MHLG, 2005).

Basically the main objective of the study is to structured solid waste management problems into hierarchy to assist in decision making process in order to select the best and appropriate technology for solid waste management. Therefore Analytical Hierarchy Process (AHP) approach which was developed by Saaty (1980) was used in this study. Generally in the AHP, a problem is structured into a hierarchy. This normally consists four levels of hierarchy structure such as goal level, criteria level, subcriteria level and alternative levels into the model.

2. Materials and methods

Kuantan, the state capital of Pahang was selected as the study area. It is situated near the mouth of the Kuantan River and faces the South China Sea, as can be seen in Figure 1.

Figure 1. Location of study area

Recently, the National Physical Plan 2005 identified Kuantan as one of the future growth centers and a hub for trade, commerce, transportation and tourism. Kuantan is also considered as the social, economic and commercial hub for the East Coast of Peninsular Malaysia due to its strategic location. Rapid development has transformed and modernized Kuantan. Presently, the amount of solid waste was produced in Kuantan is about 500 tons daily, consisting of 60% domestic waste and 40% of industrial and construction waste. However, the present sanitary landfill is nearly filled up (Ismail, 2006). Pahang will need several new landfills because at least three sites (landfill at Temerloh, Kuantan, and Kampung Cheroh, Raub) are already nearing their capacity (Hoh, 2010).

2.1 Methodology

The overview of the method used in this study is represented by Figure 2. This study involved two stages of data collection. The first stage data collection was conducted to determine the criteria, sub-criteria and alternatives for the study problem, then an AHP hierarchy model will be constructed as the output. The hierarchy model consists of objectives goal, criteria, sub-criteria, and alternatives. Then the questionnaire based on the AHP hierarchy model was prepared for second stage data collection. The purpose of the second stage data collection is to gain related information for solid waste landfill site selection ranking analysis. The knowledge and information for structuring the hierarchy diagram and ranking the solid waste landfill site selection are obtained from many sources such as literature, distribution of questionnaies, interview with experts, sites observation and secondary information on waste and landfill site management in Malaysia and Kuantan area. To choose the evaluation criteria and alternatives for the hierarchy diagram, interview is done with experts during site visits to various related solid waste management centers, as listed in Table 1. The experts are chosen based on their knowledge experiences, good communication skills, and must be an individual who actively practicing and applying their expertise, and well recognized with their expertise. Data collection from the site survey was analyzed using Statistical Package for Social Science (SPSS) and AHP procedure.

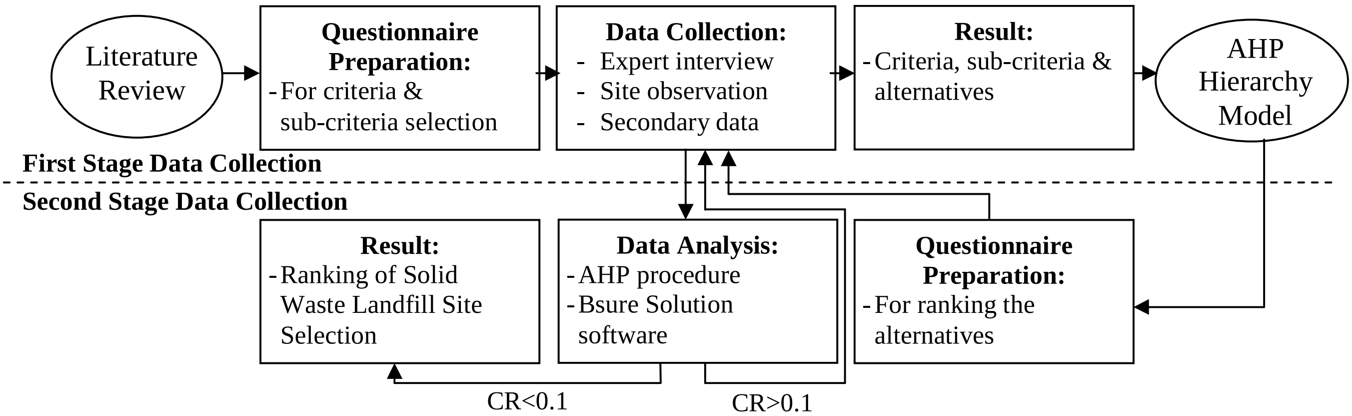

Figure 2. Overview of the method used in the study

Table 1: Sources of Human Expertise

Kuantan Municipal Council (MPK)
Solid Waste Management and Public Cleansing
Local District Plan (RTD)
University Malaysia of Pahang

2.2 The Analytical Hierarchy Process (AHP)

Analytical hierarchy process (AHP) is a decision-making technique which can be used to analyze and support decisions which have multiple and even competing objectives. To do this, a complex problem is divided into a number of simpler problems in the form of a decision hierarchy (Erkut and Moran, 1991).

Once the hierarchy has been established, a pairwise comparison matrix (PCM) of all criteria is constructed. Then, the weight (W_i) for each level are determined by solving the following system of linear simultaneous shown by equation (1) (Mohd Armi *et. al.*, 2010):

$$W_i = 1/\lambda_{\max} \sum a_{ij} w_j, i = 1,2,....n \qquad (1)$$

where λ_{max} is the largest eigenvalue. For uniqueness, the set of weight is normalized using equation (2):

$$\sum_{i=1}^{n} w_i = 1 \qquad (2)$$

To determine the consistency of decision and reveal possible need of revisions to judgments, the consistency ratio (*C.R*) will be calculated using equation (3):

$$C..I = \frac{\lambda_{\max} - n}{n-1}$$
$$C..R = C..I / R.I \qquad (3)$$

where *C.I* is the consistency index, *n* is the element being compared, and *R.I* is the random consistency value according to the size of matrix. The value of *C.R* should be around 10% (0.1) or less to be acceptable. In some cases 20% (0.2) may be tolerated but never more. If the *C.R* is not within this range, the participants should study the problem and revise their judgment.

3. Result and discussion

3.1 Criteria and sub-criteria selection

From literature review, four categories had been identified as the influenced factors that may affect the selection of landfill site. They are hydrological/hydrogeological factor, morphologic, social criteria and economic impact. Eleven sub-criteria were selected as the sub-criteria to support the main criteria, namely distance from water sources, flooding over 100 years, groundwater depth, elevation, slope, residential area, sensitive ecosystem, historical and tourism centre, proximity of waste production centre, land use and price of land. The evaluation criteria have been chose according to the data analysis of the mean statistic result from SPSS analysis and the percentages of respondent strongly agree with the criteria, as shown in Table 2.

3.2 Alternatives

Three potential solid waste landfill sites had been identified by Kuantan Municipal Council (MPK) which are located at Sungai Karang, Baserah and Tanjung Lumpur. The first site is located in BP3 (Blok Perancangan 3) Sungai Karang, Kuantan. This place is near Sungai Ular with an area of 5.5 hectare. By calculation, this site can accommodate 32 tonne of waste generation per day. The nearest residential area located within 1.5 km radius from the project site are Kampung Padang Lalang and Kampung Baru

Cherating which also known as tourism place. Besides, the distance of site area from the water sources is 4 km.

The second site is located at BP2 Baserah which is the Jabor-Jerangau Landfill area. This area is adjacent with the existing Kuantan Landfill. There have more 15 hectare to be expanded and use as landfilling area. Approximately almost 87 tonne waste per day is estimated can be placed on this 15 hectare of land. The nearest residential areas to the project site are Taman Desa Aspa, Kampung Balok and Kampung Balok Baru which are all located within a 3 km radius of the project site. There are three institutional buildings located within a 1 km radius of the project site that includes a fire station (Gebeng Fire and Rescue Station), a police station and a SIRIM building.

"Blok Perancangan‟ Penor, which is the area near Tanjung Lumpur is the third location with 10 hectare of land where it can accommodate 58 tonne capacity of waste per day. Within 5 km radius of the site area, there are located Kampung Anak Air and Perumahan Seri Indera Putra with a sea located almost 8 km of the site.

Table 2: Data analysis result for criteria selection

Criteria/Subcriteria	***Mean Statistic***	***Percentages (%)***
Hydrological/Hydrogeological Factor		
Distance from water sources	4.8	84.4
Flooding over 100 years	4.5	65.6
Groundwater Depth	4.5	59.4
Morphologic		
Elevation	3.8	43.8
Slope	3.8	37.5
Social Criteria		
Residential Area	4.8	84.4
Sensitive Ecosystem	4.8	78.1
Historical and Tourism Centre	4.3	53.1
Economical Impact		
Proximity of Waste Production Centre	4.5	62.5
Land Use	4.2	53.1
Price of Land	4.0	50.0

3.3 AHP Hierarchy Model

According to Figure 3, the hierarchical structure of the decision problem consists of three levels. The first level represents the ultimate goal of the decision hierarchy (land suitability for landfill siting), the second level represents the criteria and subcriteria utilized in this work and the third level represents the alternatives (potential landfill site) (Kontos et al., 2005).

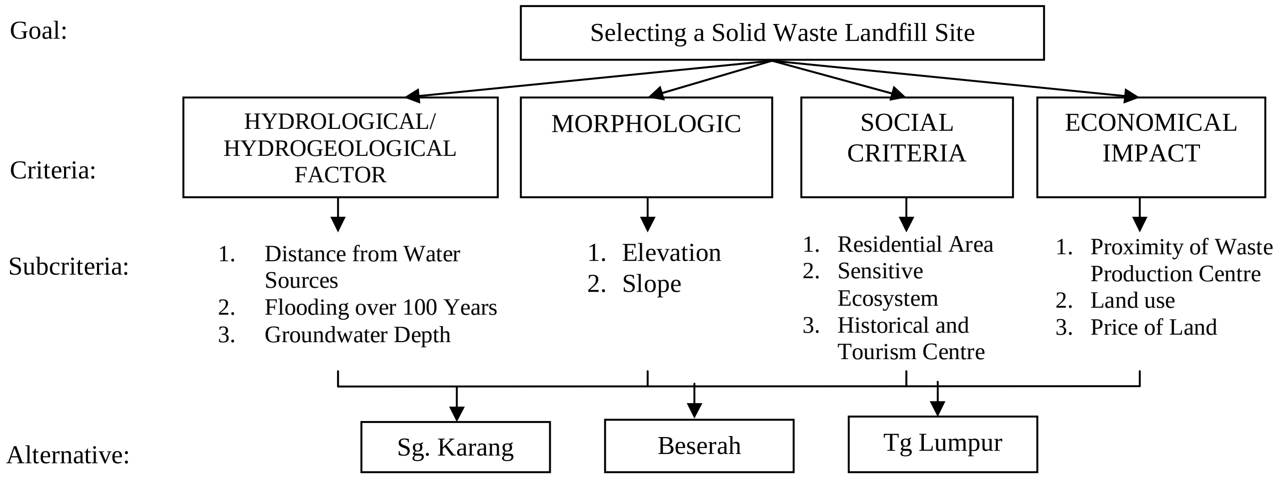

Figure 3. Hierarchy Structure Model of the Siting MSW Landfill

3.4 Analysis of landfill suitability in the study area

Comparison matrices were developed for the four criteria and eleven sub-criteria. Then, total weights of sub-criteria were calculated by a sequence of multiplication. The calculated total weight is represented in Table 3. According to Table 3, the sub-criteria of the residential area has the highest value of 0.225, and the sub-criteria of slope has the lowest value of 0.018. These results show that "residential area" is the most important criteria with the fact that the potential site in Beserah, Tanjung Lumpur and Sungai Karang is located near the residential areas. A distance of 500 m and above are considered as suitable while 200 m and below were considered unsuitable. Hence the land suitability for landfill increases with the increase in distance from the residential areas. This is to avoid residents from dust and odour emissions in order to protect public from nuisance and health impact due to potential hazard from landfill (Chang, *et. al.*, 2008).

Table 3: Total weight of the subcriteria

Sub criteria	**Total of Weight**
Distance from Water Sources	0.217
Flooding over 100 years	0.067
Groundwater Depth	0.176
Elevation	0.035
Slope	0.018
Residential Area	0.225
Sensitive Ecosystem	0.112
Historical and Tourism Centre	0.059
Proximity of Waste Production Centre	0.019
Land Use	0.030
Price of Land	0.043

The overall result from Table 4 shows that area Beserah is ranked first for solid waste landfill site selection with weight of 0.383. Followed by Tanjung Lumpur with weight of 0.360 and the last ranking is Sungai Karang with weight 0.277.

Table 4: The ranking of Solid Waste Landfill Site Selection for Kuantan, Pahang

Potential landfill site area	Weight	Ranking
Beserah	0.383	1
Tanjung Lumpur	0.360	2
Sungai Karang	0.277	3

To verify the results from AHP procedure, a decision making software named Bsure Solution had been used for further analysis. Table 5 shows the total weight of sub-criteria results from Bsure Solution software analysis. From the result, the highest weight value is subcriteria residential area with value of 0.2258 while the ranking results in Table 6 shows that Beserah is the first ranking area for solid waste landfill site selection. The analysis using AHP procedure and Bsure Solution software gives same result with the difference is in the range of 0.30% to 4.24%. The consistency ratios (C.R) for all the eleven sub-criteria of the three alternatives are less than 0.1 as illustrated in Figure 4. Hence, the consistency of the decision is proved and no revision of the judgment is needed.

Table 5: Result of total weight of subcriteria from Bsure software

Sub criteria	Total of Weight
Residential Area	0.2258
Distance from Water Sources	0.2188
Groundwater Depth	0.1772
Sensitive Ecosystem	0.1102
Flooding over 100 years	0.0673
Historical and Tourism Centre	0.0576
Price of Land	0.0429
Elevation	0.0344
Land Use	0.0292
Proximity of Waste Production Centre	0.0186
Slope	0.0180

Table 6: Comparison between AHP procedure and Bsure Solution software analysis

Potential landfill site area	Weight		Percentages of differences (%)
	AHP Procedure	Bsure Solution software	
Beserah	0.383	0.375	2.12
Tanjung Lumpur	0.360	0.359	0.30
Sungai Karang	0.277	0.266	4.24

4. Conclusion

The amount of solid waste generated in Kuantan, Pahang is expected to increase significantly due to the rapid increase in population, urbanization and improvements in the standard of living. However, the present sanitary landfill in Pahang is nearly filled up. Hence, this study was conducted to help in finding a new suitable location of landfill site in Pahang, mainly in Kuantan. In the present study, a methodology for assessing location suitability for municipal solid waste landfill was developed using AHP method. For this aim, eleven subcriteria which are distance from water sources, flooding over 100 years, groundwater depth, elevation, slope, residential area, sensitive ecosystem, historical and tourism centre, proximity of waste production centre, land use and price of land were determined and classified into four main categories, i.e. hydrological/hydrogeological factor, morphologic, social criteria and economic impact according to how they are considered to affect the landfill site suitability. Subcriteria residential area was identified as the most important subcriteria with the highest weight value obtained (0.225). As the results, Beserah is determined as the most suitable locations for the new landfill site in Kuantan. Tanjung Lumpur is in the second rank, followed by Sungai Karang in the third rank. It is expected that the finding from this study will be used by municipal council as decision support system and guideline in selecting a suitable new landfill site in Kuantan.

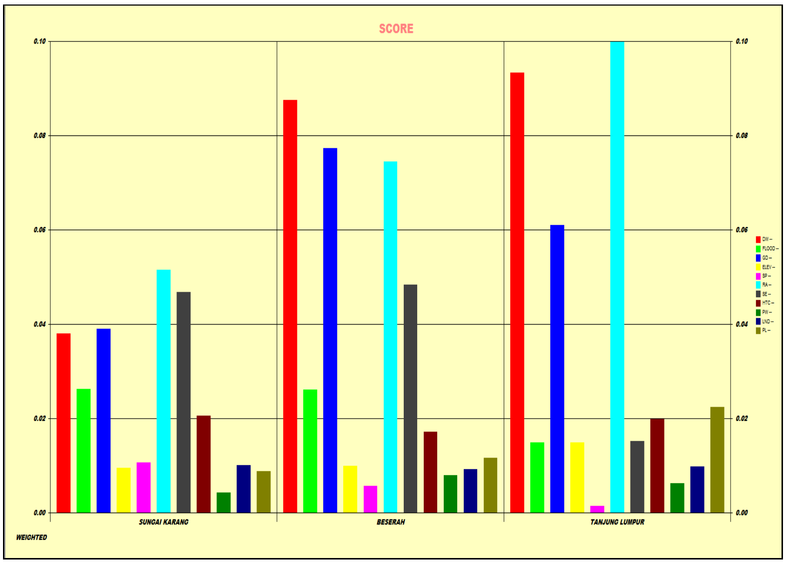

Figure 4: Consistency ratio (C.R) for sub-criteria

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