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Analysis of Landfill Site Location using Landfill Site-Selection Index

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Abstract:- The dumping of solid waste in uncontrolled landfills can cause significant impacts on the environment and human health. So, the location of landfill is a very important factor that ensures the long working life of landfill. The principle concern is focused on the locational criteria on which the site selection of landfill depends. In this paper the concept of landfill site selection index, a tool for quantifying the suitability of site for landfill construction has been described and its practical application has been demonstrated by comparing the potential of three already existing landfill sites in Delhi namely, Okhla landfill, Ghazipur landfill and Bhalswa landfill. It is observed that all the three existing landfills are in error zones and do not follow the safety criteria for all the factors on which landfill site selection depends.

I. INTRODUCTION

Landfills poses threat to the surrounding in which it is located. Threats to groundwater from the unlined and uncontrolled landfills exist in many parts of the world, particularly in the underdeveloped and developing countries where hazardous industrial waste is also co-disposed with municipal waste, and no provision of separate landfills for hazardous waste exist and numerous examples of such countries can be sited starting with South Africa, China, India and many more. Uncontrolled and unmanaged disposal of waste can lead to significant impacts on the environmental and human health. To deal with this unmanaged waste disposal the concept of Landfill can into being. Landfills are a very effective way of disposing non- radioactive waste and from here the waste can be transported to a place where it can be made useful. But, the degradation of wastes in the landfill results in the production of leachate and gases. These emissions are potential threats to human health and to the quality of the environment. Thus, to avoid such circumstances the site selection of landfill is a very important task. This is done with keeping in mind the locational criteria that are affected by the location of landfill in their vicinity. Some of these locational criteria are: River, Vegetation, Airport, etc. Some of these have more significance than others. Analysing all the location criteria we land upon to Landfill site selection index which is a quantitative measure to how good a site is for the purpose of landfill construction. We study location criteria with the help of arcgis and hence calculate an index which gives us the suitability of a site.

A. The Locational Criteria:

These are the elements considered crucial for determining the location of a landfill site and so they are to be kept at a safe distance from a proposed landfill site.There are six location criteria on which the site selection of landfills depend.

- Surface water bodies
- Vegetation
- Critical Habitation
- Highways
- Power Lines
- Airports

They influence the site selection of landfills through their distance from a proposed landfill site. The safe distances[1] for each of these location criteria are as follows:

- Surface water bodies -200m
- Vegetation - 500m
- Critical Habitation - 1000m
- Highways - 500m
- Power Lines - 700m
- Airports - 3000m

II. THE GIS ANALYSIS OF THE LANDFILLS OF DELHI

GIS Software can be applied to analyse how the locational criteria are distributed around the area that we are studying for the purpose of using it as a Landfill. This can be done by choosing a suitable distance around the Area of Study in which a particular locational criteria is being monitored. GIS Software makes it easier to measure the distance between the landfill and a particular Locational Criteria. The Area of consideration of each Locational criteria is 2*(Buffer Distance or BD of that Locational Criteria) except for Airport for which its 20km. Further information has been given in the sections below.

III. INDEXING

As we know that landfills are an area where the waste from all nearby places is being dumped for the purpose of degradation or recycling them to make useful products. But, no one would like the idea of having a landfill nearby their residence. Thus the choice of the location of landfill is a very important job, as it can affect surrounding very severely. For this purpose, an Index is being developed to take into consideration the effects on these locational

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criteria and to figure out the best place for the location of a landfill.

The Landfill Site selection Index can be used to find the effectiveness of an active Landfill site and also to predict the effectiveness of an area for the establishment of a Landfill. For the development of this Index six Locational Criteria have been taken into consideration.

A. Sub-Index Curves[2]

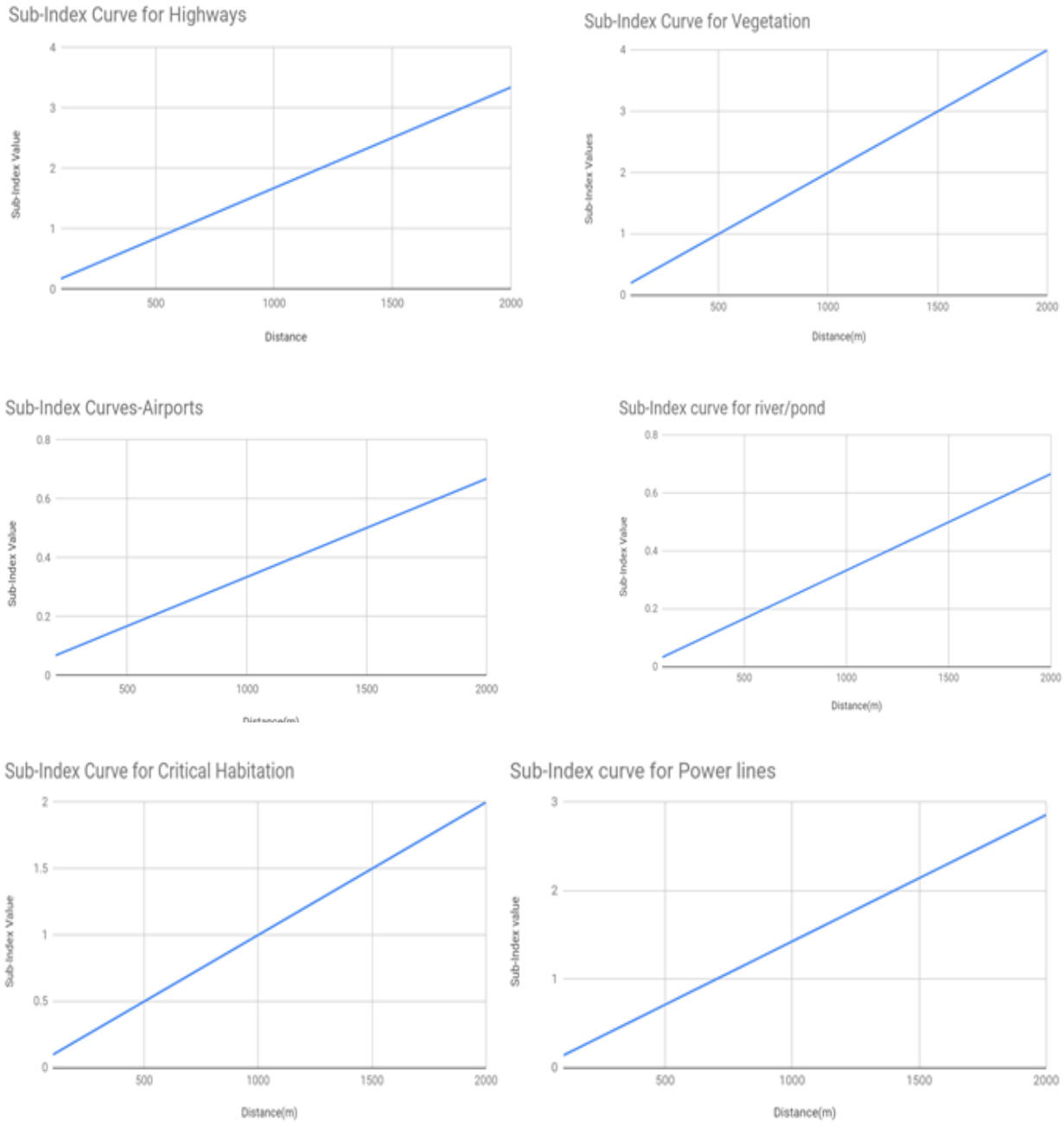

Fig 1

B. Procedure for Calculating LSI

Firstly the weighted significance of these criteria have been calculated using the following expression and the value calculated[2][3] has been mentioned in the table-1 below:

Weighted Significance $w\text{-}_i=(1/BD_i)/\Sigma(1/BD_i)$
BD_i=Buffer Distance of each locational criteria

ISSN No:-2456-2165

S.No.	Locational Criteria	Buffer distance(m)	Area of consideration(Ximax)	1/BD	Weighted Significance
1	River/Pond	200	400	0.005	0.4251012146
2	Vegetation	500	1000	0.002	0.1700404859
3	Airports	3000	20000	0.00033333	0.02834008098
4	Critical Habitation	1000	2000	0.001	0.08502024293
5	Power lines	700	1400	0.001428571	0.1214574899
6	Highways	500	1000	0.002	0.1700404859
				Total=	1

Table 1

After calculating the weighted significance, the Landfill site selection Index for an area of study can be calculated by using the following equation[2][4]:

$$\mathbf{LSI=C\times\sum(w_iX_i/\ X_{oi})/\sum w_i}$$

$\mathbf{w_i}$=Weighted Significance of each Locational criteria
$\mathbf{X_i}$=Distance of each Locational criterion from the Area of Study
$\mathbf{X_{oi}}$= Buffer distance of each Locational criteria
C is a constant(C=5)

The coefficient C is chosen to study the variation of the LSI over a larger range.The higher value of LSI indicates a better location for the use of landfill.

Some assumptions for calculating LSI:

- To find the distance of each Locational criterion(X_i), the closest distance to that locational criteria from the geometrical centre of the area of study is taken. This is done to finite the range of LSI.
- If there are more than one Locational criteria of the same type then the closest of them all is taken within the area of consideration for that criteria.
- If a Locational criteria is not within the Area of consideration then the value of X_i is taken as 2*(Buffer Distance of that Locational Criteria)

Using these assumptions, the range of LSI comes to be 0-10.65.

When all the Locational criteria are at a distance equal to their Buffer distance the value of LSI is 5 which is considered to be the bare minimum value for the Landfill to be safe for the Environment.

Thus, the range of LSI is divided into two regions:

- **0-5**: This range can be considered as unfit for the location of a landfill. The smaller values represents the closeness of the criteria near the area of study. Locating a landfill in such an area can severely affect the environment.
- **5-10.65**: This range of LSI is suitable for the location of a landfill but the higher values should be considered for using that area as a landfill. Any area having an LSI of 10.65 is considered to be best suited.

IV. GIS APPROACH TOWARDS SELECTION OF LANDFILL

For the purpose of checking the practicality of the index developed we have tried to cross-verify the value of the index with manually choosing a location for a suitable landfill site in Delhi[5] and then calculating its index using the formula generated. This helps us to analyse as to how efficient the index is in quantifying a location as a potential site for landfill creation.

The idea is simple, we take the 5 most populated areas of Delhi which generate maximum amount of garbage and then the assumptions made are as follows:

- The highly populated locations generate the most amount of garbage.
- The distance to which an area can dispose off its garbage is 25km in and out of the area(considering the economy of disposing off).

So likewise we draw up buffer zones for each of the highly populated location of Delhi and then the intersection of those circles is identified to give us a theoretical area of study to manually analyse[6] the best suited location in Delhi for landfill creation.

Over the map of Delhi the above proposed theory is applied to select a possible site for construction of a landfill. This area is divided into 6 zones based on the highest amount of population implying highest amount of waste generation and then it is considered that these zones can send in their garbage to a maximum distance of 25km in and out of that particular zone.

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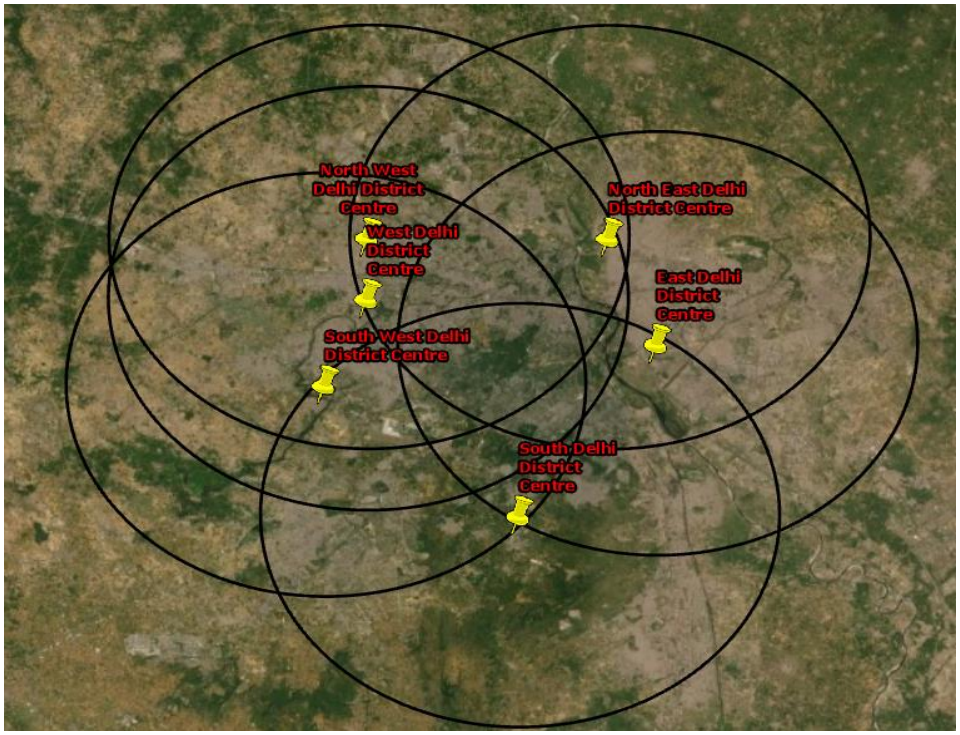

Fig 2

The above given image illustrates the zones selected and each zone's buffer distance(i.e. 25kms) and now the intersection of the circles gives us the area suitable for construction of landfill.

Fig 3

The above given image is the intersection of the circles and is finally our area of study on which the design parameters are applied and finally an area is obtained for landfill creation.

A. Location Criteria for Lakes:

The location criteria for lakes is applied here and as its buffer distance(BD) is 200m so a buffer region of 200m meters is created all around the boundary of the lake.

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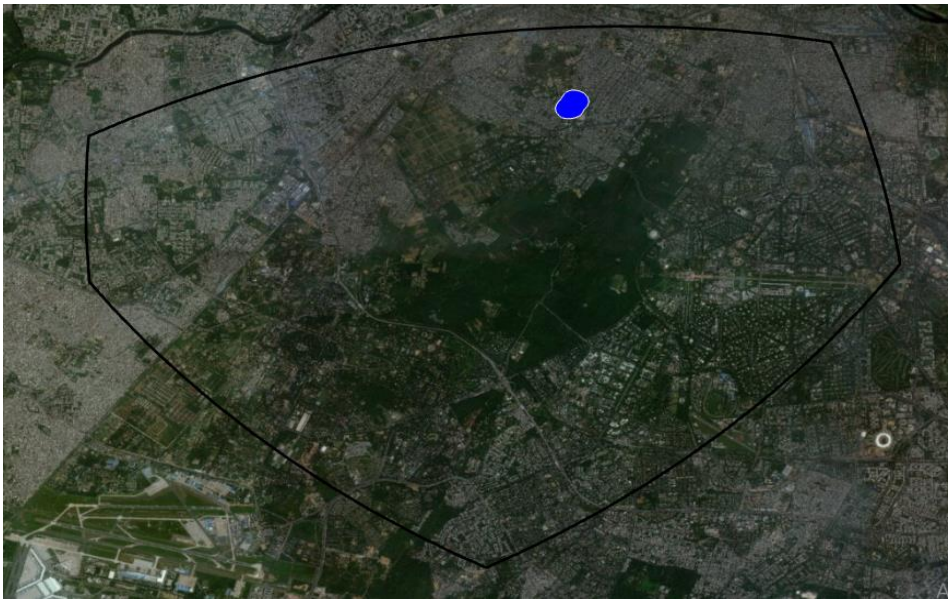

Fig 4

B. Location Criteria for Remaining Parameters:

Similarly for remaining parameters the location criteria are applied on the same area and the result obtained is displayed below:

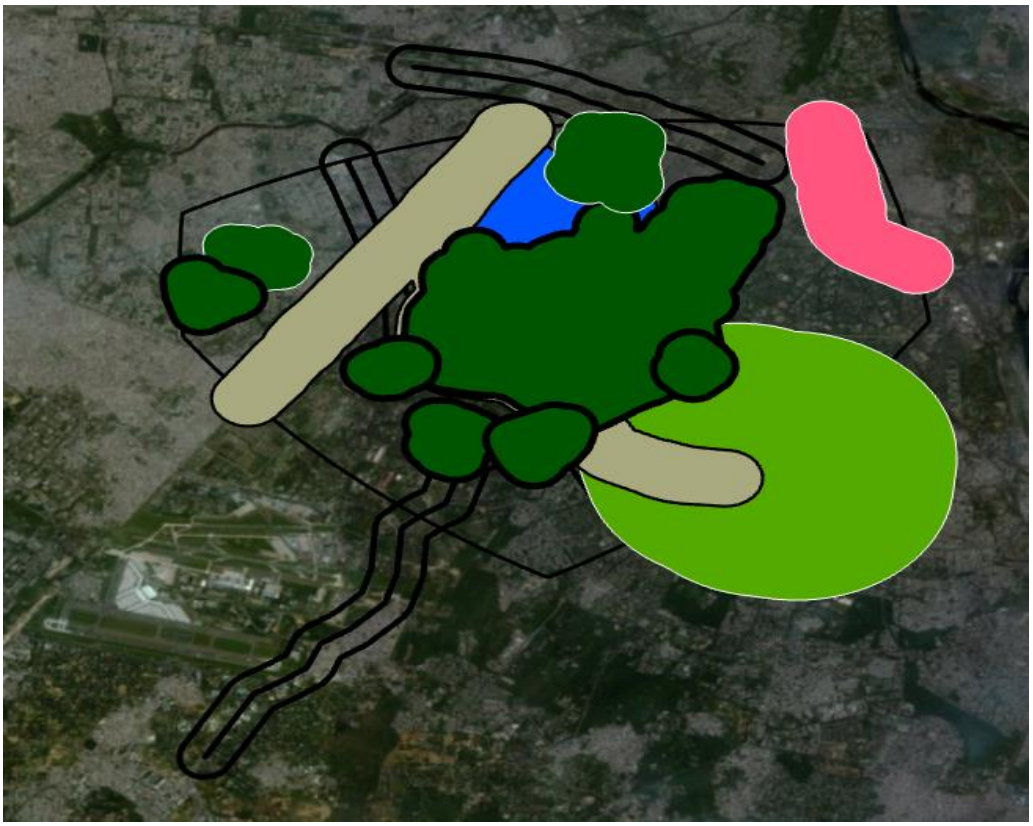

Fig 5

The final area with the overall result

So now the area remaining uncoloured is the area which is the area free of all constraints and can be used for landfill creation.

V. ASSIGNING INDEX TO LANDFILL LOCATIONS

In this section, the value of LSI has been calculated for some of the Major Landfills in Delhi namely Ghazipur landfill, Bhalswa landfill and Okhla landfill.

The values have been calculated in the tables below: **For Ghazipur Landfill**:

S.No.	Locational Criteria	Weighted Significance	Buffer distance,Xoi(m)	Xi(m)	wiXi/ Xoi
1	River/Pond	0.4251012146	200	257.91	0.5481892713
2	Vegetation	0.1700404859	500	1000	0.3400809717
3	Airports	0.02834008098	3000	12055.12	0.1138810257
4	Critical Habitation	0.08502024293	1000	2000	0.1700404859
5	Power lines	0.1214574899	700	713.53	0.1238050897
6	Highways	0.1700404859	500	658.94	0.2240929555
				LSI=5*(∑(wiXi/ Xoi)/∑wi)	7.600449

Table 2

For Okhla Landfill:

S.No.	Locational Criteria	Weighted Significance	Buffer distance,Xoi(m)	Xi(m)	wiXi/ Xoi
1	River/Pond	0.4251012146	200	400	0.8502024293
2	Vegetation	0.1700404859	500	231	0.07855870447
3	Airports	0.02834008098	3000	10410	0.09834008099
4	Critical Habitation	0.08502024293	1000	1031.38	0.08768817815
5	Power lines	0.1214574899	700	866.63	0.1503695778
6	Highways	0.1700404859	500	154.67	0.0526003239
				LSI=5*(∑(wiXi/ Xoi)/∑wi)	6.588796475

Table 3

For Bhalswa Landfill:

S.No.	Locational Criteria	Weighted Significance	Buffer distance,Xoi(m)	Xi(m)	wiXi/ Xoi
1	River/Pond	0.4251012146	200	400	0.8502024293
2	Vegetation	0.1700404859	500	1000	0.3400809717
3	Airports	0.02834008098	3000	18040	0.1704183536
4	Critical Habitation	0.08502024293	1000	2000	0.1700404859
5	Power lines	0.1214574899	700	1400	0.2429149798
6	Highways	0.1700404859	500	300	0.1020242915
				LSI=5*(∑(wiXi/ Xoi)/∑wi)	9.37840756

Table 4

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From the Values of LSI calculated we can see that it's the least for Okhla Landfill(table 1.3) and the most for Bhalswa Landfill(table-4). This can be related to the fact that maximum of locational criteria for Bhalswa Landfill are quite far away from the location of the landfill(some are even out of the area of consideration). The value of LSI for all the landfills is above 5 which means that all of them are under the safe zone but as compared with Bhalswa landfill other two have values quite close to 5. This indicates that Bhalswa landfill is located at a safer place as compared to the other two landfills. The case for Okhla landfill(table 1.3) is not very good as it has a Highway and vegetation within their buffer range. This causes adverse effects of these locational criteria which is indicated by the lowest value of LSI.

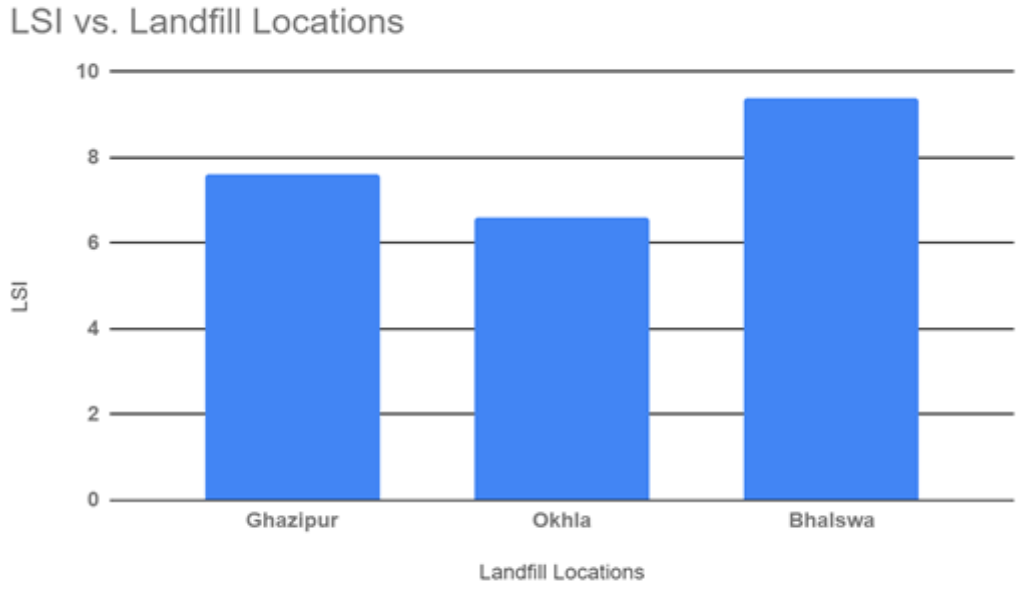

Fig 6

VI. CONCLUSION

The LSI provides a meaningful method of evaluating the potency of a site as a prominent landfill site. It can serve as an important information tool for the concerned government to assess the suitability of a particular site and also provides a quantification to how good the site is. Using it comparisons can easily be drawn between any number of given locations and the best one can be opted out of them. Among the three landfill sites considered for evaluating the landfill site selection index based on their distances from the location criteria used, the LSI value of Okhla landfill site indicates that it is currently in the most pathetic condition and the location criteria located nearby that landfill are in serious risk of getting sick to the diseases caused by the landfill. At the same time the LSI value of the bhalswa landfill clearly indicates that the landfill located near the bhalswa landfill is in comparatively very good situation and has a very high value of landfill site selection index. Here, it can also be analysed that although all the landfill site selection indexes are above the value 5 but still are in error zones. So for the purpose of selecting a landfill site not only the values of LSI is important but consideration of the elements used for the purpose of modelling the index is important as well.

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