

An Integrated Parametric Approach To Landfill Site Selection Fuzzy GIS-Based Technique For A Fast Growing Indian City

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ABSTRACT

Landfill site selection in an urban area is a critical issue in the urban planning process because of enormous impact on the economy, ecology, and the environmental health of the region with the growth of the urbanization, larger amount of wastes are produced and unfortunately the problem gets bigger every day. A selection of proper waste disposal site is a function of many parameters can be involved under the Environment, Planning & Social Functions. GIS based mapping and subsequent image analysis is proposed to be done for each of the correlating criteria for each parameter. The fuzzy multi criteria decision making (FMCDM) is used to rank different land fill sites based on decisions given by a group of experts. The selected site can be further confirmed through GIS application. This paper highlights the explained approach.

Keywords—Landfill, Fuzzy Logic, GIS

I. INTRODUCTION

Municipal Solid Waste (MSW) is being produced since earth's evolution. During the early period, MSW was conveniently disposed of in low lying areas with large open land space. The population growth lead to increase in Solid Waste generation and the problem of waste disposal and its adverse impact on the environment is recently diagnosed, may be due to enforcement. Municipal Solid Waste in India is generally disposed in an unscientific manner. Unfortunately environment planning as well as socio-economic factors are never quantified and synthesized in decision making. To select the site, an approach is designed in Indian conditions. This is based on fuzzy analysis.

II. SOLID WASTE SCENARIO IN INDIA

Overview Of Existing Method Of Landfill Site Selection

In many developed countries the site selection process could last five years or more depending on the specific local circumstances. Especially when the site selection is correlated with the design criteria of the facility the process can take up to ten years due to the detailed studies that have to be completed before the final decision. In the case of a large facility with remarkable environmental impacts, a site selection process may involve the optimization and selective action of all the parameters when viewed from a combined perspective. On the other hand, a successful site selection process may reduce the capital and operational cost of a landfill affecting the design of some expensive parts like liners, biogas collection

and management systems, leachate collection and management systems and monitoring details.

Urbanization & Solid Waste Generation Scenario

The India is the world's second highest populated country of 1.21 billion (census 2011). The annual rate of growth of urban population in India is 3.35% (Census of India, 2011). The proportion of population living in urban areas has increased from 17.35% in 1951 to 31.2% in 2011(Census, 2011). High rate of population growth, declining opportunities in the rural areas and shift from stagnant and low paying agriculture sector to more paying urban occupations. India has achieved multifaceted socio-economic progress during last 64 years of its independence. However, in spite of heavy expenditure by Civic bodies, Management of Municipal Solid Wastes (MSW) continues to remain one of the most neglected areas of urban development in India. Piles of garbage and wastes of all kinds littered everywhere have become common sight in urban life. For most of urban local bodies in India, solid waste is a major concern that has reached alarming proportions requiring management initiatives on a war-footing.

Fuzzy Multi Criteria Decision Making Method

The initial publication of fuzzy set theory was by Prof. Lofty Zadeh in 1965. It can also be considered as a modeling language that is well suited for situations that contains fuzzy relations criteria and phenomena. The fuzzy analysis for land fill site selection requires having a careful evaluation of different pre-determined criteria. FMCDM method is therefore selected for ranking different landfill site based on decisions given by a

group of experts. Then stepwise ranking procedure is proposed to determine the ranking order of all locations. When conducting the inference triangular fuzzy number (TFN) is commonly used by the experts to describe vagueness and ambiguity in the real-world system.

Multi-criteria evaluation (MCE) is used to resolve conflicts and deal with the difficulties that decision makers encounter in considering large amounts of complex information. The principle of the method is to divide the decision problems into more smaller understandable components, analyze each component separately, and then integrate the components in a logical way. The integration of GIS and MCE is a powerful tool to solve the landfill site selection problem because GIS provide efficient organization and handling of spatial data and MCE supplies consistent ranking of the potential landfill areas based on a variety of criteria.

III. SOLID WASTE SCENARIO IN STUDY AREA

Surat City Profile

Surat is located in coastal region of western India. The City is located at 21.17°N & 72.83°E. Surat is the 4th fastest growing city of India and it is business capital of State Gujarat. Total city area is 385 Square Kilo Meters. The City has main potential in forms of River Tapi; The City has CBD (Old City) and Non CBD (New City) areas. The city is administrated by local government called Surat Municipal Corporation. The development, town planning schemes are prepare by SUDA i.e. Surat Urban Development Authority. Annual Rainfall is about 45 to 50 inches, summer temperature ranging from 22 to 40 degree Celsius, winter temperature ranging from 12 to 31 degree. The city is divided in 7 zones, having population near about 48 lacs.

Present Solid Waste Generation & Disposal Scenario

- Quantity of M.S.W. generation is found to be 1500 M.T. as per the yearly average.
- Every day, Surat generates 400 gms per capita per day of waste amounting to roughly 1000 metric tons. This is collected by SMC, private contractors and the rag pickers. About 70 percent of the waste generated every day is contributed by households, shops and other commercial establishments. Just over 30 percent of the total waste generated is recyclable. This comprises of paper, plastic, metal, brick stone and glass primarily. Combustible waste accounts for 22.75 percent of the total and organic waste is nearly 42 percent. Doorstep bins are roadside cradle types and are 314 in number.

- The total number of waste collection bins is 1170. These are mainly 4.5 cu.m in size with a capacity of 1.5 tonnes (4.5 cu. m)/ dustbin and cover the entire population of the city. The spacing between waste storage depots is about 100 m.
- For door-to-door collection 3000 bins would be installed by 3 private agencies. The cradle type would be designed in such a way that revenue generation through advertisement is possible. There are also initiatives for segregation of waste at source including awareness generation through pamphlets. For this to create awareness pamphlets are distributed. At present there are 4503 sweepers engaged in the collection of waste across the seven zones of the city. Of the total waste collected, the corporation manages 98 percent i.e., 980 tons/day while the rest is collected by rag pickers.

Table 1 Quantity Of Waste Generated

Sources	Percentage
Households	53
Shops and Establishments	16
Vegetable/Fruit/Meat/Fish market	14
Construction and demolition material	8
Biomedical waste	1
Hotel/Restaurant waste	8

Source: www.suratmunicipal.org

Table 2 Zone Wise Solid Waste Generation (Metric Tons)

Zone	Area (Sq. Km)	Population (2011 Census)	Solid waste generation		
			2001	2011	2021
Central	8.18	408760	150.1	139.5	116.2
North	36.363	705163	121.7	179.1	220.6
East	37.525	1137138	210.7	295.9	337.7
West	51.279	424986	90.9	166.3	224.5
South	61.764	695028	177.6	291.4	383.1
South East	19.492	748304	59.2	97.15	127.7
South West	111.912	347447	73.2	108.7	139.9
Total	326.515	4466826	883.5	1278.0	1549.7

Source: www.suratmunicipal.org

Solid Waste Landfill Site In Practice

Salient Features are as follows:

- Location of the Site: Khajod, Dist. Surat on outskirts
- Area: 21 acres Solid waste Handling Capacity: 1500 tonne / day
- No. of trips: 150 trip/day
- M.S.W. transported from the transfer stations reaches to the final disposal site at Khajod whereat

M.S.W. is dumped and levelled by the heavy machineries. Daily cover of soil is also laid on the levelled M.S.W. Out of total collection of garbage average 400 TPD garbage is sent to processing plant which is established on BOOT basis. This plant is in operation from September 2008.

- The capacity of the land fill site is expected to be exhausted in the next three years due to which four more new Land filling sites have been proposed by the Surat Municipal Corporation.

IV. REVISED PARAMETRIC APPROACH

A suitable method is to be devised for the solid waste landfill site selection which is further enumerated to fulfill the following objectives:

- To evaluate planning and environmental parameters for the solid waste landfill site selection
- To select appropriate site using fuzzy MCDM and GIS as a tool.
- To develop fuzzy GIS Integrated Model for solid waste landfill site location.

The following are the reasons for the pursuit of the objectives:

- This area of research has never been observed in the Indian context.
- The parameters visible in similar researches are vastly different from the parameters identified in the scope of the current research.
- The level of urbanization and generation of solid waste in India is different from the territories or countries explored as per the trends observed.

Components Of MCDM Process

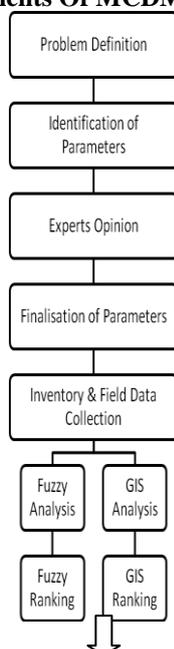


Fig 4.1 Methodology of Research Process

- The above illustrated flow chart briefly describes the methodology proposed to be adopted during the course of the research. Priority is given to the Experts' Opinion & Validation at each of the critical steps to seek necessary guidance. A combination of GIS Analysis & Fuzzy Analysis is intended to give accurate results and proactively help in decision making. Landfill site selection should be combination of planning and environmental parameters. Fuzzy composite model structures are shown in Fig 4.2 and 4.3. More over parametric justifications are tabulated in Table III.

Proposed Research Parameters

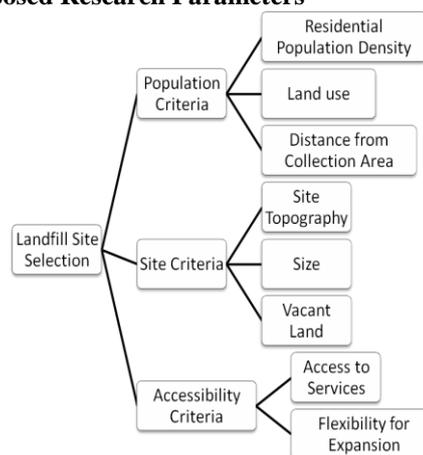


Fig 4.2 Fuzzy Composite Model for Planning Parameters

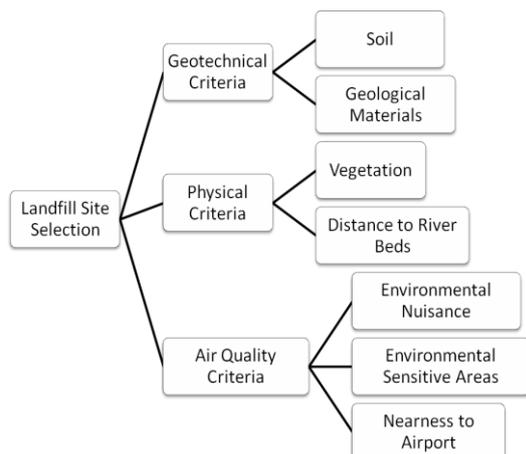


Fig 4.3 Fuzzy Composite Model for Environmental Parameters

		Environmental Nuisance	Help in checking the possibilities of pollution and critical locations
		Environmental Sensitive Areas	Help in checking the accidents and possibilities of any kind of threat to environment
		Nearness to Airport	Possibility of bird-hit to aircraft in vicinity of landfill site

V. GIS BASED TECHNIQUES

Fundamentals Of GIS

Geographic Information System is a computer system capable of assembling, storing, manipulating, displaying geographically referenced information, i.e., data identified according to their locations.

- Geographic data can be categorized into three distinct types:
 - a) Geodetic control network
 - b) Topographic basis
 - c) Geographic overlays
- With the help of a GIS, the maps can be stored in digital form in a database in world co-ordinates (meters or feet). This makes scale transformations unnecessary, and the conversion between map projections can be done easily with the software. The spatial analysis functions of the GIS are then applied to perform the planning tasks. This can speed up the process and allows for easy modifications to the analysis approach.
- Conversion of real world geographical variation into discrete objects is done through data models. It represents the linkage between the real world domain of geographic data and computer representation of these features. Data models discussed here are for representing the spatial information.
- Data models are of two types: Raster and Vector. In raster type of representation of the geographical data, a set of cells located by coordinate is used; each cell is independently addressed with the value of an attribute. Each cell contains a single value and every location corresponds to a cell. One set of cell and associated value is a LAYER. Raster models are simple with which spatial analysis is easier and faster. Raster data models require a huge volume of data to be stored, fitness of data is limited by cell size and output is less appealing.
- Vector data model uses line segments or points represented by their explicit x, y coordinates to identify locations. Connecting set of line segments forms area objects. Vector data models require less storage space, outputs are appreciable, Estimation of area/perimeter is accurate and editing is faster and convenient. Spatial analysis is difficult with

Research Parameters And Justifications

Sr.No.	Criteria	Parameters	Justifications
1.	Planning	Zoning Density	Zoning Regulation may impact the development of landfill
		Distance from Collection Area	Lesser the distance, less time and energy consumed in transporting the waste to landfill
		Site Topography	Slope should be such that it helps in transferring waste at different levels
		Residential Land-use	Land use specifications should allow the development of landfill
		Size	Comparable with the amount of waste and size of the city
		Access to Services & Utilities	Important for working staff and for developing other facilities
		Availability of Vacant Land	Facilitate ease of development
		Flexibility for facility expansion	Important as in future the waste generation quantities and the population both will increase
2.	Environment	Soil	Dense to moderately dense soil profile is most suitable for landfill
		Geological Materials	Important in determining development possibilities
		Vegetation	Help in checking the possibilities of pollution and threat to the vegetation
		Distance to River Beds	This would help in checking ground water pollution

respect to writing the software program. The vector model is extremely useful for describing discrete features, but less useful for describing continuously varying features such as soil type or accessibility costs for hospitals.

- The raster model has evolved to model such continuous features. A raster image comprises a collection of grid cells rather like a scanned map or picture. Both the vector and raster models for storing geographic data have unique advantages and disadvantages. Modern GIS packages are able to handle both models.

Scope Of GIS

- GIS is used to perform a variety of Spatial analysis, including overlaying combinations of features and recording resultant conditions, analyzing flows or other characteristics of networks; proximity analysis (i.e. buffer zoning) and defining districts in terms of spatial criteria.
- GIS can interrogate geographic features and retrieve associated attribute information, called identification. It can generate new set of maps by query and analysis. It also evolves new information by spatial operations.
- Following are the analytical procedures applied with a GIS. GIS operational procedure and analytical tasks that are particularly useful for spatial analysis include:
 - a) Single layer operations
 - b) Multi layer operations/ Topological overlay
 - c) Geometric modelling
 - d) Calculating the distance between geographic features and calculating area, length and perimeter
 - e) Geometric buffers
 - f) Network analysis
 - g) Surface analysis
 - h) Raster/Grid analysis

Proposed Use Of GIS Techniques In Landfill Site Selection

- For the case of Surat Urban Area, it is proposed to include 4 sites located at various zones of the city for the purpose of Solid Waste Landfill to satisfy the growing population of the city.
- The locations of the sites (as shown in the map) are as follows:
 - a) West-Zone (2 sites)
 - b) North-Zone (1 site)
 - c) East-Zone (1 site)

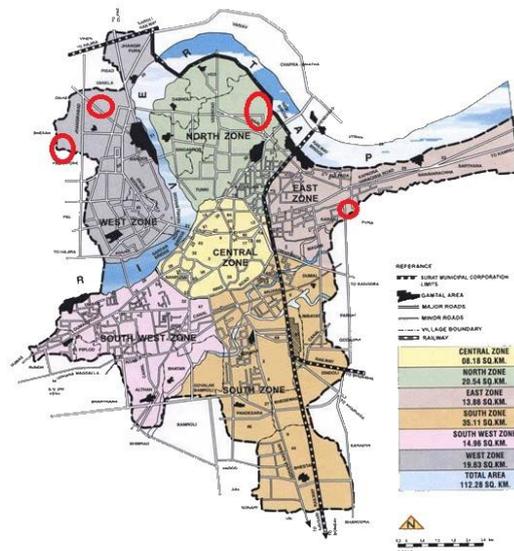


Fig 4.1 Proposed Locations of Landfill Sites

For each of the above sites as shown in the figure, GIS Maps will be prepared and subsequent comparative analysis shall be done using MCDM techniques.

VI. CONCLUSION

This study started with an objective that there should be a scientific method for the selection of site for solid waste landfill. There is a strong link between quality of life in cities and how cities draw on and manage the natural resources available to them. Projected population increase in 2031 is 8.6 Million. So therefore it is necessary to select a suitable and long-lasting efficient solid waste landfill site. As such, the transition to resource efficiency rests on a range of factors such as redefining how urban systems are understood at the global level, developing a shared language for evaluating city sustainability and reviewing indices that account for the sustainability of cities. Resource efficiency also needs to be situated within the context of human development.

From an overview of recent literature and case study reports, it was found that transition to sustainability is in three different parts: a demographic transition, rural to urban (RUrban) transition and environmental transition. The future direction of Indian urbanization is not only an important domestic concern but also a major international opportunity to demonstrate the viability of a more sustainable development. A multilevel climate adaptation framework is necessary, which works at national, state, city and neighborhood levels.

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