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FUZZY RANKING FOR LANDFILL SITE SELECTION IN INDIAN CONTEXT

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ABSTRACT: Landfill site selection in an urban area is critical issue in the urban planning process. It creates major impact on economy, ecology, and the environmental health of the region. With the growth of urbanization as well as the desire to live in cities, larger amount of wastes are produced. Therefore, unfortunately the problem gets bigger every day. A selection of proper waste disposal site is a function of many parameters pertaining to urban planning and Environmental aspects. The normal practice is to select a site where open space is available. Parameters pertaining to above aspects are hardly attended to. The right method of selection should have been based upon correct assessment of parametric evaluation. All parameters have various scales and values too. In order to integrate these values, fuzzy approach seems to be the reasonable selection method. Thus, the objectives of this paper are to highlight solid waste scenario in Indian context, to present the assessed parameters and to present a model of fuzzy ranking approach to solve the problem. The fuzzy multi criteria decision making (FMCDM) is used to rank different land fill sites. The solution suggested shall be a useful tool for urban environmental applications.

Keywords: Urbanization, Municipal Solid Waste, Fuzzy logic, analytical hierarchy process, landfill,

1. INTRODUCTION

Municipal Solid Waste (MSW) is key environmental issues for soaring urban centres. During the early period, MSW was conveniently disposed in low lying areas with large open land space. The population growth leads to increase in Solid Waste generation. The problem of waste disposal and its adverse impact on the environment is matter of great concern. Municipal Solid Waste in India has created many environmental imbalances. Unfortunately environmental planning as well as socio-economic factors are hardly quantified and considered to decide disposal locations. An approach based on fuzzy analysis is presented considering Indian situation.

In India, the growth of cities is taking place from two major perspectives. Firstly, in a natural and uncontrolled way, without following scientific principles of urban development. Secondly, few cities are growing by following certain scientific principles adopted by urban planners based on urban theories and development experiences.

India’s urban population is growing at the fastest rate globally. Therefore, it is difficult to combat the urban challenges and scientific growth pattern. A scientific decision making approach needs to be adopted for disposal of municipal solid waste, where environmentally safe landfill site selection is significant. Four sites are proposed, out of which the best site is to be identified. Fuzzy logic approach has given ranks of proposed four sites, to make decision. Analytic Hierarchy Process (AHP) is used to evaluate parametric weights. The city under study is the fastest growing urban centre in India.

2. STUDY AREA

Surat city is selected for this research work, which is a major industrial up and fastest growth centre.

Surat, the Sun City holds a population of 46 lacs as per census of India 2011. It is second largest city in Gujarat after Ahmadabad. It is located at 21°10′N 72°50′E.

Table 1 Decadal Population Growth of Surat

Census	Population	% ±
1871	107,100	-
1881	109,800	2.5%
1891	109,200	-0.5%
1901	119,300	9.2%
1911	114,900	-3.7%
1921	117,400	2.2%
1931	98,900	-15.8%
1941	171,400	73.3%
1951	223,200	30.2%
1961	288,000	29.0%

1971	492,700	71.1%
1981	912,600	85.2%
1991	1,519,000	66.4%
2001	2,811,614	85.1%
2011	4,591,246	63.3%

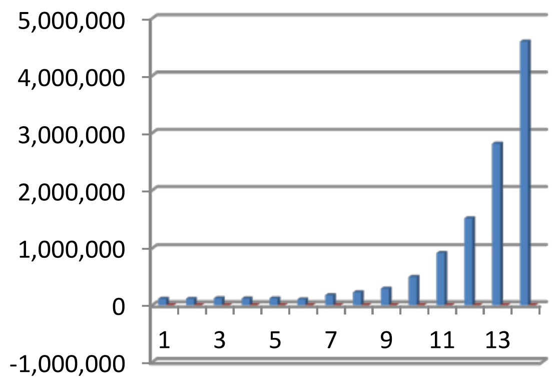

Fig 1 Population Growth Curve

It is observed that in last four decades more than 50% of the population growth occurred. So it is necessary to identify suitable landfill site selection for future need.

For the study area, it is proposed to include 4 sites located at various zones of the city for the purpose of Solid Waste Landfill disposal.
The locations of the sites (as shown in the map) are as follows:

Site I- South-Zone   Site II East-Zone
Site III-North-Zone   Site IV-West-Zone

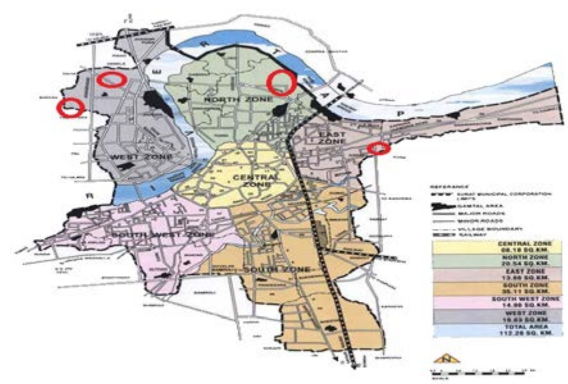

Fig 2 Proposed Location of Landfill Sites

3. OBJECTIVES

Objectives of this research are as follows

- To evaluate urban planning parameters, influencing solid waste landfill site selection.
- To determine weights of each parameters by AHP.
- To identify ranks of each landfill site by using fuzzy approach.

3.1 Review of Literature

S.M Issa et.al.[2] used eight parameters to identify landfill site in Abudhabi using similar approach,while Afzali et al[4] carried scientific studies in selecting suitable sites for landfill.V.Akbari et.al.[6] advocated for ranking based on decision making method ,zeinhom EL Alfy[3] used weighed linear combination (WLC)and AHP to rank the landfill sites, GH.R.Dini [1] used the Boolean process and followed by fuzzy approach to identify fuzzy land fill site, A.Karkazi[5] took 6 input parameters, used fuzzy logic for analysis of data and the evaluation of the final results. Juan M.SAchez[7] used MCDM method for locations while Mehnaz Eskandari and Mehndi Homaee[8]used integrated approach for environmental and socio cultural data.

3.2 Fuzzy Composite Programming Approach

This multi-objective analysis of site selection includes uncertainties in terms of fuzzy membership function. The membership in the sets cannot be defined on a scale of yes/no in fuzziness as the boundaries of the sets are unclear. The membership degree for a vague value can be found by expert's judgment based on knowledge and practical experience (Stan bury et al., 1991). Uncertainty analysis or fuzziness in site selection was included to take into account the vagueness in the data range.
Figure: 2 shows the composite structure of the basic indicators, selected for site selection from urban planning point of view.
The membership function for each of the basic criteria can be constructed, where Zi,h(x) is an interval value of the basic criteria at the confidence level (membership degree) h, [i.e., $a \le Z_{i,,h}(x) \le b$].

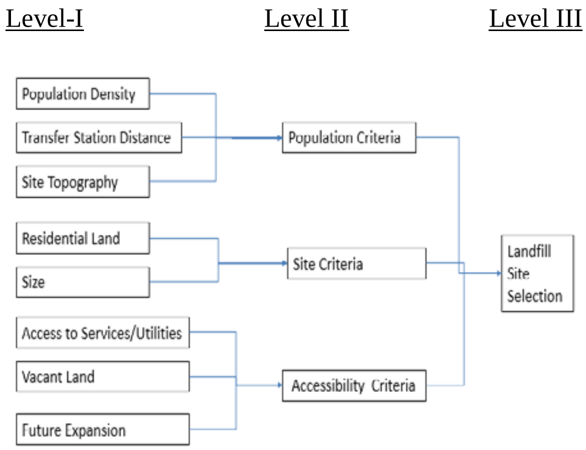

Fig 3 Fuzzy Composite Structure

The best and worst value for the basic criterion is determined by expert's perceptions. Using the best value of Z_i($BESZ_i$) and the worst value of Z_i($WORZ_i$)for the i^{th} basic indicator, the actual value $Z_{i,h}(x)$ is transformed into an i^{th} normalized basic criterion value. The actual value $Z_{i,\,h}(x)$ is transformed into an index value denoted by $S_{i,\,h}(x)$. In the model Z_{imin} is minimum value and Z_{imax} is maximum value in observed data. The normalized values for field data is determined by the following equation. (Bogardi,1992).

$$Si = \frac{(Zi-Zimin)}{(Zimax-Zimin)} \quad \text{(When } Z_{imax} \text{ is best)}$$

$$Si = \frac{(Zimax-Zi)}{(Zimax-Zimin)} \quad \text{(when } Z_{imin} \text{ is best)}$$

Where Si is normalized i^{th} fuzzy indicator; Zi is value of i^{th}fuzzy indicator; Z_{imax} is maximum possible value of i^{th} indicator and Z_{imin} is minimum possible value of i^{th} indicator. The composite distance was computed by the following equation (Bogardi, 1992)

$$Lijk_{(x)} = \left[\sum_{j}^{n} (W_{ij}\left[S_{ij}(x)\right]^{bj}\right]^{1/bj}$$

Where Lj, h(x) is fuzzy composite distance in group j, Nj is the number of elements in the first level group j; Si, hj(x) is the index value for the ith indicator in the first level group j of basic indicators; wij is the weight reflecting the importance of each basic indicator in the first level group. Pj= the balancing factor for the first level group j. The index values, Lj, h(x) of the second and third level indicators respectively can be calculated.

To calculate the weight for different indicators, (parameters) weights are selected as per Saaty's scale. Pair wise comparisons are used to determine the relative importance of each alternative. To compare indicator i with indicator j, the decision maker assigns values aij suggested in AHP method. If the degree of importance of the aji= (1/r). If i = j, then aij= aji=1. Saaty (1988) has shown that the eigen vector corresponding to the maximum Eigen value of matrix A is a cardinal ratio scale for the indicators compared.

$$AXW = f_{max} XW$$

Moreover, the unit eigenvector, (W) corresponding to f_{max}yields the preference weights for the criteria compared. The maximal deviation is presented by balancing factor p between the indicators of same group. The normal values used for balancing factors in equation are one and two. In this study balancing factor considered is 1.

4. RESULTS AND DISCUSSIONS

On the basis of survey collected from 20 experts weights of each criteria is determined using AHP. A weight of each criterion is shown in Table 1. Population criteria are having maximum weights among second level parameters.

Table 2 Weights for each criteria

Level	Indicators and Criteria	Weights
1	Population Density	0.6746
	Transfer station distance	0.0757
	site topography	0.2495
	residential land	0.7248
	size	0.2751
	access to services/utilities	0.0444
	vacant land	0.581
	future expansion	0.374
2	Population Criteria	0.4425
	Site Criteria	0.2627
	Accessibility Criteria	0.2948

Determination of best and worst values for first-level indicators is based on design standards suggested by Ministry of Environment and Forest, Government of India. The Best/Worst value of each of the indicator is shown in Table 2.

Table 3 Best and Worst Indicator Values for Criterion

Criteria	Best Value	Worst Value
Population density (ppha)	0	100
Transfer station distance(km.)	5	15
Site topography	1/10	1/1
Residential land (%)	0	35
Size (ha.)	250	100
Access to services/utilities (Km.)	0	5
Vacant land(Ha.)	50	25
Future expansion(Ha.)	25	0

Table 4 is showing existing site parameters values for all four sites under consideration.

Table 4 Values of Parameters for sites

Criteria	Site-I	Site-II	Site-III	Site-IV
Population density (ppha)	48	12	60	55
Transfer station distance (km.)	12	10	13	8
Site topography	1:5	1:4	1:6	1:8
Residential land (%)	20	10	32	30
Size (ha.)	175	200	175	150
Access to services/utilities (Km.)	2	3.5	1.6	0.8
Vacant land(Ha.)	50	30	35	40
Future expansion (Ha.)	25	20	15	20

Output of the model is tabulated in Table 4. Result shows that on the basis of population criteria, site III is least suitable, all other sites are having almost favorable conditions. Site II is best, if we look for environmentally safe site criteria. Site I is having most favorable accessibility criterion. Overall output suggest that site I is the best site for landfill with 0.6705 index and site III is least preferable site with 0.4243 index. Site II and site IV are having 0.5900 and 0.5183 index respectively.

Table 5 $L_{i,j,k}$, Second and Third Stage parameters for all Sites

Site	I	II	III	IV
Population Criteria	0.2634	0.2794	0.2282	0.2651
Site Criteria	0.1177	0.1841	0.0524	0.5130
Accessibility Criteria	0.2893	0.1264	0.1435	0.2020
Selection index	*0.6705*	*0.5900*	*0.4243*	*0.5183*

5. CONCLUSION

1. Population criteria plays major role for decision makers for urban plannin g process.

2. Site I is environmentally safe, as it is least populated and other factors are favorable for solid waste disposal.

3. Once site I is filled than other sites may be considered as per rank.

6. ACKNOWLEDGEMENT

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