Selection of Suitable Site for Solid Waste Landfill: a case study in Kirkuk City, Iraq

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Abstract: Selection of a landfill site for solid wastes is considered one of the challenges for local governments and municipalities’ directorates in particular all over the world, simply because every single city produces huge amount of solid wastes (garbage’) each day that come from homes, hospitals, schools, industry, offices and centers of markets. In this study, Kirkuk city has been selected as a case study to figure out the solutions for trash, bad odors in most of the neighbourhoods, groundwater pollution, harmful toxic wastes, etc. So, proper criteria selection is very important as a starting point of landfills to preclude unwanted long-standing effects. Otherwise the traditional process of site selection process is difficult because its time consuming and costly. An integration of Geographical Information System (GIS) and Expert Choices Process (ECP) method is best combined technique to solve complex decision making and to select based on the study area condition. Six criteria have been used to select potential suitable site landfill in Kirkuk city. It turned out that the highest criteria is the built up area and the lowest one is bearing capacity of soil (BCS). Moreover, the final produced map shows the suitable area for landfill siting. The work purports to present methodology of this inquiry and objective can make impressive solve in global environmental change and its regularly supplies an efficacious operation to select the suitable site to landfill the solid wastes.

1. Introduction:
Selection of landfill site is considered a complicated process for municipal waste management because it’s one of the major problems facing city planners worldwide and combines social, environmental and technical factors. The problem can been seen more significantly in developing rural areas where urbanization, poor preparedness, and lack of adequate resources contribute to the pitiable state of waste management practices. Unquestionably, a precise detailed landfill site location selection collection can mitigate various numerous issue issues concerns with waste disposal removal. In many countries with a population growth and their need for food supplies, as a result, there has been a boost in the quantity of generated solid waste that makes very difficult to be managed in a proper way. The accumulation and improper administration of solid wastes contribute to pollute the environment and expedite spreading of contagious diseases. The management practices of solid waste generally are controlled by definite lawful rules. These rules are meant to offer a vivid instruction to the developers, landfill workers, development offices and monitoring associations on the location choice, evolution, proposal, building, procedure, closure and post-stop-stop of community leftover management. Landfill location choice is portion of waste supervision procedure; there with the general rules and policies must be pursued with the intention of minimizing the hazard of conservational damage as portion of transitioning to a maintainable situation in the forthcoming. There are countless standard’s must be considered as well as there should be carefully evaluated. Furthermore, it has to go through both precisions and restraints on other sources in society to prevent the negative impacts on the environment, economy and ecology which should be done to enhance effective vivacity, ecological completeness, and enhanced characteristic of liveliness in a manner of advances sustainability.

There are various spatial criteria standards considered during the landfill siting positioning process progression such as surface water, sensitive considerable zone, surface water, urban area, residential...
area inhabited extent, municipal area, and slope and etc. Community healthiness reflections and environmental protection safeguard and public health considerations should be the crucial point for the site choice, the selection range of the appropriate suitable site location will minimize decrease the potential possible environmental conservational impacts and provide afford a sound complete basis source for effective applicable management administration [6]. They both agree approve that the site selection should make the maximum space extreme space of for the available existing data facts and ensure confirm that the outcome consequence of the process progression is acceptable.

The selection of landfill site will be gone through three different levels, which namely are: potential, candidate, and final ultimate site selection. Any level of selection, will consider different criteria[3]. But for the selection of the landfill location, the landfill site selection is a sophisticated land use planning problem involving the aggregation and processing of data that relevant to socioeconomic, environmental as well as functional aspects[7].

Population growth rapidly in Kirkuk city and changing in life style are two primary causes for increasing the solid wastes dramatically[8]. Maintaining this interpretation, the current investigation is carried out through identifying a suitable site for disposal of municipal waste generated in Kirkuk city using GIS and AHP. Kirkuk city suffers from the waste solid problems, and even landfill sites were taken together in randomly. There are two landfill sites, primary and secondary. The primary landfill site is located near Laylan town in the eastern side of the city towards Sulaymaniyah, see Figure (1) while the secondary one is located close to Taza town in the south of the city. However, both landfills are considered not suitable enough because in most cases, the solid wastes burn by the municipality workers in order to reduce the size.

The other vivid disadvantage from the waste incineration process is it happens in open space under uncontrollable conditions. As a result, the air qualities in the neighborhoods that are close to the landfills are exposed to be more degraded and that means gas discharge into the atmosphere will have a negative impacts on the people health. Currently, according to the Municipality of Kirkuk and Office of Environment in the city, the total solid trash generation in Kirkuk city is around 612 Metric Ton/day. It can be said that the current total generation of the garbage can be contained by current both landfills even the garbage incineration is not occurred as figure (2a and 2b). However, it is expected to increase the amount of the solid waste generation to be around 1172 MT/day in 2020.

So, the current disposal sites will not be sufficient and that’s why the city municipality is trying to find out the optimum location to be the third possible landfill to occupy whole solid waste that is mentioned by 2020. This time, Kirkuk municipality in cooperation with author is going to use scientific methodology for selecting the landfill site by using AHP and GIS techniques. In order to produce spatial digital database comprising base map, assess AHP and allocate weighting factors influences for distinctive digital thematic strata, then to incorporate them in GIS for assessing hazard, suitable waste disposal site should be chosen in and around Kirkuk based on this integrated field. The land suitability output is presented from less suitable to the highly suitable areas.

2. Study Area:

Kirkuk city is situated in the Khassa chia river, which is passing through the city and bifurcates it into Eastern and Western Kirkuk. The city was belong Al-Tameem province before 2003 while now adays is belong the same name as the city (Kirkuk province). The city position is located on the latitude of “35° 28’ 5” north and longitude of “44° 23’ 31” east, and almost at “350m” over the sea level based on the Universal Transverse Mercator System "UTMS" reference orientation project scheme zone region 38N with an area of around 99,679,679 km² and that identifies 2.2% of the entire area of Iraq (Local Census Bureau of Statistics, Kirkuk, 1997–2003) [8]. It includes 13 administrative units forming four districts, Kirkuk district region has an area of 797 km² of the area is 797 km². In 2010, the people of Kirkuk city was estimated to be 1,475,711 people in comparison to 753,171 inhabitants in 1997 and with a growth of 3.4% of the total people in Iraq (National Census Bureau of Statistics, Kirkuk, 2005; Kirkuk Food Ration Office, Ministry of Trade
Baghdad, Iraq, 2007) Census Bureau of Statistics, Kirkuk, 2005; Kirkuk Food Ration Office, Ministry of Trade Baghdad, Iraq, 2007) [9]

3. Materials and Methodology:
This paper study describes a comprehensive complete spatial criteria standard for the selection of the landfill site selections. The GIS-based landfill sitting methodology used in this study was consisted of several stages as follows:

3.1 The spatial and non-spatial criteria:
The criteria identification is rely on the six criteria which will be discussed in following section. The selection of site is achieved basically by two stages. Firstly, it is required to set the standard that should be considered criteria to be considered for municipal disposing the community solid waste and identify the site solid waste disposal site selection are identified and that broadly largely grouped collected into exclusionary. These criteria are outlined using the standards specified in the municipal public solid waste contains the landfill area needed, close to the rivers, and near the highways, and the distance from the population centers. The other criteria on the other hand are categorized in much more details into soil characteristics, topographical criteria which include the slope patterns, see the figure (3).
No landfill ought to be constructed within 500m of any waterbodies, constructed within 200mts of
Road network, a landfill area must have a distance of 1000m from a notified built up area from the expected build up region, and a landfill area should not be sited in a topographical zone that slope should be more than 10% percentage with the bearing capacity of soil should be in depth 0.654. When the criteria are prepared into an assessment hierarchy, the description for each criteria, criteria might include proximity to roads, slope gradient, exclusion of reserved lands, and so on are shown in the table 1. The weight of each criteria compared to the others is calculated by pair wise comparison judgement through AHP rule to specify the most preferred alternative shown in Table 1.

Table 1: Description of spatial criteria.

| No. | Spatial criteria                  | Unit    | Description of Criteria                                                                 |
|-----|-----------------------------------|---------|----------------------------------------------------------------------------------------|
| 1   | Road Access                       | Meter (m)| Standard that specify Road network issue concern and traffic management supervision of landfill to calculate the time and cost of trips. |
| 2   | Built up Area                     | Meter (m)| Standard that faced landfill position to be situated closely to urbanized developed area. |
| 3   | Bodies Surface Water Bodies       | Meter (m)| Standard that avoids landfill to be placed close to water bodies, including river, lakes, dams and ponds in keeping protecting water body's water body's pollution contamination. |
| 4   | Slope                             | Percent (%)| The terrain topography condition circumstances that necessary that suitable for selecting the landfill site should be in slope percentage in slope fraction. |
| 5   | Bearing capacity of soil          | Meter (m)| The criteria that determine the bearing capacity of the soil to prevent groundwater pollution and the landslide in future |

The weights are the normalized factors corresponding consistent to the supreme rates of the pair wise comparison assessment matrices created at every level of the judgment hierarchy [10]. The normalization of the criteria is accomplished by dividing distributing each every criterion element component by the sum accumulation of the criteria's of the decision judgment matrix. Once the weight of each layer or theme to be considered for the site selection are calculated, the discrete weight are summarized to obtain a final suitability index using the Expert Choice Software (ECS) [11].

In addition, constraints are constantly Boolean map in character of the sensitive areas (such as the reserved lands constraint in the selection). Certain areas will be excluded from their consideration, that avoid landfill to be in fixed distance or close to sensitive regions (i.e. oil excavation and military area) which is measure by meter. Factors and constraints can be combined in the MCE model.

3.2 Establishing GIS database:

In the second stage, the primary data sources for this study include topography geography map plan (1/200000000) which shows the elevation raise contour curve lines, positions, roads, rivers waterways and domestic zones, soil map (1/50,000) specifying soil penetration, water bodies then scanning all primary paper maps were georeferencing and digitizing to generate digital thematic maps from the collected data. Topographic, thematic and spatial data records matching to the layers containing settlements streets, roads, surface water, and soil etc). Subsequently, a GIS databank for community landfill site selection was launched by Arc GIS software. The methodology adopted for the study is shown in figure 3. It is used to calculate Euclidean Distances spaces, and mask out regions that failed any minimum given standard such as bodies of water. After screening out improper areas within each theme corresponding to several standards, all ideas are covered to arrange a complex suitability appropriateness plot. Areas not satisfying the least landfill criteria measures were eliminated excluded and other added bundle collections that lingered are further evaluated based on suitability indices values and classified into suitable, non-suitable, and moderate suitable sites. The sites within each of these three classes are further evaluated for their attributes such as distance from the point place of waste leftover invention, population density surrounding the site, proximity to settlement areas etc.
Resulting in selection of two best preeminent appropriate sites locations within suitable within appropriate and moderate reasonable suitability class division for to support the entire whole study extent. MCE tool of IDRISI software was used to exclude suitable areas for landfill. The next step is getting a short list of sites from the GIS analysis, the evaluation of attribute, e.g. adjacent road path or water body frame, inhabitants density concentration neighboring the site location and many other factors of each of these individual sites is implemented to find out which site possessed the best compromise of features for developing a landfill and are accordingly ranked. AHP is used in this research as a multi-criteria decision making in order to compare five suitability attributes with each other and estimate weight based on attributes potentiality. GIS tool was utilized to create multiple type raster map layers. Five suitable raster’s were defined with the AHP calculated weight value. A combined weighted spatial layer obtained name as suitability map which is overlapped with a restriction raster map, as result a final suitability appropriateness model prototypical using a weighted linear direct combination pattern (WLC) that involve of three tasks; the first operation is altering factors features plots to raster arrangement, the second operation is distance operation process Figure (3), and the third overlapping the criteria was obtained.

Figure 3: The N process of integration GIS and MCE for assessment site selection landfill.
6. Results and Discussions:

Multiple layers are categorized based on relative weight after AHP and weight tool bar in Arc GIS have been applied. In order to get absolute weight, the total number of the original weights have been reviewed and assessed to get a perfect suitability indicator. As every single of the relative weight contains its significance from the primary level, the ultimate increasing standards is going to provide further precise consequences. Based on the customized weight as well as obtained appropriateness index rate, total area is classed to five groups. These five groups are; exceptional set of suitability factor ranged between 0.50 and 0.60, highly suitable class with suitability index ranged between 0.40 and 0.50, moderate class with suitability index ranged between 0.30 and 0.40, and the non-suitable class with suitability index ranged between 0.10 and 0.03 with regard to landfill sitting. Upper suitability factors are the most appropriate location for waste removal while lower suitability index will lead to lower suitability site. Map 1: shows the suitability plot that is arranged for the current research.

Map 1: The suitable map after applying spatial analysis-reclassify operations.
The result demonstrates that 15.2% of the area is suitable for constructing landfill site, 3.6% is very high suitable, 5.9% is suitable and 6.7% is limited suitable. From the final output, it is vividly showed that there are a total of five criteria as can been seen in Table (1). In addition, environmental criteria describes the factors that restrict the outcome to specific topographic areas to keep the considerable eco-system and individual strength and protection likewise surface water bodies. On the other hand, physical criteria describes as the factors that influence landfill erection and process; mixing practical and operative standard for example topographic (slope) and bearing capacity of soil. Finally, socio-economic symbolizes as these limits that move the landfill to the community characteristics (i.e. built up extent) and cost-effective feature (i.e. Landfill functioning amount (road access)). The description of each criterion is showed in Table 1. The process and outcomes aspects weights are specified in Table 2 normalizing the complete parts. The group of a distinctive weight for standards through expanding pairwise assessment the weight sum of all elements is 1. The obtained plots with altogether elements were re-categorized from rank 1 to 5 by spatial data skills. The record is appointed relies on the position of every single spot. Subsequently, the ultimate appropriateness plot Figure (4) is generated by combination practice based on the weight. The absolute suitability outcomes are distributed to five distinct classes: highly suitable landfill locations, suitable and marginally landfill locations, and inappropriate landfill locations, as presented in Figure (4).

**Table 2: Spatial standard depending on the AHP of the landfill.**

| No. | Spatial standard             | Geometric Mean | Normal Geometric Mean |
|-----|------------------------------|----------------|-----------------------|
| 1   | Road Access                  | 0.187462       | 0.1878                |
| 2   | Built up Area                | 0.258162       | 0.258628              |
| 3   | Surface Water body           | 0.170142       | 0.170449              |
| 4   | Slope                        | 0.238722       | 0.239152              |
| 5   | Bearing capacity of soil     | 0.143712       | 0.143971              |
|     | *Sum*                        | 0.9982         | 1                     |

Finally, a suitable map for the landfill is generated. This suitable map is developed through incorporating element weights from AHP beside the factor plots to raster computational operation in Arc GIS software as can be shown in Figure (3). This result presents a status of superlative suitable and irrelevant locations as can be seen in Figure (4). After suitability map have been generated for the entire pixels for the investigated area, the property practice is computed from the suitability map. It could easily be calculated suitability plots using functioning raster computation. This result reveals all empty and suitable locations that could be used for the landfill location and its position that are distributed to five groups highly suitable landfill sites represent optimal sites; suitable and marginally landfill locations, and inappropriate landfill locations, as presented in Figure (4).

**7. Conclusions:**

In this analysis, a GIS-common location suitability prototype utilizing weighted direct combination “WDC”, beside the prepared aspects of build a record in a “GIS” situation have been used as a case study. Likewise, it also explains how the abilities of GIS could be employed as a powerful tool for managing many difficulties of spatial class, with the productivity of treating huge spatial information, and through quickness that is rather usual of computer-based processes. The easy accessibility of information was mainly excellent guidance to select the decision factors during the initial stage of waste disposal site selection. Integrating GIS with Analytic Hierarchy Process (AHP) method is the main source that MCE relies on. It is a best fit methodology to facilitate location choice and land appropriateness assessment. During the site selection study process, an inclusive description of AHP was given beside the accounts of the use of AHP for landfill placement.
The current field is an endeavor in a same path to location selection as a preliminary stage for landfill in Kirkuk city. It turned out very clearly that the precision of the conclusive modeling associating the GIS catalog with the AHP relies on the type of the information and on the essential principles of the AHP practice.

Six spatial site selection criteria are summarized from the office of Kirkuk city and found that the suitability plot for a landfill as shown in Figure (4). It was noticed that the suitable areas (white, brown and orange colors) are about 42% and these are located in the Eastern, same areas in Northern and Western parts of the study area. However, the areas that are not suitable are almost 58% and the areas found in the middle portion of the analysis extent. All the study objectives have been achieved meantime the application of order weights. It clearly could be noticed that obligation of influence weights is depend on preceding awareness of the influence features and the investigated extent particularities in addition to the proficiency of the professionals that contributed in the weight task development. A weight was specified as a way in the aim of the achievable concerning methods likes the AHP for assessing and selecting the prime and back-up locations that chosen for land site selection in the future. In the ultimate accumulation development, factor weights are estimated through several elements such as municipal, conservational and socioeconomic as they all played a significant function in landfill site selection. This can assist local agencies to obtain comprehensive complete description of the site selection criteria. Also, the database criteria could be applied by others researchers for their research purposes in all metropolitan cities in Iraq that are resemble somehow the nature of Kirkuk city. The final site will be constructed after field investigation in detail, other technical investigation, land ownership status and public acceptances. An integrating method of GIS with AHP is systematically good in quality to solve quite complex problem as well as it could contain huge data at time and at the end get a reliable and an accurate result. So finally, it shows that the methodology of this research and objective could make magnificent solution in global environmental change.

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