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# A Review on Solid Waste Site, Landfill Site Allocation Using GIS, Multi Criteria Decision Analysis

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***Abstract—*** Increasing use of GIS in various research fields is become a new trend to researchers, and its reason is also appreciable, It is find that GIS and other techniques combine together unexpectedly helps to researchers for doing critical investigations of huge amount of spatial and nonspatial data easily. The main aim of this paper is to review the use of GIS techniques used in sitting solid waste sites and landfills. Sitting solid waste site and landfill site is a very hard and complicated task. It involves various issues which are very sensitive to environment and human life. It is an attempt to find and group together the various researchers' research thoughts for further study, which will be a guide way for new researchers and solid waste management decision makers.

***Keywords-*** *Solid waste, Multi-Criteria analysis,Analytical Hierarchical Process, Geo-referencing, Geospatial Analysis, Geographic Information system, Disposal of solid waste, solid waste sites, land fill.*

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## I. INTRODUCTION

Every municipalities, corporation and urban city in the world are facing a problem of managing solid waste, which is a natural outcome of daily activities of human. It can never stop, and increase as there is growth in population and living standards of human. Due to lack in management and improper disposal of solid waste urban cities facing various problems like diseases transmission, fire hazards, odor nuisance, atmospheric and water pollution, aesthetic nuisance and economic loses. The only solution is Solid Waste Management. Solid waste management can be done more accurately by selection of suitable site for solid waste disposal and land fill. If this is not done at right time then everybody has to pay a lot in future. In this view broad retrospective view is taken; how Geographic Information system (GIS) is used as a tool to find solid waste and land fill sites, which are environmentally safe and acceptable to people. Particularly GIS is used to view, understand, question, interpret and visualize huge amount of spatial and nonspatial data in many ways that reveals relationships, patterns and trends in the form of maps, reports and charts, which will be important for critical decision making. By taking into consideration the problem to find site for solid waste and land filling this review helps and guide to the new researchers who are devoting their work in solid waste management.

## II. CAUSES OF SOLID WASTE GENERATION

While making the review for GIS techniques used in solid waste and landfill site allocation, it is very important for the study makers to know the reasons of solid waste problem in urban areas, and the following first two references gives it.

One of the causes of increase in the amount of solid waste is exponential rise in the urban population of the developing countries during the past decades, which accelerated the urbanization phenomenon and the great need for solid waste management becomes essential part of urban area. [1].

In [2] Shupeng Chen, an et al. study of population and urbanization shown that, in 1800, the number of urban residents represented only 2 percent of the total population of the world, while the number had reached 10 percent by the beginning of 20th century. Almost two-hundred years later, the urban population has grown to over 3.2 billion, equally half of the global population, and it increased by an average of 1,000,000 people per week. Between 1970 and 1985, the number of people below the poverty line in urban areas increased by 22 percent, so that the problem of solid waste management was more serious for those in urban areas. The negative impact of growth in population and urbanization is that we have to face a series of environmental problems, such as a water resource crisis, increased air pollution, and waste treatment problems. In this study authors have discussed how remote sensing and GIS helps for analysis of urbanization growth.

## III. REVIEW

In [3] Hala A. and Mohmed N. Hegazyb did an extensive evaluation to choose a safe landfill location for solid waste. With the help of literature review and expert knowledge a standard criteria was designed to fulfill governmental regulations and maximum high standards for landfill site. With the help of designed criteria authors were able reduce economic, environmental, health, social cost as well as negative impacts of landfill site on environment. The required geographic database of vector maps was prepared from analog maps. Constraints and factors were used as criteria along with Weighted Linear Combination. The standards of Egyptian Environmental Affairs Authority (EEAA) were used to decide criteria buffer zones for shoreline, roads, settlements, and high order streams. To generate constraint images factor images were converted into binary images with the help of ArcGIS 9.2. For suitability the factors were grouped theme as ecological, economic and social. By using Expert advice, Analytical Hierarchy process and straight rank-sum method weights were assigned to the factors. The environmental theme was built up with the factors Permeability, Ground water depth, Distance to sabkha, Distance to Shores, Distance to protected national park,

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Distance to high order streams. In the same manner Economic theme was built up from the factors Distance to cities, Slope of the terrain, Distance to power supply, Accessibility, Following factors of social theme were considered Airports, Archeological sites, Airports, Aspects. The equation

$$Wj = (n - rj = +1) / SUM(n - rk + 1) \qquad (1)$$

was used to apply Weighed Linear combination method to the theme factors. Were Wj – normalization weight for jth factor, n – number of factors, rj – rank position of factor. By using ArcGIS 9.2 spatial Analyst a suitability scale ranging from 1-10 was given to standardize factor maps. Suitability index was prepared using Simple additive weighting (SAW), which was widely used in multiple criteria problems to calculate final grading values. Equation

$$Vi = \sum_{j=i}^{n} WjVij \qquad (2)$$

which was derived by Konotos and et al 2005 used for SAW. To get the suitability index scenarios this formula was applied three times in ArcGIS9.2 spatial analyst. Environmental theme had given the highest priority and hence it ranked as first, then economic and then social theme ware ranked. All the three scenarios were reclassified into ten suitability index by choosing the highest pixel values ranging from 7-10. It was taken the care that the resultant site must meet the criteria that site must lie within 5 to 25 km from city and its minimum area must be 1.5 km2.

In [4] study was done by keeping in mind to complete the goals as, to research solid waste management in urban areas to survey about waste collection, Composition of waste and recycling for the economy; to establish waste data for monitoring and management using GIS, to improve aesthetics of the city and increase public awareness of Vientiane Capital City. A Pilot study was done on the composition of waste, recycling-reuse, sale of recyclable materials by the Vientiane Cleaning Unit, and the private company. Authors followed analysis technique to generate database, while map overlay technique was used to study the general sources of solid waste and waste distribution boundaries. The simulation of alternatives was done with the help of GIS technique to take the most effective decisions. GIS was used as a tool for mapping and spatial analysis of the Earth's features and events, to relate different data on the basis of common geographical components: as address, postal code, census block, city, country, or latitude/longitude coordinate. Different information required for study like roads, settlement, model the path of air pollution, solid waste and much was extracted from a map with the GIS tools. Authors designed a GIS database on the basis of physical data which contain digital map and photos, Attribute data which contain the static data and reports and Composition of waste in the landfill. For the awareness of public and to support state of environment, obtained results related to environment and solid waste management were spread to university with the help of GIS.

In [5] Authors described how to find dustbin locations for Ilorin metropolis, Kwara State ,Nigeria, by using the P-median Problem. The P-median problem is a Minisum Location Allocation Model, which is used to minimize sum of distances or costs to facility. In the study authors used A4 size scanned JPEG image of study area, which was converted into DXF format to be used in GIS. The digitization was done by data coding. The dustbin locations ware located by eliminating unsuitable areas and by considering various distance buffering constraints. The obtained information was stored in a spatial database. The Location Function of GIS was used to solve the P-median problem.

[6] is a thesis which was completed in fulfillment of M.S. by Monica M. DeAngelo. In the thesis author has made an empirical study to site Waste-to-Energy facilities in New York City using GIS analysis. Author has used GIS very ideally to create the database and analyses the data. While completing thesis, those Municipal Solid Waste transfer stations (MSW transfer stations) whose capacity is about and over 2000 tones/year are targeted for study. In the study author has shown that how modern GIS technology helps to find environmental and economic solution for waste disposal to the urban cities. It is also shown that implementation of WTE in New York City save about 12 million truck transport miles per year, and obviously save money in transport costs, labor costs, and the reduction of environmental impacts such as air and particulate emissions/mile, road degradation, and odor.

[7] Shaikh Moiz Ahmed and et al. has done a critical and empirical study on solid waste for Aurangabad city of Maharastra state in Indian. The study was completed with a new technology GIS in faith to save the environment and prevent the environmental degradation, health hazards and economic descend due to direct disposal of waste. Authors have taken the advantage of GIS to manipulate data in the computer, to simulate alternatives and to take the most effective decisions. They suggested simplest way to bring innovations in any system is to document and study the existing system and do the possible reforms by adopting appropriate measures at various levels through the introduction of innovative and cost effective solutions. To fulfill the goal they suggest a conceptual model. Required data of study was derived from the spatial maps and satellite image of the city. The spatial data about locations like the point of interest, waste bins and open dumps was collected with the help of GPS device; also attribute data about the spatial elements were collected. The other essential information collected through interview, questionnaires and online sources. To georectify and counter tally spatial data the victories municipal map was overlapped on satellite image. The designed GIS model considered the criteria like Economy, Environmentally sensitive areas, Identification of recyclable waste generating areas, Waste categorization of shops, Flexibility in model for perfect results. While following the designed conceptual model authors had considered total five analysis criteria as Inconvenience due to waste bin proximity, Convenient distance from the bins for all users, Proximity from environmentally sensitive areas, Recyclable bins for buildings, Recyclable bins for shops. Designed module showed that six waste bins are in close proximity of schools, hospitals and religious buildings which are to be moved out of the buffering range of the respective buildings. It need to Identify those land use areas which generate recyclable waste and then find the suitable location for placing those bins so it would be convenient of the users. Finally a cost effective with respect to budget constraints model for solid waste management system was designed for study area.

In [8] While doing the study of solid waste management for Pondicherry city of India, Sumathi and et al. followed the following mechanism.

Database Preparation: Toposheets of Pondicherry viz 58 M/13, 58 M/9 , 57 P/16 and 57P/12 of the scale 1: 50000 were used to design study area. Digitization Water bodies, road network and elevation maps were performed on the survey of India map. The maps of Geology, social, fault line, water supply sources, and ground water maps were digitized after collection of it from departments. The Indian Remote sensing Satellite IRS1D image of study area having the resolution of 28.8 m was interpreted and classified to produce land use map. The land use map used to derive the thematic maps of habitation, sensitive and waste. All it was done with the help of GIS software. From the Department of Science, Technology and Environment, Pondicherry, air quality index map was generated. Its equation is

$$AQI = \left[(Obs/Std)So2\times(Obs/Std)No2\times(Obs/Std)Spm\right]\times 1/3\times 100 \quad (3)$$

As constraint maps the buffer maps of lakes, ponds, rivers, water supply sources, habitation, highways and fault line were fixed. Water bodies map, Road network map, Land use map, Sensitive map, Infiltration map, Geology map, Elevation map, Waste land map, Groundwater table map, Ground water quality map, Air quality map, Buffer map were prepared with the help of ArcGIS.

Criteria Standardization: Authors taken the support of Delphi technique, key policy makers, guidelines of central Pollution Control Board (CPCB, 2003), Central Public Health and Environmental Engineering Organization (CPHEEO, 2000) and Review of the scientific literature, to decide the four criteria as Land use criteria, Hydro-geologic criteria, Air quality criteria and Constraint parameterization.

Constraints and method: Constraint weight (Wc) was calculated by comparing each factor against one another. Criteria Rating (Rc) was calculated depending on the relative magnitude for each criteria, also Index Score (Isub) of criteria were calculated. Using weighted sum aggregation function a Composite suitability index was calculated. Satty (1980) Analytical Hierarchy Process (AHP) was followed to find out relative importance weight of each criterion. The same process was followed for sets of sub-categories of criteria. At last an aggregate ranking was generated with the comparison matrix among alternatives and information of ranking of criteria. That alternative whose eigenvector value is highest was considered as first in the choice list.

Result: As a result of all above mechanism total 17 potential sites were identified for landfill development out of which only 3 sites were approved as most optimum ones on the basis of local criteria.

Mr. Mujibor Rahman and et al. in [9] investigated the solid waste management problem of Khulna city of Bangladesh. Authors suggested the selection of disposal sites must be done by considering residential area, clinic/hospital, educational institution, drainage network, and socio cultural and religious institution about the study area. In short it was to be done by environmental safety criteria and attributes that will enable the wastes to be isolated so that there is no unacceptable risk to people or the environment. During study GIS was used to integrate field parameters with population and other relevant data. Due to the characteristics like GIS reduce time and enhance accuracy, it easily helps to capture, store, and manage spatially referenced data, it helps to perform analysis of spatially referenced input data, GIS perform sensitivity and optimization analysis easily, GIS helps to extract or classify spatial features while searching suitable sites, GIS helps to communicate model results, GIS was used in selection of solid waste site. In the study used three phased spatial decision making process; Intelligence phase, Decision phase and Choice phase. As per authors saying deductive approach is suitable for generating the criteria. Sources of criteria were determined by indirect qualitative determination approach. To help decision maker's decision making system with expert system and computer models was designed. To generate similar type of criteria two approaches deductive and inductive were used.

The Environmental, Economic, Social and Technical operational following classified criteria were used in evaluation method. Ratings were assigned to these criteria according to their performance. The ratings like Very suitable, moderately suitable, and less suitable were assigned for hydrological evaluation. During the study; Land use pattern, Religious institutions, Health facilities, Commercial establishments, other socio cultural institutions, Administrative area were considered intensively for safe solid waste disposal site allocation.

In [10] Bilgehan Nas and et al. determined an appropriate landfill area in Cumra County of Konya City by using the integration of Geographic Information Systems and Multi-Criteria Evaluation (MCE). While determining landfill site a tremendous pressure has to face the decision makers due to the phenomenon of "not in my backyard" (NIMBY) and "not in any-ones backyard" (NIABY). Landfill sitting requires to process large volume of spatial data from variety of sources. The ability of GIS was used to process such data and simulate the necessary economic, environmental, social, technical, and political factors. Advantage of benefits such as (1) capture, store, and manage spatially referenced data; (2) provide massive amounts of spatially referenced input data and perform analysis of the data; (3) perform sensitivity and optimization analysis easily; and (4) communicate model results were taken for landfill sitting. For solving the difficulties of decision makers in handling large amount of complex information Multi Criteria Evaluation method was used (MCE). The integration of GIS and MCE was used as a powerful tool to solve the landfill site selection problem as GIS provides an efficient manipulation, presentation and MCE supplies consistent ranking of the potential landfill areas based on a variety of criteria. The objective of this study was to design a transferable and trans-national framework for site selection. Arc GIS 9.0 was used as a GIS tool for map analysis. The analog maps of Cumra, which has 1/25,000 scale topographical maps, were digitized to UTM coordinate system by applying the on-screen digitizing method. Land use and land use capability classification maps were obtained from the Turkish General Directorate of Rural Services (GDRS), Data related to Soil and water was collected form National Information Centre at 1:25,000 scales. The methodologies used are based on a composite suitability analysis using map overlays and their extension to include statistical analysis. An Indexed overlay method was used to rank maps. In the method, each factor maps will be assigned ranking, as well as the maps themselves receive different weights. The suitability criteria Distance from: urban areas, transportation network, railways, archaeological sites, wells, irrigational canals, agricultural land class, and land slope map were used. For each suitability criteria a map was created and finally all maps were overlay to each other to produce final map. Turkish Solid Waste Control Regulations were also followed while doing analysis. At the end of the analyses, appropriate MSW landfill sites were identified.

In [11] Dadras M. and et al. had done deep study for management of solid waste and landfill site selection in Bandar Abbas city, south of Iran. For the completion of goal authors has studded work of Jensen and Christensen (1986), Kiker (2005) in which guidelines about site selection by using raster as well as vector based GIS are present. In the study authors used the methodology of composite suitability analysis using thematic map overlays and their extension to include statistical analysis. To find best landfill site acceptable to environment as well as human safety, authors designed a digital GIS database of spatial information. Two different criteria were used in the study. First the criterion by using prosperity augmentation is increased. And second the criteria by using which prosperity augmentation is drop down. Maximum scaling point and minimum scaling point equations were used for standardization. By using these equations the study area was classified into two areas as Unsuitable (0) and Suitable (1). For decision making purpose AHP (Analytical Hierarchy Process) method of Saaty (1977) was implemented in Arc GIS. Percussion was taken to get weight sum to one when multi criteria evaluation is done by using weighted linear combination method. Pair-wise comparison scale from 9 to 1 i.e. 9 for extremely preferred and 1 for equally preferred are used for AHP preferences. The CR (consistency ratio) keep track for that probability matrix ratings were generated randomly. Final RIW (Relatively importance of Weight) is calculated by taking the average of each row of the matrix. The care to keep the total of all RIW will be equal to 1.0. Finally all derived zones are ranked in descending order to show priority of difference. From the topographic map a digital Elevation Model (DEM) layer was derived by using GIS. The DEM layer was categorized into various classes as Topographic, Geomorphologic, Hydrologic, Metrological, Humanistic, and Land use.

Gizachew Kabite and et al. in [12] solved the problem of suitable landfill site selection for Addis Ababa, Ethiopia. According to authors landfill site for study area was defined in 1947. This site was not suitable for human health and environment. Also it was insufficient for today's tremendous solid waste generation as there is increase in population and urbanization. As a need of time it requires such a landfill site which is selected by considering the criteria underlying soil structure, topography, surface water or hydro-geological aspects. According to the authors integration of GIS and Remote sensing (RS) helps to find suitable landfill site by reducing time and increasing accuracy. In addition to GIS and RS, Multi-Criteria Decision Analysis (MCDA) overcomes the limitations in planning and decision making. The data used in study was the geology map of Addis Ababa. From the geology map geological information was generated. Borehole points, hydraulic conductivity, soil map, land-use/land-cover were considered. To obtain above data landsat ETM+, SPOT of 2005 and master plan of the city were used. Slopes were derived by using DEM. As data; road networks and ground control were also used. The method to derive suitable site passes through two steps. In the first step GIS was employed to find unsuitable area by using various criteria. Criteria were classified into five classes as very high, high, moderate, marginal and unsuitable. Each criterion was then ranked from 5 to 1. The layers derived by applying various criteria were weighted based on minimum and maximum distance. The layers were standardized and thematic maps of each criterion were produced. In the second stage, importance of each criterion with relative to rest of the criterion was expressed by assigning weights. By assigning weights importance or preference of each criterion was decided. AHP model was used to compare tow criteria at a time based on expert judgment and a pair wise comparison matrix from which a set of weights referred to as Eigenvectors together with consistency ratios were generated for each of the criteria being considered. Weighted Linear Combination (WLC) technique was applied to produce an overall landfill suitability map. At the end of study they found 7.7 % of the study area was suitable for landfill sites. Out of suitable area 12 candidate sites were suggested, and out of 12 candidate sites; site 2 was most suitable for land filling.

[13] Is one of the most successful attempt done by Ahmad Al-Hanbali and et al. to make analysis for finding disposal site for Mafraq City, Jordan. The essential data for finding waste disposal site was acquired from various sources such as from interpretation of Landsat satellite; data maps of urban and agriculture area, from department of statistics; road network data, from ministry of water and irrigation; surface aquifer, depth to water, well maps, from geological map of scale 1:250000 fault system data, From the interpretation of digital elevation model of SRTM data available at GLCF land cover facility stream network and slope are gained. All these data stored into GIS. ArcGis software and its extensions were used to apply WLC analysis. Integrated analysis is done by using the ability to weight and combine multiple inputs of weighted sum analysis. Authors used the criteria "GIS-assisted Constraints Criteria for Planning Landfill Sites" designed by S. J. Baban and J. Flannagan for site selection by adjusting it as per study area situations. By using these criteria final map ranged from the most suitable to not suitable were generated. All the attributes of input data scored to represent land constraints ranging from 0 to 10.weights were used to show the relative importance. To obtain the output map meaningful and consistent weight was added up to 100%. For each map the same criteria was used for scoring attributes. By keeping in mind every factor is not equally important; each factor was given different importance. As there are no any regulations for solid waste site selection for Jordan authors has followed the criteria used in U.S. and from other countries derived from literature review. Total nine suitability criteria were considered in the study as distance from agricultural lands, distance from roads, aquifer media, depth to water table, distance form faults, distance from wells, distance from streams, and slope. Final map was produced using WLC after ranking each criterion to comply with a specific scheme. The factors that affect directly on the community such as distance from urban areas, distance from agricultural lands, and distance to wells are given higher weight as compare to the factors of lower effect. Equation

$$S = \sum WiXi \tag{4}$$

was used for WLC analysis. While landfill site selection generated land suitability map was classified as most suitable, suitable, moderately suitable, poorly suitable and unsuitable. From the study of land suitability map three solid waste

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disposal sites are suggested comply with minimum requirements of the landfill sites for study area.

In [14] As per Ayo Babalola, Ibrahim Busu landfill is one of the most used and cheapest methods used as a solution to municipal solid waste. It was the study to determine landfill site for Damaturu town Nigeria with the help of GIS and MCDM method known as Analytic Network process. For landfill site selection authors considered environmental factors to keep environment away from risk. Landfill site should be located away from residential, settlement, flooding areas. The other important factors like land use, roads, slope, wind direction etc were also given the importance. The land use which encompasses of residential areas, settlement, roads, water bodies, groundwater, commercial areas, sensitive areas, recreation, and educational institution, agricultural required for study was extracted from IKONOS satellite imageries of study area on Scale 1:3000. From 1:2000 topographic maps; slope, rainfall data, wind direction speed, and soil were derived. The required thematic maps were obtained by scanning primary maps, Georeferencing, Onscreen digitization of primary, Locating GPS co-ordinates and entering in the database, Conversion of the coordinates into point data, adding attributes to desired locations. The regulations established by study area guidelines, Yobe state environmental protection agency and as per requirements of data set some are modified for landfill siting. To minimize the unsuitable sites and speed up the process of landfill siting, GIS based constraint mapping was followed. The data available in analog or hardcopy format was scanned and digitized to use in GIS. Conversion of data layers from vector to raster was performed. A scoring system 0 indicating unsuitable to 1 indicating signified suitable was used for reclassification of layer values. For assigning suitability and unsuitability values buffering was done on various layers. Thematic layers were analyzed by overlaying method. ArcGis software was used to process the data. Pair wise comparison matrix method of ANP was used to obtain relative importance weight for each factor. The ANP was used to study interdependency among different layers of criteria that produce composite weights which are used to create a 'super matrix'. Contour maps were generated with the help of ArcGis software. Digital elevation model was evaluated form contour, and from DEM slope layers ware obtained. Land use, road network layers were obtained through interpretation of IKONOS satellite image and development plan of the study area. From soil map soil layer was generated. Rainfall layer, groundwater layer were prepared. From data of ministry of water resources groundwater layer was prepared. Finally 14 sits were selected out of which only 7 are selected as environmentally, socially and economically suitable for municipal solid waste land filling.

In [15] By keeping in mind to study the current status of solid waste management, to examine affecting factors in finding solid waste site and to find the suitable solid waste site by using multi-criteria analysis decision with the help of GIS, Professor Suman Paul has critically study on Nabadwip Municipality, West Bengal, India. The primary data for study was collected by survey method. A questionnaire was prepared and separate interviews were taken for household from each ward, Market owners, shopkeepers etc. The data related to industrial waste, hospital waste and other sources of waste was collected from Nabadwip Municipality. Also from the authority of Nabadwip Municipality map data about location of schools, colleges, commercial houses, water bodies, drainage lines, road network, land use etc to formulate the base of multi-criteria analysis. In the present study author implemented the capability of GIS to extract the spatial feature or classify it for searching suitable sites. The capability of GIS to support spatial decision making is structured as intelligence phase, design phase, and choice phase. A decision support system known as Multi-criteria Analysis was used to make choice of available alternatives. By using MCA various criteria were combined together to produce single composite base, a score function to make decision to achieve decided goal. Expert classification shell has been integrated with GIS software and used to locate suitable sites for solid waste disposal in the study area. Only environmental, economic, social and technical-operational criteria were considered during study even though there are numerous criteria present. The criteria altitude, the design of the site, i.e. hydrological evaluation, and grading of the surfaces/protection of the slopes, access roads, and the distance from the main source of waste consumption comes under technical-operational were rated as Very suitable, moderately suitable, and less suitable. Authors study is a solution to manage solid waste of municipality by using advanced technology GIS and MCA in which only most important criteria were considered.

In [16] H. Shahabi and et al. were used Index overlay and fuzzy logic models to find suitable locations for disposal areas to Saqqez city in Kurdistan province in North West of Iran. While finding disposal areas different data layers were used in the study. Particularly Elevation, slope, fault, Earthquake spots, land use, litho logy, Suitable area, precipitation, orchard, floodplain underground water, protected area, river, city, village, road, power pipe line were used. Limitation maps and factor maps were generated by taking into consideration the characteristics and their effect on disposal sites. By using limitation maps; areas that cannot be used for disposal sites were sorted. These are also known as binary map because the areas which are not suitable valued as 0 and suitable areas are valued as 1. For overlaying of maps Boolean operator AND is used. For deciding proximity to the roads factor maps were used in the study. Factor weighting was done for every parameter to decide the significance of each parameter. For factor maps combination Index Overlay and fuzzy logic model were used. Both Index overlay and fuzzy logic model finds the 0.12 and 0.17 per cent of the study area as suitable respectively.

[17] Is the study done by professor Surendra Kumar Yadav, in which it was showed that, how GIS helps for site selection in waste management. While finding landfill sites, integration of various environmental and socioeconomic data and evolves complicated technical and legal parameters are to be considered. In the study it was shown that GIS technology can be used not only for site selection but also for soil management parameters. There are various methods or models by using which the difficult task of site selection can be solved. These methods or models are GIS and multi-criteria decision analysis, GIS in combination with analytic hierarchy process, GIS and fuzzy systems, GIS and factor spatial analysis, GIS-based integrated methods. Except finding landfill sites, advanced GIS technology also used for sites of recycling drop-off centers, optimizing waste management in coastal areas, estimating of solid waste generation using local demographic and socioeconomic data, and waste generation forecasting at

the local level. Most unique ability of GIS technology to capture, store, manipulate, analyze and display spatial data was used for recording of spatial data, analysis and cartographic representation. GIS technology was used in various applications such as urban utilities planning, transportation, natural resource protection and management, health sciences, forestry, geology, natural disasters prevention and relief, Author has suggested following steps for GIS based modeling for landfill site selection. 1. Conceptualization of the evaluation criteria and the hierarchy of the landfill allocation problem. 2. Creation of spatial database. 3. Construction of the criteria. 4. Standardization of the criteria. 5. Estimation of the relative importance for the criteria. 6. Calculation of the suitability index. 7. Zoning of the area under investigation.

In [18] author Debishree Khan and et al. used a method based of GIS modeling to identify a set of criteria needed for MSW landfill site. In Indian cities generally MSW is disposed in an open dump. Disposing MSW in open dump is not a proper way, it causes environmental hazards. Instead it requires effective solid waste management system. One of the most common solutions for MSW management is to allocate landfill site or solid waste site. The process of siting of solid waste landfill involves processing of essential spatial data, regulations and acceptance criteria, and correlation between them. As GIS is capable to manipulation and presentation of the efficient data and AHP supports for ranking of the potential landfill areas regarding to various criteria, so integration of GIS and AHP was used as powerful tool to solve the landfill site selection problem. To solve the problem authors used total 11 map layers including topography, settlement, roads, slope, geology, land use, floodplains, aquifers and surface water. By using GIS software thematic maps of the selected criteria were developed. To get the relevant data layers scanning, georeferencing, georectification and digitizing processes were used. By studying various authors views and taking into considerations of literature reviews information about the safe distance to a landfill site was used as standard criteria buffer zones. Raster maps of each buffer zoned layer were prepared. After preparation of all required data layers, AHP method was used to analyze the data for landfill site selection. During study authors considered only financial and economical constraint while political constraints were omitted.

[19] Is empirically proved landfill site study in Al-Hashimyah Qadaa by Mohammad Ali Alanbari and et al. Author used Multicriteria Decision Analysis and GIS technology to find landfill site. For finding landfill site various 14 criteria were determined. These are urban centers, land use, airports, pipes, power lines, railways, roads, slope, streams, surface water, industrial areas, oil pipes, liquid gas pipes, soil types. Relative importance weighting of criteria was calculated with the help of MCDA. And by using GIS techniques every criteria map layer was produced. During study authors has followed the local guidelines of Town and Country Planning Department (TCPD), waste disposal siting, and the Department of Environment (DOE). Except these they took literature reviews of related study. Importance to population growth rate, MSW volume for site area requirement was also considered. The results of study were confirmed with satellite images and field visit reviews. In the study authors has 3,156,778 m2area as suitable area for MSW of volume estimate generated in next 5 years.

[20] Was a study done by Tirusew Ayisheshim Ebistu and et al. to select most suitable areas for solid waste dumping site which will be environmentally safe for Bahir Dar Town, North estern Ethiopia. Authors used spot image with a spatial resolution of 5m, digital elevation model with 30 m spatial resolution, ground control point collected by GPS and topographical map of the study area as the basic data. Required maps for study were evaluated by doing overlay and suitability analysis of GIS, remote sensing and Multi Criteria Analysis Method (MCAM). Arc map was used for overlay analyses to design the final suitability map. From the derived final map areas were leveled as high, moderate, less suitable and unsuitable. The required secondary data for study was collected from internet, reports, books, journals, government. MCAM helped authors to minimize cost and time required for selecting dumping site. For assigning weights all factors were pair wise compared as per their importance using Satty (1977) logic. Required classification of the layers was done to assign values in the range of most suitable to unsuitable. Also layers were reclassified into scoring system as 1 representing unsuitable, 2 representing less suitable, 3 representing moderate suitable and 4 representing highly suitable. The same procedure was applied for all factors and a matrix is designed with values which represents the importance of factor to factor. A Consistency ration (CR) was calculated by following the rule that CR less than or equal to 0.10 for acceptable reciprocal matrix and larger than 0.10 as not acceptable. As a result of all above work, authors come to the conclusion that 11.9% area was most suitable, 21% was moderately suitable and 1.3% was less suitable, and the remaining area cannot be used for dumping site.

Table 1 lists the Methodology used for solid waste management along with Area, Data, and Criteria used in the study of all above literature review.

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TABLE I. VARIOUS METHODOLOGIES USED IN SOLID WASTE MANAGEMENT.

| No. | Study Area | GIS Used for | Methodology | Data | Criteria/Constraint/Factors | Reference No. |
|---|---|---|---|---|---|---|
| 01 | Sinai Peninsula | Mapping potential landfill sites | Spatial multicriteria evaluation using with the help of GIS , AHP and WLC | Analog maps, vector format, | Permeability, Ground water depth, Distance to sabkha, Distance to faults, Distance to shores, Distance to protected national parks, Distance to high order streams, Distance to cities, Slope of the terrain, Distance to power supply, Accessibility, Archaeological sites, Airports, Aspect | 1 |
| 02 | Liao Dong peninsula, and the Sichuan basin | Urban Growth Analysis | - | Digital aerial orthoimages | - | 2 |
| 03 | Vientiane Capital City | Solid Waste Management in Urban Areas | Composition of physical data from digital map and photos, A Pilot Project, map visualization, Map overlay techniques | Digital map and photos, attribute data are the statistics data and report | - | 4 |

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|---|---|---|---|---|---|---|
| 04 | Ilorin, Nigeria | Spatial Location of Municipal Waste Bins. | GIS based optimization, digitization, Facility Location Function in the GIS package, p-median problem | Satellite image, spatial database, vector spatial data and attributes data | - | 5 |
| 05 | Aurangabad City, India | Solid Waste Management Planning | Collection of city information, data. Designing of database by scanning, georeferencing and digitizing, Literature review, Analysis of situation. Module design. | Satellite image (ETM), vector data, Municipal maps, spatial data, attribute information, interview, questionnaires and online sources | City boundary, Bin location, land use- (schools, hospitals, religious, theaters, Halls, offices), road network, Env. Sensitive – Water streams, Shops, | 7 |
| 06 | Pondicherry, India | Optimized siting of municipal solid waste landfill | Multi-criteria decision analysis (MCDA) and overlay analysis using a geographic information system (GIS) | Top sheets of Pondicherry (viz., 58 M/13, 58 M/9, 57 P/16 and 57 P/12 of the scale 1:50,000),Maps of water bodies, road network, elevation, Maps of Geology, soil, fault line, water supply sources, and groundwater, IRS1D imagery of Pondicherry of 22.8 m resolution | Lake and ponds, rivers, water supply sources, groundwater table, groundwater quality, infiltration, air quality index, geology, fault line, elevation, land use, habitation, Highways, sensitive sites. | 8 |
| 07 | Khulna City, Bangladesh | Suitable sites for Urban Solid waste Disposal | Multi criteria Decision Analysis and GIS integration standards. | Thematic maps, Satellite image, spatial and nonspatial data, attributes | Drainage, Accessibility, Water body, Soil, Commercial Establishment, Socio Cultural Institution, Educational Institution, Health Facilities, Administrative offices, Land use, | 9 |
| 08 | Konya City of Cumra County | Selection of MSW landfill site | Integration of geographic information Systems (GIS) and multi-criteria evaluation, map overlay. index overlaying | Digitized information, analog maps (M29-c1, M29-d3, M29-d4) of study area, topographical maps of 1/25,000 scale. | Social, environmental, technical, and financial factors, Urban, Agricultural land, Roads, Wells, Railway, Archeological sites, Irrigational canals, Land slope | 10 |
| 09 | Bandar Abbas city, south of Iran | Urban solid waste management and Landfill site selection | Composite suitability analysis using thematic map overlays and their extension to include statistical analysis, MCDM, AHP, | Spatial information, Geology map, hydrology map, Hydrogeology map, Climatology map, Eco-sociology | Slope, Class of soil, Distance from fault, Distance from river, Distance from well, Rainfall, Temperature, Distance from city and village, Distance from roads, Distance from protect area, | 11 |
| 10 | Addis Ababa, Ethiopia | Solid Waste Landfill Site Selection | GIS based multicriteria methodology, MCDM | Geology map of Addis Ababa, Litho logy data Landsat ETM+,SPOT of 2005 and master plan of the city, Topographic map(1:50,000),spot image, GPS data, | Geology, Slope, proximity to river/Streams, proximity to Faults, proximity to Airport, proximity to Roads, Ground water level, proximity to well, Hydraulic Conductivity, soil type, Land – use / Land-cover | 12 |
| 11 | Mafraq City, Jordan | Optimum Solid Waste Disposal Sites | GIS-Based Weighted Linear Combination Analysis and Remote Sensing Techniques, Integration of GIS and MCE | Landsat data of 1989, 1999, and 2009, spatial data (maps, aerial photographs, and satellite images), Landsat Thematic Mapper (TM) 1989, a Landsat Enhanced Thematic Mapper (ETM+) 1999, and a Landsat TM 2009 | Urban area, Agriculture land, Road network , Surface Aquifer, Depth to water , Fault system , Well , Stream network , Slope | 13 |
| 12 | Damaturu town Nigeria, | Selection of Landfill Sites for Solid Waste Treatment | Analytic network process (ANP) - combining geographic information system (GIS) and a multi-criteria decision making method (MCDM) | IKONOS satellite imageries of study area on Scale 1:3000, Topographic maps of 1:2000, digital thematic maps | Road Network, Infiltration Map, Elevation Map, Groundwater Table Map, Wind Orientation and Pattern, Distance from Road Network, Surface Water body, Sensitive Areas, Rainfall, Aspect | 14 |

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|---|---|---|---|---|---|---|
| 13 | Nabadwip Municipality, West Bengal, India | Allocation for urban waste disposal site | Multi-criteria analysis decision with the help of GIS, | Map data about location of schools, colleges, commercial houses, water bodies, drainage lines, road network, land use, | Road network, Population distribution, Land use Pattern, Water Bodies, Health Care Facilities, Educational Centers, Commercial Establishment, | 15 |
| 14 | Saqqez city in Kurdistan province in North West of Iran | Site selection of waste disposal | GIS model(Boolean, index overlay, and fuzzy logic models) and Spatial analysis method | Map of study area, Spatial data of study area, data layers of scale 1:250,000, Maps of all data layers | Elevation, Slope, Fault, Earthquake spots, land use, Litho logy, Suitable area, precipitation , Orchard, Floodplain, Under ground water, Protected area, River, City, Village, Road, Power Pipe line | 16 |
| 15 | - | Identify appropriate solid waste disposal site | AHP, WLC technique in GIS environment, (state-of-the-art technologies) | Thematic maps, spatial data, | Geology (litho logy), groundwater depth, water supply well points, hydraulic conductivity/ soil structure, land-use/ land-cover, slope, drainage pattern (water bodies), roads, airport locations | 17 |
| 16 | Asian Municipality | Landfill Siting for Municipal Solid Waste | GIS based modeling and AHP | 11 input maps including topography, settlements roads , slope, geology, land use, floodplains, aquifers and surface water, Thematic map of defined criteria, layer maps, raster maps | Topography, settlements roads , slope, geology, land use, floodplains, aquifers and surface water, | 18 |
| 17 | Al-Hashimyah Qadaa | Landfill Site Selection | GIS and Multicriteria Decision Analysis | Spatial data, Study area map, Thematic maps of decided criteria as layers | Surface Water, Slope, Streams, Roads, Railways, Pipelines, Power Lines, Urban Centers, Soil Types, Land use, Industrial Area, Airport, District Center, | 19 |
| 18 | Bahir Dar Town, North Western Ethiopia | Solid waste dumping site suitability analysis | Overlay and suitability analysis of GIS, remote sensing and MCAM | Spot 5 image with a spatial resolution of 5m, digital elevation model with 30 m spatial resolution, ground control point collected by GPS and topographical map of the study area | Land use/land cover, drainage density, slope, roads, Rivers, lake, Protected area, Settlement, Urban center, | 20 |