Siting of new landfill for Municipal solid waste using GIS & MCDA-A Review

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Abstract. Due to rapid change in urban areas and the exponential growth in population, accelerated the huge generation of municipal solid waste (MSW). The management of the disposal of MSW is a substantial and complex process. Landfilling is the most common method used for the disposal of MSW, at the same time identifying the suitable site for disposal of MSW is a difficult task. Stakeholders are very much concerned about the disposal of solid waste and its landfilling. Sitting of the new landfill using spatial data and Geographical Information System (GIS) approach on conflicting points among social, economic and environmental effects. In this review paper literature related to new landfill sitting using GIS &Multi Criteria Decision Analysis (MCDA) methods are cited. Review paper concentrates on MCDA techniques, method of disposal, type of solid waste and country.Most common methods have been used by researchers are Analytic Hierarchy process, Fuzzy, Dynamicmodeling, Analytical Network Process, Analytic Neural Network, site screening method&ArtificialNeural Network. It can be concluded that GIS provides accurate mapping, quick collection of data, high accuracy, better predictions, and analysis by eliminating unsuitable areas.Moreover,MCDA methods Analytic Hierarchy process(AHP) is found best from a set of available alternatives and gives the error-free solution to the users because of simplicity in pairwise comparisons,consistency in evaluation and versatility.It helps inidentifying the optimum site for the construction of a landfill. Limitations of AHP are found in random assumptions for various criteria's and due to that consistency ration increases more than10 %. Hence, there is a need forthe application of Artificial Intelligence with AHP.

Keywords: Municipal Solid waste, GIS, Landfill Sitting, MCDA techniques.

1 Introduction

In developing countries due to urbanization, industrialization, and increasing population, the problem of solid waste generation is increases and it causes environmental pollution and degradation. In India, the rate of increase in urban population changes from 11% in 1901 to about 31% in 2011. The census of 2011 indicates the fact that presently 31.2% of the total population resides in the urban centers [33]. As per Central Pollution Control Board (CPCB),thequantity of solid waste generated in India

during the year 2016-17 is 135199 tonnes per day (TPD), which has been forecast to rise to 33% in the next 15 years. Out ofthetotal waste generated, 47416 TPD is sent for landfilled [38,5].

Engineering landfill is the best-suited method used for disposal of solid waste in India but finding a location of new landfill sitting remains a critical management issue.Wherein the selection is based on a number of considerations and the process is suffered from environmental, social and political issues. In India, CPCB is a statutory organization under the Ministry of Environment, Forest and Climate Change (MoEFC) provided the guidelines for selection of appropriate landfill site selection criteria for disposal of MSW [4].

Landfill sitting method involved the conventional method as well using spatial data, GIS & MCDA techniques. Methods aim at the low impact on Environment, high social acceptance and low cost is preferable. New landfill sitting includes (i) setting up of a locational criteria; (ii) identification of search area; (iii) drawing up a list of potential sites;(iv) data collection; (v) selection of few best-ranked sites; (vi) environmental impact assessment and (vii) final site selection and land acquisition [4].The final selected site must satisfy the existing legislative guidelines.Application of GIS using spatial data and attribute data and Multi-criteria decision analysis (MCDA) is being used by many authors for analysis of best possible sites of landfilling.MCDM methods able to make the comparisons against each criterion given in the legislation and assign the weights to the available existing sites. A few of the important methods of MCDM have been summarized. [9–11, 14, 26, 40, 41].

This paper aims to review of MCDA techniques in selection criteria on landfill sitting using GIS and its future scope for further research. Various Thematic maps are required for new landfill sitting using GIS, RS for overlay analysis. These maps with different scales have been used by researchers for initial screening in order to eliminate unsuitable areas.

MCDA used in every field where we required to take a decision from the available alternatives, it gives the best solution in assigning the ranking. Various methods are developed to solve these multi-criteria problems[17,10].In the literature, many researchers considered the weights for different criteria and it was found that environmental, economic and social criteria influence more in new landfill siting.

MCDA methods used in Literature are Analytic Hierarchy process, Fuzzy logic, Dynamic modeling, Analytical Network Process, Analytic Neural Network&ArtificialNeural Network. This paper focused on MCDA techniques with GIS & RS for landfill site identification of MSW. The various factors and their weights with their importance are discussed. In available methods found the AHP technique was frequently used by researchers with its advantages and limitations.

2 Literature Review

In this paper, the various methods used by researchers have been cited for new landfill sitting of MSW. Some of the most popular methods are summarized below like AHP, ANP, Fuzzy, Sitescreening, Site Sensitivity Index & Delphi technique, C Programme, Boolean logic & binary evidence, Weighting method & Artificial Neural Network.

2.1 AHP-Analytic Hierarchy process

Analytical hierarchy process (AHP) has been introduced and developed by Saaty[31]. AHP method is used for pairwise comparisons. In AHP technique Consistency ratio is always less than 10%, which shows the strong pairwise relations in criteria's.As the pairwise comparisons were based on a random basis so there are chances of inconsistency. Hence 10% inconsistency is allowed.If the consistency ratio is not less than 10%, then the standard procedure is revised the pairwise comparisons needs to improve it. Spatial-AHP technique was used by Siddiqui et al.,[8] for Oklahoma country to give the ranking for MSW landfill site. The factors considered are Hydrogeology/geology, land use, and proximity for decision ranking. Considered factors were assigned the weights as per AHP technique and sensitivity was checked. Soil& landuse maps used were in raster format 200m cell resolution published by soil survey maps (USDA SCS 1987). Same techniques were used by Kontos et al.,[22]for MSW landfill site of the island of Lemons in the North Aegean Sea (Greece). The factors considered are hydrology/hydrogeology, Environmental, Social, & Technical/Economic.

In 2008 Sumathi et al.[38],used GIS-AHP for Pondicherry by considering the factors lake and ponds,rivers,water supply sources, groundwater table, groundwater quality, infiltration, air quality index,geology,fault line, elevation, land use,habitation, highways, sensitive sites. An algorithm was formed and it performs GIS-based constraints mapping technique to eliminate the unsuitable sites. Afterward,thesame technique was used by Sharifi et al.[37]for hazardous waste landfill sitting in Kurdistan Province, western Iran. The factors like geology, hydrogeology, hydrology, climatology, and eco-sociology were considered for identifying the best possible sites from 15 sites.

Natesan et al, [28]used AHP for Chennai city for MSW and used FIC, ANN and Delphi techniques in sanitary landfill siting.The reason of using these three techniques was that,AHP is best in giving weights to the multiple alternatives. The Delphi model sets the priority as per the opinion of the experts, but fail to establish interrelationship between the decision factors and elements in the decision factors.FIC is converted as a score of each decision factor. ANN model found to best to overcome the AHP, FIC&Delhimodels.The results obtained were15.34%, 17.33%,, 25.91% and 19.13% respe.The factors considered are Landuse;Geology, Geomorphology, Drainage Density, Slope, Soil and Runoff base map was used.

Moeinaddini et al.[26]also used AHP & weighted linear method in combination with GIS and foundeffective in handling of qualitative and quantitative data. The Landfill site was identified at Karaj, Iran, for MSW. Weighted linear Combination method and spatial cluster analysis (SCA) were used and suitable sites for allocation of landfill for a 20-year period were identified and found 6% suitable area for landfill.Same AHP technique was used by Sener et al.[36]in Konya, Turkey for MSW. Factors considered were such as geology/hydrogeology, land use, slope, height, aspect and distance from settlements, surface waters, roads, and protected areas.Four suitability classes like high, moderate, low and very low suitability areas were represented 3.24%, 7.55%, 12.70%, and 2.81%, respectively and remaining 73.7.% was found the unsuitable area for landfill. Geneletti[13] also used AHP & GIS for an inert landfill in the Sarca's

Plain, located in southwestern Trentino. Found 8 potential sites in northern Italy and gave the ranking on the basis of visibility, accessibilityand dust pollution. The ranking was given on the basis of criterion scores and weights. Finally out of the eight sites finally, compare three suitable sites.

Tavares et al.[39]investigated new landfill sitting for incineration plant in Cape Verde of Africa using AHP& GIS. The major factors were considered were economic, environmental, health, and social costs .75% weighting was given to non-environmental factors and 25% weight was given to environmental factors. The identified sites found on the basis of factors were socio-economic, technical and environmental issues with weights 48%, 41% and 11% respectively. Same AHP with ordered weighted average & GIS in combination with fuzzy was used by Gorsevski et al. [14] for landfill site selection in the Polog Region, Macedonia.Environmental factors were given more weight as compared tothe economic factor.

Gbanie et al. [31]did the Case study for Bo, Southern Sierra Leone for Municipal landfill using Weighted Linear Combination and Ordered Weighted method in addition with GIS. The results showed 83.3% ofthe land area was unsuitable for landfill construction and only 2.1% ofthe land was suitable for construction.AHP and GIS technique also used by Kumar et al.[23]. Identified six potential sites in Delhi, India. While applying AHPtechnique, difficulty was found in ranking irregularities of the considered factors used and weights are given on 9 point scale. Feo et al. [9]considered total 22 to 23 constraints for new landfill sitting for different waste disposal sites like hazardous waste, non-hazardous waste landfills, inert waste landfill, waste to energy, mechanical biological treatment using multiple criteria decision analysis and GIS. Three phases such as‘‘non-suitable areas’’,‘‘preferential and penalizing criteria’’ and “most suitable sites”were considered .Finally Apply the AHP–Priority Scale Weighting and Simple Additive weight –Paired ComparisonTechniqueapproaches to the alternatives matrix gave the same ranking lists.

Khodaparast et al.[21] used AHP & GIS for MSW in Qom city, Iran and considered the factors like geomorphology–hydrography, environmental–social factors. Different Criteria’s are selected according to the regional condition; therefore, important factors such as distance from sea and forest areas were not considered. Using AHP & WLC only 7% area was found as a suitable area for landfill construction. Md.Mohib et al[19] considered 12 constraint factors in the first attempt and screened 45.7% area was screened. Inthe second attempt with the help of location-allocation analysis 10 locations were selected. The author found this AHP technique efficient for sitting of landfill. Luciana et al.(2018)[35] identified the landfill sitting for MSW using GIS & SAW method for ranking scale 0 to 10.Author addressed the method for a limited area and got the benefit of human health protection.

In summary parameters and their weights used in the analysis during the sitting problem affects the results. Table 3 summarizes the different criteria, sub-criteria and corresponding weights used by various researchers. It can be seen that most of the researchers convinced that environmental, economic and social criteria are more sensitive.

Table 3.Criteria and their weights used in AHP from literature

Sr. No.	Criteria	Sub criteria	References									
			[38]	[26]	[37]	[22]	[14]	[27]	[12]	[13]	[20]	[39]
1	Environmental	Aspect	0.0510									0.11
2		Distance From Settlement	0.2350					0.134		0.21		
3		Distance From Surface Water	0.4080	0.1794	0.078	0.1266						
4		Distance From Protected	0.1430		0.052			0.0168				
5		Distance From Power Lines		0.0186								
6		Temp		0.0428								
7		Rain		0.0983	0.039							
8		Flooding Over 100 Yrs		0.0813								
9		Lithology			0.09							
10		Sensitive Ecosystem		0.2830		0.0731						
11		Climatic Regimes			0.053							
12		Evapotranspiration			0.039							
13		Distance From Forest										
14	Geology /Hydrogeology	Dist.from Agri. Land										
15		Vegetation				0.0252						
16		Geology/Hydrogeology	0.0950				0.2936					
17		Distance from Faults		0.1393	0.087		0.1705	0.015				
18		Permeability of Soil		0.2140						0.07		
19		Distance from Aquifers			0.12							
20		Distance from		0.0735	0.11	0.2074	0.0571	0.171		0.15	0.07	
21		Distance from					0.0571					
22		Distance from Rivers					0.0571					
23		Distance from Ground Water		0.01827								

Table 3.Continued……

Sr. No.	Criteria	Sub criteria	[38]	[26]	[37]	[22]	[14]	[27]	[12]	[13]	[20]	[39]
24	Geomorphology	Depth of Water Table										
25		Water Permeability				0.2074						
26		Morphology				0.0459						
27		Slope (%)	0.1680				0.0312	0.025	0.1623	0.13		
28		Height	0.2872		0.01		0.1705			0.08		
29		Depth Of Bed Rock										
30		Soil Type										
31		Texture										
32	Economic	Landuse&Landcover	0.6700	0.0570	0.064	0.0731	0.1058	0.073	0.3784		0.02	0.5
33		Depth Of The Soil		0.2153				0.111				
34		Distance From Road	0.5450		0.02	0.0163		0.037			0.23	
35	Socio -Cultural	Visibility/Distance From Residential Areas/Urban		0.2040 & 0.1622	0.053	0.1266	0.0571	0.052	0.1623		0.03	
36		Wind Direction And Wind Gust		0.1755		0.0252						
37		Distance From Historical & Tourism Centres		0.0883				0.026				
38		Distance From Industries		0.0332	0.2			0.014				0.41
39		Distance From Airport		0.0623				0.029				
40		Cultural Areas				0.0731						
41		Distance From Villages						0.046				
42		Distance From School										
43	Design	Distance From Power Line										0.09
44		Distance From Saline Area										

2.2 Site Screening Method

A site selection process usually proceeds through a phased approach. It begins with the use of regional screening techniques to reduce a large study area, such as an entire state or region, to a manageable number of discrete search areas.
Mehmet et al.[16]usedthe site screening method for HW landfill without using GIS in Turkey. He worked manually and used overlay technique as the methodology for preparing a final site selection map. He suggested this method is used for more general conditions and locations.

2.3 Fuzzy- logic

Fuzzy logic is an extension of Boolean logic byLotfiZadeh in 1965 based on the mathematical theory of fuzzy sets, which is a generalization of the classical set theory Zadeh[25]. Now a day's fuzzy logic has been successfully used in various disciplines.

Omar et al.(2006)[1] investigated landfill sitting using the fuzzy intelligent system at capital city Amman, Jordan. The authorconsidered mainly four factors namely topography and geology, natural resources, socio-cultural, and economy, and safety. Fuzzy techniques can be used in vast areas especially in computer vision, weather prediction, image processing, nuclear reactor control, control of biomedical processes, automatic tuning and many other fields of research[15, 29, 34].IF-THEN rule was used for the fuzzy interface. Author finds different grades for different landfill sites 91.19%, 53.00%, 23.33% & 52.09% grade I,II,III &IV resp.The first landfill site was excellent and the third landfill site has proven to be worst and unacceptable.
Chang et al.[3]used fuzzy multi-criteria decision-making methods for landfill siting in urban areas of south Texas. The author identified seven landfill sites and gave ranking to each.Landfill site one was found the ranking of 0.786689, which was the best site for landfill construction. The same technique was used by Alexandra et al.[12]for landfill siting of MSW.The author divides the factors into two parts, one part is the physical environment and the other part is the socioeconomic environment. No cost was considered in the first part and another factor was with consideration of cost. The fuzzy technique was associated with the first part as well AHP was associated with the second part. Combination of two techniques resulting in composite suitability map for landfill siting.The author considered exclusionary and exclusionary criteria and wasexamined. The final decision of landfill site suitability was also depended on public response and political issues.

2.4 Site Sensitivity Index (SSI)& Delphi technique

Paul et al.,[30] used Site Sensitivity Index, Delphi technique & RS,GIS for new landfill sitting at Kolkata India. The author considered the factors for the ranking purpose were accessibility, receptor, environmental, socioeconomic, waste management practices, and climatologically and geological. Lowest SSI score indicates the less sensitive site.

2.5 Analytical Network Process

Analytical Network Process (ANP) is a mathematical theory that was involved as a systematic with varied dependences and has been successfully employed in different fields. This method is useful in flexibility consideration in solving more complex interrelationships among different elements.

Zeynab et al.[27] used ANP, Weighted Linear Combination, Ordered Weighted Average methods and got the results ranges in 1–7, 62.69%, 32.41%, 21.45%, 18.71%,13.65%, 4.60% and 0.05% of region area is in the very suitable class. Khan et al. [20] proposed ANP techniques by considering decision models, different criteria and alternatives. The author suggested for segregation at the source only so that burden and cost invested on landfilling can be minimized.

Aragones et al.[2]usedthe ANP method in Spain for landfill sitting with its strength and weakness and suggested the best method to the decision-makers. Two ANP models were analyzed and compared with each other. The author also suggested AHP &ANP models. The factors were grouped into Plant exploitation costs, Facilities and infrastructures, Environmental issues and Legal requirements.

2.6 C Programme

Kao et al.[18] used a raster-based C program for landfill sitting, the author developed an algorithm. This technique was helpful in implementing multi-factor analysis for compactness and other siting factors with weights specified by the user. In this method sitting time is reduces using the C program algorithm.

2.7 Boolean logic & binary evidence, Weighting Method and EVIAVE

Delgado et al.[6] made an analysis of land suitability for sitting of landfills in Mexico using spatial decision-support models and overlapping index of multiple class maps. The factors considered were grouped into land use, base map, soil&Geomorphology, Geology&roads. Results show the Boolean logic model was effective to apply as compared to the other two models. Emanuel et al.[7]used a weighting method for site selection and identified the factors like cost, environmental risk & equity affects on landfill sitting decision. The dynamic model was designed by the author is a hypothetical and tested for the real world. Zamorano et al.[42] used EVIAVE method in Spain. This method is used for landfill& Environmental diagnosis. The Environmental factors considered are surface water, groundwater, atmosphere, soil, and human health. It was found that the environmental component was most affected in site selection.

Table 4.Review of papers used MCDA & GIS for landfill sitting

Sr No	Year	Author	Methodology	Location
1	1986	Jensen &christensen et al.	--- GIS	United States
2	1996	Siddiqui et al.	AHP	Oklahoma
3	2000	Natesan et al.	AHP, FIC, ANN and Delphi	Chennai,India
4	2005	Kontos et al.	AHP	Greece
5	2005	Mehmet et al.	- Site screening method -	Turkey
6	2006	Omar et al.	Intelligent system- Fuzzy	Jordan
7	2006	Alexandra et al.	AHP & OWA	--
8	2008	Chang et al.	Fuzzy	South Texas,USA
9	2008	Sumathi et al.,	AHP	Pondicherry India
10	2008	Khan et al.,	ANP	--
11	2008	Zamorano et al.	EVIAVE	Granada,Spain
12	2009	Sharifi et al.	weights	Western Iran
13	2009	Guiqin et al.	AHP	Beijing,China
14	2010	Geneletti et al.	Weight method	Italy
15	2010	Moeinaddini et al.	Weighted linear combination & AHP	Karaj,Iran
16	2010	Sener et al.	AHP	Konya,Turkey
17	2010	Kuo et al.	ANN-ANP	
18	2010	Aragones et al.	ANP	Spain
19	2011	Tavares et al.	AHP	Cape Verde
20	2012	Eskandari et al.	AHP & SAW	Iran
21	2012	Gorsevski et al.	AHP and OWA	Macedonia
22	2013	Gbanie et al	WLC and OWA	Southern Sierra
23	2013	Kumar et al.	AHP	Delhi,India
24	2014	De Feo et al.	AHP (SAW–PCT)	Southern Italy
25	2014	Paul et al.	Delphi technique	Kolkata,India
26	2015	Zeynab et al.	OWA and ANP	Birjand plain, Iran
27	2018	Md.Mohib et al.	AHP	Alberta,Canada
28	2018	Khodaparast et al.	AHP	Qom city, Iran
29	2018	Luciana et al.	AHP & SAW	Italy
30	1996	Kao et al.	C PROGRAM	--
31	1996	Emanuel et al.	weighting method,	U.S

2.8 Artificial Neural Network

Kuo et al.[24] used a combination of Artificial Neural Network and two multi-attribute decision analysis using data envelopment analysis &ANP.This technique used for the green supply chain management. The three steps involved were Input layer, Hidden layer, and output layer. Whereas the input layer represents the different criteria, the hidden layer is an experimental approximation to minimize the expected value of target variance for certain classes of problems. And the output layer used for the performance of each selection criteria. With the help of these three layers, the problem of data missing at various places can be minimized. It also overcomes traditional Data Development analysis drawbacks, limitations of data accuracy.In summary above Table no. 4 shows the review of papers MCDA & GIS techniques used for new landfill sitting by the researchers.

Conclusions

Multiple criteria decision analysis is a sub-discipline of operations research that explicitly evaluates multiple conflicting criteria in decision making, applicable everywhere.MCDA techniques are useful in giving weights and ranking so that it's easy to find the best possible. Finding a new landfill sitting using MCDA and GIS is possible. These techniques have been used since 1986 and the MCDA methods like AHP, Fuzzy, ANN, OWA&Boolean logic, binary evidence, and overlapping index. A literature survey was conducted on new landfill sitting using GIS & MCDA techniques shows the increasing awareness at the social, environmental and economic level and moving towards the research scenario.

Out of the available methods used for new landfill siting, AHP techniques was found best as compared to the other methods.One of the advantages of AHP is that there is no need for any manipulations in the data. While giving weights Environmental factors were found more weight as compared to social and economic factors. Environmental factors are more important, as it is related to human beings and health effects. The problem faced by using AHP is the weights are considered randomly so that there are chances of increasing the consistency ratio more than 10%.If consistency ratio increases more than 10%,then there is the need torevised the weights to different criteria's.Inthefuture, it is the need forthe application of artificial intelligence with AHP to minimize the errors.MCDA techniques found a scientific way as compared to the conventional method for landfill sitting, which saves time and got the accurate results, saves the money as invested in conventional methods, Scientific and technical approach in the society.MCDA required accurate inputs so that we got the accuracy in the final results and easy to find the best landfill site from the available alternatives. It was found that in India the landfill sitting was not done at up to the mark. In the future, there is the scope of research in India regarding MCDA & GIS for new landfill sitting at the social, economic, political and environmental level. GIS is also the best tool for mapping and overlay of maps. New landfill sitting using GIS and Multicriteria decision methods can save the effective use of available land resources.

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