Decision Support System for Solid Waste Sites Allocation Using GIS

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ABSTRACT

One of the most sensitive and emerging problem to every Municipality in the world is of solid waste management. Solid waste is daily outcome of human activities, which can never stop. There are various sources of solid waste which generates large and diverse nature of waste in urban cities. The main reason of increase in solid waste in urban cities is the fast increase in urban population. Nanded is one of the urban cities in Maharashtra of country India. Nanded Waghala City Municipal Corporation (NWCMC) facing the solid waste management problems as there is lot increase in population. NWCMC has not any scientifically chosen solid waste site. Unscientific waste management causes urban cities to face environmental, health and socioeconomic problems. The most common solution to solid waste management is to find a scientifically solid waste site or dumping site to city. Finding scientific and suitable solid waste site is very complicated task as it requires huge amount of spatial data to be stored, managed, evaluated and analyzed. The new technology 'Geographic Information System' which is capable to store, manipulate and retrieve huge amount of spatial data along with Multi Criteria Decision Making method was able to solve efficiently such solid waste problems with less efforts and by saving money and time.

Keywords: Solid Waste, GIS, MCDA, Decision Support System, Solid Waste Site, Land Use & Land Cover (LULC), Landfill.

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INTRODUCTION

Every municipality and urban city in the world is facing the problem of solid waste management, as there is fast growth in population. The fast growth of urban population is the main cause of tremendous increase in solid waste [1],[2],[3]. The intensiveness and importance of solid waste management will be come in light if we look at the problems caused by solid waste to human life, society and environment and economic. Unscientific solid waste management causes the problems like diseases transmission, fire hazards, odor nuisance, atmospheric and water pollution, aesthetic nuisance and economic loses. All these said problems directly or indirectly affect the human life, so it becomes the first priority problem for any municipality or urban cities in the world.[4],[5],[6,][7],[8]. Naded city

(NWMCN) is an urban city of state Maharashtra in country India. If we look at the census chart 2011 of NWMCN, we found that the population was 5, 50,564, which is increased by 1, 26,518 of census chart 1971. The amount of solid waste generated in NWMCN is about 149 tons per day. 73 percent of the waste is generated from domestic sources, 23 percent generated from commercial establishments and markets, remaining from industries. Presently Solid waste of municipality is disposed in a dumping ground at Valmiki Nagar near Maltekdi in an area of 3.32 Ha. The solid waste collected from the city is merely dumped at this site. This site has been in use since 1975. [9]. All this situation of NWCMC indicates that it need a solid waste dumping site, which is devised by using some scientific method and sustainable to people, environment and economic. Generally any Municipality uses a dumping site to dump the Municipal solid waste as a solution for solid waste management. But the process of finding optimal solid waste sites is very complicated and hard task as it requires manipulating and evaluating vast amount of spatial data. [10],[11],[12],[3]. The new recent technology known as Geographical Information System (GIS) integrated with decision making methods is used now a days for finding solid waste sites, as it is capable to easily store, manipulate, analysis and retrieve or display vast amount of spatial data as a database. The database which is built up during the process of finding solid waste site will be used to monitor the situation of dumping site or solid waste site and will be used in decision making in future.[13],[14]. MCDA is a problem solving technique in which complex and big problems are divided into smaller individual problems and these problems are solved individually and these individual solutions are combined together to solve the hole problem [14]. Up till in the various countries the integration of GIS and other techniques were used to solve the solid waste management problems. Particularly GIS is used to store and manipulate large amount of data regarding the study area by making various processes with the help of GIS tools. The table 1. lists various decision support systems for solid waste site allocation using GIS.

Table 1. Various methods used in solid waste management

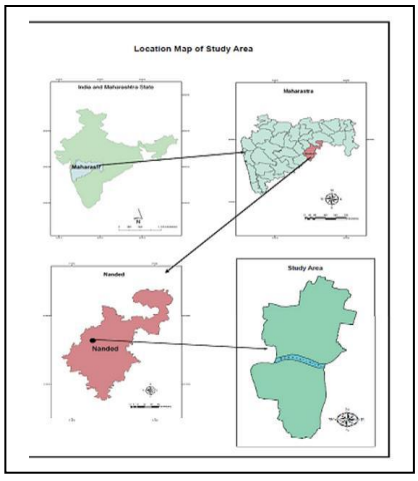
No.	Study Area	Methodology	Reference No.
01	Damaturu town Nigeria,	Analytic network process (ANP) - combining geographic information system (GIS) and a multi-criteria decision making method (MCDM)	1
02	Al-Hashimyah Qadaa	GIS and Multicriteria Decision Analysis	3
03	Pondicherry, India	Multi-criteria decision analysis (MCDA) and overlay analysis using a geographic information system (GIS)	10
04	Khulna City, Bangladesh	Multi criteria Decision Analysis and GIS Integration standards.	11
05	Bandar Abbas city, south of Iran	Composite suitability analysis using thematic map overlays and their extension to include statistical analysis, MCDM, AHP,	12
06	Addis Ababa, Ethiopia	GIS based multicriteria methodology, MCDM	13
07	Konya City of Cumra County	Integration of geographic information Systems (GIS) and multi-criteria evaluation, map overlay. index overlaying	15
08	Sinai Peninsula	Spatial multi criteria evaluation using with the help of GIS , AHP and WLC	17
09	Mafraq City, Jordan	GIS-Based Weighted Linear Combination Analysis and Remote Sensing Techniques, Integration of GIS and MCE	18

10	Vientiane Capital City	Composition of physical data from digital map and photos, A Pilot Project, map visualization, Map overlay techniques	19
11	Nabadwip Municipality, West Bengal, India	Multi-criteria analysis decision with the help of GIS,	20
12	Saqqez city in Kurdistan province in North West of Iran	GIS model(*Boolean, index overlay, and fuzzy logic models)* and Spatial analysis method	21
13	Asian Municipality	GIS based modeling and AHP	22
14	Ilorin, Nigeria	GIS based optimization, digitization, Facility Location Function in the GIS package, *p*-median problem	23
15	Bahir Dar Town, North Western Ethiopia	Overlay and suitability analysis of GIS, remote sensing and MCAM	24
16	Beijing, China	Integration of GIS and AHP	25
17	Aurangabad City, India	Collection of city information, data. Designing of database by scanning, georeferencing and digitizing, Literature review, Analysis of situation. Module design.	27

The observation of above table1 indicates that GIS was used for solid waste management along with various decision making methods MCDA or AHP or MCE or MCAM. In the present study we have used the GIS and Multi criteria and Decision Analysis method for finding solid waste sites for NWMCN. The process of allocating solid waste site must follow the rules designed by international, national and regional organizations. Generally these rules are regarding to avoid the negative impact against environment, human lives. While locating the solid waste sites it is to be kept in mind that the solid waste site should not so close to the residential, schools, hospitals, water sources, water bodies, vegetation area etc also it is long enough from the road network to minimize the cost of transportation. All these areas are considered as selection criteria for solid waste site. For selecting the site these criteria were assigned weights according to their importance and ratings, and used the MCDA decision support system to narrow the criteria in selection process. The new technology GIS, integrated with decision support system MCDA experiences us a very smooth and efficient method to carry out the work of finding solid waste site for NWMCN.

Fig1. Location map of study area

Study Area:



Nanded city is situated on the bank of river Godavari in Marathwada region of Maharashtra State. It is located at $18^{o}15'$ to 19^{o} 55' N latitude and 77^{o} 7' to 78^{o} 15' E longitude at about 489 meters above mean sea level. Total 61.74 sq. km. jurisdiction area comes under Nanded Waghala Municipal Corporation. State Andhra Pradesh and Karnataka lies to the east and south respectively to Nanded city. Along the bank of river deep black soils have distributed. Period of rainfall is from June to November. The climate of the city is generally dry and temperature ranges between 46^{o} to 18^{o} centigrade. The population of Nanded Waghala Municipal Corporation as per reports of Census of India 20011 is 719188.

METHODOLOGY

In the present study we employed the GIS and Multi criteria Decision analysis (MCDA) method to find solid waste site for NWMCN. By using MCDA factors were decided which play an important role in the process of finding solid waste site. GIS is used to characterize the factor maps. These characterized factor maps are used as layers in the process of solid waste site allocation. These maps were overlaid to each to find final optimum solid waste site considering their importance against various criteria. While moving towards the goal to finding an optimal solid waste site we strictly followed the guidelines of Central Pollution Control Board, India (CPCB) and Central Public Health and Environmental Engineering organization (CPHEEO) about solid waste site selection. With the help of literature review we have decided the following list of factors for study area. The maximum factors are decided with the reference of (Sumathi 2006) factors, which are matching for our study area.

- Ponds
- Rivers
- Water supply sources
- Groundwater table
- Geology
- Fault line
- Land use
- Habitation
- High ways
- Railroads
- Airport

The primary data used in the study is Toposheets of Nanded City of scale of 1:50,0000. The toposheets helps us to decide the boundary area of the study area, and which obviously becomes our base map for study. By considering base map and Indian map survey values we digitized the water body maps and road network maps form. The data required for digitization of geology, soil, water supply sources, and ground water maps is collected form related departments. After digitization we follow the image interpretation and classification method of GIS to prepared land use map. We referenced Indian Remote sensing Satellite IRS1D image of city to prepare land use map. Secondary data is referenced through literature review related to the study area. For the purpose of digitization and doing analysis of

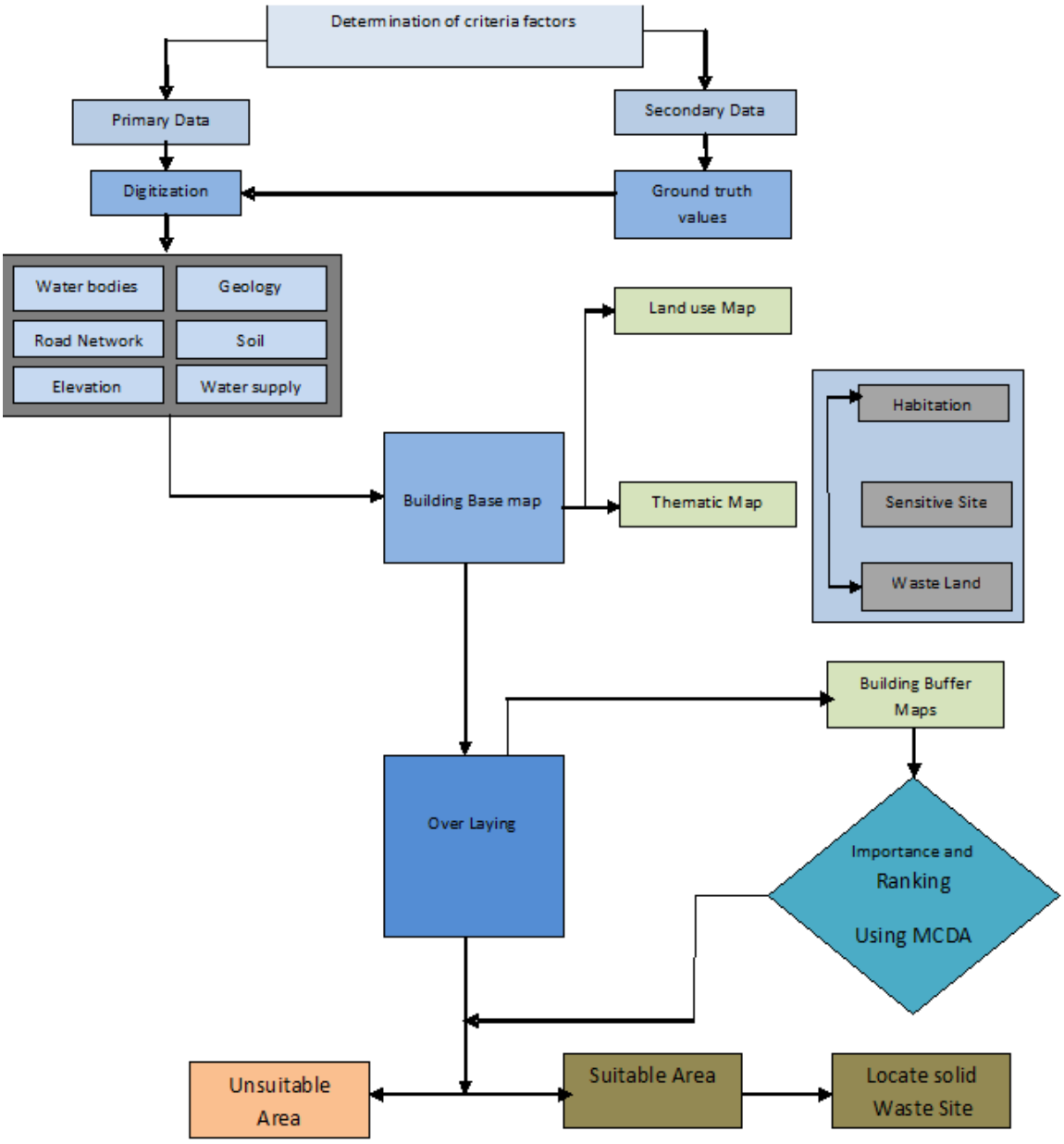
thematic maps GIS software 10.2 is utilized. After standard preparation of constraints, primary data, and secondary data, we have derived the buffer areas where a solid waste site cannot be allocated by buffering method of GIS. The buffer maps for ponds, rivers, water supply sources, habitation, high way, rail road, and airport are generated and used as constraints for study. The required standard criteria distances for buffering purpose are used form related literature. The devised factors are ranked as per their importance and their relative magnitude impact and a relative rating scheme is designed. For deciding relative rating schema we follow the criteria designed by Delphi which is a one of the standard criteria used in solid waste site selection. We classify the criteria as Land use criteria, Hydro-geologic criteria and Air-quality criteria. These criteria were ranked with the help of sequential hierarchy process. The Analytical Hierarchy Process (AHP) which was derived by (Sattya, 1980) is used for pair-wise comparison of factors (criteria). After comparison criteria are assigned weights, and as per the weights all these criteria are ranked. The process of ranking is repeated again and again to verify the optimization of criteria. After deciding weights and rating of each criteria a sub-index score to criteria is calculated. A composite Suitability Index known as (CSI) is calculated with the following formula and a comparison matrix is designed

$$CSI = \sum_{c=1}^{n} (Isub)_{TM} = \sum_{c=1}^{n} (Wc.Rc)_{TM} \quad (1)$$

Where W_c is weight of criteria, R_c is rating of criteria. This comparison matrix is used to decide the eigen vector to represent the exact ranking of criteria. After the completion deciding ranking, importance weight and eliminating all unsuitable areas i.e. buffering, we use GIS- based constraint mapping process to avoid the potentially unsuitable sites for solid waste site, and the remaining last and final map shows only the suitable sites for solid waste for NWMCN.

Following work flow diagram describes the process of finding solid waste site allocation.

Fig1. Work flow diagram



CONCLUSION

The GIS-based MCDA technique will reduce complexity of site allocation process which is in very high complex in nature. Proposed technique is also capable to make site selection process effortless by saving time and money with the help of AHP technique. The ability of GIS to store, manipulate, analysis and display vast amount of spatial data as per our need is a key involvement of GIS in solid waste site selection process.

REFERENCES

[1] Dadras M.[2], Ahmad R. M[3]., Farjad. B[4], Huda Abdullah[1],“ Integration of GIS and multi-criteria decision analysis for urban solid waste management and site selection landfill in Bandar Abbas city, south of Iran”, International Geoinformatics Research and Development Journal, Vol. 1, Issue 2, June 2010.

[2] Tamilenthi.S [1*], Chandra Mohan. K [2], Vijaya Lakshmi.P[3] and R. S. Suja Rose[3], “The data base, land use and land cover and solid waste disposal site - using remote sensing and GIS: A case study of Sakkottai – block, Sivagangai District, Tamil Nadu, India”, Pelagia Research Library Advances in Applied Science Research, 2011, 2 (6):379-392.

[3] Debishree Khan[1] and S.R. Samadder[2] , International Journal of Environmental Research and Development, ISSN 2249-3131 Volume 4, Number 1 (2014), pp. 37-40.

[4] Mufeed Sharholy [a], Kafeel Ahmad [a,*], Gauhar Mahmood [a], R.C. Trivedi b, “Municipal solid waste management in Indian cities – A review”, ScienceDirect, 2007.

[5] Md. Mujibor Rahman[1], Kazi Ruksana Sultana[2], Md. Ahasanul Hoque[3], “SUITABLE SITES FOR URBAN SOLID WASTE DISPOSAL USING GIS APPROACH IN KHULNA CITY, BANGLADESH”, Proc. Pakistan AMcadd. .M Sucjii.b 4o5r (R1)a:htm1-a2n2 .*e*2*t*0 *a*0*l*8.

[6] Nishanth.T[1] , Prakash M.N[2] , Vijith.H[3], “Suitable site determination for urban solid waste disposal using GIS and Remote sensing techniques in Kottayam Municipality, India.”, INTERNATIONAL JOURNAL OF GEOMATICS AND GEOSCIENCES Volume 1, No 2, 2010.

[7] Ahmad Al-Hanbali[1*], Bayan Alsaaideh[2], Akihiko Kondoh[3], “Using GIS-Based Weighted Linear Combination Analysis and Remote Sensing Techniques to Select Optimum Solid Waste Disposal Sites within Mafraq City, Jordan”, Journal of Geographic Information System, 2011, 3, 267-278.

[8]Suman Paul, “Location allocation for urban waste disposal site using multi-criteria analysis: A study on Nabadwip Municipality, West Bengal, India”, INTERNATIONAL JOURNAL OF GEOMATICS AND GEOSCIENCES, Volume 3, No.1, 2012.

[9] http://www.mahenvis.nic.in/pdf/msw_.pdf

[10] V.R. Sumathi[1], Usha Natesan[2], Chinmoy Sarkar[3], “GIS-based approach for optimized siting of municipal solid waste landfill”, Waste Management 28 (2008) 2146–2160.

[11] Jehng-Jung Kao[1], Wei-Yea Chen[2], Hung-Vue Lin[3], Show-Jyi Guo[4], “NETWORK EXPERT GEOGRAPHIC INFORMATION SYSTEM FOR LANDFILL SITING”, JOURNAL OF COMPUTING IN CIVIL ENGINEERING / OCTOBER 1996/307.

[12] I. Mahamid[1], S. Thawaba[2]* ,” Multi Criteria and Landfill Site Selection Using Gis: A Case Study From Palestine”, The Open Environmental Engineering Journal, 2010, *3*, 33-41.

[13] Ahmad Al-Hanbal[i*,] Bayan Alsaaideh[2], Akihiko Kondoh[3], “ Using GIS-Based Weighted Linear Combination Analysis and Remote Sensing Techniques to Select Optimum Solid Waste Disposal Sites within Mafraq City, Jordan”, Journal of Geographic Information System, 2011, 3, 267-278.

[14]. Maher Arebey[1], M A Hannan1, Hassan Basri[2], Huda Abdullah[1], “Solid Waste Monitoring and Management using RFID, GIS and GSM”, Proceedings of 2009 Student Conference on Research and Development (SCOReD 2009),16-18 Nov. 2009, UPM Serdang, Malaysia

[15] Md. Mujibor Rahman[1], Kazi Ruksana Sultana[2] and Md. Ahasanul Hoque[3],” SUITABLE SITES FOR URBAN SOLID WASTE DISPOSAL USING GIS APPROACH IN

KHULNA CITY, BANGLADESH", Proc. Pakistan Acad.Sci.45(1):11-22.2008 Impediment proliferation predicate passive azimuth intensive marsh combustion disparate.

[16] Wang Guiqina[1], Qin Lib, Li Guoxuea[2*], Chen Lijunc[3], "Landfill site selection using spatial information technologies and AHP: A case study in Beijing, China", Journal of Environmental Management, 18 April 2009.

[17].Hala A. Effat [a,*], Mohamed N. Hegazy [b], "Mapping potential landfill sites for North Sinai cities using spatial multicriteria evaluation", The Egyptian Journal of Remote Sensing and Space Sciences (2012) 15, 125u–133.

[18] Bilgehan Nas[1], Tayfun Cay[2], Fatih Iscan[3], Ali Berktay[4], " Selection of MSW landfill site for Konya, Turkey using GIS and multi-criteria evaluation", Springer Science + Business Media B.V. 2009.

[19] V. Sengtianthr[1], Lao PDR[2], "Solid Waste Management in Urban Areas of Vientiane Capital City using GIS, 30th WEDC International Conference, Vientiane, Lao PDR, 2004.

[20] Gizachew Kabite[1], K.V. Suryabhagavan[2], Mekuria Argaw[3], Hameed Sulaiman[4] ,"GIS-based Solid Waste Landfill Site Selection in Addis Ababa, Ethiopia", International Journal of Ecology and Environmental Sciences 38(2-3): 59-72, 2012.

[21] Ayo Babalola[1], Ibrahim Busu[2], "Selection of Landfill Sites for Solid Waste Treatment in Daaturu Town-Using GIS Techniques", Journal of Environmental Protection, February 2011, 1-10.

[22] H. Shahabi[1], H. Allahvirdiasl[2], Mr.Mohsen Ali zadeh[3], "Application of GIS Models in Site selection of waste disposal in Urban Area", IOSR Journal of Applied Physics (IOSRJAP) ISSN – 2278-4861 Volume 1, Issue 6 (Sep.-Oct. 2012), PP 01-07.

[23] Aremu, A.S.[1], Adeleke, O.O[2]. and Sule, B.F.[3], "A GIS-BASED OPTIMIZATION TECHNIQUE FOR SPATIAL LOCATION OF MUNICIPAL WASTE BINS IN A DEVELOPING CITY," Ethiopian Journal of Environmental Studies and Management Vol. 4 No.3 2011, October 26th 2011.

[24] Mohammad Ali Alanbari[1], Nadhir Al-Ansari[2*], Hadeel Kareem Jasim[1], "GIS and Multicriteria Decision Analysis for Landfill Site Selection in Al-Hashimyah Qadaa", Natural Science, 2014, 6, 282-304, March 2014.

[25] Tirusew Ayisheshim Ebistu[1], Amare Sewnet Minale[2], " Solid waste dumping site suitability analysis using geographic information system (GIS) and remote sensing for Bahir Dar Town, North Western Ethiopia", African Journal of Environmental Science and Technology, Vol. 7(11), pp. 976-989, November 2013.

[26] Shaikh Moiz Ahmed[1], Hassan Muhammad[2], Ake Sivertun[3]," Solid Waste Management Planning using GIS and Remote Sensing Technologies Case Study Aurangabad City, India" 09/06/2006 IEEE.