CHAPTER - III

LITERATURE REVIEW
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3.1 Introduction

The disposal of garbage has been a great problem faced by all nations over the world. As population grew and prospered, the amount of garbage generated also increased. Initially waste generated was dumped above or below ground in rural areas, which was the most economical method of waste disposal. However, due to the growing concern for ground water resources contamination, public health and safety and scarcity of suitable land, land filling has become expensive now a day. Also, due to the increased public awareness of the health and safety problems associated with landfills, finding appropriate land was a riddle for the government and the others involved in waste management. Thus, the problem of waste disposal was persistent and demands careful attention all over the globe.

The task of resolving this problem requires an integrated approach that involves not only the policy of the government, but also demands active participation of corporations nation wide and most important, the public. Apart from the practical measures, there exists a need for employing a comprehensive method of land filling which is safe, economical and acceptable to both, the people and the environment.

The existing literature on selection of appropriate sites for developing a landfill, criteria to be considered and the role of remote sensing and Geographical Information System (GIS) in selecting a disposal facility in different countries with different environmental settings was reviewed in this chapter and the applicability of the above suggested methods in the earlier works for the site selection in the present study area were critically examined.
3.2 Remote Sensing and Geographical Information System for Landfill Site Selection

Remote sensing and GIS plays an important role in site selection studies since most of the information involved include spatial component, integration of information from various levels of jurisdiction (city, zone range and health ward level), requires assimilating voluminous information for analysis, non-availability of organized maps of other data, lack of properly updated data and comprehensive or cohesive system to handle large amount of data. GIS is ideal for preliminary waste disposal site selection studies since manual method of selections is very tedious.

The ability of overlay gives it a unique power in helping us to make decision about the identification of waste disposal sites. Once a GIS database was developed, it provides an efficient and cost effective means of analyzing the best disposal of solid waste. Integration and correlation of the information related to the factors considered for site selection, which is very complex, can be handled easily with GIS. On completion of data analysis GIS helps in planning and managing the environmental hazards and risks. GIS supports activities in environmental assessment, monitoring and mitigation and can also used for generating environmental models.

Sumathi et al., (2007) carried out a study on the siting of a new landfill in the Pondichery region using a Multi-Criteria Decision Analysis (MCDA) and overlay analysis using a Geographic Information System (GIS). Water supply resources, sensitive sites, land use, air quality, groundwater quality and geology are the several factors considered in the siting process. Depending upon their relative importance, the weightings were assigned to each criterion. A set of 17 potential sites was identified in the first level of analysis while subsequent screening and refinement on the basis of existing microscopic factors led to the
optimized selection of the 3 most suitable sites for landfill construction. The sites were ranked on the basis of area availability. Sites 1, 5 and 13 covering areas of 0.36 km\(^2\), 0.11 km\(^2\) and 0.06 km\(^2\) respectively, were chosen as the most suitable for landfill construction.

Shaker and yan (2011) evaluated the use of multi-temporal remote sensing data to monitor and assess the effects of landfill sites on the environment. The study area covers the Trail Road landfill site which is the main municipal waste disposal site for the city of Ottawa. The differences of the LST (Land Surface Temperature) between the landfill sites (due to the release of the landfill gases within the landfill site) and the surrounding areas were analyzed. The LST of the landfill sites is monitored to assess the decomposition activities of the waste disposal.

Preliminary data analysis revealed that the LST of the landfill site was higher than the immediate surrounding areas and the air temperature during the decomposition process by up to 9 °C and 14 °C, respectively. On the Trail Road landfill site, the LST of the active phases of the landfill site is higher than the closed phases of the landfill site by around 3 to 5 °C. The SAVI (Soil Adjusted Vegetation Index) was used to investigate the healthiness of the vegetation of the immediate surroundings areas. The calculation of the LST of the landfill sites for the period from 1985 to 1993 shows decline in the LST of the landfill sites.

A potential site for an appropriate landfill area for Ramallah Governorate was determined by using Geographic Information System as a tool to aid the decision making process was carried out by Mahamid and Thawaba (2010). By using multi-criteria analysis, a potential site was allocated taking into consideration of the sensitive areas and found the best location for the regional landfill site. The site was selected with an area of 10.2 donums
which is located near Dir – Dibwam village with low to very low vulnerability which gives a high ability to prevent leachate comes from waste to reach ground water. Also the site is located in clayey area that has less permeability, with a slope less than 5% that will prevent any pollutant to be mixed with drainage water.

Harveen et al., (2002) carried out a study in the preparation of a zoning atlas for siting of industries in Kanpur city using a Geographical Information System (GIS). This zoning atlas was prepared based on the guidelines from the Central Pollution Control Board (CPCB, 1995), using ILWIS 3.0 GIS environment. The database mainly comprised of topographic maps, thematic maps and groundwater information. Buffering and overlaying of thematic maps has been carried out as per the guidelines of CPCB. Many industries cause air pollution as well as surface water pollution together. Their combined suitability is determined in the industrial suitability map by combining air pollution sensitivity map, surface water pollution sensitivity map and sensitive zone map. The zoning atlas classified the environment in the district and depicts the pollution tolerating potential of various sites/zones in the district.

Gholamreza et al., (2012), selected a suitable landfill site for waste disposal in Malayer region including Seven main criteria i.e., geomorphology, geology, slope, distance from faults, settlement, streams and main roads using GIS. The final suitability map was prepared by performing multi criteria analysis methods and simple additive weighting method. The total area of the Malayer city was classified into five groups as very low, low, medium, high and very high suitability for the selection landfill sites. Based on the final
suitability map, the suitable areas for landfill construction are located in northern and southern parts of the study area.

Javaheriet al., (2006) carried out a study in identification of municipal solid waste landfill site using the Analytical Hierarchy process method in Giroft city in Kerman province of Iran for landfill. Water permeability, slope, distance from rivers, depth of the underground water table, distance from residential areas, distance from generation centers, general environmental criterion and distance from roads are the criteria which have been taken into consideration in the process of analyzing. Superposing all of the raster type layers including geomorphologic, hydrologic, humanistic and landuse criteria in land suitability, the final zoning of appropriate, fairly appropriate and inappropriate districts have been identified.

Considering the relative priority of all criteria in comparison with others, a specific weight is designated to each criterion according to their total influence on the whole process of decision making. The results from the application of the presented methodology are zoned for landfill with varying zonal land suitability. Finally the zones will be ranked in descending order to indicate the priority of different options and the results achieved by this study may help policy makers of the Giroft city with a variety of options for being considered as sanitary landfill locations.

Zeinhom et al., (2010) carried out a study on locating the most suitable landfill in Mansoura city, Egypt. This was achieved by using an integration of the Geographical Information System (GIS) and Multi Criteria Decision Making (MCDM) method. Processing of a significant amount of spatial information can be done by GIS, an important tool for land use suitability analysis. Eight input map layers were prepared and two different MCDM
methods i.e., Weighted Linear Combination (WLC) and Analytical Hierarchy Process (AHP) are implemented in GIS.

The suitable areas were further examined by deploying the AHP method in order to obtain relative importance weights followed by the application of WLC methods for a calculation of suitability index. The pairwise comparison model was utilized to determine the relative weights of the decision criteria which is then integrated with the GIS Boolean and FUZZY logic model to produce feasible sites for landfill siting in the study area. The resulting land suitability was reported on a grading scale of least to the most suitable areas 1 to 5. Finally, five areas were identified as the most suitable location for landfill with the grading values greater than 2.67.

Hasana et al., (2009) assessed landfill demand for disposal of MSW of Dhaka city, by projecting population and waste generation for the period 2007-2025. Multi-Criteria Evaluation (MCE) on various raster map layers was done in GIS environment. Various map layers of Dhaka city (1734 km$^2$) were prepared using standard exclusionary criteria. Map layers were then overlaid and combined using a Weighted Linear Combination (WLC) method. In the suitability analysis for weighting of factors a pairwise comparison method provided by the Analytic Hierarchy Process (AHP) was used which was built-in the GIS environment.

Finally three suitability maps have been produced. In the final suitability maps suitable areas have been produced on a scale of suitability ranges 0 to 255. Then the best suitable areas (sites) have been identified through analysis and ranking of the sites has been done for landfill development. In this study area of which suitability ranges between 200–255 were selected for landfill construction.
Selection of potential waste disposal sites using Remote Sensing and GIS techniques for Karaikudi Municipality was identified by Tamilenthithi et al., (2011). Selection of suitable sites for waste disposal was based on several factors. On the basis of integration of various parameters IRS- P6 LISS III imagery and GIS as a tool have been found to be very useful for the interpretation and identification of solid waste disposal sites. A buffer of 5 km distance area of the municipality office is extracted and the suitable parameters viz. LU/LC, road, ground water depth, soil and litho units have been considered. GIS technology using weighted overlay analysis help to select the possible suitable solid waste disposal sites and was categorized into three categories. They are Good, Moderate and Poor. The first appropriate site is the southern portion of Illuppakudi and the second site can be selected anywhere in the 4-5kms buffer arc, which might be suitable for transportation, environmental and economic point of view.

Hanbali et al., (2011) assessed the trend of urban expansion and selected optimum solid waste disposal sites within Mafraq City using GIS based weighted linear combination. 1989, 1999 and 2009 LANDSAT data were used to support the selection process of disposal sites. A GIS combines the spatial data viz., maps, aerial photographs, and satellite images with qualitative, quantitative and descriptive information databases, which can support a wide range of spatial queries (Church, et al 2002). Weighted Linear Combination (WLC) is one of the widely used MCE methods for land suitability analysis (Murray et al 2010). It was found that about 84% of the study area were within “most suitable” to “moderately suitable” classes for landfill sites and the rest of the study area was within “poorly suitable” and “unsuitable” classes.
Yahaya et al., (2010) identified a suitable landfill site for waste disposal in Ibadan North Local Government Area of Ibadan, Nigeria. Geographical Information System (GIS) and Multi Criteria Evaluation (MCE) were applied in order to rank the sites. The overall solid waste management was said to be below standard as adequate provisions of waste collections and disposal were not made for the population especially within households and commercial centers. Most of the areas were not provided with bins and this has led to the creation of many illegal dump sites. This results in degradation of the environment at an alarming rate.

Two potential sites were identified and one selected as a better alternative using Analytical hierarchy process. This study has shown that the integration of GIS and MCE was of utmost importance for effective and efficient waste management.

Nishanth et al., (2010) determined suitable site for the disposal of urban solid waste disposal in Kottayam municipality and surrounding areas using GIS technique. The most common problems associated with improper management of solid waste include the transmission of diseases, odor nuisance, atmospheric and water pollution, fire hazards, aesthetic nuisance and economic losses. At present most of the municipal solid waste in India is being disposed unscientifically (Akolkar, 2005). The principal sub criteria that used for spatial analysis are lithology, geomorphology, slope, drainage, population and distance from major roads, distance from major streams and distance from drainage. For the analysis, all the raster datasets for different layers having different score were overlaid and the scores of each composite class were added using the raster calculator tool of spatial analyst extension of Arc Map. The final scores were reclassified to generate the output map showing various classes of suitable sites for waste dumping. Total area including buffer zone covers 24.61536 Km². The results shown that 4.2909 km² area is very less suitable , 14.1833 km² area is less
suitable, 3.90096 km$^2$ area is moderately suitable, 1.5824 km$^2$ area is highly suitable and 0.65773 km$^2$ area is very highly suitable for dumping waste. It was identified high and very high suitable areas between Manganam and Vadavathoor and also in a Mulavattam area of 0.65773 km$^2$ is very highly suitable for dumping waste.

Ansari et al., (2012) used remote sensing and GIS techniques to select the best dump site within the vicinity of Mafraq city. One of the biggest challenges was the proper site selection for solid waste disposal for its direct effect on the community and the environment (Davis and Cornwell, 1998). Sites were selected using 18 aerial photographs (scale on 1:10000) taken in the year 2000 to construct the data layers showing roads and extension of Mafraq city. All the maps were reconstructed in a "Grid" which is Raster Data composed of vertical and horizontal rows which enable Arc View 3.1 (Spatial Analyst) software to analyze the data. The conditions set for the analysis were based on the USA and EU regulations taking into consideration the special conditions related to the studied area. These are the following conditions:

a. The distance of the dump site should exceed 500 m to the nearest village.

b. The dump site should be close to roads for easy access.

c. The rocks should be impermeable to ensure protection of ground water resources.

d. The dump site should be at least 60m away from the faults and joints.

e. Ground water should be deep enough to ensure protection from leaking material.

f. The dump site should be at least 500 meters away from the nearest ground water well to prevent pollution.
g. The area to be used as a dumping site should not fall within the category of agricultural land.

h. The site to be used should be at least 200 meters away from the nearest valley or drainage system to ensure that draining water does not transport the waste dumped.

i. The area to be selected should be nearly flat (slope should be less than 4).

j. Average rainfall should be low on the selected site.

Ten sites were selected with a total area of 74,5000m$^2$. Less restriction was used for the five groups concerning the elevations and type of rocks. The overall selected sites cover an area of about 23,5500m$^2$.

Rahman et al., (2008) carried out a study on the identification of suitable sites for urban solid waste disposal using a GIS approach in Khulna city. Location of disposal sites of Khulna City Corporation (KCC) represents the unconsciousness about the environmental and public health hazards arising from disposing of waste in improper location. Based on the criteria such as drainage, water bodies, soil, land characteristics and population, disposal sites were classified as highly suitable, moderately suitable and less suitable. To gain the prime objectives of the research work the suitability of the sites was classified on the basis of different criteria as less suitable, moderately suitable and highly suitable. For highly suitable sites, the criteria such as distant 100m from drainage, 200 m from any water body, 200 m from the hotel, market and shopping centers etc., 500 m from the bank, 200 m from socio-cultural institutions, 1 km from educational institutions, health facilities and administrative offices were considered.
Suman (2012) investigated most suitable site, as a waste disposal sites for Nabadwip municipality which is located in the extreme west of Nadia district, West Bengal. A suitable disposal site must follow 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. Criteria for site selection included natural physical characteristics as well as social, land-use, ecological and economic factors. Geographical Information System (GIS) has provided an opportunity to integrate field parameters with population and other relevant data. Multi-criteria decision analysis was used in the selection of suitable disposal sites for dumping of solid waste.

In Greece, Hadjibiros et al., (2011) found several examples of inefficient MSW management and curious landfill site selection and also criticized environmental policy issues for MSW management in Greece and identified weak points in the criteria used for the selection of landfill sites. There was an urgent need to update MSW management practices, the demands of current European legislation, the fundamental weakness of landfill site selection methods, as well as the intense and extended social protests and concluded that there was a real need for rational MSW management based on high quality scientific input. For the said purpose, the following directions were suggested:

- The country should go for recycling, by sorting at the source directly.
- Actual national and regional MSW management planning schemes should be revised.
- MSW sorting systems at the source and public awareness campaigns could be financed by EU structural funds earmarked for mechanical sorting and landfill facilities.
Naser and Hajizadeh (2011) carried out study on landfill site selection for disposal of hazardous waste in Khorasan Razavi Province. The disposal was the final step of any hazardous waste management plan. An inappropriate landfill site may have negative impact on environment, ecology and economy. In the present study, potential sites for hazardous waste landfills in the northeastern Khorasan were determined using the integration of Geographic Information System and landfill susceptibility zonation methods. Inappropriate areas were first removed from the model and the suitability of remaining regions were evaluated using 15 different criteria in two steps.

Nine suitable sites were selected as the most suitable locations based on environmental impact assessment (Leopold matrix) and economical studies. This study has shown that the Maasumabad, Kheirabad, Mayamey and Yonsi are the best locations for the constitution of landfill in Khorasan Razavi province, respectively.

Singhet al., (2012) marked out the selection of best alternative site for municipal solid waste land filling, using inputs from Global Positioning System (GPS) and Remote Sensing and analysis using GIS tools. Urban solid waste management needs careful considerations and it has become one of the most serious environmental problems with municipal authorities in developing countries like India. Selection of SW (Solid Waste) disposal site involves various parameters like geology, land use, water table, economy and government rules have been stored in the form of the GIS database. Overlay and buffer analysis have been performed in Arc GIS 9.1. In this investigation Dhuankhera site found appropriate for the waste disposal and the methodology can be implemented. The only inert portion of MSW may be land filled in properly designed engineered landfill site at Kajrikheda (Dhuakherachichali) Kolar municipality.
3.3 Land Use Land Cover Mapping

Sateesh and Sandip (2011) used remotely sensed data to fill the gap in the knowledge on the state of land use and Land cover in Tikamgarh district. Tikamgarh district is located in the northern part of Madhya pradesh. An attempt was made to generate the land use land cover map from IRS satellite image using unsupervised classification. SOI Toposheets, IRS-1C LISS-III + PAN data were used. A detailed, spatially explicit inventory of local trends in land use and land cover changes was taken and the data were coupled with the interdisciplinary assortment of scientific methods. The causes and consequences of land use/cover change across a range of spatial and temporal scales were investigated. The area of cropland was more than the others and it was clearly shown by land use and land cover map. The superior performance of neural network in terms of good classification accuracy has reported.

Prakasam (2010) made an attempt to study the changes in land use and land cover in the Kodaikanal Taluk over a 40 year period (1969-2008). It was studied through remote sensing approach using, SOI Taluk map of Kodaikanal (1969) and LANDSAT imageries of the year 2003 and 2008. The land use land cover classification was performed based on the Survey of India Kodaikanal map and Satellite imageries. Thematic maps were prepared using GIS software. The forest area that occupied about 70 % of the area in 1969 has decreased to 33 % in 2008. The changes in built up areas, agricultural land, harvested land and wasteland are studied. Settlements have increased from 3 % to 21 % of the total area.

Wani and Khairkar (2011) investigated the land transformation of Srinagar city. Land use/ land cover change study was very important aspect of the natural resources database
study. The land use/land cover for the year 2011 was carried out using SOI Toposheets, IRS – 1D LISS – III and PAN merged satellite imageries. The data were classified into 13 land use land cover spread over a total of 23, 446.5 hectares of the Srinagar city. The statistical analysis of the multi – temporal land use / land cover maps of the Srinagar city reveals that significant changes have taken place since 1970-2011. Urbanization of Srinagar city and land transformation has severely affected the aerial extent of cultivated land, water bodies, marsh area etc. The built up area of the city has increased from 2556.50 hectares in 1971 to 6626.03 hectares in 2011 whereas non – built up area had drastically decreased from 20890.00 hectares in 1971 to 16820.47 hectares in 2011.

Kalpana and Thanush (2011) presented a clean way of multi-scale amalgamation for high resolution remote sensing images for change detection. Image classification is perhaps the most important part of digital image analysis. The image processing software system was used to develop a statistical characterization of the reflectance for each information class and was often called “Signature analysis”. The age old methods of change detection are not suitable for high resolution remote sensing images. The limitations of traditional pixel-level change detection of high resolution remote sensing images were overcome by georeferencing and analysis method. It was shown that this method has a stronger advantage than the traditional pixel-level method for high resolution remote sensing image change detection. The remote sensing data has analyzed to fix the land cover classification of Coimbatore city.

Manonmani and Mary (2010) carried out a study on detection of the land use changes in Villivakkam between 1990 to 2005 using satellite images of LANDSAT- 7 ETM+ (1990), IRS-LISS III (2005) and digital topographic maps of Villivakkam block of Thiruvallur.
district. The land use/land cover changes in urban areas and hotspots of land cover changes were detected using multi temporal satellite data. The relationship between human pressure on land use/land cover and its impacts in the vital urban habitats were also studied.

Land use changes are detected using an image processing method in ERDAS imagine software to predict the change in urban habitats and land use/land cover changes occurred. Built up area has increased and was shown as change detection between 1990 and 2005 by 15.83% from 6513.29 ha to 9300.97 ha. The area with irrigated land farms have been decreased to 436.99 ha (2.48%) and the scrub land decreased to 5.19%.

3.4 Ground Water Assessment Study

A detailed study has been carried out using Geographical Information System (GIS) to understand the spatial variability of surface water and groundwater quality in Erode City by Rajkumaret al., (2011). Forty three groundwater samples and seven surface water samples were collected during February, 2009 and they were analyzed for various physical and chemical parameters such as pH, Total Dissolved Solids, Electrical Conductivity, Alkalinity, Hardness, Na\(^+\), K\(^+\), Ca\(^{2+}\), Mg\(^{2+}\), Cl\(^-\), HCO\(_3\)\(^-\), CO\(_3\)\(^2-\), SO\(_4\)\(^2-\), NO\(_3\)\(^-\) and F. The concentrations of physical and chemical constituents in the water samples were compared with the Bureau of Indian Standard (BIS) and World Health Organization (WHO) standards to find the suitability of water for drinking.

The water quality parameters were exceeded the permissible limits for drinking at many locations led to unsuitable for drinking. The groundwater quality spatial variation parameters were also plotted using GIS and found that only at four locations, the chloride concentrations were found to exceed the permissible limits during February 2009.
Spatial variations in ground water quality in the corporation area of Gulbarga City has studied using Geographic Information System (GIS) technique by Balakrishnan et al., (2011). 76 water samples were collected from the bore wells and open wells representing the entire corporation area and were analyzed for Physico-chemical parameters like TDS, TH, Cl\(^-\) and NO\(_3^-\), using standard techniques in the laboratory and compared to the standards. By using a GIS spatial interpolation technique, the ground water quality information maps of the entire study area were prepared for all the above parameters. The spatial database established in GIS for the study area has helped for monitoring and managing ground water pollution. The spatial integration for final ground water quality zone mapping was carried out using ArcGIS Spatial Analyst extension. Mapping was coded for potable zones and non-potable zones in the study area based on water quality. The spatial distribution analysis of ground water quality in the study area indicated that half of the city having non-potable ground water.

Sarala (2012) carried out the identification of groundwater prospects for Palleru sub basin using remote sensing and GIS. Quantification of the resource is basic to the formulation of plans for its exploration, management and conservation. The area partly covers three districts namely Warangal, Nalgonda and Khammam of Andhra Pradesh. The study area covers 15 mandals from these districts. The palleru basin is one of the sub-basins of river Krishna. Both spatial and non-spatial database was created with the help of Survey of India toposheets and satellite imageries. Drainage map, soil map, contour map, slope map, hydro-geomorphology map and lineament maps were prepared. After integrating all the thematic maps, the groundwater prospects map was generated for the study area using weighted overlay analysis. The areas obtained for good ground water prospects is 503.91
km$^2$, good to moderate is 658.95 km$^2$, moderate is 459.86 km$^2$, moderate to poor is 289.86 km$^2$ and poor is 29.22 km$^2$.

Asadi et al., (2007) evaluated the ground water quality in municipal corporation of Hyderabad using remote sensing and GIS techniques. Groundwater quality in Hyderabad has special significance and needs a great attention of all concerned since it was the major alternate source of domestic, industrial and drinking water supply. Various Thematic maps for the study area were prepared by visual interpretation of SOI toposheets and linearly enhanced fused data of IRS-ID PAN and LISS-III satellite imagery on a standard scale using AutoCAD and ARC/INFO GIS software.

The Physico-chemical analysis data of the groundwater samples were collected at predetermined locations formed the attribute database and the spatial distribution maps of major water quality parameters were prepared using the curve fitting method in Arc View GIS software. To find the suitability of water for drinking purposes Water Quality Index (WQI) was calculated. The water quality index of the study area revealed that most of the study area with $> 50$ standard rating of water quality index exhibited as poor, very poor and unfit water quality except in places like Banjara Hills, Erragadda and Tolichowki and suggested some methods for improving the water quality in affected areas.

3.5 Spatial Decision Support Systems for Site Selection

The most current and well-established applications of Geographic Information Systems (GIS) are complex forms of spatial analysis such as facility planning, site selection and land use planning (Tomlin and Jhonson1988; Tomilinson, 1987). Poor locational decisions in facility siting may result from a variety of factors, the most common of which
are uninformed land use planners (Hare et al., 1983). However, recent advances in GIS provide decision makers with efficient tools to organize and structure the spatial decision making process.

Methods of designing spatial models for site planning were first discussed over 30 years ago by McHarg before the advent of automated Geographic Information Systems. McHarg (1969) mapped thematic site criteria onto Mylar transparencies and when superimposed, was able to differentiate between acceptable and unacceptable zones. The methods developed were applied to a variety of social, economic and environmental problems. Spatial decision support systems have evolved out the need for high-level planners make efficient and well-informed decisions based on complex spatial tasks (Densham, 1992). The concept of spatial decision support systems (SDSS) represents an effort to address complex spatial problem solving and assist spatial decision making. Densham (1992) argues that by providing the user with a flexible problem-solving environment, the user is able to increase their awareness and understanding of the problem task, as well as refine his or her knowledge of undesirable solutions.

Lotfi et al., (2008) tried to integrate some of the models to propose a new integrated model using GIS. Many different spatial models are used worldwide for urban facility site selection, such as fuzzy logic, artificial neural network, regression, index overlay and taxonomy are the most common models, which each have its advantages and weaknesses. To increase the efficiency of the urban facilities with less environmental cost it is necessary for urban authorities to find the right way.
The fuzzy logic and Analytical Hierarchy Process (AHP) model were integrated with many environmental and socio-economic factors to select the best location for the solid waste disposal with less negative environmental impact on urban areas. The results revealed that the multi criteria models have the potential to be generalized to all cities. Moreover the model used multi factors to evaluate the different alternatives to find the most appropriated option. The presented model has a higher accuracy than the traditional methods which are common in developing countries.

Afzali et al., (2011) selected site for Isfahan city by using Fuzzy Logic and Analytic Hierarchy Process. Selecting the most suitable site for landfill can avoid any ecological and socio-economic effects. With the increase in population growth of Isfahan city, industrial and economical development also increased and generates a tremendous amount of solid waste within the region. GIS combination with decision analysis as a decision supporting system can assist decision makers in each site selection problem as an effective tool.

The Analytic Hierarchy Process (AHP) was used for weighing the information layers. The superimposing of the information layers related to topography, soil, land use, water table, sensitive ecosystems, and geology maps was performed by using the fuzzy logic method (classification of suitable areas in the range of 0 to 255 byte scale). The AHP method also facilitated decision making by breaking a complicated decision problem into easier ones, helps in reducing the complexity of the decision problem.

Asadi et al., (2010) attempted to demonstrate the capabilities and utility of remote sensing and GIS technology for the selection of suitable sites for waste disposal for Hyderabad city. A multi-criteria decision making technique called the Analytic Hierarchy
Process (AHP), provided a systematic approach for assessing and integrating the impacts of various factors at different levels of dependent and independent, qualitative and quantitative information.

According to the weightage allotted and the suitability index value obtained, entire area is categorized into 5 classes as excellent class with suitability index ranging from 0.5 to 0.6, good class with suitability index ranging from 0.4 to 0.5, moderate class with suitability index ranging from 0.3 to 0.4, poor class with suitability index ranging from 0.2 to 0.3 and very poor class with suitability index ranging from 0.1 to 0.2 with respect to landfill siting and finally the suitability map was prepared.

Tayyebi et al., (2010) presented an integrated approach which utilizes Multi Criteria Decision Making (MCDM) with Dempster Shafer Theory of evidence (DST) for the selection of landfill sites. Two stage analysis was made for selecting landfill sites in the urban region of Zanjan. The first-stage analysis made use of the maps in the Geographical Information System (GIS) in conjunction with different variables leading to support the second-stage analysis using the MCDM and DST as a tool.

GIS was performed to eliminate unsuitable land followed by utilization of MCDM and DST method to identify the most suitable site. The DST and Analytical Network Process (ANP) are used to get an individual weight for each criterion. Furthermore, sensitivity analysis was performed using Monte Carlo simulation where the decision weights associated with all criteria were varied to investigate their relative impacts on the rank ordering of the potential sites in the second stage. The results indicated that the potential site still completely dominate the other sites despite variations of the decision weights within a range of 15%. 

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Shukla et al., (2012) used Decision Support System for selecting a suitable site for disposing solid waste in and around Roorkee area, city of Uttarakhand, India. A suitable disposal site must have environmental, resource, and planning criteria that will enable the wastes to be isolated so that there is no unacceptable risk to people or the environment. The weighted linear combination method was used for combining different factors and pairwise comparison matrix was used for developing suitable weights.

Result of image provided the multi choices of land suitable for landfill operation with variable suitability scale 0 to 255. The image has a suitability range of 0 to 154. No land has suitability of above than 154 and 2 best potential sites were identified. Sites D1 and D2 are the best suitable disposing sites with suitability score 154 for solid waste with an area of 68060m² and 66799m² and distances from Roorkee center is 7588 meters and 8228 respectively.

Hanbali et al., (2011) determined Landfill siting within Mafraq City, through the integration of Geographic Information System (GIS), Weighted Linear Combination (WLC) analysis and Remote Sensing techniques. Number of parameters were collected from various sources in vector and raster GIS formats and then, used within the GIS-based WLC analysis to select optimum solid waste disposal sites. Urban areas, agricultural lands, land slope, fault system, access roads, surface aquifers, groundwater table, water wells and streams were considered. The trend of urban expansion within the study area was monitored using the LANDSAT data of 1989, 1999 and 2009 to support the selection process of disposal sites. It was found that about 84% of the study area were within “most suitable” to “moderately suitable” classes for landfill sites, while the rest of the study area was within “poorly suitable” and “unsuitable” classes. Finally, three sites were suggested as alternatives to the
existing disposal site taking into the consideration of the environment, biophysical and economical variables applied in the GIS-based WLC analysis.

Chang et al., (2008) presented a fuzzy multicriteria decision analysis alongside with a geospatial analysis for the selection of landfill sites. The method employed a two stage analysis synergistically to form a Spatial Decision Support System (SDSS) for waste management in a fast-growing urban region, south Texas. Use of the thematic maps in Geographical Information System (GIS) in conjunction with environmental, biophysical, ecological and socioeconomic variables is the first-stage analysis leading to support the second-stage analysis using the Fuzzy Multicriteria Decision-Making (FMCDM) as a tool. This process was different from the conventional methods of integrating GIS with MCDM for landfill selection because the approach follows two sequential steps rather than a full-integrated scheme.

GIS was performed as an initial screening process to eliminate unsuitable land followed by utilization of FMCDM methods to identify the most suitable site using the information provided by the regional experts with reference to five chosen criteria. “Site-1” was selected as the most suitable site for the new landfill in the suburban area of the city of Harlingen, based on initial GIS screening and final FMCDM assessment. Sensitivity analysis was performed using Monte Carlo simulation to investigate their relative impacts on the rank ordering of the potential sites in the second stage.

Jun-pin et al., (2007) reviewed several models developed to support decision making in the area of Municipal Solid Waste Management (MSWM). Many modern decision making support systems are already partially considering the social factor analysis in addition to
environmental effects, expenses and benefits, technical issues and management aspects. The PIPA (Policy Impact Potential Analysis) method was developed to predict the possible impacts of a policy on particular alternatives. Subsequently, a novel decision-making model for waste management is framed. Fly ash management in Taiwan was presented as a case study to demonstrate the practicality of this model.

It is found that many decisions based on traditional policy analysis that has considered multiple criteria including social factors still encounter the public resistance and failed to be implemented. The Policy Impact Potential Analysis (PIPA) is therefore developed to complement the traditional analysis by assessing the risk of failure of implementation. The decision-making model presented here provided a useful tool for aiding decision making for real-world waste management problems. The PIPA method improved the scientific decision-making model by considering human aspects, thereby reducing risks and enabling sustainable waste management. The decision-making model could also be applied to environmental management of various issues besides waste management policy.

3.6 Environmental Impact Assessment Studies For Site Selection

An assessment of the potential environmental impacts was made by Irtwange and Sha (2009) in Nigeria and measures for mitigation were preferred. The Environmental Impact Assessment (EIA) of the Integrated Waste Treatment Facility (IWTF) was conducted through multidisciplinary assessment of the baseline status of the site specific environment using standard methods for EIA. An Environmental Sensitivity Index (ESI) was conducted based on environmental and economic values and an Environmental and Social Management Plan
(ESMP) was formulated. The project was economically, commercially, technically, managerially and environmentally sustainable.

The EIA has provided all necessary information and evidence required by the regulators of environment to develop an Environmental Impact Statement (EIS) for the IWTF for Makurdi. Ameliorative measures were preferred for the significant potential environmental impacts, most of which were recommended for incorporation in the design and layout of the entire study. A field survey was carried out to determine the waste generation profiles in parts of the Makurdi urban area that made the Pilot Project Area (PPA) indicated that the bulk (82%) of the solid waste generated in the PPA originates from households rather than from commercial, institutional or industrial premises.

Adefemi and Awokunmi (2009) examined the effects of municipal solid waste disposal in Ado metropolis, with a view of creating environmental awareness for both the government and the public about the status of various dump sites in the metropolis. Continuous and effective monitoring of some heavy metals to source and distribution in the environment is highly necessary. Soil samples from four public waste dump sites (three samples from each location at 10 m interval) and plant sample (root and leave) from the Igbaletere dump site were analyzed for heavy metals such as Fe, Cr, Cu, Mn, Pb, Co, Zn and Ni. High concentrations of Cu, Mn, Fe, Pb, and Zn were found in the soil samples collected at the center of the landfill site.

Plant sample is the ability of plants to take up metals either as mobile ions presented in the soil solution through the roots or through foliar absorption. The high correlation (0.9985) of the metals examined in the soils and plants from the Igbaletere dump site indicated similarities in the origin of the metals. The studies have shown that the heavy metal
is hazardous at high concentration, looking at the concentration of the heavy metals in the soil and plant samples. The soil and plant will constitute a serious threat to the health of people living around such areas and can be controlled by adopting a good waste management approach to the waste disposal.

Kassenga and Stephen (2009) investigated environmental pollution impacts of a solid waste disposal site in the Dar Es Salaam city, Tanzania. Soil samples of wet and dry seasons, surface water, groundwater, and river sediments from sites suspected to be affected by the dumpsite were analyzed for chemical, physical, and bacteriological parameters, including heavy metals such as Cr, Cd, Zn, and Pb, and nutrients (N and P). The disposal site was found to be a source of pollution to groundwater quality, surface water, soil and riverbed sediments in its neighborhood. Levels of Cd and Pb in ground water were as high as 15 and 35 mg/L, respectively. Proper design, construction and operation of landfill sites will reduce the infiltration of rainwater and leachate generation.

Long term effect of the municipal solid waste amendment on the soil heavy metal content of sites used for periurban agriculture in Ngaoundere, Cameroon by Adjia et al., (2008). Waste samples were collected in the month of November and soil samples were collected in the months of November, January, April and July. The total concentration of heavy metals in urban wastes differed significantly among sites and ranged from 0.48 to 7.64 mg/kg for Cd, 38.3 to 236 mg/kg for Cu, 44.06 to 58.03 mg/kg for Ni, 117 to 528 mg/kg for Pb and 270 to 2110 mg/kg for Zn. The levels of these metals were out of the critical level for agricultural use at the Camp prison (for Pb and Zn), Norvegien (for Cd, Cu and Zn), and SabongariGare site (for Cd, Cu and Zn). The levels of Ni in urban wastes from all sites and
the levels of all heavy metals in urban wastes from the DouzePoteaux site were lower than the critical level. The levels of Ni were found to be within the normal range at all sites.

The highest available concentration of Zn (139.17 mg/kg) was found in November, Fe (843.23 mg/kg) and Pb (38.82 mg/kg) in January and Cu (19.09 mg/kg) and Ni (8.98 mg/kg) in July. The available concentrations of Cd did not differ among periods. The highest Bioavailable Factor (BF) of Zn, Ni and Pb was found at DouzePoteaux site and of Cd and Cu at SabongariGare site.

3.7 Waste Processing and Solid Waste Management

Das and Mahanta (2011) studied the solid waste disposal habit in different types of residential area and estimated the expected probability of willingness to pay in different types of residential areas if door to door solid waste collection service is provided. In the last few years the problem of solid waste has raised its ugly heads in the city of Guwahati. Total MSW generated per day varies between 350-500 metric tonnes of which 53.69 percent is compostable and 23.28 percent is recyclable.

Guwahati Municipal Corporation (GMC) is assigned for institutional responsibility of solid waste disposal system. The GMC is neither providing door-to-door solid waste collection services nor supplying an adequate number of dustbin in the city. MSW disposal system in the city was not up to the mark. Systematic collection, proper transportation and adequate disposal systems are not followed in the city. Door-to-door waste collection service requires a master plan and huge amount of resources. Private agency or Private Public Partnership (PPP) is one of the best alternatives suggested.
Xiao et al., (2006) conducted correlation analysis and carried out study on the composition, trend and impact of urban solid waste in Beijing. The generation of municipal solid waste in Beijing has been growing steadily, showing high correlations to the total GDP, per capita income, and the population. Since 1990 food waste shown an increasing trend. Ash and wood chips contained in 2003 declined from 56% to 17%, while the percentage of paper and plastic increased from 10% to 29% over the same period compared with the results of 1990. Carbon emission rose significantly through sanitary landfill and incineration with the increase of the amount and carbon content of municipal solid waste. Future challenges include: (1) Effective waste minimization program implementation (2) Planned urban solid waste management and (3) improvement in data availability and methodology in monitoring the quantity and characteristics of municipal solid waste.

Shukti et al., (2011) discussed the available methods of environmental quality assessment and characterize air, soil, noise and groundwater pollution in sufficient detail to facilitate proper site management. The need of environmental quality assessment is to assure that concentrations of specific contaminants resulting from hazardous waste site will not exceed the acceptable levels for protection of public health and the ecosystem. Four sites were selected for sampling and air, soil, ground water parameters and noise were analysed.

Site I: Behind Solar Pond
Site II: Near Tarpura Village
Site III: Borewell B1, B2, B3, B5, B6, B7
Site IV: Open dugwell near TSDF and near temple

The Soil parameters viz., pH, Electrical Conductivity and Metals were analysed. The Water parameter viz., pH, Electrical Conductivity, Total Dissolved Solids, Sulphates, Nitrates,
Alkalinity, Hardness and Chlorides were analysed and noise quality was monitored at the sites. Detailed analysis of soil, ground water and air is concluded that all the analytical parameters are within the prescribed limit.

Weitz et al., (2002) conducted a study by using a life-cycle methodology to track changes in GHG emissions during the past 25 years from the management of MSW in the United States. Emphasis on resource conservation, environmental regulations, technological advancements and recovery have greatly reduced the environmental impacts of municipal solid waste management including emissions of Greenhouse gases.

For the baseline year of 1974, MSW management consisted of limited recycling and combustion without energy recovery and land filling without gas collection or control with data for 1980, 1990 and 1997, accounting for changes in composition, MSW quantity, management practices and technology. The results shown that the MSW management procedure adopted by U.S. communities has significantly reduced potential GHG (Green House Gas) emissions despite an almost twofold increase in solid waste generation. GHG emissions from MSW management were estimated to be 36 Million Metric Tons Carbon Equivalents (MMTCE) in 1974 and 8 MMTCE in 1997.

3.8 Optimization Techniques in Solid Waste Management

Solid waste management using optimization technique gains considerable attention through the last few decades due to the limited availability of disposal sites as well as the recent environmental objective concerns. Various deterministic mathematical programming models have been applied for planning solid waste management systems. Some of those deterministic modeling techniques include Linear Programming (LP), Mixed Integer
Programming (MIP), Dynamic Programming (DP), Gray Integer Programming (GIP), Fuzzy Interval Multi Objective Mixed Integer Programming (FIMOMIP), Goal Programming Techniques (GP), Fuzzy Multi Objective Nonlinear Integer Programming (FMNLP) and multi objective programming.

Laxmi and Nagarnaik (2011) presented a novel technique for treatment of biodegradable waste (which forms a major part of MSW). It involved the processing of biodegradable waste by thermal process in presence of catalyst at high temperature to give liquid fertilizer and coke as a product. This technology has a definite goal of exploiting the commercial aspects of two universal problems i.e. problem of managing the biodegradable waste in the municipal solid waste and overcoming the fuel shortage indigenous. This process utilized all the waste and converts it into a useful liquid product having fertilizer, pesticide and insecticidal properties along with coke as a solid product. It is found that 1000 tones of biodegradable waste is treated by this process, about 750 tones of Liquid Fertilizer and 150 tones of coke having an energy potential of 12 MW was obtained.

Wang and Nie (2001) evaluated the current status and identified the problems of municipal solid waste management in China to determine appropriate remedial strategies. Major difficulties were identified in MSW management in China include MSW land, air, and water pollution, commingled collection, poor administration, shortage of funds, lack of facilities, and problems of training and public awareness. To solve these problems and to improve MSW management in China, remedial strategies in three areas were recommended viz., Institutional reforms, Technology development, Legislation and Administrative improvement. China must apply the advanced landfill technology in reference to
international standards in landfill siting, design, construction, operation, closing and post closure management.

To reduce the cost of landfill construction, China must develop its own technology for manufacturing liner materials, landfill gas collecting and utilizing equipment and landfilling machines. The final solution suggested “polluter-pays” principle, MSW generators pay for everything.

Amar and Katkar (2012) identified the most cost effective system for solid waste collection and compare it with the existing methods adopted by the municipal authority. Optimization technique was used for the identification of optimal routes in the case of municipal solid waste collection. It was estimated that, of the total amount of money spent in the collection, transportation and disposal of solid waste, approximately 60 to 80% is spent on the collection. The proposed collection system was based on the positions of waste bins, the road network and the population density in the area. Minimal spanning tree technique was used to locate the shortest possible routes to collect waste from all dustbins in the study region.

Warith (2003) suggested one approach through the mass processing of municipal solid waste in "bioreactor" landfills. In a bioreactor landfill environment, the solid waste actively decomposed rather than being simply buried in a "dry tomb". The active decomposition in the bioreactor landfill is possible because over half of the MSW waste stream is comprised of organic material (food, paper, etc.), which will decompose fairly rapidly under the right conditions. Under this model, landfills become processing facilities. This model represents a dramatic shift from the dry tomb model currently designed in various
parts of the world. Rather than being kept dry, the solid waste is actively moistened by injecting leachate into the land filled solid waste to accelerate decomposition.

Additionally, air may be actively introduced into the solid waste to further hasten decomposition by establishing aerobic conditions, replacing the anaerobic conditions that prevail in a conventional landfill. The bioreactor landfill significantly increased the extent of organic waste decomposes, conversion rates and process effectiveness over those that otherwise occur within the traditional landfill sites.

Apaydin and Talha (2007) was performed a study on emission control with route optimization in solid waste collection process in Trabzon City with 39 districts. A shortest path model was used in order to optimize solid waste collection/hauling processes to minimize emissions.

Geographical Information System (GIS) was used as an optimization tool, to analyze elements such as numerical pathways, demographic distribution data, container distribution data and solid waste production data. In addition, thematic container layer was having 777 points for the entire city. By using the software, the optimized route was compared with the route in use. By using the optimized route in solid waste collection system, the route distance and route time decreased by 24·6% and 44·3% respectively. By performing the stationary container collection process and route optimization, the emission of CO₂, NOₓ, HC, CO, PM decreased significantly.

Shafiqul et al., (2012) had introduced an integrated system of Radio Frequency Identification (RFID), Global Position System (GPS), General Packet Radio Service (GPRS), Geographic Information System (GIS) and Web camera. The built-in RFID reader in trucks
automatically retrieved all sorts of customer information and buying information from RFID tags, mounted with each bin. The GPS revealed the location information on the collection truck. All the information was updated in the central server automatically through the GPRS communication system. Truck monitoring was done by GIS map server.

The bin and truck database was developed by incorporating information on the bin and truck ID, date and time of waste collection, bin and truck GPS coordinates information, bin status and amount of waste were compiled in a data packet and stored for monitoring and management activities. The performance of the implemented system was satisfactory in terms of high speed data transmission, processing, real-time data communication and reliability.

Chua et al., (2011) studied Integrated MSW management provides an avenue to achieve sustainable development in Malaysia by allowing economic growth without jeopardizing the environment. The scenario of the potential mitigation efforts such as enhancing recycling of waste, promotion of organic waste management either at the macro or micro level and application of integrated solid waste management through sanitary landfills was analysed. The recycling rate in Malaysia is reported as 5%. This percentage is low compared to other countries such as Philippines which has 23% recycling rate in 2003. By promoting recycling rate to 22%, it can reduce the GHG emission from waste sector by 25.5% in the year 2020.

The potential emission reduction from the promotion of organic waste treatment at source such as composting, anaerobic digestion at shopping malls, hotels and canteens was studied. The challenges are changing public behavior and attitude towards recycling, generation of waste and sorting out of waste at source. It is imperative for the government to
implement the solid waste and Public Cleansing Management (PCM) Act, 2007 in order to achieve GHG abatement in Malaysia.

Chan et al., (2012) suggested the probable ways to resolve the waste/landfill problems and its implications upon the degrading environment in Hong Kong. Possible control at the source and reducing wastage from individual, society and government perspectives were examined. Recovery via recyclable materials and waste minimization methodologies were revisited through quantitative approach by questionnaires sent to major parties.

Land shortage for waste disposal was a problem in urban cities, especially as that of Hong Kong. The landfill space has projected an alarm locally due to the escalating amount of municipal waste, putting a pressure over the limited land supply and severe impacts towards the environment. According to local government, the remaining land suitable for landfill for dumping waste as derelict land is becoming scarce. Thus waste minimization was the way forward mentioned.

3.9 Remote Sensing and GIS in Transportation Management

Worldwide, the transportation problems faced by various nations have increased manifold, necessitating search for methods that ensure efficient, feasible and faster means of transport. This is all the true in a country like India, where in the population growth is increasing significantly. Rapid improvements in remote sensing technology and the hardware and software for GIS have enhanced their potential for solving various types of transportation engineering and management problems. The applications of GIS in transportation planning which includes travel demand planning, network maintenance and updating, short range
planning, dynamic segmentation and networking, shortest path analysis, deficiency analysis and allocation of resources.

The collection, transport and disposal of solid waste, which is a highly visible and important municipal service, involves large expenditure but receives scant attention. A constructive heuristic which takes into account the environmental aspect as well as the cost is proposed in this study by Amponsah and Salhi (2004) to solve the routing aspect of garbage collection. A hook-ahead strategy which is enhanced by two additional mechanisms, namely the minimization of both the cost and the effect of the environment is put forward to solve the routing aspect of garbage collection. Enhancement procedures namely a switching mechanism that adoptively shifts to the least cost rule whenever necessary and a refinement procedure are embedded within the look-ahead strategy. It has been shown to be computationally efficient and performs well on all the test problems, besides having the advantage in producing several solutions. This flexibility, which considers both cost and environment, could assist local authorities in choosing from the pool of solutions, the one which suits best their need.

Bhambulkar (2011) carried out study on municipal solid waste collection routes optimized with ArcGIS Network Analyst. In the present study the ArcGIS Network Analyst is introduced for best routing identification applied in municipal waste collection of Laxmi Nagar, Nagpur city. In the municipality of Nagpur, in order to collect Municipal Solid Waste that couldn’t be collected by the standard waste collection trucks, due to size and other prohibitive obstacles. The Network Analyst is used to estimate interrelations between the dynamic factors, like network traffic changes (closed roads due to natural or technical causes, for example, fallen trees, car accidents, etc.) in the area under study and to produce optimized
solutions. Some essential restrictions were taken into account such as the streets’ directions, no U-Turns rules (with the exception of the dead-ends) and also, the fact that the truck should follow true-shape route. With the GIS technique, optimum route was identified which found to be cost effective and less time consuming when compared with the existing run route. Finally, the optimal solution is identified by a function that takes into consideration various parameters, for example the shortest distance, road network as well as social and environmental implications. The route was obtained by Arc GIS is 5.1 km. and time was 8 hr. 35 min. The cost for these operation are 965 rupees per day, 28,950 rupees per month and 3,52,225 rupees per year. The cost is saved up to 14% per month.