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APPLICATION OF GEOSPATIAL TECHNOLOGY AND ANALYTIC HIERARCHY PROCESS (AHP) FOR MUNICIPAL SOLID WASTE LANDFILL SITING AT NASHIK CITY,INDIA.

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ABSTRACT

The rapid increase in global waste generation necessitates the identification of suitable landfill sites to mitigate environmental impacts. This study employs a scientific approach to determine optimal landfill locations in Nashik, India, using Geospatial Analysisand the Analytic Hierarchy Process (AHP). By integrating Geographic Information System (GIS) technology with AHP, the study evaluates morphological, environmental, and socio-economic factors crucial for landfill siting. Data from online portals, government institutions, and recent waste production records from the Regional Environmental Office were analyzed. Expert judgement was applied to 13 criteria for landfill site selection, ensuring a comprehensive assessment. The findings reveal that 9.78 hectares are veryhighly suitable 10.87 hectares are highly suitable, and 4.14 hectares are moderately suitable for landfill sites, while the remaining areas are unsuitable. This research aims to support sustainable waste management policies and assist stakeholders in making informed decisions to reduce environmental impacts.

Keywords: Sanitary landfill, Site selection, Geographic Information System, Analytical hierarchy process.

1. INTRODUCTION

The escalating challenge of municipal solid waste management represents a critical issue for urban centers worldwide, with Nashik—a rapidly expanding city in India—serving as a notable example. Effective landfill siting is crucial to mitigating the adverse environmental impacts associated with improper waste disposal and ensuring the long-term sustainability of waste management practices (Jouybari et al., 2019). This research integrates Geospatial Analysis with the Analytic Hierarchy Process (AHP) to systematically identify optimal landfill sites in Nashik.Geospatial Analysis, enabled by Geographic Information System (GIS) technology, provides a sophisticated tool for evaluating spatial data, facilitating the identification of potential landfill locations basedon a diverse set of criteria. GIS allows for detailed spatial

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assessments, including land use patterns, proximity to sensitive areas, and environmental constraints, providing a nuanced view of potential sites (Monghasemi et al., 2021). Complementing GIS, the AnalyticHierarchy Process (AHP) offers a structured framework for multi-criteria decision-making. AHP enables the systematic evaluation and prioritization of critical factors such as topography, environmental impact, and socio-economic conditions, ensuring a comprehensive assessment of each site's suitability.This study utilizes a broad array of data sources, including online databases, government records, high-resolution satellite imagery, and recent waste production statistics from the Regional Environmental Office. Key criteria assessed include proximity to residential areas, water bodies, and protected lands; land use and land cover; soiltype and stability; slope and elevation; and accessibility. Thirteen criteria essential to landfill site selection were meticulously evaluated through expert judgement, ensuring the analysis's relevance and accuracy within Nashik's specific context. Advanced spatial analysis techniques, such as overlay analysis, suitability mapping, and multi-criteria evaluation, were employed to integrate and analyze these diverse datasets, enhancing the robustness of the assessment.The findings of this research will not only identify viable landfill sites but also provide a replicable model for other urban areas confronting similar waste management challenges. This comprehensive study ensures that the proposed sites are environmentally sustainable, socially acceptable, and economically viable. The outcomes are designed to inform and support the development of sustainable waste management policies, offering valuable guidance to policymakers and stakeholders. By emphasizing the integration of scientific methodologies into urban planning and environmental management, this research contributes to advancing a cleaner and more sustainable urban future for Nashik and beyond.

2. MATERIALS AND METHODS

2.1Study 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 Deccanpeninsula 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 mostindustrialized city in Maharashtra after Mumbai and Pune. Nashik has been on the tourist map of India.

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Fig.1 Location map of the study area.

Methodology overview

The research was carried out in several stages: initially, data was collected from various online portals and government institutions, providing a comprehensive foundation for further analysis. The next stage involved selecting criteria for site selection through a review of international literature, national legislation, and expert judgment, ensuring the relevance and comprehensiveness of the criteria. Subsequently, a Multi-Criteria Decision-Making (MCDM) approach, integrated with Geographic Information Systems (GIS) and the Analytic Hierarchy Process (AHP), was utilized for a structured and systematic evaluation of potential landfill sites. The final stage focused on identifying the most suitable locations for landfill siting by applying the results of the GIS-AHP analysis to determine optimal sites for sanitary landfill development. By employing a holistic and multi-disciplinary approach, this research not only identified optimal landfill sites but also provided a framework for future studies and practical applications in municipal solid waste management. The methodologies and findings presented herein can serve as a valuable reference for urban planners, environmental managers, and policymakers aiming to achieve sustainable and environmentally sound waste management solutions.

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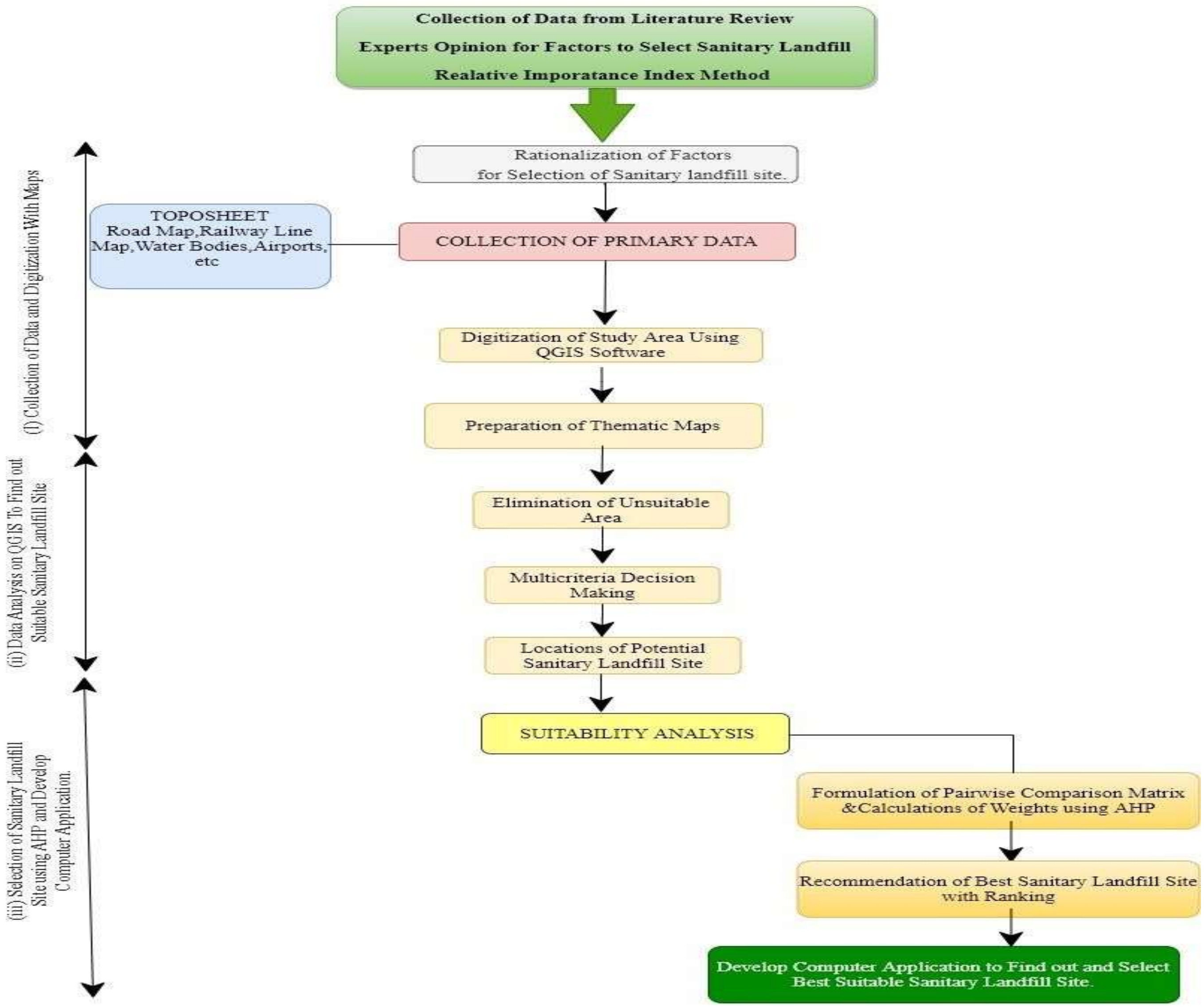

Data CollectionFig.2 Flowchart for methodology.

For the evaluation of suitable locations for siting Municipal Solid Waste (MSW) landfills in Nashik City, India, a comprehensive datacollection process was undertaken. The following sources and types of data were utilized:

1. Waste Production Centers: Up-to-date information on waste production centers within Nashik City was obtained from the Municipal Corporation of Nashik. This data is crucial for understanding the spatial distribution and volume of waste generated.
2. Groundwater Table and Aquifer Data: Groundwater levels and aquifer characteristics were

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acquired from the Central Ground Water Board (CGWB), India. This information is essential for assessing potential impacts on groundwater resources and ensuring that landfill sites are not located in areas vulnerable to contamination.

3. Surface Water and Hydrology: Data on surface water bodies and hydrological features were sourced from the National RemoteSensing Centre (NRSC) and local water authorities. This data helps in evaluating proximity to water bodies and potential risks of leachate contamination.
4. Road Network: Information on the road network was obtained from the National Informatics Centre (NIC) and local transportation departments. The road network data aids in assessing accessibility to potential landfill sites and planning for transportation logistics.
5. Soil Texture and Land Use: Soil texture and land use data were collected from the Indian Council of Agricultural Research (ICAR) and the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP). This data is used to evaluate soil suitability for landfill operations and to understand current land utilization patterns.
6. Topography: Topographic data, including slope and elevation contours, were acquired from the Survey of India. This information is important for analyzing site stability and drainage patterns.
7. Floodplain Data: Information on floodplains was obtained from the National Flood Control Authority and remote sensing data.This helps in avoiding areas prone to flooding, which could impact landfill operations.
8. Historical and Geological Data: Historical site data and geological fault lines were sourced from the Geological Survey of India (GSI) and local geological departments. This data is used to avoid sites near historical landmarks or geological hazards.

Each dataset was carefully evaluated for relevance and accuracy to ensure a robust analysis for landfill siting. The sources of thesedatasets, along with their formats and specific details, are described in the subsequent sections of this page.

Thematic maps

Following maps showing details of a)Road Network. b)Railway line. c)Agricultural area d)Residential area e)Airport area f)Waterbodies g) Existing landfill site using geospatial platform on QGIS software.

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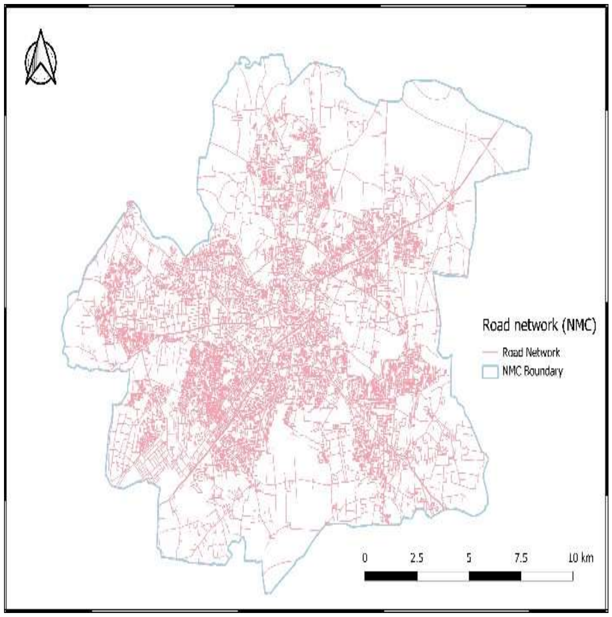
(a)



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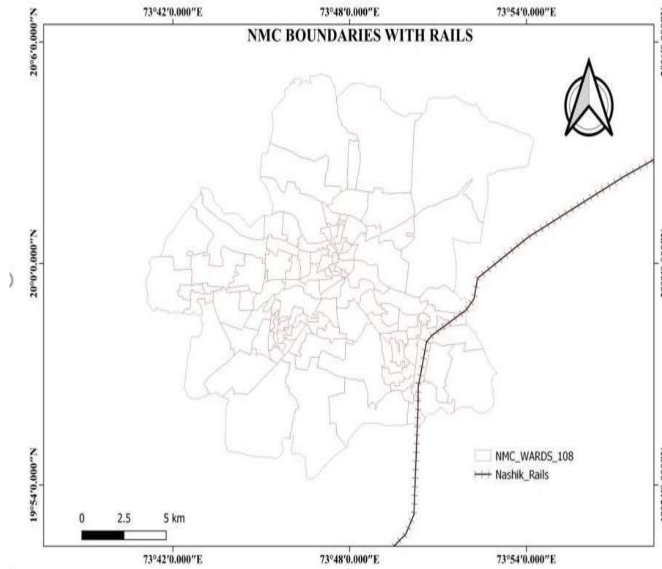

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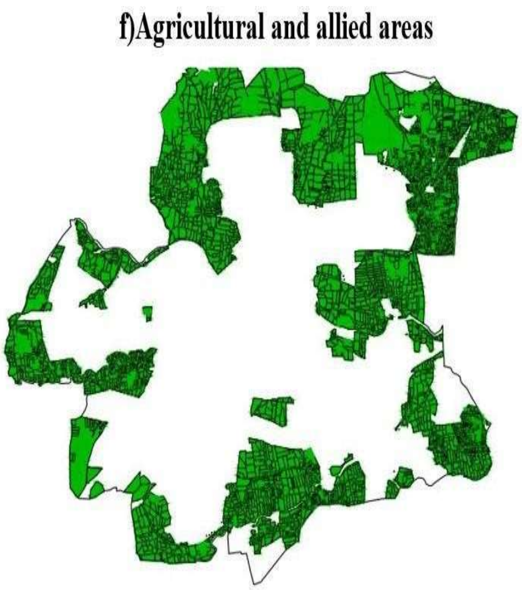

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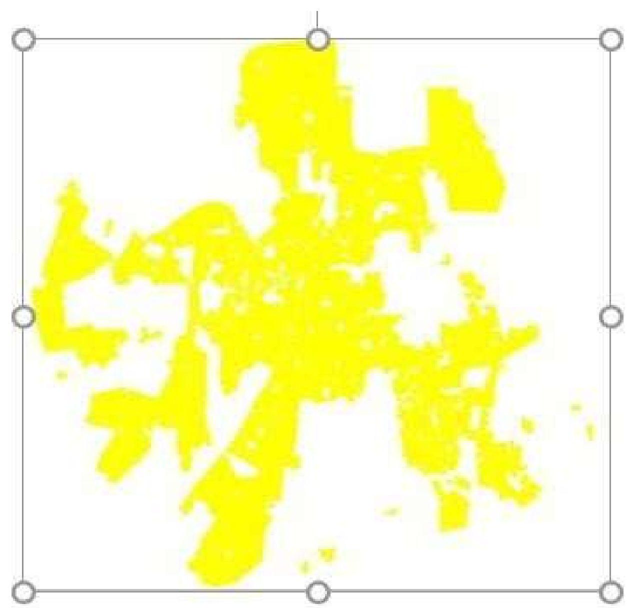

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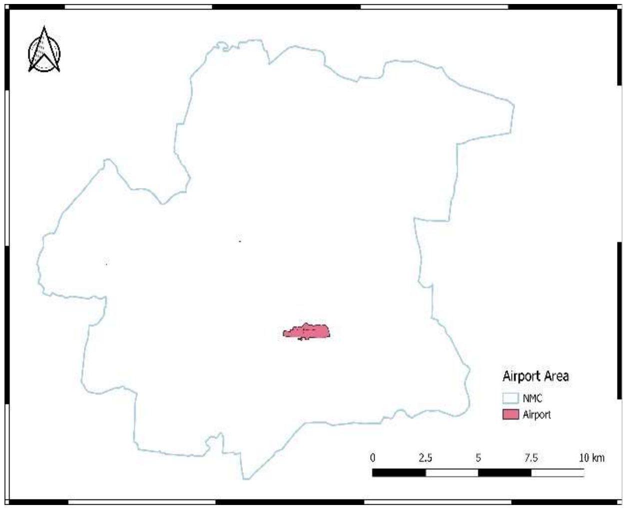

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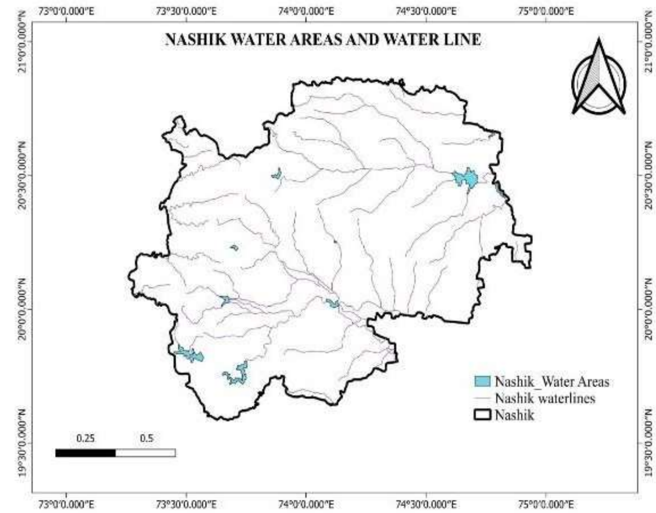

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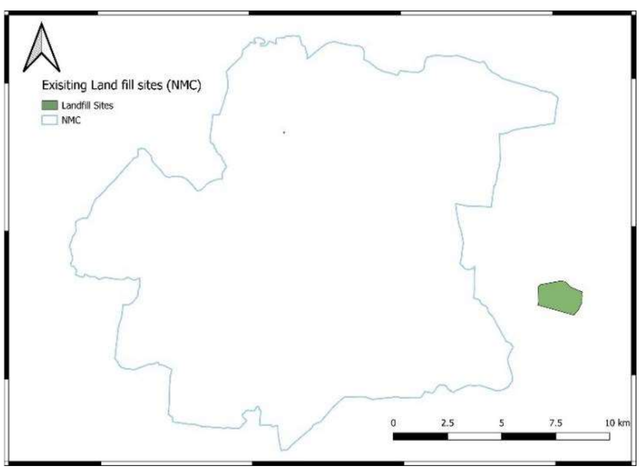

2.4.1 buffer maps

Following maps showing details of h)Road Network with buffer. i)Railway line with buffer. j)Water bodies with buffer. k)Airportarea with buffer l) Existing landfill site and predicted sites.

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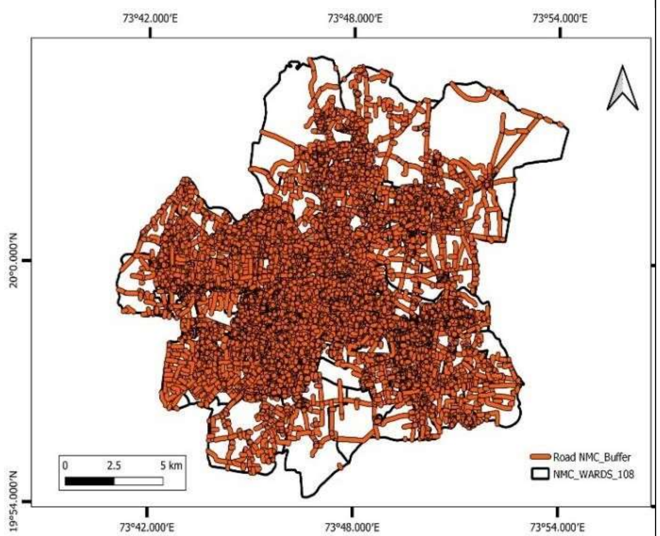
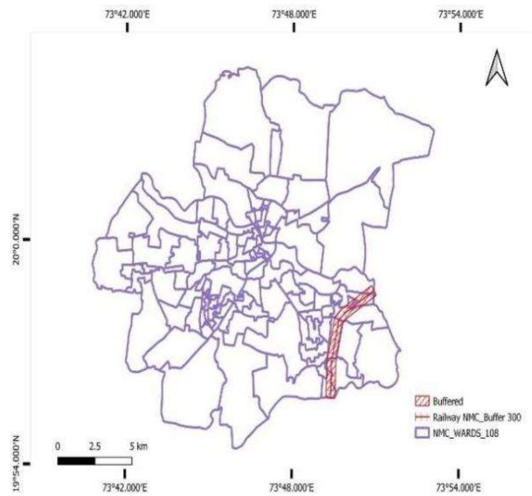
h)



i)



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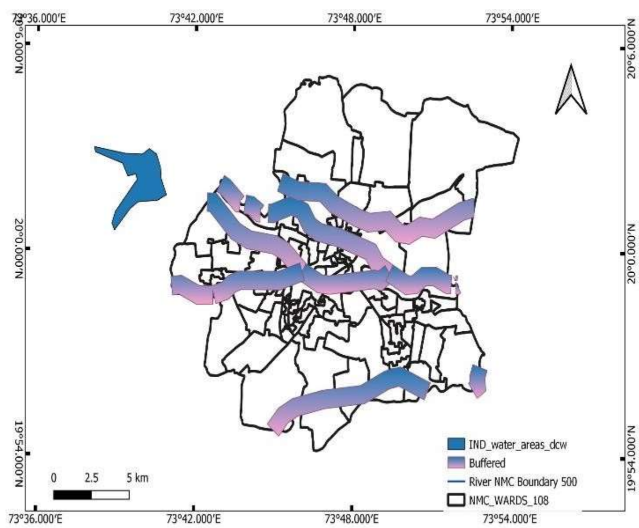

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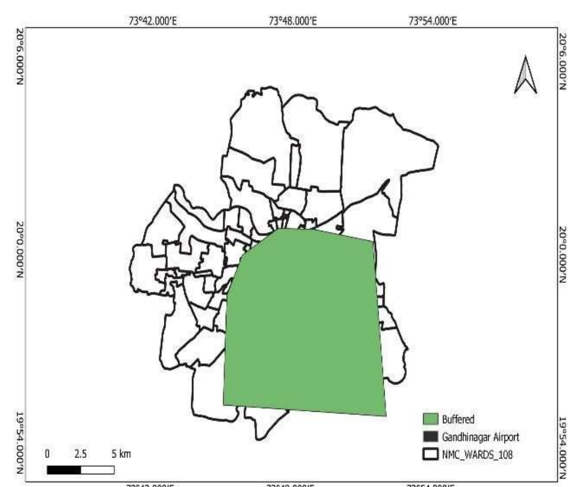

l)

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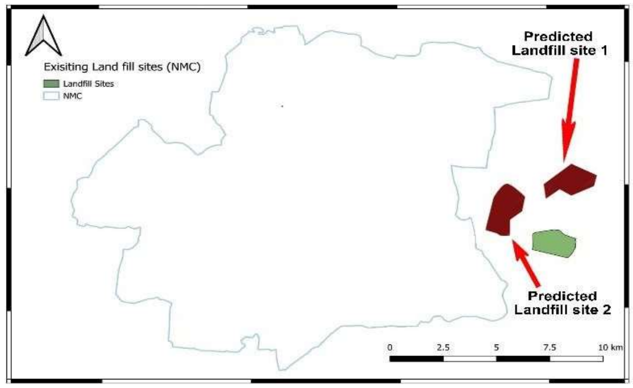

3. Criteria selection Rationlisation of Factors for Selection of Sanitary Landfill Site

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 component like 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 Polution boar, Government of India, on landfill site selection specification. this studyassessed 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, slightly importance, Neutral, Moderately important, Very important with their weightage ranging from 1 to 5. Expert survey is conducted on google form.

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

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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 forevaluating multiple criteria, ensuring that the selected alternatives align closely with the decision-makers' objectives and preferences.

Table.1 Saaty'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

4. RESULT & DISCUSSION

A) Analytical Hierarchy process

Pairwise comparison matrix A1 calculated through row wise.

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Table.3 Pairwise comparison matrix

Criteria	**RW**	**RL**	**WB**	**AT**	**RA**	**AR**	**BA**	**S**	**LS**	**GF**	**T (A1)**
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

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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 aftercalculations consistency index and consistency ratio is calculated using AHP Formulae's as shown follow,

Consistency index
(CI) = λ Max – n /

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n-1 Where,
λ max = Average
of A4 Matrix =
11.96n = No.of
Criteria's
11.96-10 / 10-1CI = 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.

5. Conclusion

The increasing generation of global waste requires the identification of appropriate landfill sites to effectively reduce environmental impacts. This study utilizes a scientific method to determine the best locations for landfills in Nashik, India, by employing Geospatial Analysis and the Analytic Hierarchy Process (AHP). The integration of Geographic Information System (GIS) technology with AHP allowed for the evaluation of essential morphological, environmental, and socio-economic factors for landfill siting. Data were collected

from online portals, government agencies, and recent waste production records from the Regional Environmental Office. Expert judgment was applied to 13 criteria, ensuring a thorough and meticulous assessment. The findings reveal that 9.78 hectares are very highly suitable, 10.87 hectares are highly suitable, and 4.14 hectares are moderately suitable for landfill sites, while the rest of the areas are unsuitable. This research aims to support sustainable waste management policies and help stakeholders make informed decisions, ultimately reducing environmental impacts and fostering sustainable urban development in Nashik City.

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