SOLID WASTE LANDFILL SITE SELECTION USING ANALYTICAL HIERARCHY PROCESS (AHP): A CASE STUDY IN KUANTAN, PAHANG, MALAYSIA.

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ABSTRACT

Site selection is crucial and necessary for waste management in areas where are growing rapidly. Due to the complexity of waste management systems to choose a new landfill as appropriate, a number of alternatives and evaluation criteria required for consideration. A study was carried out in the Kuantan, Pahang to overcome the problem of critical capacity of waste disposal sites. The aims of this study are to determine the appropriate evaluation criteria for the selection of waste disposal site and to identify and rank the potential disposal site in Kuantan, Pahang. A multi criteria decision making technique, Analytical Hierarchy Process (AHP), which utilizes a multi-level hierarchy structure consist of objective, criteria, sub-criteria, and alternatives is applied in this study. 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 (0.390), followed by Tanjung Lumpur (0.323) and Sungai Karang (0.287).

ABSTRAK

Pemilihan tapak adalah penting dan perlu bagi pengurusan bahan buangan di kawasan yang berkembang pesat. Oleh kerana kerumitan sistem pengurusan sisa untuk memilih tapak pelupusan baru yang sesuai, beberapa alternatif dan kriteria penilaian diperlukan untuk dipertimbangkan. Satu kajian telah dijalankan di Kuantan, Pahang untuk mengatasi masalah kritikal kapasiti tapak pelupusan sampah. Tujuan kajian ini adalah untuk menentukan kriteria penilaian yang sesuai bagi pemilihan tapak pelupusan sisa dan untuk mengenal pasti dan pangkat tapak pelupusan berpotensi di Kuantan, Pahang. Teknik Proses Hierarki Analisis (AHP), menggunakan struktur hierarki pelbagai peringkat keputusan multi kriteria terdiri daripada objektif, kriteria, subcriteria, dan alternatif yang digunakan di dalam kajian ini. Input daripada pakar-pakar telah digunakan untuk menentukan kriteria penilaian. Sebelas kriteria telah dipilih dan dikelaskan kepada empat kategori utama, yang merupakan faktor hidrologi / hidrogeologi, berhubung dgn ilmu, sosial dan impak ekonomi. Tiga tapak pelupusan berpotensi telah dikenal pasti sebagai alternatif, yang Sungai Karang, Tanjung Lumpur dan Beserah. Sebagai hasilnya, Beserah telah disenaraikan sebagai alternatif pertama dengan dengan nilai tertinggi (0.390), diikuti oleh Tanjung Lumpur (0.323) dan Sungai Karang (0.287).

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INTRODUCTION

1.1 BACKGROUND OF STUDY

Many countries and institutions currently pay great attention to landfill site selection. The increasing development of urban areas and population growth caused a tremendous amount of municipal solid wastes generation, presenting a problem in urban environment. When current waste disposal site are filled, the search for a new waste site can be a time consuming process. Landfilling has been used for many years as the most common method for the disposal of solid waste generated by different communities (Komilis et al., 1999).

Landfill sites are where local authorities and industry can take waste to be buried and compacted with other wastes (Environment-Agency). Many landfills are also used for waste management purposes, such as the temporary storage, consolidation and transfer, or processing of waste material. Landfill disposal is the most widely used method of solid waste management because it is the most economically and environmentally acceptable method throughout the world. Landfill technique consists of loading, scattering, and covering of waste material with soil in a sanitary manner. Landfill site selection is a serious issue in the urban planning process due to enormous impacts on the economy, ecology, environment and public health. The issue is particularly severe in developing-country cities where increased population, poor planning, and lack of adequate resources contribute to the poor state of municipal solid waste disposal causing environmental and health hazards (Tchobanoglous et al, 1993).

The waste generation situation is similar in most countries with each inhabitant producing between approximately 0.5 and 2.0 kg of disposal refuse each day (Sarsby, 2008). The solid waste generated in Malaysia per capital has increased from 0.5kg/capital/day in the 1980's to current volume of 1kg/capital/day. This represents a 200% increased in 20 years (Agamuthu, 2011). At 2007, about 7.34 million tones of solid wastes generated enough to fill up 42 buildings the same size as that of the world renowned Petronas Twin Towers (Alam Flora Sdn Bhd). Therefore, the alternatives to solve the problem of increasing solid waste, government should find and construct the new landfill site.

1.2 PROBLEM STATEMENT

Pahang is one of the states which need several new landfills because at least three sites are already nearing their capacity, the landfill site in Temerloh had already exceeded its capacity and waste material was now being sent to the neighbouring district of Bera. The landfills in Kuantan and in Kampung Cheroh, Raub, are also nearing their capacity and there is a need to open new sites (Hoh, 2010). The Jabor sanitary landfill in Kuantan has reached critical stage because waste is still being dumped at the site which was supposed to be closed for rehabilitation on Dec 31, 2006 (Roslina., 2008). A strategic location of landfill must be adhering with environmental, economical, and political consideration. A landfill must be chosen by the evaluation criteria determined to achieve landfill site suitability.

1.3 OBJECTIVE OF STUDY

1) To identify the criteria factors that influencing the solid waste disposal site selection.
2) To identify and rank potential landfill site in Kuantan, Pahang using Analytical Hierarchy Process (AHP) and Bsure Decision Software.
3) To verify the AHP calculation by using Bsure Decision Software.

1.4 SCOPE OF WORK

1) Developing the questionnaires. The questionnaires involved two stages:
   i. The first stage questionnaire is to identify the suitable criteria and sub-criteria for the potential landfill site.
   ii. The second stage questionnaire is to identify the potential landfill site.
2) Identify expert such as engineer and academician to fill the questionnaire (data collection).
3) Analytical Hierarchy Process (AHP) calculation to rank the potential landfill site.
4) Determine the rank of potential landfill site using Bsure Decision Software to verify the result from AHP calculation.

1.5 EXPECTED OUTCOME

At the end of the study, a AHP model which consist of goal (objective), criteria and alternatives (potential landfill site) will be developed. Besides that, potential landfill site can be ranked from the analysis using AHP and software. Then, a comparison result between AHP and software will be obtained for verification.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In recent years, there has been growing support for the notion of integrated waste management and strategies to reduce waste.. Waste materials are first considered for reuse and recycling, and the rest are disposed at landfill sites (Ngoc and Schnitzera, 2009). At present, landfill site is the most common method for the disposal of solid waste generated by different communities for many years (Komilis et al., 1999; Multürk and Karagüzel, 2007). The demand for land to dispose of this waste will increases proportionately with population. The net waste production increases as population grows, and the per capita generation of waste is also increasing, particularly in developing countries (The World Bank, 1999). When current waste disposal sites are filled, the search for a new waste site can be a time consuming process. The selection of landfill sites has targeted areas that are financially efficient and minimize hazards to environmental and public health (Mcbean et al., 1995; Kontos et al., 2005; Yeşilnacar and Ćetin, 2007). According to Bagchi (1990) and Tchobanoglous (1993), landfill cannot be located within certain distance from the aspects such as lakes, ponds, rivers, wetlands, flood plain, highway, critical habitat areas, water supply, well, and airports. Moreover, landfill sitting is prohibited in areas where potential contamination of groundwater or surface water bodies exists. It is believed that the care taken in the initial siting of a landfill will reduce the necessity for future clean-up and site rehabilitation. Due to these and other factors, it is becoming increasingly difficult to find suitable locations for new landfills. Easily accessible open space is becoming scarce and many communities are unwilling to accept the siting of a landfill within their boundaries.

Many major cities have already exhausted their landfill capacity and must export their trash, at significant expense, to other communities or even to other states and countries.

2.2 WASTE MANAGEMENT METHOD

Waste management is involved collection, transport, processing, recycling, disposing, and monitoring of waste. The wastes are produced by human and without waste management, can harming a beauty and health of our environment and also affect our health. Waste management significantly differs for developed and developing countries. Many developing countries are still many years away from developing proper waste management systems. There have four basic waste disposal method which open dumping, landfill, sanitary landfill, and incineration (Wikipedia).

2.2.1 Open Dumping

The oldest and common method of disposing solid waste is Open Dumping. It is requires large amount of space, aesthetic nuisance, pest breeding, health hazard with air, water and soil pollution. Open dumps refer an uncovered site used for disposal of waste without environmental controls. The waste is untreated, uncovered, and not segregated. In spite of its simplicity in execution, the financial involvement for this traditional method of waste management has been quite high particularly for the big metropolis. Uncontrolled, open dumps are not a sound practice. Open dumps are exposed to flies and rodents. It also generates foul smell and unsightly appearance. Loose waste is dispersed by the action of wind. Drainage from dumps contributes to pollution of surface and ground water and also the rainwater run-off from these dumps contaminates nearby land and water thereby spreading disease. A WHO Expert Committee (1967) condemned dumping as "a most unsanitary method that creates public health hazards, a nuisance, and severe pollution of the environment. Dumping should be outlawed and replaced by sound procedures (Parshurame et al., 2010).

2.2.2 Landfill

Landfill involves burying the waste, and this remains a common practice in most countries. Landfills are generally located in urban areas where a large amount of waste is generated and has to be dumped in a common place. The equipment required to operate is relatively inexpensive and can be used for other municipal operations as well serious threat to community health represented by open dumping or burning is avoided. Landfills were often established in abandoned or unused quarries, mining voids or borrow pits. Unlike an open dump, it is a pit that is dug in the ground. The waste is dumped and the pit is covered at the dumping ground with debris/ soil and spread evenly in layers. At the end of each day, a layer of soil is scattered on top of it and some mechanism, usually earth moving equipment is used to compress the garbage, which now forms a cell. Thus, every day, garbage is dumped and becomes a cell. The organic waste undergoes natural decomposition and generates a fluid, which is known a leachate, and is very harmful to the ecosystem. After the landfill is full, the area is covered with a thick layer of mud and the site can thereafter be developed as a parking lot or a park (Wikipedia).

2.2.3 Sanitary Landfill

A modern landfill that can reduce or eliminate the risks that waste disposal map pose to the public health an environment quality is called sanitary landfill. They are usually placed in areas where land features act as natural buffers between the landfill and the environment. For example the area may be comprised of clay soil which is fairly impermeable due to its tightly packed particles, or the area may be characterized by a low water table and an absence of surface water bodies thus preventing the threat of water contamination. In addition to the strategic placement of the landfill other protective measures are incorporated into its design. The bottom and sides of landfills are lined with layers of clay or plastic to keep the liquid waste, known as leachate, from escaping into the soil. The leachate is collected and pumped to the surface for treatment. Boreholes or monitoring wells are dug in the vicinity of the landfill to monitor groundwater quality. A landfill is divided into a series of individual cells and only a few cells of the site are filled with trash at any one time. This minimizes exposure to wind and rain. The daily waste is spread and compacted to reduce the volume, a cover is then applied to reduce odours and keep out pests. When the landfill has reached its capacity it is capped with an impermeable seal which is typically composed of clay soil. Some sanitary landfills are used to recover energy. The natural anaerobic decomposition of the waste in the landfill produces landfill gases which include Carbon Dioxide, methane and traces of other gases. Methane can be used as an energy source to produce heat or electricity. Thus some landfills are fitted with landfill gas collection (LFG) systems to capitalise on the methane being produced. The process of generating gas is very slow, for the energy recovery system to be successful there needs to be large volumes of wastes. These landfills present the least environmental and health risk and the records kept can be a good source of information for future use in waste management, however, the cost of establishing these sanitary landfills are high when compared to the other land disposal methods (Wikipedia).

2.2.4 Incineration

Incineration facilities generally do not require as much area as landfills. Incineration reduces the waste volume and helps generate heat for commercial use; in many instances the heat is further utilized to generate power. Although waste-to-energy (WTE) facilities are not popular in the United States, they are widely used in Europe and Japan. Japan incinerates 50%, and Switzerland and Sweden incinerate 75 and 60%, respectively (Kreith, 1994), of their MSW. Waste-to-energy or energy-from-waste is broad terms for facilities that burn waste in a furnace or boiler to generate heat, steam and/or electricity. At the end of the process all that is left behind is ash. It is recognized as a practical method of disposing of certain hazardous waste materials (such as biological medical waste). Incineration is carried out both on a small scale by individuals and on a large scale by industry. It is used to dispose of solid, liquid and gaseous waste. Combustion in an incinerator is not always perfect and there have been concerns about micro-pollutants in gaseous emissions from incinerator stacks. Particular concern has focused on some very persistent organics such as dioxins which may be created within the incinerator. Both the fly ash and the ash that is left in the furnace after burning have high concentrations of dangerous toxins such as dioxins and heavy metals. Disposing of this ash is a problem. Cost of incinerator and additional investment on pollution control devices make the process capital - intensive. Under Indian conditions large scale incineration plants are economically non - viable in view of their capital - intensive character and the low calorific value of city garbage available (Parshurame et al., 2010).

2.3 BACKGOUND OF SOLID WASTE MANAGEMENT

2.3.1 Waste Management in Japan

In Japan, most waste is treated in incineration, dehydration, or milling plants. The amount of waste buried in landfills is limited and has been decreasing. Nearly 40 million tons of the industrial solid wastes (ISWs) are discharge every year. The total amount of these ISWs is reduced by some kinds of intermediate treatments, and then about 5 million tons residual ashes are landfilled in dump yards. Japan's definition of waste is "discarded materials which cannot be sold to other people". Therefore the statistics for Japan often look different to MSW statistics in other countries, although the non-municipally collected recyclables are often added back in to provide a more comprehensive picture of recycling activities. Therefore, in 2008 for Japan as a whole, with a population of 127 million, more than double that of the UK, France or Italy, for example, there were 2.34 million tonnes of recyclables collected by municipalities, 4.51 million reclaimed by intermediate treatment and 2.93 million collected by citizens' groups, totalling 9.78 million tonnes or 20.3% of Japan's MSW.

Besides that, households in Tokyo have to put their waste out in translucent bags segregated into three types: bulky wastes, packaging and paper, combustible and non-combustible, at a place shared by 10-20 households, the discipline of separation at source is reinforced among residents. In addition, citizen groups collect paper for recycling and local fund raising, and because Japan's definition of waste is different to many other places, calculating the reclamation rate for MSW becomes more difficult.

2.3.2 Waste Management in United States

In the United States, waste management is done under the control of the Resource Conservation and Recovery Act (RCRA) established in 1976, and waste is divided into two major categories: hazardous and non-hazardous. Among the method of waste management in Unites States is recycling. The recycling rate, including recovery for composting for municipal solid waste in 2005, was 32.1 percent, twice the 16.2 percent of 1990. The reduction rates have been relatively low, e.g., 13.6 percent in 2005 because the cost for incineration is much higher than that for landfills and there is a strong fear about air pollution caused by emission of waste gases from incineration plants.

According to research by the Environmental Research and Education Foundation about solid wastes managed off-site, including both municipal and industrial solid waste, 63.5 percent of solid waste is managed in municipal solid waste landfills, 5.1 percent in construction and demolition landfills, 20.9 percent in material recycling facilities, 4.8 percent in compost facilities, and 5.8 percent in incinerators. This means that 68.6 percent of solid waste is buried in landfills and 25.7 percent of it is recycled. The cost of waste management is low. According to an investigation by Solid Waste Digest, the average solid waste tipping fee in 2001 was a little less than $40 per ton. The price for incineration is from $50 to $60 per ton except in the western states, where it is about $40 per ton. The price for landfills, on the other hand, varies depending on the area. In the western states, the average landfill price is about $20 per ton. In Nevada, the price is particularly low, at $10.54 per ton. In the northeast, however, the average landfill price is about $55 per ton, almost that same as for incineration, which is about $60 per ton. The price is the highest in Massachusetts, at $69.25 per ton. This difference is caused by the difference in land price (Wikipedia).

2.3.3 Waste Management in India

India is the second largest nation in the world, with a population of 1.21 billion, accounting for nearly 18% of world's human population, but it does not have enough resources or adequate systems in place to treat its solid wastes. The per capita waste generation rate in India has increased from 0.44 kg/day in 2001 to 0.5 kg/day in 2011, fuelled by changing lifestyles and increased purchasing power of urban Indians. Urban population growth and increase in per capita waste generation have resulted in a 50% increase in the waste generated by Indian cities within only a decade since 2001. Big cities collect about 70 - 90% of MSW generated, whereas smaller cities and towns collect less than 50% of waste generated. More than 91% of the MSW collected formally is landfilled on open lands and dumps. It is estimated that about 2% of the uncollected wastes are burnt openly on the streets. About 10% of the collected MSW is openly burnt or is caught in landfill fires. Such open burning of MSW and landfill fires together releases 22,000 tons of pollutants into the lower atmosphere of Mumbai city every year. Figure 2.1 shows the hierarchy of waste management in India (RV Bhoyar., 1996).

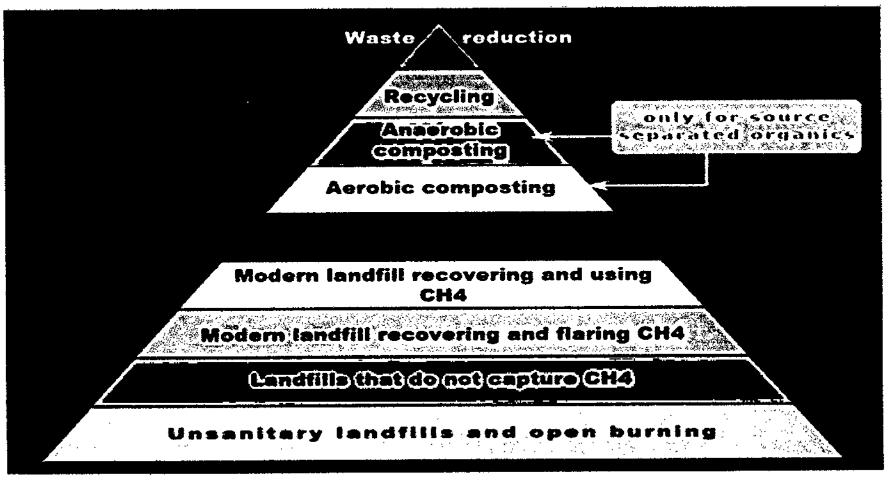

Figure 2.1: The hierarchy of waste management

2.3.4 Waste Management in China

China has the largest population (1.33 billion) on Earth and is experiencing rapid economic growth. Urbanization, population growth and industrialization are three key reasons behind the large magnitude of China's increase in total waste generation. In general, China still has a long way to go in the management of solid waste with respect to solid waste recycling, treatment technology and management strategy when compared with many more developed countries, e.g., Germany, Sweden, Japan, and the United States (Yuan et al., 2006). Currently, there are about 660 cities in China that produce about 190 million tonnes of solid waste annually and, account for 29% of the world's MSW each year (Dong et al., 2001, Yuan et al., 2006 and Zhuang et al., 2008). According to Yuan et al. (2006), China's per capita waste generation rate is 0.8–1.0 kg/capita/day, while a typical developed country generates 1.43–2.08 kg/capita/day (Troschinetz and Mihelcic, 2009). The MSW generation rate also varies among different cities in China, e.g., with rates of about 0.85 kg/capita/day in Beijing (Li et al., 2009), 1.11 kg/capita/day in Shanghai (Zhu et al., 2009), 1.08 kg/capita/day in Chongqing (Yuan et al., 2006), 1.51 kg/capita/day in Lhasa (Tibet) (Jiang et al., 2009), 1.17 kg/capita/day in Hangzhou (Zhao et al., 2009a and Zhao et al., 2009b), and 1.33 kg/capita/day in Hong Kong (Ko and Poon, 2009). China's waste management approach will gradually switch from putting refuse in landfills to incinerating it, in order to reduce environmental impact. By the end of 2015, incinerated waste will account for 35 percent of China's total managed waste, said Xiao. Currently, waste in China is processed via landfills, incinerators and composting facilities. Landfill currently accounts for 85 percent of refuse, while incineration accounts for 17 percent. Many cities in China, including Dalian and Xiamen, are constructing large incinerators. Beijing plans to build nine large-scale incinerators by the end of 2015.

2.3.5 Waste Management in Sweden

Waste management in Sweden is focusing more on waste minimization and waste prevention. Figure 2.2 shows types of waste management in Sweden. Sweden is one of the leading nations in waste management an impressive 99 percent of the household waste is recycled as energy or material. The environmental objective to recycle at least 50 percent of household waste, including biological treatment, by 2010 was essentially met. In 2005, Sweden made it illegal to landfill organic waste. Instead, the waste is biologically treated to create compost, biogas and fertilizer. Today, 10 per cent of all household organic waste is treated biologically, a share that is expected to increase dramatically in the near future. In 75 percent of Swedish municipalities, external actors, private companies, manage household waste collection, while in the rest the municipalities provide this service. Waste treatment is effected either by the municipalities themselves or by an external actor, often a municipal enterprise or sometimes a private company (Avfall Sverige., 2009).

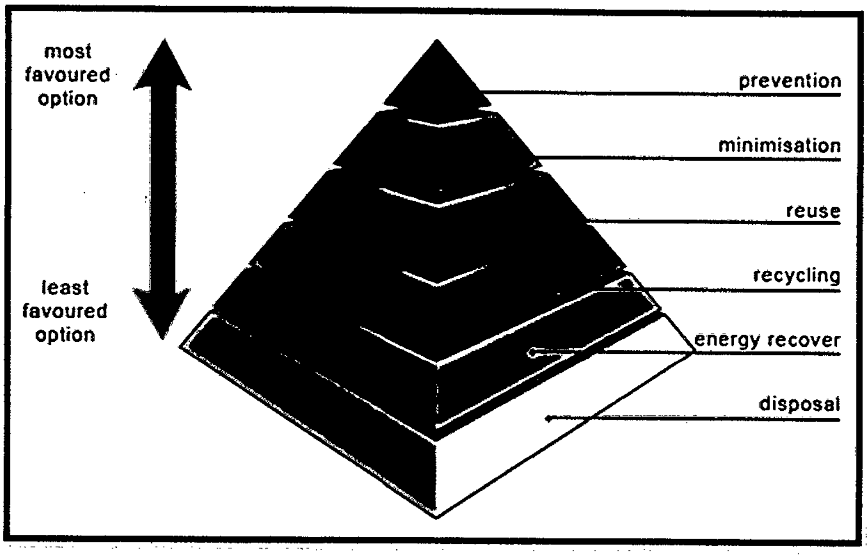

Figure 2.2: Types of waste management in Sweden

2.3.6 Waste Management in Malaysia

The Malaysian population has been increasing at a rate of 2.4% per annum or about 600,000 per annum since 1994. With this population growth, the municipal solid waste (MSW) generation also increases, which makes MSW management crucial. In 2003, the average amount of MSW generated in Malaysia was 0.5–0.8 kg/person/day; it has increased to 1.7 kg/person/day in major cities (Kathirvale et al., 2003). By the year 2020, the quantity of MSW generated was estimated to have increased to 31,000 tons. The sources and quantities of municipal solid waste vary among local authorities in Malaysia depending on the township size and level of economic standards. The amount generated may range from 45 tonnes/day of municipal solid waste (MSW) in Kluang, which is a small town in a southern part of Peninsular Malaysia, to 3000 tonnes/day in Kuala Lumpur (Agamuthu et al., 2004). Waste is grouped into three different categories in respect of disposal – solid waste, medical waste and hazardous waste. According to a study by E. Grant Anderson in five states (KualaLumpur, Selangor, Pahang, Terengganu and Kelantan) representing 64 % of the waste is domestic waste. The share of industrial waste stands at 15 % followed by commercial waste and construction and institution waste. Information on the quantity of solid waste generated is fundamental to almost all aspects of solid waste management (Tchobanoglous et al., 1993). Most