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Rationalization of the Factors for Selection of Sanitary landfill siteusing multicriteria evaluation techniques Case study of Nashik City, India.

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ABSTRACT

Municipal solid waste Sanitary landfill site selection is challenging problem to the developing countries. Present study focuses on the selection of a criteria's to select best suitable landfill site for Solid Waste Management (SWM) which is an important component of urban planning. The problem of SWM has assumed a significant proportion for the municipal authorities in the wake of rapid industrialization, urbanization, and the resultant pressure on existing resources, while planning for suitable sites various factors need to be considered for sanitary landfill site selection. To identify a suitable landfill site conventional process takes huge time for analysis. In this study, the selection of a landfill site in an urban area like Nashik is a captious issue due to the involvement of a multitude of parameters. The decisive parameters are environmental, economic, and social in nature, some of them conflicting, which makes landfill site selection a tedious and complex process. This study concentrates on the Rationalization of Factors affecting the selection of sanitary landfill sites the relative Important Index (RII) is used to determine the most important factors from different parameters with multicriteria technique AHP with validation, thirty factors were weighed for analysis, and the ten most important factors are identified with their acceptable weights.

Keywords: Sanitary landfill, Site selection, Relative important index, Analytical hierarchy process.

1. INTRODUCTION

India is a developing country where waste generation is increasing day by day due to the boom in industrialization, urbanization, and population growth. With a population exceeding 138 crores, India is the second most populated country in the world, accounting for 17.5% of the global population. Approximately 35.39% of India's population lives in urban areas, significantly contributing to the generation of municipal solid waste (MSW). The Government of India introduced the MSW Rules, 2016, which outline various stages in municipal solid waste management, including waste collection, transportation, storage in transfer stations, processing, and scientific disposal. Disposal is the final and a major element of SWM. Worldwide, different methods are practiced for waste disposal, such as thermal treatment or incineration, burial, biological treatment or composting, and landfills. In low and medium-income countries like India, landfills remain the most preferred method due to their relative simplicity and cost-effectiveness (Sumathi et al., 2008; Kim and Owens, 2010).Forming a solid waste landfill is a complex process, as it can adversely impact the economy, ecology, and environmental health if an unsuitable site is selected without a proper decision-making process. Waste generation in India presents challenges due to the country's rapid urbanization, diverse climate, geography, ecology, social structures, culture, and languages. Rapid population growth is a major factor contributing to the increase in municipal solid waste in India (Kumar et al., 2018). The generation of MSW in India is approximately 0.136 million tonnes per day, of which 0.111 million tonnes per day are collected, 0.026 million tonnes per day are treated, and 0.073 million tonnes per day are landfilled (CPCB, 2016). Only 75-80% of the municipal waste is collected, and only 22-28% of this waste is processed and treated. The per capita waste generation rate in Indian cities ranges between 0.2 to 0.87 kg per day.Furthermore, inadequate waste segregation at the source exacerbates the inefficiency of the collection and treatment processes. Selecting the best suitable landfill site is influenced by various factors. Analyzing these different factors for site selection is tedious and time-consuming, necessitating the optimization of parameters. In our study, we use the Relative Importance Index (RII) method to optimize these factors. Out of thirty-two parameters analyzed, the ten most affected parameters for the study area were identified.This study underscores the need for a systematic approach to landfill site selection, which is essential for managing the increasing waste generation in India effectively. By rationalizing the factors and optimizing the parameters involved, the study aims to facilitate a more efficient and effective approach to municipal solid waste management.

2. SANITARY LANDFILL SITE SELECTION.

Selection of a landfill site usually comprises of the subsequent steps, landfill sites are available: (i) putting in place of a locational criteria; (ii) identification of search area; (iii) drawing up a listing 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. However, in municipalities where availability of land is restricted, the choice process is also confined to only 1 or two sites and should involve the subsequent steps: (i) putting in place of locational criteria; (ii) Data collection; (iii) Environmental impact assessment and (vi) Final site selection.

A locational criteria could also be specified by a regulatory authority (e.g. Pollution Control Board). Within the absence of regulatory requirements, the subsequent criteria are suggested. If it's absolutely essential to site a landfill within a restricted zone(s) then appropriate design measures are to be adopted and permission from the regulatory authority should be sought:

(a) Lake or Pond: No landfill should be constructed within 200 m of any lake or pond. Due to concerns regarding runoff of waste water contact, a surface water program should be established if a landfill is sited but 200 m from a lake or pond.

(b) River: No landfill should be constructed within 100 m of a navigable river or stream. The space is also reduced in some instances for no meandering rivers but a minimum of 30 m should be maintained all told cases.

(c) Flood Plain: No landfill should be constructed within a 100 year flood plain. A landfill is also built within the flood plains of secondary streams if an embankment is made along the stream side to avoid flooding of the world. However, landfills must not be built within the flood plains of major rivers unless properly designed protection embankments are constructed round the landfills.

(d) Highway: No landfill should be constructed within 200 m of the correct of way of any state or national highway. This restriction is principally for aesthetic reasons. A landfill could also be built within the restricted distance, but no closer than 50 m, if trees and berms are wont to screen the landfill site.

(e) Habitation: A landfill site should be a minimum of 500 m from a notified habituated area. A zone of 500 m around a landfill boundary should be declared a No-Development Buffer Zone after the landfill location is finalized.

(f) Public parks: No landfill should be constructed within 300 m of a public park. A landfill could also be constructed within the restricted distance if some reasonably screening is employed with a high fence round the landfill and a secured gate.
(g) Critical Habitat Area: No landfill should be constructed within critical habitat areas. A critical habitat area is defined because the area during which one or more species live. It's sometimes difficult to define a critical habitat area. If there's any doubt then the administrative body should be contacted.
(h) Wetlands: No landfill should be constructed within wetlands. It's often difficult to define a wetland area. Maps could also be available for a few wetlands, but in many cases such maps are absent or are incorrect. If there's any doubt, then the administrative unit should be contacted.
(i) Spring water Table: A landfill mustn't be constructed in areas where groundwater level is a smaller than 2m below ground surface.
(j) Airports: No landfill should be constructed within the limits prescribed by regulatory agencies (MOEF/ CPCB/ Aviation Authorities) from time to time.
(k) Water Supply Well: No landfill should be constructed within 500 m of any facility well. It's strongly suggested that this locational restriction be abided by a minimum of for down gradient wells. Permission from the administrative unit is also needed if a landfill is to be sited within the restricted area. Coastal Regulation Zone: A landfill should not be sited in a coastal regulation zone.
(l) Coastal Regulation Zone: A landfill mustn't be sited in an exceedingly coastal regulation zone. Buffer Zone: A landfill should have a buffer zone around it, up to a distance prescribed by regulatory agencies.
(m) Unstable Zone: A landfill mustn't be located in potentially unstable zones like landslide prone areas, fault zone etc.
(n) Buffer Zone: A landfill should have a buffer zone around it, up to a distance prescribed by regulatory agencies.
(o) Other criteria is also decided by the planners.

3. MATERIALS &METHODS

3.1 Description of study Area

Nashik, (19.9975° N, 73.7898° E) a city located within the northwest of Maharashtra State in India, is 180 km off from Mumbai and 202 km from Pune. Nashik is that the administrative headquarters of Nashik District and Nashik Division. Nashik, which has been observed because the "Wine Capital of India", is found within the Western Ghats, on the western fringe of the Deccan peninsula on the banks of the River Godavari. in keeping with the Census of India, 2011, Nashik had a population of 1,486,053 and present population is estimated to be 2,123,018 (projected in year 2021) The population of Nashik is predicted to grow from 1.08 million to 1.75, 2.6 and 3.75 million by 2011, 2021 & 2031 respectively. Notably there are variations in population projections in various studies and DPRs. This variation in population projection has serious implications for future planning. with a complete area of 264.2 km2 which makes it the fourth largest geographical area in Maharashtra in terms of population. Nashik is that the third most industrialized city in Maharashtra after Mumbai and Pune. Nashik has been on the tourist map of India.

Fig.1 Location map of the study area.

3.2 Rationlisation of Factors for Selection of Sanitary Landfill Site

The selection of an acceptable landfill site requires evaluation of in depth environmental similarly as socioeconomic criteria to evade succeeding trouble and long-term effects on environmental componentlike contamination of groundwater, surface water, and soil. it's not always essential that the identical criteria would be important all told study regions; instead, the importance of criteria differs with changing geographical location. As far because the present study is anxious, the Relative importance method (RII) were well-thought-out by the observance of local environmental and economic factors, and Highest Weights were considered by following the detailed literature survey and guidelines of the Pollution board, Government of India, on landfill site selection specification. this study assessed 30 decision criteria, out of which Ten criteria were taken from an environmental point of view,Socioeconomic related,Waste management and climatological related and geological related where considered.

The expert opinion and rating of things was a qualitative approach towards the study.following figures showing different criterias considered for questionnary survey. Criterias considered based on Accessibility Related, Environmental related, Socio economic related, Waste Management and Climatologial related, Geological related under.by using relative important index method each criteria analyse using its importance by giving following options low importance, slightlyimportance, Neutral,Moderately important,Very important with their weightage ranging from 1 to 5. Expert survey is conducted on google form.


SURVEY FOR MAJOR FACTORS AFFECTING SANITARY LANDFILL SITE SELECTION

THIS SURVEY IS ONLY FOR ACADEMIC PURPOSE (Ph.D Thesis)

SURVEY FROM SELECTED EXPERTS AND LOCAL RESIDENTS ONLY.

Research Scholar -Ashish.R Gaikwad (Veermata Jijabai Technological,Institute Mumbai)

Guide- Dr.Vikas B. Varekar (Ph.D IIT Bombay) (Ass.Professor VJTI,Mumbai)

Instruction and Request
Please Verify Below Factors for Sanitary Landfill Site Selection and Give Rankings As per your Perspectives.

weighting (assigning values) the factors ranging from 1 (low importance) to 5 (very important)

1 = Low Importance , 2= Slightly Importance , 3= Neutral , 4= Moderately Important , 5= Very Important

Fig.2 Introduction page of the RII analysis questionnaire survey

3.3Relative Importance Index

The selection of an appropriate landfill site requires evaluation of in depth environmental furthermore as socioeconomic criteria to evade succeeding trouble and long-term effects on environmental component like contamination of groundwater, surface water, and soil. this study assessed 30 decision criteria, out of which ten criteria were taken from an environmental point of view, Socioeconomic related, Waste management and climatological related and geological related where considered.to Rationlise this Criterias The expert opinion crazy Weights after calculation by using Relative Importance Index Method Ranking is Given.

$RII = \Sigma W / (A*N)$

Where,

RII = relative importance index;

W = weighting given to each factor by respondents (ranging from 1 to 5);

A = highest weight (i.e., 5 in this case);

and N = total number of respondents.

RII Analysis Results a complete of 30 questionnaires were circulated to pick Parameters for the study, Experts Opinions on Google form Collected.Experts from Academics,MPCB Board,NMC,Local Resident out of 30 Parameters 10 Top Ranking Parameters are identified with the assistance of Relative Imporatant index method. List of Selected Parameters are as follows with Rankings.

4.ANALYTICAL HIERARCHY PROCESS

The Analytic Hierarchy Process (AHP) is a structured technique for organizing and analyzing complex decisions, developed by Thomas Saaty in 1980. Combining Geographic Information Systems (GIS) with AHP forms a robust tool for creating policies relevant to urban growth (Aburas et al., 2015). This integration is particularly effective in addressing complex decision-making processes, providing a systematic approach that aids decision-makers in arriving at optimal decisions. AHP simplifies complex decisions by breaking them down into a series of pairwise comparisons, facilitating a clear evaluation process (Sener and Suzen, 2006; Barakat et al., 2017).The relative importance between two criteria in AHP is measured using a numerical scale from 1 to 9, as proposed by Saaty. The weight of each criterion is calculated based on these pairwise comparisons (Hecson and Macwan, 2017). A criterion is deemed more important if it has a higher weight. AHP assigns a score to each alternative based on the decision maker's evaluation. The higher the score, the better the performance of the alternative concerning the considered criterion (Barakat et al., 2017).The final step in AHP involves combining the weights and scores to determine a final score for each option, resulting in a ranking of alternatives. This final score is a weighted sum of the scores across all criteria. AHP also includes a mechanism for checking the consistency of the pairwise comparisons to minimize bias in the decision-making process. This is achieved by calculating the Consistency Ratio (CR), which is the ratio of the Consistency Index (CI) to the Random Index (RI). The CI and RI are derived from the pairwise comparison matrix through specific operations. For the matrix to be considered consistent, the CR should not exceed 0.1 (Saaty, 1980).The integration of AHP and GIS enhances decision-making in urban planning by providing a clear, quantifiable, and systematic method for evaluating multiple criteria, ensuring that the selected alternatives align closely with the decision-makers' objectives and preferences.

Table.1Saaty's scale for AHP process.

Intensity of Importance	Description
1	Equal importance
2	Weak or slight importance
3	Moderate importance
4	Moderate plus importance
5	Strong importance
6	Strong plus importance
7	Very strong importance
8	Very, very strong importance
9	Extreme importance

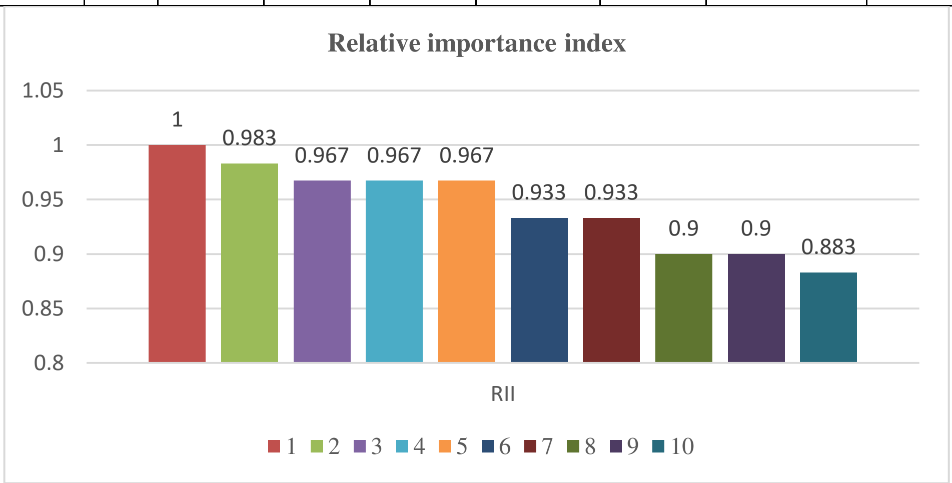
5. RESULT & DISCUSSION

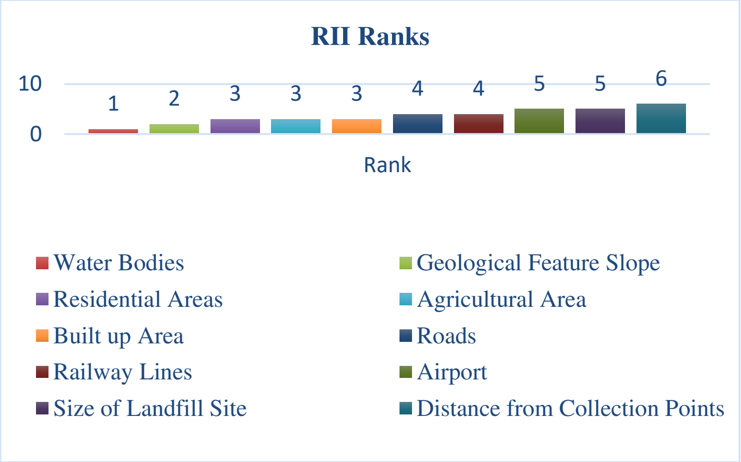
Following results are obtained after 12 Experts Suggestions collected on google form with relative important index method out of thirty parameters ten most significant factors calculated and rank for identification.

A) Relative Impotance Index

Table.2 Relative important index sheet for selected parameters.

Sr.No	Selected parameters after survey &analysis	LI (01)	SI (02)	MI (03)	N (04)	VI (05)	T	No.of Experts (12)	Max Weight	RII	Rank
1	Water Bodies	0	0	0	0	60	60	12	5	1.000	1
2	Geological Feature Slope	0	0	0	4	55	59	12	5	0.983	2
3	Residential Areas	0	0	3	0	55	58	12	5	0.967	3
4	Agricultural Area	0	0	3	0	55	58	12	5	0.967	3
5	Built up Area	0	0	3	0	55	58	12	5	0.967	3
6	Roads	0	0	6	0	50	56	12	5	0.933	4
7	Railway Lines	0	0	6	0	50	56	12	5	0.933	4
8	Airport	0	0	9	0	45	54	12	5	0.900	5
9	Size of Landfill Site	0	0	9	0	45	54	12	5	0.900	5
10	Distance from Collection Points	0	0	9	4	40	53	12	5	0.883	6





Where,
LI- Low importance,SI-Slightly importance, MI-Medium importance-Neutral, VI-Very Importance, T-Total
Results are obtained from relative important index to find out best suitable site using geospatial platform need to analyze in analytical hierarchy process to calculate weightage of each criteria with its verification. Analytical hierarchy process needs expert analysis done withsaaty's scale ranging from 0 to 9.
Following results are obtained from analytical hierarchy process.

B) Analytical Hierarchy process

Pairwise comparison matrixA1 calculated through row wise.

Table.3 Pairwise comparison matrix

Criteria	**RW**	**RL**	**WB**	**AT**	**RA**	**AR**	**BA**	**S**	**LS**	**GF**	**T (A 1)**
RW	1	1/3	1/4	1/6	1/5	1/4	1/5	1/4	1/5	1/3	0.273
RL	3	1	1/6	1/4	1/9	1/9	1/3	1/5	1/6	1/9	0.268
WB	4	6	1	1/2	1	1/2	1/3	1/2	1/2	1	0.933
AT	6	4	2	1	1/9	1/9	1/3	1/3	1/4	1/4	0.577
RA	5	9	1	9	1	1	1/2	1/2	1/3	1/7	1.170
AA	4	9	2	9	1	1	1/2	1/4	1/3	1/3	1.246
BA	5	3	3	3	2	2	1	1/2	1	1/3	1.568
S	4	5	2	3	2	4	2	1	1	1	2.130
LS	5	6	2	4	3	3	1	1	1	1	2.155
GF	3	9	1	4	7	3	3	1	1	1	2.417

RW = Roadway, RL= Railway line, WB = Water bodies, AT= Airport, BA= Built up Area, S=Slope, LS= Landfill size, GF =Geological features.

Sample calculations for Road way Criteria (RW) $(1+1/3+1/4+1/6+1/5+1/4+1/5+1/4+1/5+1/3)^{(1/10)} = 0.2731$

Table No.4 Weights of different criteria A 2 Matrix& A3 Matrix

Sr. No	**Criteria**	**Weightage (A2)**	**A3 =A1 X A 2**
1	RW	0.021	0.261
2	RL	0.021	0.254
3	WB	0.073	0.848
4	AT	0.045	0.613
5	RA	0.092	1.197
6	AA	0.098	1.243
7	BA	0.123	1.345
8	S	0.167	1.822
9	LS	0.169	1.781
10	GF	0.190	2.342

Table No.5 Weights of different criteria A 3 Matrix & A4 Matrix

Sr. No	**Criteria**	**A3 =A1 X A 2**	**A4= A3/A2**
1	RW	0.261	12.154
2	RL	0.254	12.064
3	WB	0.848	11.572
4	AT	0.613	13.507
5	RA	1.197	13.017
6	AA	1.243	12.702
7	BA	1.345	10.921
8	S	1.822	10.890
9	LS	1.781	10.518
10	GF	2.342	12.333

Above A1 ,A2, A3, A4 Matrix are shown calculations of weightage for different criteria's using, Analytical Hierarchy process after calculations consistency index and consistency ratio is calculated using AHP Formulae's as shown follow,

Consistency index (CI) = λ Max – n / n-1

Where,

λ max = Average of A4 Matrix = 11.96

n = No.of Criteria's

11.96-10 / 10-1 CI = 0.217

Consistency Ratio (CR) = Consistency index / Random Index

CR = 0.217 / 1.49 = 0.14≈ 0.1

Consistency ratio should not greeter than 0.1 so above pairwise comparison is accepted for further analysis.

8. Conclusion

The objective of this study was to spot the factors that influence landfill site selection. during this study, we discover out the important factors must consider for landfill site selection for Nashik City, India. the foremost important, namely:1.Water Bodies;2.Geological features slope;3.Residential Areas;4.Agricultural Area;5.Built upArea;6.Roads;7.Railway lines;8.Airport;9.Size of landfill;10.Distance from Collection points.30 factors considered within the study were divided in 5 groups. Which were ranked consistent with their Relative Importance Index from 30 factors 10 factors identified. Using multicriteria decision making AHP is use for pairwise comparison of different criterias and validate with consistancy index and consistancy ratio we founfd

0.217 & 0.14 respectively. In this study we can conclude that above muticrieria techniques are more easy and suitable to select most important criterias for further process and MCDM Techniques saves more time and tedious analysis to select best suitable sites

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