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Solid Waste Disposal Site Selection for Belagavi City - A Case Study

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***Abstract*—Global environmental crisis has been a challenge continuously for degradation and sustainable living on earth. Vast quantities of waste generation by the cities are one of the serious outcomes of the unplanned development. Selection of suitable sites for waste disposal has been normally carried by traditional approaches i.e. throwing it at all types of vacant land in or around the city. With increase in population and solid waste generation in future, finding alternate solid waste disposal sites for Belagavi city was necessary. Hence, the present case study is taken up for selection of solid waste disposal site for the Belagavi city. Therefore, the city of Belagavi has been divided into three zones namely north, central and south zone to decentralize the waste management such as waste collection, transfer & transport and ultimate disposal. Six disposal sites have been identified, namely: Hallbhavi, Bambarge, Turmuri, Khasbag, Kinaye and Desur. The appropriate disposal sites have been selected by considering attributes used for decision- making. Based on literature, data collection and field survey, weightages were assigned to each attribute following the pair wise comparison and sensitivity index method. The attributes were then grouped and analyzed to assign the total score and evaluate the best ranked sites based on sensitivity of the site. The best three ranked sites for the three zones have been selected and they are Hallbhavi in north zone, Turmuri in central zone and Kinaye in south zone.**

Keywords—Degradation; decentralize; attributes; decision-making; sensitivity index.

I. INTRODUCTION

Municipal Solid Waste Management (MSWM) is one of the major problems faced by city planners worldwide. The problem is especially severe in developing countries where urbanization, poor planning and lack of adequate resources contribute to the poor state of Solid Waste Management (SWM) practices. Landfilling method is most common way for the disposal of solid waste generated by different communities. Despite of the intensive efforts that are made for recycling and recovery of solid wastes, landfill method remains and will remain an integral part of most SWM plans [1].

Selection of landfill site is a complex task and needs evaluation of various needs. There are many different methods to evaluate a site like decision and policy making which is based on detailed information. Modeling is widely used for solving various environmental and ecological problems [2].

Indian cities generate an estimated 0.115 million metric tonnes of waste per day and 42 million metric tonnes annually. The per capita waste generation ranges between 0.2 and 0.6 kilograms/day in the Indian cities i.e. lower than that in developed countries. However, lifestyle changes due to economic growth and fast rates of urbanization have resulted in per capita waste generation increasing by about 1.3% per year. Tata Energy Research Institute (TERI) has estimated that waste generation will exceed 260 million tonnes per year by the year 2047 [3].

II. STUDY AREA

Belagavi city (15° 51’ 58” N and 74° 31’ 27” E) is situated nearly 762 meters above the Mean Sea Level (MSL) and is the head quarters of Belagavi district which borders the state of Goa and Maharashtra. Belagavi (earlier known as “Venugrama” or the “Bamboo Village”) is one of the oldest, strong, prominent and well cultured historical place nestling near the Western Ghats. The population of Belagavi city as per 2014 census is 5,23,600 and the area of Belagavi city is 94.00 square kilometers. The total road length is 769 kms. Total quantity of Municipal solid waste generation is 262 tonnes per day and collection by the Belagavi City Corporation (BCC) is 190 tonnes per day. BCC consists of 58 wards, out of which sanitation work of 43 wards has been outsourced. Remaining 15 wards are managed by Corporation sanitary workers (Pourkarmikas). The 43 wards have been divided into 10 packages [4].

Following are six locations which were selected as the study areas for solid waste disposal site selection that is Hallbhavi, Bambarge, Turmuri, Khasbag, Kinaye and Desur site.

III. MATERIALS & METHODOLOGY

A. Site Selection Methodology

The study was conducted to define and understand the current problem of waste disposal in Belagavi city and to suggest best possible sites for waste disposal. In the present study, six suitable government lands are identified with the help of BCC and Tahsildar office. There are number of methods available to address problems like selection of solid waste disposal site. The method adopted in this study is Site Sensitivity Index (SSI) method as

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described by Rami Reddy [5]. The site selection for solid waste disposal facility involves comparison of different options based on community impact. Thus the problem requires human judgement at all the levels. Hence based on experience and likely impact on the surrounding environment weights were assigned to all the attributes (parameters). In order to achieve the objective, SSI method has been adopted in which weightages of different attributes were assigned on the basis of their importance. The methodology comprises of the following steps:

- Selecting criteria for evaluation of sites.
- Apportioning a total score of 760 among the assessment criteria based on the importance.
- Developing Site Sensitivity Index.
- Estimating the score for each attribute for various sites alternatives using SSI.
- Adding the score for individual site alternatives to rank the alternate sites based on the total score.
- Classification and selection of the site based on the total score.

B. Site Sensitivity Indices Method

The seven attributes were selected based on the literature [5], data obtained through investigations in and around the sites. The following are those attributes:

- Accessibility related,
- Receptor related,
- Ecological related,
- Sociological related,
- Waste management practice related,
- Climatologically related,
- Geological related.

A total of 22 top raking parameters were short-listed and weightage of attributes (Wi) was assigned such that the total weightage will be for 760 points. The measurement of each attribute is taken in terms of a Sensitivity index (Si) within a scale of 0 - 1 i.e. (0.0 – 0.25, 0.25 – 0.5, 0.5 – 0.75, 0.75 – 1.0) to calculate cumulative scores called Risk Index (RI) that can be used for short listing of solid waste disposal sites. While "1" indicates highest potential hazard, "0" indicates no or very less potential hazard. SSI is a scale indicating less sensitive to highly sensitive attribute. [6] Table 1 indicates the attributes assigned.

C. Site Evaluation-Estimation of Score for Attributes and Ranking of Sites [6]

Based on the actual measurements, the corresponding site sensitivity index will be given for each attribute. The value of the sensitivity index will be multiplied by the corresponding weightages of the attributes. This will result for weightage score or RI for each of the attribute. The RI of the site is calculated by using the following Equation (1):

$$RI = \sum (Wi)\,(Si) \quad (1)$$

Where,

RI = Risk Index variable ranging from 0 – 760

Wi = Weightage of the variable ranging from 0 – 760

Si = Sensitivity index of the variable ranging from 0 – 1

In this same way, score for each attributes and then for all the categories of an individual site will be added to calculate the total score for the site. The same procedure has to been repeated for all the alternative sites. The result will be interpreted on the basis of the total score (out of 760 points). The total score of all the alternative sites will be compared and will be ranked on the basis of less sensitivity. The site with the least score will be less sensitive, that is there will not be significant impact on the environmental quality due to the disposal site and hence will be the most acceptable. The site suitability accordingly will decrease with increase in the total score. Therefore, the site with least score will be selected for disposal. A broad score is developed to identify which site is acceptable. The generalized scores are given in Table 5.

TABLE 1: ATTRIBUTES, ATTRIBUTE WEIGHTAGE AND SENSITIVITY INDICES [5]

Sl. No	Attribute	Attribute Weightage	Sensitivity Index			
			0.0-0.25	0.25-0.5	0.5-0.75	0.75-1.0
Accessibility related						
1	Type of road	25	National highway	State highway	Local road	No road
2	Distance from collection area	35	< 10 km	10-20 km	20-25 km	>25 km
Receptor related						
3	Population within 500 meters	50	0 to 100 m	100 to 250 m	250 to 1000 m	>1000 m
4	Distance from the nearest drinking water source	55	> 5000 m	2500 to 5000 m	1000 to 2500 m	<1000 m
5	Use of site by nearby residents	25	Not used	Occasional	Moderate	Regular
6	Distance to nearest building	15	>3000 m	1500 to 3000 m	500 to 1500 m	<500 m
7	Land use/ zoning	35	Completely remote (zoning not applicable)	Agricultural	Commercial or Industrial	Residential

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8	Public utility facility within 2 kms	25	Commercial and Industrial area	National heritage	Hospital	Airport
Ecological related						
9	Critical environment	45	Not a critical environment	Pristine natural areas	Wetlands, flood plains and preserved areas	Major habitat of endangered or threatened species
10	Distance to nearest surface water	55	>8000 m	1500 to 8000 m	500 to 1500 m	<500 m
11	Depth of ground water	65	>30 m	15 to 30 m	5 to 15 m	< 5 m
12	Water quality	40	Highly polluted	Polluted	Potable	Confirming to standard
Sociological related						
13	Health	40	No problem	Moderate	High	Severe
14	Job opportunities	20	High	Moderate	Low	Very low
15	Odour	30	No odour	Moderate	High odour	Intensive foul odour
16	Vision	20	Site not seen	Site partly seen (25%)	Site partly seen (75%)	Site fully seen
Waste management practice related						
17	Waste quantity/day	45	<250 tonnes	250 to 1000 tonnes	1000 to 2000 tonnes	> 2000 tonnes
18	Life of site	40	> 20 years	10 to 20 years	2 to 10 years	< 2 years
Climatological related						
19	Precipitation Effectiveness index	25	< 31	31 to 63	63 to 127	> 127
Geological related						
20	Soil permeability	35	> 1 x 10-7 cm/sec	1 x 10-5 to 1 x 10-7 cm/sec	1 x 10-3 to 1 x 10-5 cm/sec	< 1 x 10-3 cm/sec
21	Slope pattern	15	< 1%	1-2%	2-5%	>10%
22	Seismicity	20	Zone I	Zone II	Zone III	Zone IV & V

TABLE 2: SITE EVALUATION CRITERIA FOR HALLBHAVI AND BAMBARGE.

Attributes and weightages			**Site evaluation – Hallbhavi**			**Site evaluation – Bambarge**		
Sl. No	**Attribute**	**Attribute Weightage**	**Attribute Measurement**	**Sensitivity Index**	**Attribute score**	**Attribute Measurement**	**Sensitivity Index**	**Attribute score**
Accessibility related								
1	Type of road	25	National highway	0.25	6.25	Local road	0.5	12.5
2	Distance from collection point	35	20-25 km	0.75	26.25	10-20 km	0.5	17.5
	Total	60			32.5			30
Receptor related								
3	Population within 500 meters	50	250 to 1000 m	0.55	27.5	>1000 m	1	50
4	Distance from the nearest drinking water source	55	<1000 m	1	55	1000 to 2500 m	0.55	30.25
5	Use of site by nearby residents	25	Not used	0	0	Occasional	0.3	7.5
6	Distance to nearest building	15	500 to 1500 m	0.5	7.5	1500 to 3000 m	0.45	6.75
7	Land use/ zoning	35	Agricultural	0.3	10.5	Industrial	0.55	19.25
8	Public utility facility within 2 kms	25	No public facility	0	0	No public facility	0	0
	Total	205			100.5			113.75
Ecological related								
9	Critical environment	45	Not a critical environment	0.05	2.25	Not a critical environment	0.05	2.25
10	Distance to nearest surface water	55	>8000 m	0	0	>8000 m	0	0
11	Depth to ground water	65	5 to 15 m	0.55	35.75	5 to 15 m	0.7	45.5
12	Water quality	40	Potable	0.5	20	Potable	0.5	20
	Total	205			58			67.75
Sociological related								
13	Health	40	No problem	0.1	4	No problem	0.1	4
14	Job opportunities	20	Moderate	0.3	6	Moderate	0.3	6

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15	Odour	30	No odour	0.1	3	No odour	0.1	3
16	Vision	20	Site fully seen	0.75	15	Site partly seen (75%)	0.65	13
	Total	110			28			26
Waste Management practice related								
17	Waste quantity/day	45	<250 tonnes	0.2	9	<250 tonnes	0.2	9
18	Life of site	40	30 years	0.2	8	30 years	0.2	8
	Total	85			17			17
Climatological related								
19	Precipitation Effectiveness index	25	63 to 127	0.55	13.75	63 to 127	0.55	13.75
	Total	25			13.75			13.75
Geological related								
20	Soil permeability	35	1 x 10-4 cm/sec	0.6	21	1 x 10-3 cm/sec	0.6	21
21	Slope pattern	15	1-2%	0.25	3.75	>10%	1	15
22	Seismicity	20	Zone III	0.75	15	Zone III	0.75	15
	Total	70			39.75			51
	Grand Total	760			289.5			319.25

TABLE 3: SITE EVALUATION CRITERIA FOR TURMURI AND KHASBAG.

Attributes and weightages			**Site evaluation – Turmuri**			**Site evaluation – Khasbag**		
Sl. No	**Attribute**	**Attribute Weightage**	**Attribute Measurement**	**Sensitivity Index**	**Attribute score**	**Attribute Measurement**	**Sensitivity Index**	**Attribute score**
Accessibility related								
1	Type of road	25	National highway	0.25	6.25	National highway	0.25	6.25
2	Distance from collection point	35	10-20 km	0.5	17.5	<10 km	0	0
	Total	60			23.75			6.25
Receptor related								
3	Population within 500 meters	50	250 to 1000 m	0.55	27.5	0 to 100 m	0	0
4	Distance from the nearest drinking water source	55	2500 to 5000 m	0.25	13.75	<1000 m	1	55
5	Use of site by nearby residents	25	Not used	0	0	Not used	0	0
6	Distance to nearest building	15	500 to 1500 m	0.5	7.5	<500 m	1	15
7	Land use/ zoning	35	Industrial	0.55	19.25	Industrial	0.55	19.25
8	Public utility facility within 2 kms	25	Hospital	0.55	13.75	Hospital	0.55	13.75
	Total	205			81.75			103
Ecological related								
9	Critical environment	45	Moderate environment	0.1	4.5	Critical environment	0.75	33.75
10	Distance to nearest surface water	55	1500 to 8000 m	0.45	24.75	500 to 1500 m	0.65	35.75
11	Depth to ground water	65	5 to 15 m	0.55	35.75	<5 m	0.8	52
12	Water quality	40	Polluted	0.4	16	Polluted	0.4	16
	Total	205			81			137.5
Sociological related								
13	Health	40	High	0.5	20	Moderate	0.3	12
14	Job opportunities	20	Moderate	0.3	6	Low	0.75	15
15	Odour	30	Moderate odour	0.25	7.5	Moderate odour	0.25	7.5
16	Vision	20	Site fully seen	0.75	15	Site fully seen	0.75	15
	Total	110			48.5			49.5
Waste Management practice related								
17	Waste quantity/day	45	<250 tonnes	0.2	9	<250 tonnes	0.2	9
18	Life of site	40	30 years	0.2	8	30 years	0.2	8
	Total	85			17			17
Climatological related								
19	Precipitation Effectiveness index	25	> 127	0.8	20	63 to 127	0.55	13.75
	Total	25			20			13.75
Geological related								
20	Soil permeability	35	1 x 10-4 cm/sec	0.6	21	1 x 10-4 cm/sec	0.6	21
21	Slope pattern	15	2-5%	0.55	8.25	1-2%	0.25	3.75
22	Seismicity	20	Zone III	0.75	15	Zone III	0.75	15
	Total	70			44.25			39.75
	Grand Total	760			316.25			366.75

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TABLE 4: SITE EVALUATION CRITERIA FOR KINAYE AND DESUR.

Attributes and weightages			Site evaluation – Kinaye			Site evaluation – Desur		
Sl. No	**Attribute**	**Attribute Weightage**	**Attribute Measurement**	**Sensitivity Index**	**Attribute score**	**Attribute Measurement**	**Sensitivity Index**	**Attribute score**
Accessibility related								
1	Type of road	25	State highway	0.3	7.5	National highway	0.25	6.25
2	Distance from collection point	35	10-20 km	0.5	17.5	10-20 km	0.5	17.5
	Total	60			25			23.75
Receptor related								
3	Population within 500 meters	50	>1000 m	1	50	>1000 m	1	50
4	Distance from the nearest drinking water source	55	1000 to 2500 m	0.55	30.25	<1000 m	1	55
5	Use of site by nearby residents	25	Not used	0	0	Occasional	0.3	7.5
6	Distance to nearest building	15	500 to 1500 m	0.5	7.5	<500 m	1	15
7	Land use/ zoning	35	Agricultural	0.3	10.5	Agricultural	0.3	10.5
8	Public utility facility within 2 kms	25	No public facility	0	0	No public facility	0	0
	Total	205			98.25			138
Ecological related								
9	Critical environment	45	Not a critical environment	0.05	2.25	Not a critical environment	0.05	2.25
10	Distance to nearest surface water	55	>8000 m	0	0	>8000 m	0	0
11	Depth to ground water	65	< 5 m	0.8	52	< 5 m	0.8	52
12	Water quality	40	Potable	0.5	20	Potable	0.5	20
	Total	205			74.25			74.25
Sociological related								
13	Health	40	No problem	0.1	4	No problem	0.1	4
14	Job opportunities	20	Moderate	0.3	6	Moderate	0.3	6
15	Odour	30	No odour	0.1	3	No odour	0.1	3
16	Vision	20	Site partly seen (25%)	0.25	5	Site fully seen	0.75	15
	Total	110			18			28
Waste Management practice related								
17	Waste quantity/day	45	<250 tonnes	0.2	9	<250 tonnes	0.2	9
18	Life of site	40	30 years	0.2	8	30 years	0.2	8
	Total	85			17			17
Climatological related								
19	Precipitation Effectiveness index	25	63 to 127	0.55	13.75	63 to 127	0.55	13.75
	Total	25			13.75			13.75
Geological related								
20	Soil permeability	35	1 x 10-4 cm/sec	0.6	21	1 x 10-3 cm/sec	0.6	21
21	Slope pattern	15	2-5%	0.55	8.25	2-5%	0.55	8.25
22	Seismicity	20	Zone III	0.75	15	Zone III	0.75	15
	Total	70			44.25			44.25
	Grand Total	760			290.5			339

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TABLE 5: SITE SCORES

Total score	Site description
Score below 228	Very low sensitivity
Score between 228 – 342	Low sensitivity
Score between 342 – 456	Moderate sensitivity
Score between 456 – 570	High sensitivity
Score above 570	Very high sensitivity

IV. RESULTS AND DISCUSSIONS

In the present study, analysis has been done to find out the most suitable solid waste disposal site for Municipal solid waste generated by the Belagavi city. The analysis has been carried out using the SSI method. Based on the methodology and sensitivity index assigned to the attributes, evaluation is done for Hallbhavi, Bambarge, Turmuri, Khasbag, Kinaye and Desur solid waste disposal sites for Belagavi city. The details of the attribute index for each of the six sites are furnished in Table 2, 3 and 4. The results of the analysis are discussed below.

A. Ranking of Sites

The total score for all six sites were calculated on the basis of the ranking methodology of RI. The site with least score indicates that the site is less sensitive to impact. Hence these sites were ranked first as shown in Table 6.

TABLE 6: RESULTS OF TOTAL RI SCORE FOR THE SOLID WASTE DISPOSAL SITES.

Ranks	Sites	RI score	Sensitivity
I	Hallbhavi	289.5	Low sensitivity
II	Kinaye	290.5	Low sensitivity
III	Turmuri	316.25	Low sensitivity
IV	Bambarge	319.25	Low sensitivity
V	Desur	339	Low sensitivity
VI	Khasbag	366.75	Moderate sensitivity

According to the results, the three best ranked sites identified and selected are Hallbhavi with 289.5 points for the north zone, Kinaye with 290.5 points for the south zone and Turmuri with 316.25 points for the central zone.

V. CONCLUSIONS

Belagavi city has been divided into three zones viz north, central and south zone having 18, 20 and 20 wards respectively. This is done to decentralize the waste collection, transfer and transport and ultimate disposal activity to achieve economy and time saving. Six potential disposal sites have been identified and studied for solid waste disposal namely Hallbhavi, Bambarge, Turmuri, Khasbag, Kinaye and Desur based on SSI method. A set of 22 parameters required for site selection were studied and evaluated based on literature, Central Public Health and Environmental Engineering Organisation (CPHEEO) manual for MSWM, field survey and data collected in and around the sites for the best site selection. Three best ranked sites i.e. Hallbhavi with 289.5 points, Kinaye with 290.5 points and Turmuri with 316.25 points were selected for the three zones of Belagavi city (north, central and south) based on sensitivity as less score and a better rank. With this decentralized way of disposing waste of the city, it will result in reduction of traffic inconvenience, reduction in haul distance and haul time from waste source to the disposal site. Also the segregation and treatment of the waste can be done at the site.

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