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Appointment of appropriate sites for waste disposal by GIS

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Abstract

This paper deals with the problem of locating proper waste disposal areas for cities. Because of the huge impact waste depots has on the environment as well as human's health, particularly in a long term, special care should be exercised for locating potential areas for waste disposal. With the growth of urbanization as well as the desire to live in cities, lager amount of wastes are produced and unfortunately the problem gets bigger everyday.

A proper waste disposal area is a function of many parameters including distance to urban and rural areas, distance to industrial and agricultural areas, distance to permanent and seasonal rivers, distance to faults, terrain slope, underground water level, transportation network, soil type, geology and present and future land use of the area. As there is quite a few parameters to be studied for locating a proper waste disposal area, it is practically very difficult, if not impossible, to use traditional methods for this purpose.

This paper shows how Geospatial Information Systems (GIS) can be used to solve this problem more efficiently. As a case study, locating the potential waste disposal areas for Bandar Abbas, Iran is discussed. It is shown how the necessary data is collected, stored, and properly weighted to do the necessary analysis.

Key words: waste disposal, GIS, land cover, soil permeability, transportation routes.

1. Introduction

The purpose of this research is to use Geographic Information System (GIS) as a tool to aid the decision-making process and to test its effectiveness using some established government guidelines in the state of Sabah.

During the last few years, Malaysia has come up with more structured waste management systems. In 1998, the Ministry of Housing and Local Government announced a policy known 2 as "A Beautiful and Clean Malaysia (ABC)", which contained a strategy, by the government to immediately improve the level of waste management in all levels of administration especially in the Municipal Councils and Local Authorities.

Along this line, in 1995, the Department of Environment had published a guideline for selecting landfills sites known as Constraint Mapping Techniques (CMT). According to the guidelines, CMT shall be used to designate areas, which have unsuitable physical and other environmental characteristics. With unsuitable areas excluded, potential sites can simply be selected based on the remaining areas. According to the guidelines, sites can be

selected based on performance basis, on ability and on economic grounds. Potential sites are then subject to rapid preliminary screening to narrow down numbers to more desirable sites which would then be subjected to detail evaluation studies.

The second step suggested by the guideline was to further screen the potential sites. A minimum of 3 sites should be selected in order to allow a reasonable comparison and allow the retention of alternate sites if the preferred site proved unworkable. Screening is conducted based on conceptual design and costing for the sites in question in addition to a selected specific set of critical environmental criteria. Due consideration must be given to key environmental issues associated with a specific project either by quantitative or qualitative ranking systems so that the best site can be designated for landfill site. The landfills site selection guidelines produced by the government in 1995 stressed that although the above process can identify a preferred site, its selections cannot be confirmed prior to completion of the feasibility study and the Environmental Impact Assessment (EIA) studies. This particular research will only cover the first step of the said guideline.

2. General Site Selection Criteria

Criteria used to determine the most suitable site for landfills have been identified based on the guideline produced by the Ministry of Environment, Malaysia in 1995 and also in collaboration with the Bandar abbas Spatial Planning Working Group. The criteria were both constraints and factors for an ideal sitting of landfills. The constraints were related to roads, open water, protected areas, urban, rural residential areas, soil permeability and soil type, land use/land cover and distance to transportation routes. The above criteria were than refined according to the existing and established guidelines in Sabah and also in agreement with the Bandar abbas Spatial Planning Working Group, which are briefly explained in the following paragraphs.

2.1 Proximity to surface water

A landfill must not be located near any surface streams, lakes, rivers or wetlands. For this reason, a 100-meter buffer would be placed using the function in GIS software, which will be used to generate the buffer around all surface waters such as streams, lakes and wetlands. The 100-meter buffer is in line with riparian reserve guidelines produced by the Drainage and Irrigation Department, Sabah.

2.2 Distance from transportation routes

Aesthetic considerations would be of good practice for good planning and based on this principle, landfills shall not be located within 100 meters of any major highways, city streets or other transportation routes. The 100 meters was chosen based on the current practice provided under supplementary guidelines for development of residential, industrial and commercial sites under the Department of Town and Regional Planning, Sabah.

2.3 Distance from environmentally sensitive or protected areas

The location of a landfill in close proximity to sensitive areas such as fish sanctuaries must be avoided, and mangrove areas and areas gazetted for special protection would be excluded. Apart from the area being excluded, a 3,000 meters buffer would also be created surrounding the environmentally sensitive area. The 3,000-meter buffer is in line with the guidelines produced by the Department of Environment, Sabah.

2.4 Distance from urban areas

Landfills should not be placed too close to high-density urban areas in order to mitigate conflicts relating to the Not in My Back Yard syndrome (NIMBY). This guards against health problems, noise complaints, odour complaints, decreased property values and mischief due to scavenging animals. For this reason, population density was then generated based on the 1991 and 2000 Census in GIS ready format produced by the Department of Statistic, Malaysia.

2.5 Distance from rural settlements areas

Due to the same conflicts relating to the NIMBY syndrome, development of landfills shall be prohibited within 3000 meters from village settlements. The rural settlement area was designated either by point location or by polygons in the Sabah map and a 3000-metre buffer shall be created around it. There is no pre-qualification of the use of 3,000-metre buffer but such a distance should be sufficient to guard the interests of the rural settlement area

2.6 Landform and Soil Type

The permeability of the underlying soils and bedrock will greatly influence how much leachate is escaping a landfill site; therefore, preference is given to a landform that is somewhat located in flat or undulating land.

2.7 Land use/land cover

The Land use and Land cover must be known in order to determine which areas are more suitable for a landfill. Land use types such as grassland, forests and cultivated land would be considered and assigned an appropriate index of land use suitability. The Department of Agriculture, Sabah has identified several classes of land cover and for the purpose of this research seven (7) classes were used.

2.8 Haul distance

Whilst a landfill should not be located within 100 meters of a road it would be more cost efficient for landfills to be located not too far away in order to avoid high transportation costs. From the discussions with the Bandar abbas Municipal Council and Spatial Plan Working Group, it was decided that a sanitary landfill for Bandar abbas District shall be located within 25km from the town centre.

3. Methodology

This particular research applied Constraint Mapping Technique to reduce the search area over vast land coverage and to leave only those areas that are suitable for sitting a landfill. The exact operation of the research methodology is presented in the following sequences:

1. Problem Identification,
2. Research Objective,
3. Choose a Study Area,
4. Decide on the Criteria,
5. Acquire Data,
6. Convert Criteria into GIS Layer,
7. Perform Spatial Operation,
8. Analyze Results and
9. Identification of Potential Search Area.

This research began with problem identification and thereby establishing the objective, which was tied to a specific study area. In step 4, the input criteria have to be discussed and agreed by the proponent or the owner of the project. This particular study has taken the advantage of the "The Spatial Plan Working Group" for Bandar abbas District, which at the same time of this research was in the process of preparing the overall district physical planning in collaboration with DANCED and Town and Regional Planning Department. Fig. 1 presents the summary of the methodology for this research.

Fig 1: Sequence for Constraint Mapping Technique

Steps 4 and 5, as demonstrated in this particular research, involve some degree of public participation whereby the proponent was given the opportunity to express their wishes on the location criteria. The working group consists of several government departments, private 5 individuals and representatives from non-governmental originations. Some of the government departments involved in this project is the owners of specific data.

Steps 6, 7 and 8 are the intelligent part where GIS operations take place. Step 9 provides the final result of this study, which is potential search area for landfill for Bandar abbas

District. It is pertinent to note at this point that step 4 which is the input criteria plays a very important role because it can influence the result of the GIS operation. Therefore, this particular research made use of the existing mechanism where the author presented the process and example of how the methodology works with the Bandar abbas Spatial Planning Working Group. The purpose here was to make the working group understand the process and requirement.

4. Case Study

The case study focused on Bandar abbas District which covers approximately 218,200 hectares; one of the 23 districts in Sabah and located on the East Coast with the population of 347,334 (Census 2000). The Bandar abbas Municipal Council administrative area covers 18,500 hectares and according to year 2000 census, there are 70,192 living quarters for Bandar abbas district. The majority of the housing estates are located within 13km radius from the town centre.

The daily average waste collection for Bandar abbas Municipal Council was about 165,000 kilograms or about 0.468 kilograms per persons per day in the year 2000 and expected to double in year 2005 (MPS 2002). The current landfills site is located at Jalan Sin Fook Kim, about 13 kilometres from the town centre but under the current planning exercise, Bandar abbas Municipal Council (SMC) is planning to relocate the present landfill. At about the same time, SMC also received a directive from the Ministry of Local Government and Housing, Sabah (KKTP.100 44/25 dated 24th April 2002) to plan its landfill operation up to year 2030.

4.1 Input Data

Data for this study comes from seven (7) different agencies, which include Town & Regional Planning Department, Department of Environmental Conservation, Department of Forestry, Lands and Survey Department, Department of Drainage and Irrigation, Department of Public works and Department of Agriculture.

4.2 GIS Spatial Operation

The spatial operations for constraint mapping began by identifying the criteria or conditions for constraint mapping and after that the criteria was then converted into GIS layers. From the GIS layers the spatial operation was performed. The spatial operation is normally performed in conjunction with GIS functionality found in most GIS software. Fig 2 summarizes the workflow for the spatial operation.

This particular study used the quarry functionality to a create buffer surrounding the theme such as river, road and others. In particular, spatial operation to produce the buffer was conducted for the following 5 themes:

1. Create 100 metres buffer from surface water and water sources,
2. Create 100 metres buffer from transportation routes,
3. Create 3,000 metres buffer from environmentally sensitive or protected areas,
4. Create population density map based on enumeration blocks of 1991 and 2000 census,
5. Create 3,000 metres buffer from rural settlements areas.

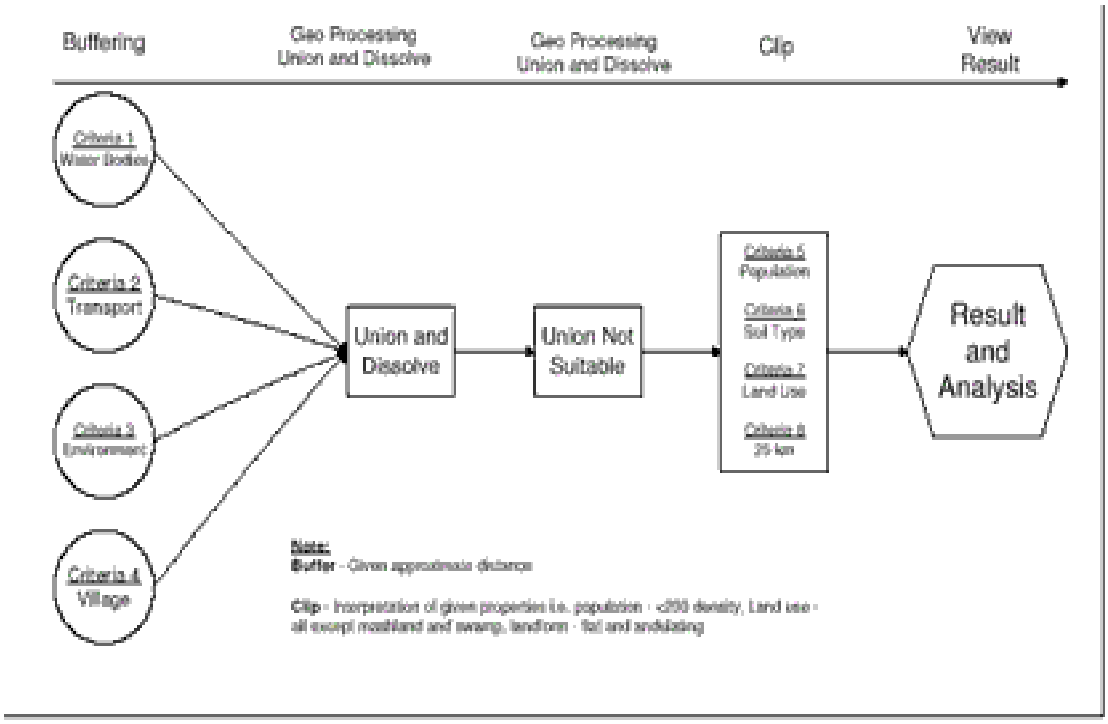

Fig 2: Workflow for the Spatial Operation

For the 4 remaining criteria, the spatial operation was performed by identifying the layer not suitable for landfill site, for examples, under the Landform and Soil Type, there were 9 different layers of Landform and Soil Type identified. These are the mangrove swamps (43,019 ha), sandy beach strips (5,072 ha), flood plain (6,298 ha), freshwater (peat), swamps (part of flood plain) (4,562 ha), raised (old) alluvial terraces (2,884 ha), undulating to gently rolling, low to very low hills, and valley floors slopes 0-15 degrees, relief amplitudes 15 to 30 meters (93,139 ha), strongly rolling to moderately steep, moderately high hills, slopes 10-20 degrees, relief amplitudes 60-150 meters (35,528 ha), steep to very steep high hills and ridges; slopes steeper than 25 degrees relief amplitudes 150 to 300 meters (14,980 ha) and finally the very steep, very high hills and mountains at 6,779 ha.

Data for land use/land cover was obtained from the Department of Agriculture and here 9 different classes of land use/land cover were identified: urban, horticulture, perennial and tree crops, cropland, grassland, forest and marshlands and swamps. The working group for Bandar abbas District decided that all land use/land cover should be compatible for building a landfill except for marshlands and swamps.

For the haul distance, the criteria identified that a 25km radius from the urban centre is the most appropriate distance for site location. Thus, a 25 metre radius was then identified in the map using the functionality in GIS ArcView software. There was not enough data to perform the spatial operation for the 9 th criteria, which concerns the slope of land and thus slope analysis was not conducted. This particular analysis acknowledges the limitation of this research due to the unavailability of data in digital format; however hard-copy maps were available from Department of Surveys and Mapping, Malaysia and have been used to manually cross check the data where necessary.

5. Results

The outlined methodology did produce the expected result and thus the GIS spatial operation using map layers as specified in the constraint criteria works very well using the GIS software in particular the ArcView 3.1 and 3.2.

the total area of Bandar abbas District is 218,200 hectares. The constraint mapping exercise manages to narrow down the search area by 57,273 hectares or about 26.98% of the total area which represented a 73.74% reduction. The search areas were located in 6 different locations.

Potential Search Site was found to be scattered in 6 different areas. Therefore, it is necessary to rank the areas from 1 to 6, where area 1 indicates the most preferred search area and 6 which is the least preferred. In order to achieve that, GAM 1 rating was chosen as the most appropriate technique and the GAM scoring shows that Search Area A found to be the most preferred site followed by Search Area B.

Further work by the Bandar abbas Municipal Council would be to make use this information to finalize the location of Bandar abbas Dumping Site based on the GIS analysis provided under this research.

6. Discussion

The on-going discussions with Bandar abbas Municipal Council (SMC) concerning the determination of new landfills sites have something to do with management issues and budget allocation. On one hand the advocate proposed that the existing landfill should be maintained due to lack of funding to open a new one. The existing dumping site was large enough to cater for many years to come and the only requirement was that budget must be allocated for better maintenance and management. However, the question to be asked was whether the groundwater was unacceptably at risk from leachate from a landfill. This begs two further questions, firstly, was the groundwater beneath the landfill site part of a significant aquifer? Secondly, was the landfill likely to generate leachate in sufficient quantity that it might migrate to and contaminate the groundwater in the Bandar abbas area?

Another advocate proposed that a new landfill site must be sited. Budget allocation might be available from relevant agencies that would only be available for a new landfill site. Whatever the decision may be, a key element in the upgrading of the existing site or the identification of new one was the provision of effective site management which include among others site preparation, site management and method of dumping such as spreading, compacting and sourcing of cover materials and even to explore other method of solid waste disposal.

Perhaps one of the immediate solutions for SMC would be to maintain the existing site and to build a containment wall facing the Seguntor River. Whilst this may prove to be more expensive, it is one of the ways to improve the protection of the local environment; a compromise solution must be sought between cost and benefit. At any rate whatever the situation may be SMC must make a stand. For good planning practice, a landfill site must be made available for the future generations.

Along with this study, SMC was also looking for a potential site for town extension and it was found that the 6 potential search areas for Bandar abbas Landfills were also potential

for town expansion. The management of SMC than would have to re-evaluate the constraint criteria and to run the exercise to see its effectiveness.

6.1 Search for a Specific Landfill Site

SMC shall identify a new site within the Search Area proposed under this study. This could only be done by the SMC as they are the owner and managers of the areas with local knowledge on their side. This would include site visits and taking technical notes of the proposed new sites. If site access was not available, high resolution satellite images or aerial photographs could be use for this purpose.

6.2 Applying the same Techniques for other Districts

It is also recommended that all Local Authorities in Sabah use the GIS analytical modules presented in this research. This is in line with the intention by the Ministry of Local Government and Housing (KKTP.100-44/25 dated 24 th April 2002) and State Economic Planning Unit (UPEN.600-1/2 9 (97) dated 30 th April 2002 to produce "Local Authorities Waste Management Master Plan and Feasibility Study in Sabah" which aimed to establish haulage distance, transition sites, disposal sites for all the 22 Local Authorities and proposed disposal methods in Sabah up to the year 2030.

7. Conclusion

GIS as decision support tools for landfill siting using constraint mapping techniques has been proven to be useful. The total area eliminated by applying constraint criteria was 73.74%, thus leaving the balance of the Potential Search Area at 26.26%. The remaining search areas were located in 6 places and identified as Search Area A, B, C, D, E and F. The 6 areas were then further ranked using GAM rating and it was found that Search Area A ranked first, which represents about 3.90% of the total area followed by Search Area B which represents about 3.54%. This research therefore concluded that GIS utilizing CMT can be used effectively and has the potential to identify possible search areas for landfill siting.

Planning for future land use and deciding on the appropriate zoning for particular areas demand comprehensive analysis and sound judgment. These processes often take longer to achieve but with the introduction of appropriate tools, decision making can be made faster and more reliable. It is hoped that relevant government agencies would co-operate and work together especially on data exchange and data production in an integrated manner as demonstrated through this study.

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